Hazard Survey of
Remote Control Locomotive Operations
On the General System of Railroads
In the United States

Brotherhood of Locomotive Engineers and Trainmen
Division of the Rail Conference of the
International Brotherhood of Teamsters

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Abstract: The data and analysis sections, 1 through 14, of this exploratory report for mapping human reliability consist of ethnographic, self-reported narratives with contextual analyses, gathered from Remote Control Operators (RCOs) of Remote Control Locomotives (RCLs) and related railroaders. The purpose of the entire report is to learn more about RCOs and their interface with RCLs in railroad yard and other operations including any generating of hazards. An RCO, using a body-mounted Remote Control Device, having controls and indicators, operates an RCL through its on-board control computer, via digital coded radio signals. The narratives are classified by topic. From the narratives, the report provides a working catalogue of ways in which RCL tasks and equipment could be a problem (difficult to deal with to the point of creating a hazard) in U.S. rail operations. Regarding RCL operations, discussed in the catalogue are potential paths of human performance error and physical device failure and the Human-Machine Interface of these. Eight appendices provide greater depth on methodology, conceptualization, and additional explanatory information: A. The Human-Machine Interface (HMI) and Human-Automation Interface (HAI), B. Definitions (wide-ranging and orienting on railroad work emphasizing RCL operations), C. Ethnographic Method and Reporting, D. Risk Assessment and Its Uncertainties, E. The Loci of Human Error, F. The Variability in North American Railroad Switching, G. Typical Locomotive Engineer and RCO Training, and Appendix H. Classification of Autonomous vs. Human Caused Braking in RCL Operations.

Key Words: Remote Control Locomotive (RCL) operations, Remote Control Operator (RCO) tasks, Remote Control Locomotive technology, railroad safety, railroad operating rules and practices, human error, human reliability, technological failure, Human-Machine Interface, Human-Automation Interface

CAUTION: The numerous narratives written by subjects of research are in a Times New Roman font and the rest of the report is in this Arial font. Changing fonts will destroy this ease of identifying narratives from subjects.

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Abbreviations

CC	Conventional Crew
CYL	Conventional Yard Locomotive
EPP	Electronic Pullback Protection
HAI	Human-Automation Interface
HEI	Human-Error Identification
HFACS	Human Factors Analysis Classification System
HMI	Human-Machine Interface
HRA	Human Reliability Assessment
MTBF	Mean-time between Failures
OCC	On-Board Control Computer (also labeled in some uses LCU and RCR)
PSFs	Performance Shaping Factors
RCD	Remote Control Device (also labeled in some uses OCU and RCT)
RCL	Remote Control Locomotive (also labeled in some uses LRC)
RCLS	Remote Control Locomotive System
RCO	Remote Control Operator
RCZ	Remote Control Zone
SME	Subject Matter Expert

Executive Summary

Part 1 – Introduction to the Study of RCL Hazards

This study examines and catalogues safety hazards associated with Remote Control Locomotive (RCL) operations in the United States, to develop a better understanding of significant safety issues related to this technology. A unique aspect of this study is that the RCL safety data discussed herein was compiled almost exclusively from the unsolicited reports and accounts written and submitted by Remote Control Operators (RCOs) themselves – the men and women who run the hundreds of RCLs that are in operation on the railroads – and railroader workers and officers who interact with them.

In March of 2005, the Brotherhood of Locomotive Engineers and Trainmen (BLET), a Division of the International Brotherhood of Teamsters' Rail Conference, sponsored this study to identify and understand safety issues related to the use of RCL technology. Notwithstanding BLET sponsorship, that labor organization gave the authors complete independence regarding all aspects of the study, including methodology, conceptualizations, scope, recommendations, and particular data content. The vast majority of data presented in this report were collected independently by Dr. Fredrick C. Gamst over a period of about three years beginning in January 2002. Dr. Gamst is a noted railroad authority who has published many articles and books and written many papers on railroad operations and safety during the past 50 years. He has also represented railroads and rail unions as a consultant on operations, including safety, and labor relations and as an expert witness. Mr. George A. Gavalla assisted Dr. Gamst. Mr. Gavalla is a former Associate Administrator for Safety at the Federal Railroad Administration (FRA). Mr. Gavalla helped organize the information and assisted with providing analysis and context to the data. During his six and a half year tenure as head of the FRA Office of Safety, rail related fatalities declined 19 percent and railroad employee fatalities declined 48 percent, to their lowest levels in history. He was also instrumental in the development of FRA's recommended safety guidelines for the RCL operations

This study was designed as a Human Reliability Survey that examines the Human-Machine Interface (HMI), and its subset Human-Automation Interface (HAI), involving RCL operations in the U.S. railroad industry. Modern accident theory holds that chains of events and not a single event cause most accidents (Reason 1990, 1997; Reason and Hobbs 2003; Bahr 1997; Manuele 1997; Kletz 1991, 1993, 2001; Wiegmann and Shappell 2003). Thus, blaming just the operator on the point of an operation is seldom a useful assessment for accident comprehension and reduction. The same can be said for blaming the technology alone. That is not to say that accidents cannot be caused from single point failures, indeed the sole error of a single person or the failure of single piece of equipment can cause an accident. However, if the aim of an accident investigation is to determine an accident's root cause(s) and contributing factors for preventing a future occurrence, it is necessary to examine the interactions of the human and technological factors together. As the body of conceptualization of Human-Machine Interface posits, the technological and human components of operations are inextricably intertwined. Accordingly, in this report, both the technological and the human aspects of the RCL hazards reported by RCOs and other railroaders are examined together to understand better the nature of these hazards and to craft effective hazard mitigation strategies.

The methodology employed for compiling the data and information contained in this study is a form of "exploratory ethnography", a collection of narrative accounts provided by the subjects of research who are closest to issues of RCL safety, the RCOs and those railroaders who interact with them.

Background: A Remote Control Locomotive or RCL is a locomotive which can be operated by a person who is not located in the locomotive and not using the conventional locomotive controls contained in the locomotive cab. The people who operate RCL's are known as Remote Control Operators or RCOs. They control the RCL by the use of control box which we call a Remote Control Device (RCD) or Operator Control Unit (OCU). This box the RCO typically wears on a specially designed vest. The RCD suspends from the vest just above the RCO's waist. The RCD has a series of controls that the RCO uses to operate the RCL, it also contains a data-radio to transmit radio signals to an On-board Control Computer (OCC) mounted on the RCL. Both the RCD and the OCC contain microprocessor circuitry to carry out their functions. Thus when an RCO wants to move or stop an RCL, he or she will operate the appropriate controls on the RCD, the RCD will then transmit instructions to the OCC which will then operate the throttle and braking systems on the RCL to make it move forward or in reverse, accelerate, decelerate, or stop.

The latest generations of RCDs have dial-in speed controls where the RCO selects a desired speed on the RCD. When the RCD transmits that speed to the OCC via the data-radio, the OCC then manipulates that throttle and braking systems on the RCL to maintain the desired speed. Other controls typically found on an RCD include an emergency brake switch to initiate an emergency stop of the RCL, and switches to operate the RCL horn, bell, headlight, and sanders. Most RCDs also contains several safety features including an “alerter”, a “tilt” or “man down” feature and a variety of warning messages and alarms. For a more complete description of the safety features, warning messages and alarms found on RCDs, see Appendix H.

Some contend that the RCL control technology replaces the locomotive engineer or other locomotive operator; but the operational reality is more complex. RCL control technology does not simply replace the locomotive engineer, it executes the input commands of the RCO according to his judgments and consequent manipulation of his RCD controls similar to the way a control computer does the input commands of an engineer in Distributed Power operations. (See Distributed Power in Appendix B). Additionally, in RCL technology, the OCC executes autonomous commands apart from any input by the RCO. (See Autonomous, control system in Appendix B and see section 2.1, paragraphs 1 and 2). As one RCL system manufacturer stated:

> “Furthermore, the LCS Unit [RCL] was never designed as a robotic automaton but as a Remotely Controlled Locomotive. The LCS Operator [RCO] is still ultimately responsible for the consist movement” (CANAC: 1996).

Additionally, in many circumstances, the RCL technology makes autonomous decisions controlling or affecting the movement of the RCL. Despite the human RCO having the *responsibility* for safe movement of the RCL, he does not have *full control* of the movement of the RCL, but must share that control with the RCL control systems, in particular with the OCC.

Although the privacy of all subjects is protected, this study distinguishes between subjects who actually operate RCLs (they are identified as RCOs) and subjects who are railroad officials and other railroad employees who work around RCLs. These latter two groups are identified under the umbrella of “railroaders.”

Part II – Catalogue of RCL-Related Hazards

RCL Hazards Related to Technological Failures

RCL systems introduce additional layers of technology into switching and main track operations that do not exist in conventional locomotive operations. The controls and microprocessor circuitry in the RCD, the data-radio signals that transmit information from the RCD to the OCC, and the microprocessor circuitry and control devices on the OCC that interpret and execute the data-radio messages are all complex technological subsystems necessary to control the RCL.

Switching casualties are responsible for more fatalities among railroad workers than any other kind of work activity, accounting for 128 railroad employee deaths and 928 serious injuries from January 1992 thru June 2004. During that period, there was not a single instance where the failure of the conventional switching locomotive was implicated as either a causal or contributing factor in those tragic accidents. Since 2001, there have been a number of instances where RCL technology failed to operate properly causing uncontrolled acceleration of failure to brake properly. Some of those cases were because of RCL component failure, other cases involved improper installation of components. In a May 2004 report to Congress FRA stated:

> FRA is aware of four instances where an RCL failed to reduce speed when commanded to do so. These malfunctions were associated with computer software or wiring errors and have since been corrected. There were no accidents or injuries associated with these failures. (FRA Interim Report - Safety of Remote Control Locomotive Operations May 2004:7)

An RCO reported about another RCL overspeed incident, as follows:

> “an RCL constantly accelerated out of control and did not respond to the RCO's radio commands. Investigation found the cause: incorrect installation of control chips regarding normal and hump operations

> in the OCC. This misinstallation and consequent uncontrollable speed were not supposed to happen but they did occur. All RCLs at the terminal had the misinstallation."

Another RCO reports about a derailment caused by a defective antenna on an RCL. The antenna is suppose to pick up radio transmissions from a device mounted in the tracks that should automatically slow and stop the RCL movement:

> "A wire connecting the RF antenna beneath the RCL to the OCC was broken or defective. Thus, the RCL went over a PSP [EPP] track without receiving the pucks' track-controlling radio transmissions. That is the RCL could not and did not recognize any of the [safeguarding] pucks."

In yet another incident, an RCL began to move for no apparent reason and none of the RCD controls was successful in stopping the uncontrolled movement. Fortunately, the RCL was close enough to the RCO and moving slowly enough to allow the RCO to climb onto the RCL and shut it down manually.

> " . . .but after the Secondary-RCO exited from between the cars, the RCL revved up to the equivalent of a high throttle setting and began shoving the cut of cars. The Primary-RCO had not moved his RCD from the Neutral and STOP positions. The Primary-RCO placed his brake override lever in EMERGENCY position, yet the RCL continued its revved up state and unauthorized shoving of the cut, for about three car lengths. To control completely this RCL, an RCO had to mount the RCL and turn its isolation switch to ISOLATE from RUN position to kill the tractive power."

With conventional locomotive operations, an engineer is present in the locomotive to respond immediately to an equipment failure, that is not usually the case with RCLs.

RCD Component Failures

RCOs report cases of RCD component failure that can diminish RCL safeguards. One such concern involves the "vigilance button." In many RCDs, the Primary RCO must depress a vigilance button before he can execute a speed command. This design procedure is supposed to prevent the RCO from causing the unintentional movement of the RCL by inadvertently moving the speed selector dial; however, some vigilance buttons can become stuck as this RCO notes:

> "Regarding the Vigilance Button falling into a permanently depressed state due to debris between the button and its housing, I found some fine dirt fell into the crack around the button. The button looked only semi-depressed (not that you would notice) but the Vigilance Alarm was deactivated (it did not sound even after 50 secs of movement). More importantly, the locomotive could be moved by switching from STOP to any other setting without prior use of the Vigilance Button."

Another RCD component problem involves the "reverser switch" which can inadvertently move from the NEUTRAL position into FORWARD or REVERSE. This occurrence negates three-step protection (a commonly used railroad operational safeguard to prevent the inadvertent operation of a locomotive). An RCO states:

> "The 3-step setup for disaster illustrated above is surely remote and unlikely to happen. Or is it? I recently worked with an RCT [RCD] that had a defective REVERSER switch. I finally noticed that the box would switch itself into reverse without actually moving the switch out of the centered position. A mere bump was enough to do this"

Placing the reverser in neutral and shutting off the generator field are two of three steps for three-step protection. On an RCD, the reverser switch also controls the generator field (the electric current that provides the power to the traction motors that make the locomotive move). This could explain the inadvertent movement of an RCL described by this RCO:

> "In the process of wrestling with the EOT to attach it, he apparently moved the REVERSER switch out of neutral, pressed a vigilance button, and moved the speed control lever. He happened to look back in time and saw his locomotive moving slowly toward him."

System Design Issues

RCOs commented about various design features of their RCL systems, including design features that may introduce hazards into RCL operations and reported problems with design features not functioning as intended.

One issue involves the Tilt Feature, which warns by sounding an alarm when the RCD is tilted beyond 45 degrees for more than a few seconds. If the RCO does not right the RCD within ten seconds, the OCC (the RCL's On-board Control Computer) automatically initiates an emergency brake application to stop the RCL. The purpose of this feature is to prevent one RCO from operating the RCL while another RCO is working on or under the attached cars. However, RCDs also have a Tilt Extension feature which, if activated allows the RCD to be tilted for up to 50 seconds before the automatic brake application is initiated. When the Tilt Extension is engaged a Secondary RCO can work in between or under cars, e.g., coupling an air hose, while the Primary RCO can continue to move the RCL. RCO's have noted that the Tilt Extension feature can introduce a hazard into RCL operations :

> "Yes this is possible. It is part of the design. Operators [RCOs] need to know what the tilt extend function does and does not do. It's not there to provide protection. It's function is to facilitate your work by REMOVING your protection."

Another feature on some RCDs includes a "COAST" setting, which allows the RCL to coast to a stop, after which it can be moved without the use of the vigilance button, simply by dialing in a speed on the speed selector. RCOs note that if an RCL coasts to a stop, it can be moved unintentionally if the speed selector is moved accidentally.

The computer-controlled autonomous braking of RCLs has caused flat spots on the RCL wheels. To prevent this, some railroads have elected to reduce the braking capacity of their RCL by as much as 50 percent compared to the braking capacity of conventional switching locomotives. There have been no reported instances of an RCL accident caused solely by the intentional reduction in RCL braking capacity; however, insufficient braking capacity was believed to have been a factor in an RCL collision that caused two tank cars to rupture and burst into flames, as this RCO observed:

> "The two RCOs of an RCL-powered cut of 20 cars could not stop their movement. Their cut collided with two standing tank cars carrying hazardous chemical loads, which consequently burst into flame. Authorities evacuated some 140 neighboring residents from their houses in pre-dawn hours but allowed them to return in about four hours. Local employees think that the weight of the cut exceeded the braking capacity of the independent brakes of the RCL."

A railroader reported that soon after this accident, the railroad changed its rules regarding the weight handled by the local RCLs, thereby insinuating that insufficient braking capacity of the RCL was indeed a causal factor in the accident. He commented:

> "[The railroad] has revised its weight rules for the locomotives that were used as RCLs." Did [the railroad] do this for conventional operations as well? Why did the [railroad] not discover this safety problem with many years of conventional use of the same locomotives with the same cuts of cars?"

The OCC controls the speed of the RCL by alternating between the application of throttle and brakes. This can cause excessive slack action (cars in a train lurching forward or bunching together) so severe that it can damage the cars. One RCO reports:

> "Slack action occurs more often due to the constant [OCC-controlled] brake application and release just to maintain speed, rather than simply using throttle modulation."

This unanticipated slack action can be severe enough to pull out a car drawbar from its housing. Such drawbar is designed pull 20,000 or more trailing tons with normal slack action in a train. As a group of RCOs explained:

> "We had a discussion about the way our current RCLs were operating (a whole lot of [unanticipated] lurching and jerking going on) the day RCL job [name] managed to rip out a drawbar while switching."

Another RCO reported regarding autonomous brake application and resultant slack action:

> "By the way, the afternoon RCL switch job got a [broken coupler] knuckle [while] switching."

The dial-in speed control on an RCL does not function automatically at the push of a control on the RCD. Instead, in using these controls, the RCO must use train handling skills, judgment, and experience in selecting the proper speed setting or an accident can result such as this one that occurred on December 26, 2002, at BNSF, Galesburg, IL:

> "an RCO pulled train while switching over the hump causing cars to roll down hump into a cut of cars, derailing fourteen cars. These derailed cars went into the side of a coal train on an adjacent track derailing three cars in that train. The cause of the derailment was determined to be human error. The RCO used too much power to pull the train. He put the speed control to 10 MPH, instead of gradually increasing the speed as the cut of cars began to move."

Unlike a conventional switching locomotive run by an engineer, some RCDs do not permit the operation of the locomotive braking system and the train braking system (automatic brake) at the same time. One manufacturer's manual reads:

> "Whenever train brakes are applied the locomotive brake portion of the train brake application is automatically bailed off."

The automatic brake is the train's emergency braking system, but not every RCL has the automatic air brakes cut in, as an RCO explains:

> "There is no control of the brake pipe in the cars (at least at [terminal name]). You brake with independent engine brake power only. I'm told that there are belt packs [RCDs] that allow trainline control of the brakes but they are not used here yet."

RCL Safety Features That Can Cause Hazards

The latest generations of RCL systems have a variety of features designed to detect operational anomalies or conditions that can pose a hazard to RCL crews or movements. When the system detects such conditions it, then, autonomously acts immediately to stop the movement of the RCL by initiating either a full service or an emergency air brake application. Unfortunately, times exist when abruptly stopping the movement of a train can itself cause hazards. There are a large number of conditions which can trigger an emergency or full service brake application. These conditions are described more fully in Appendix H.

One such condition is a communications loss between the RCD and OCC which will cause the OCC to abruptly apply the brakes and which can result in serious injuries to train crewmembers, as in this example:

> "Another incident in 'VBN' caused broken ribs and lacerations when a helper [switchman] who was riding the point of a long cut of cars experienced a comm break. The [RC] locomotive responded as it had been programmed, and applied full independent and automatic brake. When the slack ran out, the helper was thrown from the end of the cars."

Another RCO reports a similar accident as follows:

> "There was a recent RCL accident on the 'RTU RR' involving an inexperienced RCO riding a '99' car shove and being thrown off when the air dumped [air brakes went into an autonomous emergency application]. Let's see. What does that beeping mean? What do I have to do to recover - oooops. Too late."

The current generations of RCD provide warning alerts or send voice-radio messages intended to warn RCL crewmembers that an emergency or full service stop is occurring but these alerts are not always effective in preventing injuries from excessive slack action as a group of RCOs observed:

> "Once again it's the matter of theoretical v. actual. I am sure that [MANUFACTURER] (or [ANOTHER MANUFACTURER]) engineers feel that they have designed away the problem in the vacuum of their own laboratories. But in the real world, there sometimes exists an embarrassing time lag between what's happening on the box [RCD] and what's happening with the RCL. You might be in the middle of a [task] before you get the alert. Then there is the problem of what do you do when the alert arrives. Do you immediately hunker down in preparation for the slack action or do you take the time to look down at your box in order to read and process and react to the LED display's message? What will you be doing when the slack runs out? It's easy to say that we are being alerted to this in a timely fashion but our experience has been that the stop can arrive suddenly and that people have complained about being severely jostled because of it."

In another instance, a communications loss triggered an automatic emergency brake application that caused such a severely abrupt stop that the slack action broke a knuckle (a coupling device that holds adjoining railroad cars together) which resulted in the following accident:

> "'HIJ' yard job [number and location] was shoving a cut of cars eastbound when the remote control operator lost communication with the locomotive causing it to go into emergency. The train then suffered a broken knuckle on [an] east car, allowing those cars to roll away and into the path of [a] train. The derailment left seven cars on each train derailed, including two empty hazardous materials cars on their sides."

The human factors literature describes the condition that caused this accident as a latent hazard. The safety feature of this technology functioned as intended: unfortunately, under these circumstances, the technology caused the accident. Describing this accident as one not caused by the RCL technology is a matter of word play.

Autonomous emergency braking has also resulted in collisions between RCLs and the cars that they were switching. Such collisions can occur during a switching maneuver known as a drop, where a cut of cars are rolling freely behind on an RCL that is accelerating away from them. An RCO described a collision during a drop:

"The RCL lost radio-signal continuity, which results in either a Penalty or Emergency air brake application. Unfortunately, at that moment they were in the process of making a Drop. So, the RCL did what it's supposed to do [with a radio-signal fault] - IMMEDIATELY STOP - which in this case was a rather poor automation choice."

Another RCO comments regarding an undesired autonomous stop:

"There are times when dead in the water is the last thing you want to be. There are many recollections of incidents where an alert engineer was able to go fast and escape disaster. Cars rolling back out of tracks to foul the lead, unexpectedly meeting a train coming at you, racing to catch a car that got loose down the wrong track."

Hazards that can result from undesired autonomous stops include halting: on a grade crossing, in the area of a fire, near a hazardous material spill or other hazardous event, when in the path of uncontrolled runaway car(s), and when not in the clear of an approaching train movement.

Another recent design feature on some RCDs allows an RCO to operate the RCL while the Tilt Feature is disabled. This practice had been prohibited by most railroads and is discouraged in the FRA safety guidelines. Also, many instances were reported where only one person in a two person RCL crew was equipped with an RCD, thus one person was working without Tilt protections. A group of RCOs commented on an accident that resulted in an amputation to an employee who was working with an RCL crew but was not wearing an RCD:

> "Inside sources reveal that the brother was working as a utility man and was on the same track as an RCL assignment at the time of his injury. We think this speaks to the problem of one-man RCL jobs, one and two-man RCL jobs utilizing a non-RCL helper who may not even be RCL qualified, and the recent proposal in some places to allow the secondary RCO to DISMISS his box and turn it off for an indefinite amount of time, thereby deactivating all the safety features that were originally engineered into the system. As inconvenient and annoying as it is to wear the box all day, at least if you get into trouble and fall down, things will soon come to a halt, alerting your partner that something is wrong."

Remote Control Zone (RCZ) Issues

A Remote Control Zone (RCZ) is a section of track usually in a yard having RCL operations under special rules and procedures designed to protect against the intrusion into the RCZ of other operating crews, other employees, or contractors. In most cases, when an RCL is operating in an RCZ, its crew is not required to provide point protection. (*Point protection* is the practice of having a crewmember stationed at the end of the rolling equipment, or point, to observe the tracks are not obstructed and that switches are properly lined.) Some RCZs have an electronic system installed in the tracks known as Electronic Pullback Protection (EPP) that automatically stops an RCL at the end of the RCZ to prevent it from traveling outside the RCZ when no one is protecting the point. However, a railroader reported a blind movement leading to an RCL accident where the EPP system had been disabled, unbeknownst to the RCO:

> "It is the only track designed as an RC zone at the 'KLM', the only one with 'pucks', and the only track that can be used as a 'pull-back' track without someone physically being on the engine. The RCL (with no one aboard) ran passed the red Absolute Signal protecting movement onto the main track at 'UVW,' ran thru the power switch there, and continued eastward down the Main Track a ways. The RCOs were unaware of this (can't see it at night) and were somewhat perplexed as to why the cut of loaded cars they were handling only moved a little ways when they issued the command to the RCL to back up. The reason being, of course, that [equipment was] derailing in a general pileup on top of the run-thru power switch."

Many RCZs have remotely controlled switches operated via portable radio keypads. A crewmember punches in the identification number of the switch in the same way one dials a telephone, and a digital radio signal transmits to the appropriate switch for throwing to either the normal or reverse positions. A number of RCOs expressed concern that switches are thrown without the knowledge of the RCL crew working in the RCZ, as the following comments illustrate:

> "Now, twice in the last two weeks, a remote control job working at the 'RRR' Yard has pulled out into the activated remote control zone that they 'owned' only to find that the radio controlled switch was lined into [another location]. Fortunately, there was someone on the locomotive both times. But the job had the authorization to pull out without anyone on the point and the outcome could have been much different. Some of us think that we must keep someone on the locomotive at all times until this situation is remedied."

> "There was yet another incident with a remote control switch found wrong in a previously inspected and activated remote control zone."

Some RCOs question the effectiveness of RCZs in preventing RCL accidents in the absence of point protection:

> "Some kind of RC Zone rule whereby you initially ascertain that your track is lined up and clear and then anyone who enters the zone or misaligns switches within it is at fault. This won't prevent mishaps, only ensure that someone other than the RCO is to blame."

Several other RCOs agreed with the sentiment expressed below:

> "an RCZ does not prevent all possible accidents in the zone. The RCZ does provide a fixing of blame away from the RCO and the carrier."

Another concern about RCZs is that they may pose a danger to nonrailroaders who have authorization to work on railroad property but may be unfamiliar with RCL operations. An RCO reports a contractor began fueling an RCL that was operational:

> “while he was checking his RCL when it was stopped, a contract fueler was fueling one of the two RCL units from his tank truck. The RCL's strobe light was flashing and signage for RCL operations was in place. When the RCO question the contract fueler about RCL operations, the man proved to be entirely uninstructed and was not notified about them.“

Many contractors are unaware that the cab of a moving RCL may be unoccupied. Unless briefed on RCL operations, the time-honored assumption was that a locomotive engineer occupied a moving locomotive, as this RCO observed:

> "On an RCL job we witnessed the following. A truck pulling a large trailer was attempting to make a U-turn between the [track] and the activated RCL zone we were using. It fouled the zone on two occasions while it struggled to turn around. We were pulling out but I was in position to see them. When I talked to the crew that was on the property to load [material] I asked them if anyone had explained the concept of RCOs, zones, etc. They were private contractors and totally unaware of what I was talking about. These guys weren't trespassers. They'd been invited on the property to work in a dangerous zone. Wouldn't you think a briefing on the dangers involved would be in order? Oh, I guess that's our job too."

Another significant concern involves the experimentation with the use of remote cameras to operate RCLs over highway rail grade crossings. The remote cameras permit an RCO to monitor the grade crossing from a video monitor at a remote location. A railroader reports a number of problems with this approach:

> "While observing these [on-screen] images during the day, the sun and shadows blur out almost the entire screen. It is extremely hard to make out the conditions of the crossing, let alone see what traffic is at or approaching the crossing. In addition to the problems with the screen, shadows cast by the [highway] overhead bridge at the location of the grade crossing creates an very large 'black' area that nothing can be seen in. The cameras are each aimed directly at the crossing and are zoomed to only show the area between the gates. An operator cannot tell if there is any traffic or pedestrians approaching or attempting to go around the gates."

Some RCOs have reported difficulty in keeping track of other train movements into and out of the RCZs under their control. In addition to the responsibilities of switching cars and running the RCL, an RCO in charge of an RCZ must take on the added duty of controlling the movements through their zones, a task normally handled by a yardmaster in conventional switching operations. All of this can lead to task overload. A railroader discussed a collision that resulted from a lapse by an RCO in charge of an RCZ as follows:

> "The train consisting of a couple of locomotives and [X cars] was given permission by job '99' to enter [a] Remote Control Zone and proceed to the yard office where the outbound crew was to get on. They stopped at the yard office with their entire train still in the zone, without reporting clear, and handed the train over to the outbound crew. There was another light power move that was authorized to enter the zone and proceed [elsewhere]. This they did and reported clear of the zone. Job '99' then apparently assumed that there was no train occupying the zone and without making the inspection required by the rule proceeded to make an unprotected pullout. The unoccupied RCL coupled into the rear end of the train and pushed it a short distance. The RCL then attempted to move [in the other direction] but without success. There may have been more backward and forward movements attempted until a [officer], seeing what was happening, ordered the crew to stop and walk down and inspect the situation."

Human Factor Issues That Involve RCOs

The following section examines a wide variety of errors that can be committed by both the individual and the managers and supervisors of organizations that are engaged in RCL operations. One question to keep in mind as each issue is examined, is there something about the nature of RCL operations that fosters the occurrence of the error or affects the severity of its consequences?

One human factors issue involving RCL operations concerns blind movements. As noted previously, "point protection" is the practice of having a crewmember stationed at the end of rolling equipment, (on the point) to observe that the tracks are not obstructed and that switches and derails are properly lined. When rolling equipment moves without point protection it is called a blind move. If the locomotive is pushing a cut of cars with no one to protect the leading end of the movement, it is called a blind shove. Blind shoves can be implicated in more than half of the human factor caused train collisions reported to the FRA. Failure to protect the point, switches not properly lined, cars left in the foul, nearly all collisions reported under these FRA cause codes could have been prevented if effective point protection was provided during the train movement.

Blind shoves figure prominently as a cause for conventional switching accidents but there is a concern that RCL operations may create added pressures and incentives for crews to conduct blind shoves. Because of the reduced number of crewmembers found in RCL operations (one and two person crews), a temptation is present to save the bodily effort and expended time of walked steps and, hence, to make the blind shoves. As Badler et al. note: "People usually move in ways that conserve resources (except when they are deliberately trying to achieve optimum performance)." (Badler et al. 1993:13). One railroader explains the tendency to make blind shoves as follows:

> "Blind shoves increase the efficiency of yard and road switching operations greatly, and the rules ALL BUT FORBID MAKING BLIND SHOVES. Many accidents have resulted over the years from the practice, and the rules are tightened up a bit -- or at least the interpretation -- but they just can't seem to find it in themselves to remove that always popular, "when practicable" or "when conditions require". If you have to put a man on the point or ahead of the movement each time you shove a track, with a two-man ground crew -- with or without an Engineer -- and you're talking about A LOT OF WALKING to and fro!!!"

The following is a sampling of reported RCL accidents caused by blind shoves:

> “not providing point protection, an RCL crew ran onto a track for which they were improperly lined and ran past a red block, through a power switch, and out onto the main track. This was some time before a passenger train was due on that track. The RCO then changed the direction of the movement and piled up a half dozen cars at the consequently run-through power switch. With the right timing of events, a passenger train accident could have occurred.”
>
> “A collision occurred on [date and location] between a RCO Locomotive and a road switcher. The RCO was not providing protection when it rammed into the parked road switcher on the [location].”
>
> "These two [Internet] links are from [location] last Friday. Remotes were pulling out a cut with no point protection. I saw the engine last night. Took a good beating."

Blind shoves, but not blind pulls, have been part of railroading since time immemorial. Blind pulls are unique to RCL operations because in conventional switching, the engineer in the locomotive is necessarily at the point to provide point protection when the locomotive pulls the rolling equipment. However, the motivation of individuals to perform these blind pulls and company supervisors and officers to permit them appears to be the same as for blind shoves. An RCO notes regarding blind pulls, saving effort, and violation:

> “The blind pull [is] one of several potential problems. Leaving aside the question of innocent civilians maimed and killed by the blind pull, you can write all the rules you want, but if the RCOs are still subject to pressures to produce and their own human nature (let's just cut this corner - I don't want to take the effort to comply - we've gotten away with this so many times surely once more won't hurt, etc.) then you must expect to experience such accidents and worse. Get used to it.”

The following is a sampling of reported RCL accidents involving blind pulls:

> “A remote control at ‘ABC’ yard was lined out to the main line at ‘DEF’ and ran by a Red Block and through the power switch at ‘GHI.’ The unit then backed up and derailed five cars blocking the main line. The crew thought they were lined down the ‘Z’ lead and since there wasn't anyone on the locomotive, there wasn't anyone to stop the unit. This could have been a potentially deadly accident since Amtrak ‘999’ was the next train that was to use the main line.”
>
> “ ‘ABC’ has had other RCO derailment [on day]. The local [RCL] switcher ran over a derail. The Brakeman has a [recent] date. Had there been an engineer on board there would not have been a derailment; the engine was facing the derail.”
>
> "[Name] obtained the attached photos documenting yet another RCO collision at the 'VVV' terminal. The latest occurred yesterday and it is not yet know if anyone was hurt. The unprotected lead locomotive collided with an inbound train, overturning at least one car and extensively damaging locomotive 'XYZ 888.'"

One of the possibilities afforded by RCL switching operations virtually unthinkable with conventional switching operations is the establishment of one-person crews. It did not take the railroad industry long to begin to implement this practice, although it does not appear to be widespread. Concerns about single person RCL operations include the increased temptation to conduct blind moves, increased stress and fatigue on a single RCO, and the lack of nearby aid in the event of an emergency.

Task overload is another human factor concern for RCL operations. Given the number of specific tasks required of RCOs, an opportunity exists to become distracted from the main objective, to switch cars safely, even when handling relatively simple switching movements. A common concept used to explain the actions of many victims of severe switching accidents is “loss of situational awareness.” (For Situational awareness, see Appendix B.) One way for an RCO to lose situational awareness is becoming distracted by a multitude of individual tasks that must be done to accomplish the overall objective of switching cars. The following comments expressed the sentiments shared by RCOs and railroaders alike:

> "We have a lot to think about, like how we are going to make the moves to block the train correctly, is the list wrong, what is the footing like on the ground, where is the next cut (to name just a few examples). Now we have to think about what the locomotive is doing and who should be operating the box. I think this is information overload for us."
>
> "The bottom line is you're taking a switchman / trainman who already has his hands full dealing with switching cars, reading lists, planning work, trying to protect his butt to avoid injury, often working in adverse conditions (rain, wind, cold, dark), and are now adding operating a locomotive by remote control to his list of duties. At what point in time does this employee get to the point where he can't do anything safely because he's got way too much to deal with."
>
> "As far as missed signals, this occurs because as my responsibilities have increased on my own duties, my attention is drawn to myself instead of where it should be, with the men in the field."
>
> "Mental overload: I am required to do too many difficult and dangerous tasks all at the same time."
>
> "Difficult to coordinate duties. Too many things to do. Must focus on one thing at a time."

Related to the concept of task overload is “attention capture” where an individual must focus on the immediate, most complex task at hand, which could result in a loss of situational awareness. An RCO comments on attention capture as follows. (For Attention capture, see also Appendix B. Definitions.)

> “I noticed while operating my box that my attention was divided between the movement of the cars and mastering the sometimes complex rco functions needed to control a movement. This is unavoidable. The question is to what extent does such a divided attention impinge on safe movements. I'm going to wait and see. Clearly the more proficient one becomes on the box, the less focused attention its operation will claim. The risk factor here is not whether an operator is neglectful or inattentive. The risk is in where the operator's attention directed.”

Another significant safety concern for RCL operations is the practice of having RCOs ride on moving cars while operating the RCL. If a Primary RCO rides with three-point contact on the side of a car while manipulating the RCD, the potential for error in controlling the movement increases because the RCL operator: (1) must manipulate controls on the RCD and manipulate other devices such as a portable radio; (2) might slip from but not release the supporting ladder, or stirrup, or grab irons; (3) might actually drop to the ground from his car-side stance but not fall; (4) might brush against objects and be knocked to the ground; or (5) might be distracted because of the need to maintain personal safety.

An RCO group reported about these concerns, as follows:

> "The operations [RCL MANUFACTURER] that require two hands are applying the sand (must hold both vigilance buttons depressed for several seconds) and the unauthorized selection of display of speed on the box (must press both vigilance buttons and toggle the Time/Status switch.) You can also try and get creative and use the Speed lever and Independent Brake Override lever simultaneously to modulate your speed. We have been instructed to just ‘hook an arm around something’ to comply with the rule about 3-point stance. And no two cars are alike (let alone two tank cars). Tank cars can be a particular problem (even with a real 3-point stance -- two feet and a hand) when they start or stop suddenly. You almost need both hands firmly gripping something in order to avoid being swung around the end of the car. The point of all this is that, instead of un-encumbering us to allow us to maximize our safety, they are making it more difficult to hang on and to pay attention to what's happening."

Another RCO stated:

> "It's physically difficult and takes a lot of concentration and attention to hang onto equipment while operating a remote control box [RCD]. The [MANUFACTURER] Beltpack has the most-used controls, the reverser and the speed controller, on the right side. The independent brake override (which includes the emergency function, unlike in normal locomotive controls) and automatic brake controls are both on the left side. Vigilance has an acknowledgment button on both sides; either button may be used."

Yet another human factors, RCL issue is the possibility for RCL movements in the wrong direction. An RCO could have his RCD's reverser in the wrong position and move his RCL in the wrong direction. If the RCO does not (or cannot) observe his RCL, this error can result in a move of some distance, perhaps leading to an accident. An engineer in conventional operations immediately receives the kinesthetic "feel" of a wrong-direction move and can immediately stop it. (See Kinesthetic in Appendix B.) An RCO comments:

> "One [RCO] thinking that he was moving forward and was actually in reverse shoving out the end of a track."

The following are accounts of RCL accidents caused by movement in the wrong direction:

> "RCO foreman placed the direction switch into reverse position and began walking away from the RC locomotive. He should have placed the direction switch into forward position to move away from the adjacent locomotive and watched the locomotive more closely. CSXT 1224 struck the occupied locomotive that was stopped on the same track at approximately four m.p.h., causing neck and lower back discomfort to the engineer in the cab."

> "At least twice, newly trained [RCL] operators have moved engines at low speed in the wrong direction and into the side of cars on adjacent track fouling them."

The lack of "kinesthetic sensation" can also result in continuing the movement of an RCL after a derailment or collision. The problem appears to stem from the fact the RCO is usually not in the RCL cab and thus has no "kinesthetic sensation" or feel of the movement. In conventional switching operations, a locomotive engineer on the locomotive can feel when the train is no longer rolling smoothly. These kinesthetic sensations can include acceleration, deceleration, and velocity stasis; variable pressures of slack run-in and run-out; smell of hot metal from heavily used locomotive brakes; spinning powered wheels on locomotive; sliding locomotive wheels; and the feeling of resistance when starting a heavy cut of cars. There have been several reports where the damages resulting from RCL derailments and collisions were exacerbated because of lack of "kinesthetic sensation."

> "Watched a RCO derailment yesterday at [CCC]. It was kinda weird. Ice and snow was all over the place and I guess switch points did not fit up properly and the cars split the switch. But the weird thing was that when they hit the ground the RCO operator speeded up and then when they really got to derailing he speeded up again. Then as they were about to turn over he plugged it [put the movement into emergency braking]. I guess he could not feel it [the movement] dragging him down as an Engineer would have so he just needed more speed. Two set of trucks were laying near the tracks with about 10 cars derailed with some leaning on their sides. No one hurt."

A railroader noted regarding a blind RCL movement that hit a standing train three times in succession:

> "Now, with proper supervision and the 'feel' of the movement that an Engineer would have had, that surely would not have gone on to a major mess. If nothing else, a 'view' from the cab would have stopped it. Simply put; You can't 'feel' the movement of the cars from a beltpack, but seated on an engine ... yes! You really do. And, for the most-part you know when something's 'not right'."

There have been a few reports of unexplained movement of the RCL. Although the explanation for these movements may not be known with certainty, it is possible that a combination of factors could cause these unexplained RCL movements. For example, a combination of faulty reverser switch or vigilance button, in conjunction with the inadvertent movement of a control lever. The following are brief accounts of unintentional RCL movements.

> "I was lining up two long drawbars when I heard the bell on engine go off [sound]. Engine was approx. 4 cars away. I immediately removed myself from between the cars thinking I had actually tripped the bell. I looked down at my box and my selector lever was in 10 MPH and the cars, at the same time as I looked down, began to move. I immediately put it to stop. Somehow, and I have no idea how, I must have knocked the reset button and the speed selector button causing a movement." (Or could the vigilance [i.e. reset] button have been stuck in the on position?)
>
> "A brother who was working recently on an RCL assignment reported the following: He was the primary operator and wrongly agreed to help a utility man by attaching an EOT [End-of-Train Device] to the end of a train he had doubled up. The train had neither locomotive attached nor crew assigned. His RCL was on the same track, behind him and separated by the required distance. In the process of wrestling with the EOT to attach it, he apparently moved the REVERSER switch out of neutral, pressed a vigilance button, and moved the speed control lever. He happened to look back in time and saw his locomotive moving slowly toward him." (Or could the reverser have slipped out of neutral and into reverse unnoticed?)

There was previous discussion about the dangers of abrupt stops caused by emergency brake applications. The unintentional operation of the wrong control device at the wrong time is another condition that can cause these emergency stops, which create excessive slack action. The following are reported instances were the abrupt stops were triggered by the unintentional operation of a control device on the RCD:

> "At approximately [time], two yard employees working on a RCL (remote control locomotive) yard job were riding a loaded open center beam bulkhead flatcar containing bundled plywood while protecting the point of a shove. Both employees were riding the point on either side of the car in the stirrup position. The employee operating the RCT (remote control transmitter) inadvertently activated the 'pitch' button on the control box causing the locomotive to fully apply the independent brake. This caused a rapid deceleration of the equipment. When the employees heard the slack running out, they each braced themselves by placing a portion of their bodies between the bulkhead and the lading. As the slack ran out, the lading on the car shifted toward the bulkhead, pinning both employees."
>
> ". . . while throwing the switch, the [switch stand] handle caught the reverser toggle switch [on the RCD]. This is considered an illegal reverser change and the RCL stopped but was not in the clear." (A collision followed.)

Numerous narratives were received on the effects of RCL radio transmissions on railroad radio frequencies, but the range of opinion was diverse. In some localities, crews complained that autonomous RCL radio transmissions coupled with RCO transmissions increased radio chatter to a level that interfered with safety critical radio transmissions. On the other end of the spectrum were complaints that RCL operations diminished intracrew radio transmissions so much that they masked the existence of RCL operations to other train crews working in the vicinity. Many others reported that RCL operations had no effect on the overall level of radio transmissions in a given area. The effects of RCL operations on the capacity of railroad radio frequencies appears to vary greatly, depending on the location and nature of the switching operations. Thus, any attempts to mitigate hazards associated with the increase of decrease in radio traffic must be site specific.

One of the highly touted safety benefits of RCL operations is the elimination of communication errors between a locomotive engineer and his ground crew. Some RCL proponents reason that because RCOs perform the functions of both the engineer and the ground crewman, such communications, and by extension, such communication errors are virtually eliminated in RCL operations. But many RCOs disagreed with this assessment as the following comments indicated:

> "In the course of giving commands to the [Primary] RCO (via [voice-] radio) and making several joints, I noticed there was no improvement over conventional engineer operations and, in fact, the process was slower and more tedious. More importantly, the same potential for miscommunication exists in this type of scenario as more than once I had to repeat my instructions to the RCO (who had stopped the movement account he either didn't understand my command or could not clearly hear my command over the radio). As you know, one of [manufacturer's] marketing claims is the total elimination of communication errors between the locomotive engineer and the person on the ground. I would think this proves the same potential for communication errors exist with remote control as with conventional locomotive engineer operations."

A railroader explained regarding a Secondary RCO fatality:

> "The operator of the pitch and catch operation [the Primary RCO] was not on the point of the movement. That should have been the deceased. The operator was the conductor who was kicking the car that eventually killed [name]. This practice nullifies the railroad and supplier argument that errors such as these are eliminated because the point of control is being done by the person with closest vision to the work."

Switching long, heavy cuts of cars without the use of automatic brakes is an important RCL issue that was touched on earlier. It appears that on some railroads, using an RCL without the automatic brake system is a matter of company policy. An RCO comments:

> "I believe that if remotes [RCLs] were used to handle a certain amount of cars at one time, say 25 loads, then they would work fine. Where I work, the company wants you to handle 60 loaded tri-levels at one time without air---and that is crazy, and beyond dangerous."

Fatigue is a safety issue that warrants attention throughout the railroad industry. The National Transportation Safety Board has estimated that fatigue might be a contributing factor in as many as one-third of all human factor caused transportation accidents. Fatigue may be an especially significant hazard in RCL operations. It is possible that the performance of complex and physically demanding RCL switching tasks, along with the added responsibility for conducting skilled RCL train handling tasks, may make RCL operations more stressful than conventional switching operations. Increased stress can lead to increased fatigue.

Ergonomic Issues

A prominent feature of RCL systems is that an RCO must have an RCD attached to him via a specially designed vest. The evolution of RCD designs clearly indicates that manufacturers have given thought to ergonomic issues, for example, the current generation of RCDs is less than half the weight of earlier designs, with some models weighing four and one-half pounds with the battery installed. Also, RCD's are attached to the vests with break-away attachments to prevent an RCO from being dragged under rolling equipment should the RCD become tangled with this equipment. Despite the ergonomic improvement, ergonomic concerns continue to be reported.

By far the most prevalent complaint was that the RCD causes significant back and neck strain, especially when worn for long periods of time. There were many complaints from RCOs about this matter, only a sampling of which are presented as follows.

> "mostly back strain and neck strain, which had never occurred before use of RC."

> "I'm finding after working a shift that I now have much stiffness in my back, shoulders, & neck that I didn't have before."

> "Pain in the neck (literally); lower back pain; stress."

Other RCOs report that back and neck pains have diminished or ceased completely when they stopped wearing the RCD:

> "pain in the stomach area. nausea. tenderness. After box is removed, symptoms decrease somewhat."

> "I've had the good fortune lately to be able to work jobs with engineers. (My back is thanking me.)"

Some RCO's recently reported that a new rigid vest appears to distribute the weight of the RCD more evenly on the RCOs shoulders, thus reducing the strain on neck and back:

> "Initial vests distributed with RCD's were inadequate and caused neck and back aches, however new vests that are rigid and distribute weight on shoulders rather than neck have improved any aches and pains."

Despite the breakaway features on RCD vests, their have been reports of individuals becoming entangled in rolling equipment. Also, portable radio cords can catch on moving equipment causing a hazard. Several RCOs provided the following reports:

> "A brother here got his RCT [RCD] vest 'hooked' on some moving equipment and instead of 'breaking away' it dragged him some distance until he was able to 'undress.'"
>
> "At a low speed derailment, man [RCO] riding side of car snagged his vest on something causing box to land upright on ground, cars still moving for a while. Man broke collarbone but could have been killed."
>
> ". . .an RCO's RCD vest caught on moving equipment and the man was dragged about three car lengths. The RCL was not hurt, however."

Another complaint about wearing an RCD is that it blocks the view of one's feet, making it difficult to walk:

> "A significant complaint about wearing the box is that you cannot see your feet. This might seem trivial, but try it out. Hang something around your neck or affixed to your waist which obstructs your view of your feet."

Training and Experience

A number of the RCL-related hazards discussed above could be mitigated if RCL crews were better trained and had the opportunity to gain more experience. Training and experience are inseparably critical for operational safety on railroads. Experience comes with time but, as has occurred, sometimes an accident comes first. Also, experience, without proper training has a tendency to reinforce bad habits. Many RCOs expressed the belief that more and better training is needed. Railroads comment about the importance of RCOs needing to gain experience. Training concerns expressed by the RCOs included, insufficient training time, failure to train in the most demanding type of service the RCOs will be expected to perform, and poorly qualified instructors. (See Training and experience in Appendix B.)

The following comments are representative of the complaints about sufficient training time:

> "2 weeks of training for me was NOWHERE NEAR ENOUGH! Engine controls should belong to the engineer, not me!"
>
> "The training program does a terrible job of training on the Train handling and air brake rules, as well as the FRA rules that apply to RCL. We covered 'Authority' in less than 5 minutes, and train handling in 4. As long as a job stays in the yard, and handlings short cuts, the only real consequence is inefficiency. But, in unfamiliar circumstances, guys can get into trouble fast."
>
> "Subtract long lunch breaks & coffee breaks and long periods of inactivity because leads were blocked and congested and I estimate I only received 3 or 4 hours of actual hands on operation" [in one week].

An RCO reports that insufficient training may have been a factor in an RCL accident:

> "There was a little incident here involving our box [RCD] student who is actually a prodigy of sorts in comparison to other new hires and who consequently got certified after only about 20 minutes of observation by the [officer] (what's the rule on that?) He was training on a night flat switching job and cornered [sideswiped] a hazardous tank car that had slowly rolled back out of a track it had been switched into."

Another training concern was that some training facilities lacked a sufficient number of qualified instructors:

> "As far as the field training is concerned, there were 4 people per instructor so the 40 hrs was really split between 4 people."

FRA regulations require that anyone who operates a locomotive, including an RCO, needs training for every class of service he or she will perform. Some carriers instruct their RCOs that they can request training for a class of service for which they do not feel trained or adequately trained. But such a voluntary request for additional training puts the onus and pressure on the RCO-requester. How likely will an 18 to 20 year old student-RCO, new to railroading, say, "I need more training?"
An RCO comments:

> "FRA has placed the onus for determination of 'qualification' on the uninformed operator. Remember the Arabic proverb--He who believes he knows and knows not is a fool... FRA and the railroads are making fools of the unqualified RCOs." (Actually, it is the railroad's responsibility to determine whether an RCO is qualified.)

At some locations, RCOs also report the qualifications of RCL instructors are a concern. An RCO comments on inadequate training coupled to inadequacies of the trainer:

> "One of the field trainers was a [ZXC RR] human resources employee, and apparently he was a switchman [seniority date]. When we got more into spotting cars and were having a hard time stopping on a dime, we asked him to show us how it was done. His response to us was, 'You guys will get the hang of it.' Later he admitted to [us] that he had never used the remotes while performing his job but only during the training that they put him through."

Perhaps the most damming assessment of the quality of RCL instructions came from this RCO:

> "The training program was a joke. It has consisted of 6 classroom days, 2 of which nothing was done. By nothing I mean no equipment or no instructor. We sat around and talked about fishing, vacations, cars, and etc.... Somewhere in the middle we got a 50 question hostler test, and at the end a 50 question RCL test. They spoon fed us the tests-nobody fails. 'Course nobody learned anything but the answer to #42 was yes. Then we had 5 days on the job training with switchmen but no instructors."

Another issued raised about RCL training was insufficient instruction about the nature of the technology and about switching itself. Obviously, experienced switchmen, conductors, and brakemen were not concerned about the latter. As one RCO said:

> "I'm still dazed by the quick lesson in modern airbrake systems. And I think I knew a little about this. Enough to surreptitiously move an engine if I had to. Mr. [officer] claimed at the end of the class that we now know as much as any locomotive engineer about this stuff. We got him to admit that we are in fact taking on many of the responsibilities of the locomotive engineer. But whenever I turned the discussion to issues of train handling he slipped and slid and avoided the question."

Formal classroom and in-field instruction are important parts of effective training but such instruction alone is no substitute for experience. A group of RCOs caution regarding the potential for a lack of experience for an entire RCO crew of two:

> "Of course, our RCL assignments are still 2 men. Of course, there is the real possibility, given the current manpower shortage, that 2 of these new hires will end up on the same job. And, possibly, with an RCL student. It's madness. That's our story and we are sticking to it. Of course no one is listening to us."

That group's cautioning is realized in the real world. An RCO provides the following report about inexperienced RCOs:

> "An RCL moving a long, heavy cut ran out of a yard, past a stop signal, through a power switch, and into a train on the main track. Eleven cars derailed and one of the two coupled m-u RCLs toppled. The two RCOs did not provide point protection for their movement. The two RCOs were new employees, one having less than two weeks as an employee. Nevertheless, the two were assigned a student-RCO to train."

The issues of RCL training and experience may be paramount with the railroad industry for some time. In June 2004, the railroads estimated that they would have to hire 80,000 new employees across six years, and 140,000 in ten years, or about 13,000 annually. (anon. 2004a) Thus, railroads will be flooded with inexperienced employees, in a workplace having fewer employees than traditionally to mentor the waves of neophytes working in a potentially catastrophic setting.

Part III – Recommendations and Conclusions

Strategies to Promote RCL Safety

The following are recommendations to promote RCL safety:

Develop Baseline RCL Accident and Casualty Data Based on FRA Audited Accident and Injury Reports: FRA maintains an extensive database of railroad accidents, casualty statistics and operational data. The data are provided by the railroads, which are required to report railroad accidents and casualties meeting a specific criteria mandated by Federal law. However, some rail industry critics question the accuracy of accident and casualty data whose source is the industry itself. The implication usually given by these critics is that local officers cover up the less severe accidents and casualties to protect their career records as managers. As Trevor Kletz points out in *Lessons from Disaster: How Organizations Have No Memory and Accidents Recur*, skepticism of industry generated accident data is by no means limited to the railroad industry. Addressing the motivation of those responsible for reporting industrials accidents, Kletz observes, "they consciously or unconsciously present themselves and their companies in as good a light as possible. . . . Try to look beyond the printed words" (Kletz 1993:108, 138-140).

RCOs and railroaders have expressed skepticism about railroad industry reporting of [RCL] accidents and casualties. That skepticism appears especially pronounced regarding the reporting of RCL accidents and casualties, as the following comments reveal:

> “The FRA Blair [RCL] accident report is ‘laughable’ and shows the deficiencies of the FRA's data base. Although the codes available are fairly comprehensive, the actual report is prepared by the railroad and usually the information provided is based on an agenda to fix blame or mitigate a railroad's liability. They do not always reveal what actually occurs."

Several RCOs submitted the following reports about RCL related injuries and accidents:

> “I should note that, while we work for the [UIO RR] and their policy of firing employees who get injured on the job, they have been extremely nice with [Mr. Y,] in this instance. The official report on this [his] injury mentions **nothing** about remote control!"

> “While I was [location], my [crewmember] called me and said that they were dropping some cars (something we do everyday). Well while they were sawing back in the remote [RCL] lost comm and stopped. Needless to say the cars hit the locomotive and made it a convertible. From what my [crewmember] said, the first managers out there were looking for blood, saying they were gonna fire the whole crew. However, when the senior managers came out, it died down a little bit and heard them saying that because it was an RCL incident, it might have to be swept under the rug."

> "Here in 'DEF,' a local chairman ran through a switch with an RCL movement and reversed and put cars on the ground. The accident never happened."

This RCO sarcastically described the attitude that no one is held accountable for RCL accidents in this way:

> “We as RCO's don't need job insurance because the company protects us.”

Perceptions both shape and reflect beliefs and beliefs motivate human actions. Therefore, a widespread perception among RCOs and other railroad employees that the industry is not serious about identifying RCL accidents and hazards can only have a detrimental effect on employee attitudes toward RCL safety. Rank-and-file cynicism about an organization’s commitment to safety, by necessity, will diminish their commitment to working safely.

Although the criticisms for railroad accident reporting in general are likely to remain so long as the railroad industry generates the vast majority of accident and casualty data, something can be done to generate baseline data of RCL accident and casualty rates with a fairly high degree of reliability. FRA should undertake a comprehensive audit of RCL accident and injury reporting. Auditing railroad RCL accident and casualty reports from a broad cross section of RCL operating environments would help provide a more accurate picture of RCL risks.

Given the significant degree of diversity in RCL operations, the audit should be conducted in selected divisions, terminals, and yards, that cover the range of RCL operating environments. Some of these RCL operating environments include, yards with extensive RCL service, small isolated yards, yards with RCZs, yards without RCZs, hump classification yards, flat switching yards, industrial spurs, secondary track, main tracks with RCL local freight trains, and RCL operations with different crew configurations (e.g., pitch and catch, multiple-person crews with one RCD, and single-person crews). An FRA audit of the RCL operating data for these areas could facilitate an accurate normalization of accident and injury data.

Develop RCL Accident Investigation Protocols to Increase Understanding of Factors That Cause or Contribute to RCL Safety Risks: Accident data reported by railroads can never be the sole source of our knowledge about railroad risks and hazards. Another quite valuable source of information about railroad hazards and risks can be gleaned from the accident reports of major accident investigations conducted by FRA. By fully reconstructing events and conditions leading up to and triggering an accident, much can be learned about the hazards and the measures to mitigate those hazards.

Unfortunately, because of the relatively recent introduction of large-scale RCL operations and technology into the U.S., there is little institutional knowledge within the industry about the intricacies of RCL technology and the finer points of RCL operations. Government regulatory and accident investigative agencies should develop protocols to guide inspectors in the investigation of RCL related accidents and injuries. Possible investigative protocols might address some of the following topics:

- Teach investigators to understand the causes of the OCC's autonomous stops and other actions to determine if they may have caused or contributed to the incident.

- Investigate the condition and operation of the RCD involved in the incident, and poll other RCOs who work in the yard or vicinity to determine if there is a history of RCD problems.

- Verify the integrity of the RCD assignment process to ensure that only the authorized RCD(s) could operate the RCL in question.

- Investigate training of RCOs involved in an incident to determine the amount of training received, including the amount of operating time and whether a qualified instructor was present. Also, investigate whether the RCO was trained on the most demanding type of service that he or she subsequently performed.

- Check OCC data logs, if they were created, and compare RCL data with locomotive event recorder data.

- Review RCZ rules and procedures. Also, investigate reliability of pullback protections, where in use.

RCL Stakeholders Should Work Together to Address RCL Safety Issues: FRA established a taskforce consisting of representatives from the Class I railroads, the American Shortline and Regional Railroad Association, RCL manufacturers and the rail labor organizations that represent trainmen, locomotive engineers, and RCOs to examine RCL issues. However, the group has only met twice and has not met at all since May 2003. Consideration should be given to establishing a standing committee or task force to systematically study RCL safety issues. The group could also explore strategies to mitigate RCL hazards.

Bringing together RCL stakeholders with differing interests and approaches to problem solving may foster innovative ideas to mitigate RCL safety risks. To be sure, each group will have its own agenda reflective of the organization’s core mission. Railroads will look to increase productivity and minimize costs of RCL operations; RCL manufactures will be concerned about market share and protecting proprietary information; labor organizations will care about jobs, wages, and benefits. However, safety is an issue that all stakeholders can embrace, since it can serve all of their interests. FRA has ample experience in bringing together diverse railroad stakeholders to work together on safety issues.

Special Attention Should Be Devoted to Ergonomic Issues: This recommendation is not a strategy, to improve RCL safety; rather, it is an important safety issue that appears to be so pervasive among RCOs that it warrants special attention. This may be one area where the traditional railroad stakeholder groups may benefit from the help offered by ergonomic specialists.

Consider Adoption of Mandatory RCL Safety Standards: Serious consideration should be given to the promulgation of mandatory safety standards for RCL operations and technology. Whether this is done in the context of broader standards that address railroad switching safety in general or as a more narrow set of standards that focuses exclusively on RCL safety, is a decision best left to the regulator. However, the point is that many RCL operations are conducted far outside the parameters of the FRA's voluntary safety guidelines. Furthermore, railroads continue to stretch the envelope by using RCL in ways never contemplated by the regulators, for example, operating RCLs over grade crossings with the use of cameras and remote monitors.

In its 2001 RCL Safety Advisory, FRA stated that because of the relatively recent introduction of RCL technology into the U.S., it had decided to proceed prudently in issuing its guidelines. However, now that our nation's railroad system has seen widespread RCL operations for several years, prudence may call for a change in direction away from purely voluntary guidelines to mandatory safety standards. Some topics that should be considered for inclusion into mandatory RCL safety standards include:

- Standards for RCL microprocessor systems. Perhaps this may be accomplished by covering RCL microprocessor systems under the newly issued regulation for microprocessor-based signal and train control systems. Thought should be given to covering Electronic Pullback Protection systems under this regulation.

- RCZ Standards. Develop rules and procedures for the establishment and operation of RCZs as a method to protect RCL operations. Also, standards for remotely controlled switches and derails that are used within these zones should be considered.

- Consideration should be given to requiring training in the rules and procedures of an RCZ for all persons authorized to be near an RCZ, including contractors. If contractors cannot be trained, an RCO-certified pilot should be provided for them.

- Railroad rules and practices for point protection should be examined to determine whether mandatory rules and procedures are necessary.

- The conduct of RCL operations outside of yards needs to be examined. In more than a decade of use in Canada, RCL operations remain largely confined to yards. Within only a few years, their use in the U.S. has proliferated well beyond the yard switching environment.

- Restrictions on RCL switching without Automatic Brakes is an important issue to examine.

- The practice of an RCO riding the side of a car while operating an RCD should be prohibited.

- Consideration should be given to requiring the installation and use of data logs on OCCs to determine messages received from the RCDs and the commands sent to the RCL control systems. Requirements for retaining the data in the event of a reportable accident or casualty could mirror the requirements for event recorder data. Given that RCL systems can make autonomous decisions that control the movement of the RCL, it is imperative that these autonomous systems can be closely monitored to detect flaws in design and operation.

- Training of RCOs, also needs greater scrutiny. Attention should be paid to the amount of training, the quality of the training and instructors, and qualification processes for RCOs. Although existing Locomotive Engineer Certification regulations cover RCO training programs, it appears many RCO training programs are less than effective.

- The mandatory use of Tilt protection and other RCL safeguards should be explored. With the recent development of allowing RCOs to disable tilt protection, this entire issue needs to be considered in a regulatory context.

- Fatigue is an item that warrants enhanced attention throughout the railroad industry. However, the stresses that can accrue from the performance of complex and physically demanding RCL switching operations and along with the added responsibility for conducting skilled RCL train handling operations make fatigue an especially significant safety issue that should be addressed.

- Consider mandatory reporting requirements for RCL accident, casualty, and operational data, to allow more thorough monitoring and analysis of RCL safety issues. In 2003, FRA introduced RCL reporting codes to identify accidents and casualties involving RCL operations. However, to normalize this data, railroads should be required to report the number of hours worked by RCOs and other RCL crewmembers and the number of RCL miles operated.

- Particular attention should be focused on the unique problems of Human-Machine Interface present in RCL switching operations. RCL accidents can be triggered by the actions of the RCO, the autonomous actions of the OCC, or a combination of the two. Once HMI risks are identified and analyzed, mitigation measures should be adopted.

Conclusions

With change comes challenge. To meet the safety challenges posed by RCL operations, at least three things are required:

> First, a better understanding is needed about how RCL operations impact the safety of switching operations. Simply put, a concerted effort is needed to identify the hazards that can result for RCL operations. The collection of more comprehensive accident and operational data, better accident investigation protocols, and the systematic pursuit of RCL safety information from all relevant railroad industry stakeholders is needed to accomplish this task.
>
> Second, a risk analysis of the RCL operations should be undertaken to understand and prioritize the severity of the consequences that RCL hazards may pose. This risk analysis should not be narrowly and selectively focused on human issues alone, but must include RCL technology and, most importantly, the interactions of RCOs and associated railroaders with the RCL systems (the Human-Machine and Human-Automation Interfaces). As this study illustrates, the belief that RCL technology plays little or no role in RCL accidents is widely disputed by those who work with and around this technology. Both the autonomous and authoritarian actions of RCL control systems and the possible RCL technological failures appear to have caused or contributed to RCL accidents.
>
> Third, efforts must be undertaken to mitigate known RCL safety risks. Of course, laudable attempts have already been made in this area. RCL operating rules and practices issued by the railroads and FRA's voluntary RCL guidelines are all attempts to address RCL safety risks. As well intentioned as these efforts may be, the experience of the past few years shows that more needs to be done. The extensive proliferation of RCL operations on U.S. railroads exposed a number of prominent safety issues that have not been controlled by either railroad rules or voluntary federal guidelines.
>
> The time has come to consider seriously mandatory federal safety standards for RCL operations.

Acknowledgments

This report presents the first-ever results of research almost entirely from a collection of self-reported narratives written by Remote Control Operators (RCOs) and other interacting railroaders on the subject of Remote Control Locomotive (RCL) operations in the United States.

Accordingly, the authors give their heartfelt thanks to all of these railroad operating personnel who selflessly contributed their valuable time, effort, and concern in drafting their narrative raw materials used in the study. Given the nature of railroad discipline and its sanctions, these personnel must remain nameless and without any identifying characteristics in the report. Yet, these faceless contributors demonstrated that their direct involvement in study of railroad safety, with a subject-matter expertise, reflects their indisputable regard for enhancing such safety for all. Their regard became the very foundation of this report, and rather than just talk the talk on the job about RCO operations, they walked the walk with material participation in the research for this report.

The authors thank the Brotherhood of Locomotive Engineers and Trainmen (BLET) for its financial support enabling the authors to discuss, develop, and write in numerous drafts this independent technical report.

The content of the report reflects the authors' comprehension of railroad operational facts and their applications of methodology and conceptualizations useful in developing the study reported herein. Neither the BLET financially supporting nor the individual subjects of research contributing to this report are responsible for its generalizations, recommendations, and framing of the subjects' narratives. This responsibility rests entirely with the authors.

Part I

Introduction to the Study of RCL Hazards

1.0 Introduction

The use of remote control technology to operate locomotives has grown dramatically in the United States during the past four years. In the beginning of 2001, only a few shortline and regional railroads conducted remote control train operations in the U.S. By the end of 2003, six of the seven Class I railroads and more than 17 regional and shortline railroads had implemented Remote Control Locomotive (RCL) operations on their systems. In the period of less than two years from when they were first introduced, RCL operations grew to over 23 percent of all yard and switching operations on those railroads, accounting for more than 16 million train miles on an annualized basis (FRA, Interim Report to Congress: May 2004).[1] Many yard jobs must operate over main tracks during the course of their assignments. RCL operations include some road switchers and local freight trains operated by an RCO conductor and RCO brakeman.

One of the central concerns of any new railroad technology is its impact on safety. The U.S. railroad industry ships more than two-million tank car loads of hazardous materials and transports more than 500 million railroad passengers every year. With such high volumes of both deadly and precious cargos, maintaining a high degree of safety is of paramount importance. Hazards, however, exist in all transportation systems. The key to maintaining safety is to systematically identify hazards and design strategies to prevent, or at the very least, minimize their occurrence.

The purpose of this study is to examine and catalogue safety hazards associated with RCL operations in the United States to develop a better understanding of significant safety issues associated with this technology. One of the unique aspects of this study is that the RCL safety data discussed herein were compiled almost exclusively from the unsolicited reports and accounts submitted by Remote Control Operators (RCO) themselves – the men and women who run the hundreds of RCLs that are in operation on the U.S. railroads – and railroader workers and officers who interact with them.

This study was sponsored, in March of 2005, by the Brotherhood of Locomotive Engineers and Trainmen (BLET), a Division of the International Brotherhood of Teamsters' Rail Conference, to identify and understand safety issues related to the use of RCL technology. The BLET is a railroad labor organization with a 142-year history of representing locomotive engineers and trainmen in the U.S. and Canada. Despite BLET sponsorship, the authors were given complete independence regarding the study's content. The vast majority of data presented in this report was collected independently by Dr. Fredrick C. Gamst over a period of nearly three years beginning in 2002. Dr. Gamst is a noted railroad authority who has published many articles and books and written many papers on railroad operations and

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[1] Typically, railroads estimate yard miles by recording the number of hours of operation of yard locomotives and multiply by a standard estimated average number of miles per hour. Thus, *train miles* for yard locomotives are not the same as the actually covered train miles for freight trains running over the road.

safety during the past 44 years. He has also represented railroads as a consultant on operations, including safety, and labor relations and as an expert witness. Dr. Gamst was assisted by George A. Gavalla, a former Associate Administrator for Safety at the Federal Railroad Administration (FRA). Mr. Gavalla helped organize the information and assisted with providing analysis and context to the data. During his six and a half year tenure as head of the FRA Office of Safety, rail related fatalities declined 19 percent and railroad employee fatalities declined 48 percent, to their lowest levels in history. Mr. Gavalla was also instrumental in the development of FRA's recommended safety guidelines for the RCL operations (Notice of Safety Advisory 2001-01: February 2001).

This report is divided into three parts. Part I provides a brief introduction to RCL operations and the key concepts underlying this study. A brief discussion about the history of RCL operations in the U.S. and about FRA's exercise of oversight over RCL operations can be useful to those who may not be aware of the rapid technological developments and expansion of RCL operations in the U.S. railroad industry during the past decade. This discussion is contained in Section 2.0 – Background.

Because this study uses a number of terms and concepts that may be unfamiliar to the general public, a brief explanation about the key terms and concepts that describe how the data for this study was collected, organized and analyzed is warranted. In essence, this study was designed as a Human Reliability Survey that examines the Human-Machine Interface, and its subset Human-Automation Interface, involving RCL operations in the U.S. railroad industry. The definition and meaning of these concepts is briefly discussed in Section 3.0 – Scope. This section also introduces the concepts of "hazard" and "risk"; terms which, to the general public, are often synonymous but which have separate and distinct meanings in the context of safety analysis. A more detailed discussion of the aforementioned concepts is presented in Appendix A. The Human Machine Interface (HMI) and Human Automation Interface (HAI), Appendix B. Definitions, and Appendix D. Risk Assessment for readers who wish to examine this study within the broader context of modern safety analysis.

Section 4.0 – Methodology contains a brief discussion of the techniques used to compile the data and information that are at the heart of this study. This methodology is a form of "exploratory ethnography," a classified collection of narrative accounts provided by the subjects of research who are closest to issue of RCL safety, the RCL operators, and those other railroaders who interact with them at work. Appendix C. Ethnographic Method and Reporting sheds further light on the merits of exploratory ethnography as a technique for examining the safety of complex open systems such as that posed by the railroad industry.

Part II of this report is a catalogue of RCL hazards. It consists of Sections 5.0 through 12.0 and constitutes the core of this study. These sections contain detailed, firsthand accounts of RCL safety hazards experienced and reported by RCOs and other railroad operating employees and railroad officers. The authors placed the accounts in context and analyzed them in the construct of a Human-Machine Interface (HMI). Simply put, RCL safety hazards in operations are organized along a continuum ranging from issues primarily technological to issues primarily human. As the HMI model posits, the technological and human components are inextricably intertwined. Therefore, both the technological and the human aspects of the reported RCL hazards are examined together to understand better the nature of these hazards and to craft effective hazard mitigation strategies.

Recommendations and conclusions are offered in Part III of the report. Section 13.0 suggests some strategies to promote the safety of RCL operations and Section 14.0 has concluding thoughts.

2.0 Background:

2.1 What Is an RCL?

A Remote Control Locomotive or RCL is a railroad locomotive which can be operated by a person who is or is not located in the locomotive but not using the conventional locomotive control devices that are contained in the locomotive cab. As the name implies, RCL's can be operated remotely by a person on the ground (or on the locomotive). The people who operate RCL's are known as Remote Control Operators or RCOs. They control the RCL by the use of a portable console that we label as a Remote Control Device (RCD) or Operator Control Unit (OCU), which the RCO typically wears on a specially designed vest. The RCD suspends from the vest just above the RCO's waist. The RCD has a series of controls that the RCO can use to operate the RCL. The RCD contains a data-radio transmitter and transmits coded, data-radio signals to an On-board Control Computer (OCC) mounted on the RCL. Both the RCD and the OCC contain microprocessor circuitry to carry out their functions. Thus, when an RCO wishes to move or stop an RCL, he or she manipulates the appropriate controls on the RCD. The RCD, then, transmits instructions to the OCC which, next, operates the throttle and braking systems on the RCL to make it move forward or in reverse, accelerate, decelerate, or stop. An RCO, however, can and does manually use the speed selector, reverser (direction selector), and air brake controls on his RCD to override the OCC — in a manner according to his judgments regarding both his tasks and the requisites of the switching environment. He also uses on his RCD, controls for rail-sanding, bell, whistle, and headlight in the same manner.

Because the OCC is designed to function autonomously, in addition to processing commands from the RCO, RCL systems need to be distinguished from Distributed Power (DP) systems. DP locomotives are typically located at the rear end of a train and/or in the middle of a train. A locomotive engineer on a conventional locomotive located at the head of the train controls his DP locomotives. When the engineer operates the locomotive controls on the head end of a DP system, a data-radio transmits instructions to the DP locomotive(s) in the train. Thus, at the control option of the engineer on the lead locomotive of the train, a DP locomotive is designed to both operate directly controlled by the engineer and operate in tandem with the lead locomotive.

DP allows control by the engineer from the lead locomotive of the power and braking of locomotives placed at separate locations in a train consist. With DP, the engineer can handle long, heavy trains more safely than by non-DP methods. The engineer sends control signals via coded, data-radio telemetry to each remote locomotive the engineer operates. Thus, the road engineer no longer has to rely on transmitting voice-radio signals to a helper engineer on a separately crewed locomotive back in the train. The DP distribution of power and braking throughout a train results in quicker and smoother starting and stopping of a train, reduces train transit time, and allows trains of great tonnages otherwise not feasible. DP reduces in-train forces, preventing the lifting off the rails of a light car and the buckling of a train, and reducing damage to lading, thus enhancing safety. Study of DP finds some of the same issues as with an RCL, including chip failures and control via coded data-radio signals. Formerly, the name for DP operations was remote control locomotive operations. (For more information, see Distributed Power, DP, in Appendix B. Definitions.)

2.2 Brief History of RCL Technology

The use of RCLs to move cuts of cars on a regular basis in the U.S. began, not on the major railroads, but on small, localized plant railroads that ran within the confines of an industrial complex or mining facility. These plant railroads, as they are commonly called, are not common carriers of freight and do not operate on the General System of Railroads (the name for the network of railroads that are familiar to most Americans).

The first railroad companies in North America to make regular use of RCL technology were the Canadian railroads, beginning in the latter part of 1989. Previously, only limited RCL operations were conducted at a few Canadian classification and flat switching yards. After the first use of RCLs in the U.S. at large industrial plants and mining operations, in 1992, a regional railroad petitioned FRA to begin RCL operations. By the mid 1990s, approximately nine regional and shortline railroads were conducting RCL operations. In February of 2001, FRA issued Safety Advisory 2001-01, which set forth recommended minimum safety standards for RCL operations. These recommended standards were not mandatory regulations, but voluntary guidelines. Within a year after FRA issued the Safety Advisory, most major railroads and many regional and shortline railroads began to implement RCL operations. By November of 2003 at least 23 railroads were conducting RCL operations, including the largest railroads in the country.

By the early 1990s, a few regional and shortline railroads in the U.S. began to use RCLs in their operations. By this time, FRA also began to consider the safety implications of RCL operations. In November of 1994, FRA set forth a proposal to conduct a national test program for RCL operations. FRA followed this proposal by conducting a public hearing in February of 1995 to collect information about possible RCL safety and operating issues. A wide variety of rail industry stakeholders, including railroads, RCL equipment manufacturers, and rail labor organizations presented differing views on the subject. However, the national RCL testing program was not implemented.

Five years later, on July 19, 2000, FRA held a technical conference that examined various safety aspects of RCL operations, including various design features of RCL technology, operating practices and procedures, test and inspection procedures, issues regarding training for RCOs, the security of RCL data transmission systems, ergonomic issues, and other matters related to RCL safety. The technical conference was chaired by Mr. Gavalla, one of the co-authors of this report.

In February of 2001, FRA issued Safety Advisory 2001-01, which set forth recommended minimum safety standards for RCL operations. Again, these recommended standards were not mandatory regulations but suggested guidelines. They closely mirrored many of the conditions that FRA had proposed for RCL operations in its test program five years earlier. The Safety Advisory noted that, “Because this technology is not widely used in railroad operations, FRA has limited data on which to base an objective safety analysis and must therefore proceed prudently."   The Advisory urged railroads to identify RCL related accidents when submitting accident and casualty reports to FRA. The agency also asked railroads to collect operational data for RCL operations so that accident statistics could be normalized to facilitate further studies of RCL safety.   Some of the RCL safety recommendations issued by FRA are referenced in this study.

Within a year after FRA issued the Safety Advisory, most major railroads and many regional and shortline railroads began to implement RCL operations. By November of 2003, at least 23 railroads were conducting RCL operations, including the largest railroads in the country.

3.0 Scope

3.1 Human Reliability Survey

This study is a Human Reliability Survey (HRS) that provides information to help assess human reliability in RCL operations. In general terms, Human Reliability concerns the probability that a person or team of individuals will successfully perform a given task(s), in accordance with specified task sequences. The term HRS is actually somewhat of a misnomer, because an HRS examines much more than human behaviors and human issues that relate to safety. An HRS examines all the factors that affect whether a person or team of individuals will succeed in a given task. Thus, an HRS attempts to identify technological factors, organizational factors, and other factors that can influence an individual's or team's ability to accomplish a given task. Applying the concept of an HRS to RCL safety, this study will examine the interaction of human performance with RCL technology, operational directives (company rules, manufactures procedures, etc), and regulatory guidelines and mandates, to identify how these interactions may cause, permit, or contribute to the existence of hazards.

In common parlance, the terms "hazard" and "risk" are often used interchangeably to describe something that is dangerous or unsafe.   However, when used by safety analysts, these terms have very precise and distinct meanings.   As used in this study, the term *hazard* means *any condition that could lead to a loss of life, injury to a person, or damage to property or the environment*.   (For the sake of brevity, the term *loss* means *death, bodily injury, or damage to property or the environment*.) Thus, the term *hazard* denotes something (e.g. a human action, a procedure, a rule, an item of technology or technological system, chemical or substance, etc.) that, if not controlled, could result in a loss. Inherent in this definition of hazard is the idea of *potential* to cause harm or damage. Fortunately, many of the hazards described in this study did not result in an actual human casualty or damage to property; however, the potential for these hazards to cause bodily harm or property damage is readily apparent.

The term *risk* in this study to refers to *the probability that a hazard will result in a loss and the severity of the consequences of that loss*. It is common for safety analysts to attempt to quantify risk in relative terms. Thus, hazard A could engender greater risk than hazard B if A is more likely to occur than B. Furthermore, if the consequences of hazard C are likely to be more severe than the consequences of D, then C would carry more risk than D. Of course, in the transportation environment, as in other environments involving human agents, there is a great deal of subjectivity in the assessment of risk. (For further discussions, see Appendix D. Risk Assessment and Appendix E. The Foci of Human Error.)

With these concepts of *hazard* and *risk* in mind, it is important to stress just what this study is and what it is not. As noted previously, this study is a hazard survey; i.e., it is a *catalogue of reported conditions and factors involving RCL operations that have the potential to cause death, injury, or damage to property or the environment*. This study does not claim to be a definitive catalogue of all possible RCL hazards nor is it a catalogue of all RCL hazards that have been identified throughout the railroad industry. However, it is a catalogue of all RCL hazards that have been reported to or identified by the authors following the data collection protocols described below.

Furthermore, this study is not a Probabilistic Risk Assessment (PRA) of RCL safety risks. It does not attempt to quantify and prioritize all known RCL safety risks. To our knowledge, such a resource-intensive study has not been done and is not now in progress. While this study does contain ample discussion of the consequences associated with RCL hazards, it does not attempt to quantify or prioritize the RCL risks. For example, the study contains several accounts of accidents caused by the RCL stopping by autonomous command of the On-board Control Computer (OCC) because of a communication loss between the RCL and the RCD. (The RCD is the “box” that the RCO mounts on his vest and uses to control the RCL.) Although the circumstances that led to these accidents are examined and their consequences are analyzed, no attempt is made to quantify how many RCL accidents have been caused by a communication loss, nor is there an attempt to calculate the probability that such an accident would result in a loss of life, serious injury, or catastrophic damage to property. The purpose of this study is merely to illuminate the fact that these kinds of accidents have indeed occurred and must be taken into account by those who craft RCL safety policies and procedures.

Finally, this study makes no attempt to compare the relative safety of RCL operations with the safety of conventional switching operations. From the discussion of RCL hazards contained in herein, it will be apparent that some hazards appear more likely to occur during RCL operations than during conventional operations, while for other hazards, the reverse appears to be true. However, to make a meaningful comparison would require a more formal PRA of both RCL and conventional switching operations. (For further discussion about merits of and biases associated with risk assessment techniques, see Appendix D. Risk Assessment and Its Uncertainties.)

Once again, this study is a Human Reliability Survey that catalogues RCL related hazards identified by those who use or work with or around RCL technology. It is intended to supplement other efforts that examine RCL safety by bringing to light RCL hazards that have been identified throughout the country in many different and varied railroad switching environments. It is intended that this study will provide a useful supplement to other efforts that examine RCL safety.

The FRA sponsored studies of RCL operations in 2003 by the firm Foster-Miller. The data in one study were compiled from a series of focus groups conducted in four cities. A total of 78 individuals, all RCOs, participated in the focus groups where they discussed their views about the safety of RCL operations and technology. FRA has not made the full results of that study public; however, the issues that were raised in the focus groups were summarized and presented to representatives of rail industry stakeholders who advised concerning the study. Also, in May 2004, FRA published an Interim Report to Congress that identified RCL safety issues. The interim report was in response to a Congressional mandate and will be followed by a more detailed report on RCL safety issues due this year. The interim report discussed a number of safety issues identified by FRA along with efforts to address some of those safety issues. The interim report also compared the number and rate of reported switching accidents between RCL and conventional switching operations during a six-month period. The accident data were compiled from accident reports that the railroads are required to submit to FRA as having met the damage or injury threshold for reportability. Thus, the reports do not represent the totality of railroad RCL accidents.

The FRA intended the Foster-Miller studies and its interim report to provide useful information to help evaluate the safety of RCL operations but each was quite limited in scope. Also, the differing methodologies (focus groups versus accident data comparison) have relative merits and limitations. Neither of these FRA RCL safety examinations pretended to be definitive or all-encompassing. The same can be said for the present study and its methodology. What this study is intended to do is to identify RCL hazards and serve as a starting point to quantify, understand, and mitigate better those hazards.

3.2 Human-Machine and Human-Automation Interfaces

The conceptual framework employed by this study to analyze and classify RCL hazards relies on the concepts of the Human-Machine Interface and its component Human-Automation Interface (HMI and HAI). The HMI generally involves the interactions among RCL technology and the human beings who use that technology. The HAI specifically involves interaction among automated, sometimes autonomous, aspects of RCL technology and the humans who use it. With an HMI and HAI approach, the RCL technological and the RCL human factors issues are not viewed as separate and distinct categories, but interrelated points along a continuum. In other words, technological safety issues are considered to have a human component and human safety issues are intertwined with the technology.

The concepts of HMI and HAI are particularly important in the conduct of safety assessments. The role that technology plays in the causation of an accident cannot be isolated from people who use, interact act with, design, manage, or regulate that technology. Furthermore, the assessment of human performance in the causation of an accident cannot entirely ignore the technology in the operation. Modern accident theory holds that chains of events and not a single event cause most accidents (Reason 1990, 1997; Reason and Hobbs 2003; Bahr 1997; Manuele 1997; Kletz 1991, 1993, 2001; Wiegmann and Shappell 2003). Thus, blaming just the operator on the point of an operation is seldom a useful assessment for accident comprehension and reduction. The same can be said for blaming the technology alone. That is not to say that accidents cannot be caused from single point failures, indeed the sole error of a single person or the failure of single piece of equipment can cause an accident. However, if the aim of an accident investigation is to determine an accident's root cause(s) and contributing factors for the purpose of preventing a future occurrence, it is necessary to examine the interactions of the human, technological, and organizational factors together. Multiple-cause chains of events can also be responsible for noncompliance with government regulations. The EPA finds, for the chemical industry, that: "Multiple causes were identified for 94 percent of noncompliance events identified" (USEPA 1999:iv).

A few examples will help illustrate the concept of HMI and HAI analysis and the interaction of human, technological, and organizational factors in accident causation.

One example that illustrates the interface of human operations with technology in the RCL environment concerns derailments that occur during switching operations. There have been a number of instances where RCOs operating their RCLs from the ground outside of the RCL cab were unaware that one or more cars in their train derailed. Instead of applying the brakes at the derailment, either the RCO or the autonomously acting OCC continued to accelerate the throttle, which exacerbated the damage caused by the derailment. Although such actions can and do occur during conventional switching operations they are relatively rare because the locomotive engineer sitting in the locomotive cab has a kinesthetic sensation of the movement. In plain English, a conventional engineer can “feel” when the locomotive is having difficulty pulling or shoving the train. Also, the conventional engineer has the benefit of monitoring gauges which show how much electrical current the locomotive traction motors are using. Thus conventional switching technology allows a conventional locomotive engineer to gain pertinent information about the locomotive performance (traction motor amperage readings) and to feel that the locomotive is experiencing unusual difficultly in moving the train. This information would help the engineer to recognize the hazard and act promptly to stop the movement. Conversely, RCO technology deprives the RCO on the ground of this additional information about the traction motor current because RCL systems were not designed to provide that information to the RCO. Also, the RCO is deprived of the kinesthetic sensation. All of this results in an increased likelihood that a derailment will not be detected promptly. Characteristics inherent to the RCL technology may increase the likelihood and severity of the hazard thus increasing the risk. It is neither the operator alone nor the technology alone that increases the risk of an undetected derailment, rather it is the interaction of the two. (For Kinesthetic, see Appendix B.)

Another example, which does not involve RCL operations, illustrates how a safety issue which may appear to be purely technological in nature can have a significant human component. During much of the 1990s, FRA found that the number of mainline train derailments caused by broken rails showed a steady increase. To many observers these accidents appeared to be caused solely by a failure of the technology, in this case the rails. However, upon deeper examination these accidents could also be linked to changes in railroad operations and track maintenance practices. Improvements in rail metallurgy and advances in knowledge about rail grinding practices led to a significant extension in the useful life of rails. In the span of a few decades, the maximum life of mainline rails increased from 50 million gross tons to 200 million gross tons. What was not anticipated was that the increased life of these rails would lead to the growth of internal rail flaws. As rail heads wore down, many of the tiny internal flaws in the steel itself, would wear away before they had a chance to propagate to a size that would cause the rail to break. However, the increase in rail life, coupled with increased tonnages carried by many mainline tracks resulted in an increase in the number of internal rail flaws that could grow to the size that would cause a rail fracture. Thus, while the improvements in rail technology (metallurgy and grinding practices) diminished train derailments caused by worn rail heads and allowed tracks to carry greater tonnages than had ever been dreamed possible, these improvements had the unintended consequence of escalating the number accidents cause by internal rail flaws. Although there is no doubt that rail technology has improved, and that the overall number of track caused derailments declined because of these technological improvements, the technological improvement brought about operational changes (heavier tonnages and longer rail life) which had an unanticipated consequence of more broken rails caused by internal rail flaws. Thus, a combination of technological factors and operation factors (including managerial decisions) affected the risk of broken rails.

Applying the principles of the HMI, this study will look at the broad spectrum of technological and human issues as follows:

- The examination of RCL technology includes hardware, software, and data transmissions that involve the RCL and its on-board equipment; the Remote Control Device (RCD) or “box” that the RCO uses to control the movement of the RCL; any wayside or in-track equipment designed to support RCL operations; and the data transmission systems used to link these various systems together.

- The people who interact with RCL operations including, Remote Control Operators (RCOs), other railroad personnel, railroad officials, and non-railroad personnel (including contractors).

- Organizational issues affecting RCL safety will also be discussed, including railroad operating rules, practices, and policies and regulatory standards and policies affecting RCL operations.

This report will also recommend strategies to understand better and analyze RCL safety hazards, including forums and ideas to enhance the collection and analysis of RCL safety data to gain more insight into the nature of RCL hazards.

Finally, this report will suggest strategies or options to help mitigate some of the RCL hazards that have been identified.

4.0 Methodology

The method used to uncover the basic data and information found in this study mainly comes from the unsolicited reports of RCOs and related railroad operating personnel (both management officials and rank-and-file employees) collected since the beginning of 2002 by Dr. Gamst. Thus, the method of data collection is a form of “exploratory ethnography,” which is the collection of topical narrative information from a particular bounded group of indigenous individuals (who, in this case, are railroad operating personnel engaged in RCL operations).

The concept of ethnography is most often associated with the disciplines of anthropology and sociology but other social and behavioral sciences and humanities now use it. Ethnography literally means writing/reporting about a particular people. Ethnography refers to a method of research and can also refer to the findings or results of that research. As method, ethnography studies human social and cultural phenomena; as findings, it describes them. The subjects of research of this ethnography are Remote Control Operators and conventional crews, plus other interacting railroaders in their social setting of work. Results of this research include the present report. An ethnographic approach, thus, can focus on a particular sector and situation in an encompassing society. In this case, the focus is on RCL switching and main track operations in the larger environment of railroad operations.

The information reported by the members of this group of railroad workers can be classified as *local knowledge*. This knowledge comes from the experience, perception, and skills of persons indigenous to a work environment. Local knowledge is not the product of system designers, upper level managers, policy makers, or outside researchers and experts; thus, it is less susceptible to bias about how a particular technology or operation is *suppose to wor*k. Here local knowledge is knowledge from experiences and discussion of these experiences among rank-and-file employees and first-line supervisors. Of course, the knowledge possessed by experts and higher-level organization leaders is also valuable. However, for safety analysis to be effective in an open work environment like the railroad switching where rank-and-file train crew members have an extensive amount of autonomy and work far from the gaze of supervision, it is imperative that expert knowledge be supplemented by a healthy dose of local knowledge. Local knowledge permits safety analysts to understand how technology works and is used by humans in the real world.

The idea of systematically collecting local knowledge for the purposes of a safety study has been around for a very long time. In fact, the Foster-Miller RCL study that utilized a series of focus groups consisting of RCOs and conventional railroaders was a systematic attempt to harvest local knowledge. However, focus group studies such as this typically have a very small universe of research subjects who are from just a few areas (these focus group members were from four cities). Also, the focus group members are taken away from their work or home environment and queried with a short range of focus topics in what can best be described as an artificial setting of the focus group directed by one or more strangers who, frequently, may be perceived as authority figures.

The ethnographic approach to collecting local knowledge is much more comprehensive and intensive. An ethnographer typically becomes immersed in the culture or subculture that is being studied. Ethnographic studies of the railroad industry are nothing new. Previous researchers have immersed themselves in the railroad work environment of a particular railroad, division, or other railroad unit to glean the local knowledge from rank-and-file railroad workers as part of a study of railroad operations or technology. It has been more than sixty years since sociologist and former shopcraftman W. Fred Cottrell published his study *The Railroader* with Stanford University Press (Cottrell 1940). He was followed by a number of other researchers such as anthropologist and former conductor Luis S. Kemnitzer who published two studies of railroad workers (Kemnitzer 1973, 1979). Railroad switching has been the focus of previous ethnographic studies. Sociologist and former switchman John Spier wrote a thesis on the work of railroad switchmen (Spier 1963), and more recently anthropologist and former switchman Birgitta Edelman published a study of railroad switching in Sweden (Edelman 1997). But there is perhaps no more prolific ethnographer of the railroad workplace than Dr. Gamst himself. He has produced more than 100 reports and papers on the railroad industry and related matters and has conducted ethnographic research outside of the railroad industry. Some of his most noteworthy ethnographic studies of the railroad work environment include studies about the impact of technological change on train crews (Gamst 1961, 1963); an ethnographic study of locomotive engineers

(Gamst 1980); a study of railroad apprenticeship (Gamst: 1989); and a monograph about the practice of running trains in the context of all of the operating rules with the use of train orders (Gamst 1990).

While the methodology employed to collect the data for this study is in the tradition of many previous ethnographic studies of the railroad industry, it does differ from the aforementioned studies in several significant ways. First, instead of becoming immersed in one geographically limited area of railroad operations over a concentrated period of time, Dr. Gamst collected information from a widely dispersed group of railroad subjects spread all across the country from many different railroads and many different railroad operating environments. A few subject RCOs were from Canada. Second, he did not become immersed with his subjects for a period of months. Rather, he has been collecting general information on RCL technology and operations, in the U.S. and elsewhere, since 1984 and specific information on RCL work for a period of about three years (since January 2002) from a vast network of railroad workers and managers that he cultivated during his fifty-year, firsthand contact with railroads. That network of railroad contacts grew even larger when word spread among RCO's that Dr. Gamst represented an outlet for their ideas and views about RCL activities.

But how can vast amounts of information from such a large and diverse population of people be gathered without spending vast sums of money? The answer lies in the third innovation that this study brings to the discipline of ethnographic research – the use of the internet, primarily e-mail, as a medium of communication between the researcher and his subjects. Ethnographic researchers have always known that collecting a sufficient base of local knowledge takes a lot of time, money, and hard tedious work. The internet can instantly and cheaply link together people from around the world, thereby greatly reducing costs and speeding up communications. Alas, there can be no substitute for the hard work, research skill, and subject-matter experience that the effective researcher must bring as a background to conduct Internet ethnography.

The Internet has allowed Dr. Gamst to communicate with his subjects. The self-reported narratives about RCL technology and operations presented in this study are all direct quotes from the RCO's and other railroad workers themselves. The authors do not paraphrase or modify words of the subjects of research. In most cases, names of individuals, locations, and companies have been redacted to protect the privacy of the subjects and the privacy of those about whom they are commenting. The only exception to this practice of redaction is when the study cites accounts of published accident reports such as those published by the FRA or in the press. Moreover, while the authors have received numerous verbal reports regarding the views of rank-and-file railroad workers about RCL operations, only those comments that were committed to writing (either via e-mail or on paper) where used in this study. Written reports were generally more clearly thought out and more clearly articulated. Additionally, by relying on subject-written reports, the authors did not have to worry about misinterpreting the information provided by the subjects.

The authors do offer contextual information and analysis concerning the comments and topics raised by the subjects. They also occasionally cite documents and other sources in the course of these discussions. However, the quotations from the subjects are clearly and readily distinguishable from the views and comments of the author and other nonsubjects.

Although the privacy of all subjects is protected, this study does distinguish between subjects who actually operate RCLs (they are identified as RCOs) and subjects who are railroad officials or other railroad employees who work around RCLs. These latter two groups are identified under the umbrella of “railroaders”.

Part II

Catalogue of RCL-Related Hazards

Some contend that the RCL control technology replaces the locomotive engineer or other locomotive operator; but the operational reality is more complex. RCL control technology does not simply replace the locomotive engineer, it executes the input commands of the RCO according to his judgments and consequent manipulation of his RCD controls similar to the way a control computer does the input commands of an engineer in Distributed Power operations. (See Distributed Power in Appendix B). Additionally, in RCL technology, the OCC executes autonomous commands apart from any input by the RCO. (See Autonomous, control system in Appendix B and see section 2.1, paragraphs 1 and 2). As one RCL system manufacturer stated:

> "Furthermore, the LCS Unit [RCL] was never designed as a robotic automaton but as a Remotely Controlled Locomotive. The LCS Operator [RCO] is still ultimately responsible for the consist movement" (CANAC: 1996).

Additionally, in many circumstances, apart from commands of the RCO, the RCL technology makes autonomous decisions controlling or affecting the movement of the RCL. Thus, the RCL control technology does not function as a “robotic automaton” that makes and executes all the decisions that control the movement of the RCL. But it is not a mere extension of the RCD control panel that permits the RCO to operate the RCL in the same manner that a locomotive engineer uses his controls and indicators to operate a conventional locomotive.

Despite the human RCO having the *responsibility* for safe movement of the RCL, he does not have *full control* of the movement of the RCL, but must share that control with the RCL control systems. The following sections will examine the interrelationship between the RCL technology and the human beings who interact with it to identify hazards associated with RCL switching and main track operations.

5.0 RCL Hazards Related to Technological Failures

RCL systems introduce additional layers of technology into switching and main track operations that do not exist in conventional locomotive switching operations. The controls and microprocessor circuitry in the RCD, the data-radio signals that transmit information from the RCD to the OCC, and the microprocessor circuitry and control devices on the OCC that interpret and execute the data-radio messages are all complex technological subsystems necessary to control the RCL. These subsystems control the movement, speed, direction, and rates of acceleration and deceleration of the RCL. They also control peripheral RCL safety devices such as the locomotive horn, bell, headlight, and sanders. Whenever we introduce additional levels of complex technology to a system, we create additional opportunities for technological failure. This chapter discusses reported instances and observations regarding hazards associated with the failure of RCL technology.

5.1 The Safety Record of Conventional Switching Locomotive Technology

Before examining safety issues related to the failure of RCL technology, it is useful to gain some perspective regarding the degree to which the failure of conventional locomotive technology has affected the safety of switching operations. Yard and road switching casualties are responsible for more fatalities among railroad workers than any other kind of work activity, accounting for nearly 44 percent of railroad employee on-duty deaths since 1992. In 1999, FRA formed a task force, known as the Switching Operations Fatality Analysis (SOFA) Task Force, to study this problem and recommend solutions. SOFA examined all of the 128 switching related fatalities that occurred from January 1992 through June of 2004 and 929 switching related serious injuries that occurred from 1997 to 2003, inclusive. Although the SOFA study identified a variety of causal factors for these accidents, there was not a single instance where the failure of a conventional switching locomotive was implicated as either a causal or contributing factor.

When examining the safety of RCL technology, it is useful to remember that the failure of conventional locomotive technology has rarely, if ever, caused or contributed to serious switching accidents. (RCL technology did not begin to come into widespread use until the middle of 2001; thus, the majority of incidents studied by the SOFA Task Force relate to conventional switching operations.) That is not to suggest that conventional locomotives do not succumb to technological failures. Considering that conventional switching locomotives logged more than one billion miles of operations during the years of the SOFA study period and that each locomotive has thousands of moving parts and electrical circuits, conventional switching locomotives do indeed break down. However, because of safety design features of the locomotives and operational safeguards executed by locomotive engineers and other crewmembers, technological failures of conventional switching locomotives have not been a significant factor in switching casualties during the past decade.

5.2 Technological Failures in RCL Control Systems

The reliability of RCL technology is a hot topic among RCL supporters and critics alike. The FRA Interim Report to Congress states.

> FRA is aware of four instances where an RCL failed to reduce speed when commanded to do so. These malfunctions were associated with computer software or wiring errors and have since been corrected. There were no accidents or injuries associated with these failures. (FRA Interim Report - Safety of Remote Control Locomotive Operations p. 7. May 2004.)

Other components of the RCL system found to have failed are the microprocessor chips in the OCC. One of the four overspeed incidents cited in the Interim Report occurred on January 6, 2003 and was attributed to the failure of a microprocessor chip. The incident was reported by the FRA as follows:

> "On January 6, 2003, in Grand Rapids, MI, at approximately 7:35 EST, CSX locomotive 2530 failed to reduce speed when given the proper radio signal from the [MANUFACTURER] device. As a result of the communication failure, CSX 2530 attained 34 MPH before the operator was able to stop the movement of the locomotive."

A railroader reported, for another location,

> “While shoving on a main track, the RCL accelerated out of control, to slightly over twice the speed commanded by the RCO-P. No speed command would cause a response in the RCL. The RCO, finally, used the STOP button to apply the brakes and stop his runaway movement. The RCO learned that the problem was a chip failure for the OCC and its peripheral devices. Such failure-prone chips have been replaced."

A Canadian RCO reported this instance of an RCL system failure:

> "3 cars from joint I put selector lever to couple. I heard units start revving up so I put selector to stop. Units were still increasing in speed so I put units into emergency and stopped approx. 2 feet short of joint."

5.3 Improper Microprocessor Chip Installations

Careful examination of the Human-Machine Interface reveals that some technological failures can be caused by "organizational error." *Organizational error* actually means human error(s) removed from the machine operator at the point of operations. In the following case, it could be, at least, errors of installation personnel and supervisory personnel. Such appears to be the case in another RCL overspeed incident reported by an RCO:

> “an RCL constantly accelerated out of control and did not respond to the RCO's radio commands. Investigation found the cause: incorrect installation of control chips regarding normal and hump operations in the OCC. This misinstallation and consequent uncontrollable speed were not supposed to happen but they did occur. All RCLs at the terminal had the misinstallation.”

FRA also learned of an RCL overspeed incident caused by the improper installation of a speed sensor. The sensor was place on an RCL wheel that was connected to a hand brake. When the RCL received a command from the RCO to accelerate, the brake on the wheel with the sensor became stuck which impeded the rotation of that one wheel. The RCL control system interpreted the slow turning wheel to mean that the entire RCL itself was moving slowly and kept increasing the throttle, causing the RCL to accelerate well beyond its intended speed. The railroad involved corrected the problem.

5.4 Microprocessor Programming Error – Multiple Addressing

Apart from processor chips is the issue of address duplication in the digitally coded telemetry furnishing the control link between an RCD and an RCL. No problems of this kind have surfaced in the present research for RCLs but have for the related and older Distributed Power (DP) operations (see Appendix B. Definitions). A railroader comments regarding DP addressing:

> "This [DP] equipment is manufactured by [supplier name]. There are several layers of security to prevent accidentally linking or controlling one unit with another, including [list of physical safeguards], and ROM chips that are 'supposed' to have a uniquely coded address. About 'X' years ago, two DP trains were departing 'FGH' and one unit started being controlled

> by the other train. Short version of the story is that [the supplier] coded the same address into two separate locomotive units. 'OPA RR' went ballistic and demanded a recheck of each of the units in use, and I seem to recall they found one or two other sets that were duplicated."

Here the technology that is designed to prevent the improper linking of a DP unit to the master locomotive did not function properly because of a programmer's (and a supervisor's?) error. The current generation of RCL technology is designed to allow only one or two RCDs (in the case of pitch and catch operations) to be assigned to a single RCL, and that RCL should only respond to signals from the one or two RCDs to which it has been assigned.

Question: Are RCO claims about unintentional movement of RCL investigated to determine if RCL is receiving foreign signals from a source other than the RCD to which it was most recently assigned?

5.5 Antenna Connection Failure Causes Loss of Pull-Out Protection

Some railroads have installed technology in the certain yard tracks to prevent an RCL from traveling beyond the limits of a track on which it is authorized to operate. This system, known as Electronic Pull-Back Protection (EPP), consists of sensors/transmitters known as “pucks” which are installed on the ties between the rails. The pucks are arranged in sequence at intervals along the tracks. When an RCL passes over the first puck in the sequence, the puck sends a radio signal that commands the RCL to decelerate by one mile per hour. Each succeeding puck commands an additional one mile per hour of deceleration, until the last puck, which stops the RCL. Although EPP is not itself a component of an RCL system, it is used to control the movements of RCLs over a particular section of track. (See Section 9.0 Remote Control Zones.)

An RCO reports about a derailment where a defective antenna on an RCL permitted it to run off the track:

> "A wire connecting the RF antenna beneath the RCL to the OCC was broken or defective. Thus, the RCL went over a PSP [EPP] track without receiving the pucks' track-controlling radio transmissions. That is the RCL could not and did not recognize any of the [safeguarding] pucks."

Such a defect is one in the RCL equipment and not in its sometimes electronically linked EPP.

5.6 Ability of RCO to Mitigate Failures of RCL Technology

In most of the reported instances where a failure of RCL technology resulted in a hazardous condition such as on overspeed, the RCOs were able to detect the problem and safely mitigate it with the use of one of the control mechanisms on the RCD. But this is not always the case as can be seen from the following report by an RCO regarding an incident that occurred in his yard:

> "The Primary-RCO had his RCD in reverser NEUTRAL and speed STOP positions, as required when the Secondary-RCO voice-radioed that he was going between the cars in a cut to couple air hoses. In these two RCD positions, it is supposed to be impossible for the RCL to exert tractive power. Shortly thereafter, but after the Secondary-RCO exited from between the cars, the RCL revved up to the equivalent of a high throttle setting and began shoving the cut of cars. The Primary-RCO had not moved his RCD from the Neutral and STOP positions. The Primary-RCO placed his brake override lever in EMERGENCY position, yet the RCL continued its revved up state and unauthorized shoving of the cut, for about three car lengths. To control completely this RCL, an RCO had to mount the RCL and turn its isolation switch to ISOLATE from RUN position to kill the tractive power."

In the above instance, none of the RCD controls were successful in stopping the uncontrolled movement of the RCL. Fortunately, the RCL was close enough to the RCO and moving slowly enough to allow the RCO to climb onto the RCL and shut it down manually.

A railroader discusses what may be a failure of the conventional technology on an RCL (i.e., failure of a piece of equipment that is present in all locomotives) but the consequences of this technological failure seemed to be affected by the nature of the RCL operations. As is frequently the operation, the RCL and its cars moved from a yard over the main track to an industrial switching area with full public access:

> "Last year at 'ABC', an outside-yard RCO crew was using [RCL] engine '999'. They had been sent to switch an industry that was located some distance from the yard, and the track was slightly uphill. Upon arriving at the industry switch, they stopped and both RCOs got off to line the switch, then walked ahead to open the gate, then walked further to where the cars were. The RCO gave the locomotive a 'come ahead' command, and both RCOs heard the [diesel] engine rev up. After about a minute, they realized that the '999' was rolling backward down the hill. They sent it a 'stop' command, which it did. They again sent a 'come ahead' command, and could see the exhaust come out the stacks, but the unit continued to roll away down the hill. They again stopped it and called the yardmaster, who in turn called the [supplier] help line. [The supplier's] response was that what was happening to the '999' was impossible. As it turns out, the incident was caused because the '999' had stopped loading [powering]. Each time the RCO would issue a 'come ahead' command, the brakes would release, but since the unit wouldn't load, it simply rolled away down the hill. So, do we consider this a failure of the RC technology? Of course not! Was there a collision, a derailment, or an injury? Nope."

Hence the failure of the locomotive equipment was not RCL control equipment. However, if the locomotive had been crewed in a conventional manner with a locomotive engineer on board, the undesired rollaway would not have occurred. Of course, the RCL crew remained in sufficient proximity to control the hazard of the rollaway to prevent an accident from occurring.

Question: If RCOs work outside of their RCL and attend to other duties beside the operation of the locomotive, would they be less likely to prevent failures of RCL technology, including its underlay of conventional components, from resulting in accidents than would their locomotive engineer counterparts?

6.0 RCD Component Failures

The previous section dealt with failures of equipment or components located on board the RCL. This section discusses reported hazards associated with the failure of components contained in the RCD.

6.1 Vigilance Button Stuck in ON Position

The vigilance button on the latest generations of RCDs can serve several purposes. One of those functions is to serve as a check to prevent the RCO from unintentionally initiating the movement of the RCL. When an RCO wishes to initiate the movement of a stopped RCL, he must execute a two-step sequence of commands. First, the vigilance button must be depressed, then, the speed selected. This design procedure is supposed to prevent the RCO from causing the unintentional movement of the RCL by inadvertently moving the speed selector lever.

Another function of the vigilance button is to acknowledge and reset the alerter. Alerters are devices common to both conventional locomotives and RCLs. As the name implies an alerter helps ensure that the RCO (or locomotive engineer) remains alert. If the RCL is not stopped with brakes fully applied and the RCO does not change or adjust the speed settings or the brakes for a set amount of time (many alerters are set to 50 seconds) the alerter sounds an alarm. Once the alerter alarm is sounded, the RCO has a particular number of seconds to push the vigilance button, which will turn off the alarm and reset the alerter. Failure to acknowledge the alerter by pushing the vigilance button within the prescribed time will cause a full service brake application, stopping the RCL. Thus, if the RCO should fall asleep or become incapacitated while the RCL is moving, the alerter is designed for the OCC to take control and stop the movement.

One RCO reported about a tendency of vigilance buttons to become stuck which apparently can be traced to weakness in the design:

> "Now to the design flaw. The vigilance button is a smooth dome-shaped switch, an inch in diameter. The lower portion of the dome is the holding ring by which the button is mounted to the device. The gap between the ring mount and the depressible, functioning part of the switch may become shimmed with dirt or metal shavings. In practice, the result has been that the RCO is in a constant state of 'vigilance'. This means that all movements of the speed controller out of the STOP position (the safety function) are preacknowledged so that unintentional movements are possible. It also means that the alerter function is likewise effectively disabled."

An RCO similarly reported:

> "Vigilance button crammed with crud, thus not recognized by the engine."

Another RCO stated:

> "Regarding the Vigilance Button falling into a permanently depressed state due to debris between the button and its housing, I found some fine dirt fell into the crack around the

> button. The button looked only semi-depressed (not that you would notice) but the Vigilance Alarm was deactivated (it did not sound even after 50 secs of movement). More importantly, the locomotive could be moved by switching from STOP to any other setting without prior use of the Vigilance Button."

An RCO group reported regarding dirt in the depression around the vigilance button:

> "This can definitely happen with [MANUFACTURER] and a permanently depressed state of the vigilance button will allow an accidental movement from Stop if the Speed Lever is bumped."

An RCO reported that the problem of the stuck vigilance button has been given attention by this same manufacturer.

> "A note on the application of sand with [MANUFACTURER] which is done by simultaneously holding down both vigilance buttons: they reprogrammed the boxes, and now there is a stuck vigilance button message which will eventually shut things down. This seems to interfere with the application of sand over an extended period of time."

The question is, what tasks and for what duration can an RCO perform with a stuck vigilance button before the new program "will eventually shut things down"?

6.2 Reverser Unintentionally Goes Into Reverse -- Negating Three-Step Protection

In conventional train operations, the railroads devised a procedure to prevent the engineer from accidentally initiating movement of the locomotive. This procedure is *three-step protection*. Engineers use it whenever anyone is required to work on, under, or between the cars when attached to a locomotive. An engineer establishes three-step protection by 1) fully applying the independent brake, 2) shutting of the generator field (this is electric power produced by the diesel-powered generator which energizes the traction motors that move the locomotive), and 3) placing the reverser in neutral (the reverser selects the direction that a locomotive will move; it can be placed in forward, neutral, and reverse) Once these three precautions have been taken, there is virtually no chance for the locomotive engineer to cause the locomotive to move through the inadvertent manipulation of the throttle. However, RCDs are not equipped with a Generator Field Switch. The generator field is automatically turned on and off when the reverser is placed in run (either forward or reverse) or neutral, respectively.

An RCO reports:

> "Thought you'd be interested in the observations of many box users here that the RCTs [RCDs] are starting to show their age. Besides looking beat up, we are starting to see failing switches, loose levers, and sticking vigilance buttons. The box I turned in several weeks ago because the reverser switch was going into REVERSE without being actually switched, only bumped, may have reappeared on the job I worked yesterday. This box had a problem with the same switch only it had gotten worse. It would go into forward or reverse with a bump but it was a struggle to cajole it into neutral."

Another RCO makes a similar finding:

> "The 3-step setup for disaster illustrated above is surely remote and unlikely to happen. Or is it? I recently worked with an RCT [RCD] that had a defective REVERSER switch. I finally noticed that the box would switch itself into reverse without actually moving the switch out of the centered position. A mere bump was enough to do this"

Thus, when the reverser unintentionally moves out of neutral, two of the three steps in three-step protection are negated. If this condition were to happen simultaneously with the stuck vigilance button described above, it could quite easily lead to the accidental movement of the RCL. It is significant to note that a number of RCO's have reported instances where the RCL moved unexpectedly. (See Section 10.10.)

An RCO reported one such incident as follows:

> "A brother who was working recently on an RCL assignment reported the following: He was the primary operator and wrongly agreed to help a utility man by attaching an EOT [End-of-Train Device] to the end of a train he had doubled up. The train had neither locomotive attached nor crew assigned. His RCL was on the same track, behind him and separated by the required distance. In the process of wrestling with the EOT to attach it, he apparently moved the REVERSER switch out of neutral, pressed a vigilance button, and moved the speed control lever. He happened to look back in time and saw his locomotive moving slowly toward him. (Or could the reverser have slipped out of neutral and into reverse unnoticed?)"

6.3 RCD Malfunctions Causing Unintended Stops

There are reports of frequent unintentional full service braking of RCLs because the RCD is "worn out" and presumed to lose its ability to communicate with the RCL, specifically, its OCC. An RCO says:

> "The other day another [worn] box was decommissioned because it was causing COMM LOSSES."

A full service brake application is automatically initiated when a communication loss between the RCD and the OCC occurs. Although the automatic brake application is designed to be a safeguard, there are times when it can be a hazard. (See Section 8.0. RCL Safety Features That Can Cause Hazards.)

7.0 System Design Issues

A number of RCOs commented about various design features of their RCL systems. Some of the commenters reported problems with design feature not functioning as intended. Other reports involve design features introducing hazards into the RCL system when operating as intended.

7.1 Temporary Tilt Extension Allows Primary RCO to Move RCL while Secondary RCO Is Working under Equipment

RCDs have a Tilt Feature which detects when the RCD is tilted beyond 45 degrees for more than a few seconds and sounds an alarm for ten seconds. If the RCO does not right the RCD within those ten seconds, an emergency brake application is automatically initiated which stops the RCL movement. The purpose of this feature is to prevent one RCO from moving rolling equipment while another RCO is working on or under the cars. However, the RCDs also have a Tilt Extension feature which, if activated allows the RCD to be tilted for up to 50 seconds before the automatic brake application is initiated. The RCL designers intended the Tilt Extension to allow RCOs to perform incidental switching tasks such as bending over to throw a switch or derail without bringing the RCL movement to a stop. If the Tilt Extension is engaged, a Secondary RCO can work in between or under cars, e.g., coupling an air hose, while the Primary RCO can continue to move the RCL. This creates a hazard for the Secondary RCO.

As a group of RCOs responded on this matter:

> "Using [MANUFACTURER] equipment, the Primary Operator can Tilt-Extend and then initiate movement from Stop. Similarly, the Secondary Operator can Tilt-Extend (while Stopped) and then the Primary can initiate movement." Another RCO concurs: "Yes. This operation is permitted with [MANUFACTURER] Beltpack & I use it routinely."

Another RCO reported regarding moving an RCL while one of its crewmembers is under tilt protection:

> "Yes this is possible. It is part of the design. Operators [RCOs] need to know what the tilt extend function does and does not do. It's not there to provide protection. It's function is to facilitate your work by REMOVING your protection."

A third RCO declared:

> "As primary RCO, I gave myself a tilt extension, and, since I completed my task before the 50 second extension expired, and since I was eager to accomplish as much as possible within the constraints they have imposed on us, I initiated movement of the train while I was still in tilt extend. There was no other way. We have not been given any way to re-enable the tilt protection feature before the extension times out. During that time between commencing to move and the automatic re-establishment of tilt protection, I was at the mercy of the RCL system and of myself. There is no specific 'generator field' switch on the box [RCD] to eliminate the possibility of tractive force and movement and to provide the recommended '3 step protection' that the FRA talks about in their guidelines."

This RCO expressed a similar concern:

> "This seems a gray area that they [officers] are reluctant to visit. Common sense dictates that the man in the red zone must have some kind of protection. Yet, the original 'bug' in the system that permits a secondary operator to extend his tilt time while the primary moves the loco (not fixed because local management viewed this as a bonus feature) is still with us. They want the

> primary to be able to operate while the secondary is coupling air on another track. But perhaps he's in harms way on the track that the primary is moving."

7.2 Three-Step Protection Reduced to Two-Step Protection Because Generator Field Works Simultaneously with Reverser

This issue was touched upon in section 6.2 in the discussion of the hazards associated with the unintentional movement of the reverser switch. Here we consider the appropriateness of the design feature that combines the reverser lever and generator field switch into a single control lever on the RCD. As was noted previously, with personnel working around a stopped conventional locomotive and any attached cars, a three-step stop safeguard is required on many roads: generator field switch in OFF (down) position, reverse lever in NEUTRAL position, and independent air brake valve handle in full independent application position plus an automatic brake application if necessary. Of course, the throttle is in IDLE position. Some RCOs have expressed concern about whether they can provide three-step protection in RCL operations because RCL designers combined into one device the reverser control and generator field switch.

As an RCO explains, in RCL operations:

> “The generator field switch in the [RCL] cab must be set to OFF. The box [RCD], however, has no switch or other feature that lets you ‘take things off line’ [isolate the electrical tractive power] and prevent the application of motive force.”

It appears that the three-step protection has been reduced to two steps, since only two operations by the RCO are needed to establish this protection. As noted previously if the reverser level becomes defective, the direction selector could be "bumped" from a NEUTRAL to a FORWARD or REVERSE position, thereby simultaneously losing two of the three steps of protection with one error of commission.

As one RCO put it:

> "The 3-step setup for disaster illustrated above is surely remote and unlikely to happen. Or is it? I recently worked with an RCT [RCD] that had a defective REVERSER switch. I finally noticed that the box would switch itself into reverse without actually moving the switch out of the centered position. A mere bump was enough to do this."

Question: If three-step protection is deemed a necessary safeguard in conventional switching operations, what, if anything, about RCL switching operations renders it unnecessary? Should RCDs be equipped with separate reverser levers and generator field controls?

7.3 Coast to Speed Negates Two-Step Process to Initiate RCL Movement

As noted in section 6.1, the RCD is designed to prevent unintentional RCL movement from stop to go by means of a vigilance button. The RCO must first press the vigilance button before a second action to initiate any movement from STOP. An RCO, however, can go to COAST mode and coast to a complete stop (against the resistance of grade, track, or rolling equipment), remain there for a while and then move the Speed Control lever only (without any vigilance button precursor) and start moving. This movement could be intentionally or unintentionally triggered. Here the RCL safeguard of requiring two separate control manipulations on the RCD to begin an RCL movement is negated. Hazards associated with this feature explained in the following comments from a group of RCOs:

> "This is still true, within the limits of the VIGILANCE timeout feature. We take advantage of this all the time. A conscious circumvention of an intended safety feature. Why would we do such a crazy thing. Because the boxes [RCDs] are driving us crazy. Seriously. . . . Anyway, the point of this long-winded story is to convince you that people have become so frustrated with the box telling them that they failed to do what they know they did, and having to do the same thing over again to get the locomotive to move, that they are willing to take the shortcut of STOPPING THE LOCOMOTIVE WITH COAST/B when they have to throw a [track] switch or adjust a knuckle or remove and EOT [End-of-Train Device], knowing that they will have to move again shortly. Unsafe? Absolutely. Human nature? Of course."

An RCO explains a variation on the above COAST stop:

> "RCOs are, however, innovative. I worked with [name] yesterday who taught me a new trick. While flat switching, after kicking some cars he would stop, not by moving the SPEED CONTROL to STOP, but by moving it to COAST while applying FULL INDEPENDENT BRAKE. Then, while in the state discussed recently (stopped but able to initiate movement without use of the VIGILANCE BUTTON), he would enter his RED ZONE to open the knuckle or possibly adjust the drawbar of the car to be kicked next. His next kick was performed by first moving the SPEED CONTROL lever to 10MPH in order to build up some amps and then releasing the INDEPENDENT BRAKE. This clever but potentially dangerous practice accomplished at least two things. First, it avoided the problem with system mistakenly telling you that you had failed to utilize the VIGILANCE BUTTON. Second, it resulted in a brisk kick that avoided 'sawing' the switch. This is also a guy who has very strong beliefs about everything and doesn't take criticism or suggestions well. I reminded him of the story of the brother who almost coupled himself up while removing an EOT. He had stopped by using the COAST/B setting."

A third RCO notes yet another variation:

> "There are techniques not taught in RCO training that can speed up the work, if that is the operator's aim. My own preference is not to use the independent brake feature at all. I control speed by placing the speed selector in full stop position, then quickly changing to another speed (without touching the vigilance button) before the movement has come to a complete stop. The technology allows this."

This RCO sums up quite simply the hazard of moving the RCL without the vigilance feature:

> ". . . there is one scenario where an RCO could be stopped, think he was stopped, and yet unintentionally bump a lever and move, without reference to the vigilance button (at least for the duration of its 50-second cycle)."

A railroader reports a slightly different scenario where an RCL temporarily stops because it couples into a cut of standing cars that have their brakes applied. In this instance, it could be possible for the RCO to forget to place the RCD in STOP. An RCO describes the scenario as follows:

> "And if the operator is not aware of the locomotive's response to changing load, it could result in a personal injury or fatality. For example, let's assume an operator couples into a cut of three cars that have air or handbrakes applied. The movement stops, and the operator forgets to place the speed selector lever in stop position before going between the cars to release a handbrake or adjust a drawbar. At some point, one of several things will happen: In 50 seconds, the alertness monitor will begin to sound, and in 10 more seconds, it will stop the movement. Within that 50-second window, the amperage on the locomotive will continue to build until the unit is able to move the cut of cars, possibly running over the operator in the process. At least one of the system vendors, [supplier], had a software check that would unload the unit if it did not move within 30 seconds, however I think that check may have been removed."

7.4 Reduced Braking Capacity to Prevent Wheel Sliding

Some railroads have reduced the braking capacity of the RCL brakes by as much as fifty percent to prevent the formation of rail-pounding flat spots on locomotive wheels. The automated intermittent braking initiated by the OCC attempting to maintain a constant speed can cause the wheels to slide. Lowering the braking capacity minimizes the tendency of the wheels to lock up and slide along the rail surface. Reducing the maximum available air pressure in the brake cylinder or eliminating one of the two brake shoes mounted on each wheel of the RCL are methods employed to accomplish this reduction of braking capacity.

There are no known instances where this practice of intentionally reducing braking capacity has led directly to an RCL accident. Insufficient braking capacity has been reported to result in an RCL collision that caused two tank cars to rupture and burst into flames.

An RCO reported this accident where he believed that the braking capacity of the RCL was insufficient to handle the weight of the train:

> “The two RCOs of an RCL-powered cut of 20 cars could not stop their movement. Their cut collided with two standing tank cars carrying hazardous chemical loads, which consequently burst into flame. Authorities evacuated some 140 neighboring residents from their houses in pre-dawn hours but allowed them to return in about four hours. Local employees think that the weight of the cut exceeded the braking capacity of the independent brakes of the RCL."

Another railroader reported that soon after this accident, the railroad changed its rules regarding the weight handled by the local RCLs, thereby insinuating that insufficient braking capacity of the RCL was indeed a causal factor in the accident. He commented:

> "[The railroad] has revised its weight rules for the locomotives that were used as RCLs." Did [the railroad] do this for conventional operations as well? Why did the [railroad] not discover this safety problem with many years of conventional use of the same locomotives with the same cuts of cars?"

Another railroader thought that, the RCOs did not have a "seat-of-the-pants feel" (a kinesthetic sensation) from their handling of the heavy movement.

7.5 Dial-in Speed Systems Can Cause Excessive Slack Action Because of Constantly Alternating Throttle and Brake Actuation

The latest generations of RCDs are not equipped with a graduated throttle control and graduated independent brake control. Instead, they are Dial-In Speed systems where the RCO merely selects a speed setting. Then, the OCC automatically controls the RCL's throttle and brakes to achieve and maintain that speed. However, the automated OCC can only make decisions for which it is designed; it cannot exercise judgment or respond to conditions that were not anticipated by its designers.

As the following comments illustrate, maintaining the speed of a train is as much an art as it is a prescribed sequence. Frequent actuation of the brakes and throttle by the OCC can cause the cars in the train to lurch frequently forward and back. This motion is referred to as "slack action" and can become severe enough to be hazardous to crew members and the rolling equipment itself.

Regarding the OCC's autonomous mixing of braking and throttling to maintain automatically a set speed, an RCO notes:

> "The 'hunting' behavior while the RCL attempts to maintain a constant speed is still a problem with some consists. This is still resulting in slack action that is sometimes violent. The computer applies unnecessarily extreme correction measures in an attempt to maintain a constant speed."

A railroader comments regarding the slack action caused autonomously by the OCC's operation of the RCL (which operated as designed):

> "While [the RCO is] riding a cut of cars, the computer without operator knowledge goes into 'fail-safe' mode causing the slack to jettison the RCL operator from the end car. The report stated that the equipment operated as intended, it was 'human error somewhere."

One RCO reports:

> "Slack action occurs more often due to the constant [OCC-controlled] brake application and release just to maintain speed, rather than simply using throttle modulation."

This unanticipated slack action can be severe enough to pull out a car's drawbar from its housing. Such drawbar is designed pull 20,000 or more trailing tons with normal slack action in a train. As a group of RCOs explained:

> "We had a discussion about the way our current RCLs were operating (a whole lot of [unanticipated] lurching and jerking going on) the day RCL job [name] managed to rip out a drawbar while switching."

Similarly, another RCO reported regarding autonomous brake application and resultant slack action:

> "By the way, the afternoon RCL switch job got a [broken coupler] knuckle [while] switching."

Thus, the unanticipated slack action can be quite severe.

Another RCO wrote:

> "If you're riding the rear of a cut of cars and protecting your shove it can get quite bouncy."

Reporting what he thinks is the greatest RCL hazard this RCO said:

> "Riding cars due to excessive slack action associated with RCLs."

A railroader summarizes regarding some aspects of OCC autonomous control:

> "The software simply cannot anticipate grades or adjust to changing conditions as well as a human can. Speed regulation is specified at plus or minus 1 mph, however in reality, 3-4 mph variations are common. At times, the locomotive will seem to be unresponsive to commands sent from the OCU or Beltpack [RCD]. In the incidents I am familiar with, this was the result of either a comm loss or the locomotive attempting to adjust to an increased load."

An RCO comments:

> "You can't teach a computer about the minor dip in the tracks that causes the slack to run in."

An RCO group reports:

> "Unexpected slack action is still a problem. This takes you back to the problem of whether a 3-point stance is sufficient to ensure safety in a context of unexpected slack action. In the days of manned cabooses, locomotive engineers were certainly sensitive to conductor's complaints about train handling, and in the context of switching operations, engineers were certainly sensitive to complaints from crew members who had to ride the side of cars for any distance. The RCR [OCC] doesn't care what is happening at the hind end of a cut of cars it is pulling or shoving. (In case we didn't report this already, the car department here has been complaining about the increasing number of BO's [bad orders--damaged cars] involving damaged drawbars and couplers, etc. since the onset of RCOs. Is this an objective measure of the manner in which these RCLs are handling the cars?)"

Surges occur in ordinary RCL operations, as an RCO reports:

> "Also, the [RCL] units do not react as smoothly, or quickly, as an engineer. They also regulate their speed in a very poor/inefficient manner. They surge on the throttle, then apply the independents, then surge again."

Echoing the sentiments expressed by many others, this RCO observes:

> "The RCL creates a lot of slack in the train. It starts in Notch 2 and when it gets to the right speed, it jams on the brakes. Notch 2, jam. Notch 2, jam. Notch 2, jam. A person can get seasick from this."

7.6 Dial-in Speed RCL Systems Can Pull Train Apart if Initial Speed Selection Is Too High

An RCL-involved derailment and consequent pair of collisions were reported to have occurred on December 26, 2002, at BNSF, Galesburg, IL:

> "an RCO pulled train while switching over the hump causing cars to roll down hump into a cut of cars, derailing fourteen cars. These derailed cars went into the side of a coal train on an adjacent track derailing three cars in that train. The cause of the derailment was determined to be human error. The RCO used too much power to pull the train. He put the speed control to 10 MPH, instead of gradually increasing the speed as the cut of cars began to move."

Regarding this same accident, a railroader observed:

> "An RCO moved his speed control to 10 mph, instead of taking the slack and gradually increasing the speed of his cut [of cars]. Using poor judgment and too much throttle [power], the RCO broke his cut in two. The uncoupled cars rolled away and collided with standing cars and shoved some of these into the side of a standing train."

Here we see that the RC system does not function automatically at the push of a control on the RCD. Instead, in using these controls, the RCO must use train handling skills and judgments, in accordance with the changing circumstances of the operating environment.

More such examples could be given.

However, some RCOs have become quite accomplished at modulating the speed and braking of their RCLs.

One RCO explains:

> "We still operate like this [adjusting the controls on the RCD] as it is the only way to achieve speeds that fall between the gaps in the fixed settings. It is also necessary to deal with the still existing problem of hunting that results in quite a variation in speed under certain conditions (e.g., light power or handling only a few cars) and with certain locomotive consists. And the few given choices in speed settings are insufficient to cover all circumstances. Thus we often toggle quickly and frequently between adjacent settings in order to maintain some intermediate speed. By listening to what the locomotive is doing one can be quite precise in this mode of speed control. Sometimes the Coast with Brake setting is too slow to affect a speed reduction and you have to go to the Independent Brake to get quicker results. When you are moving tonnage with train air it is often helpful to utilize the Automatic Brake to control speed. Or a combination of Automatic and Independent braking (you gotta be quick to avoid that pesky Brake Dragging message)."

Clearly, an RCO operating his RCL via an RCD requires substantial skill and experience. RCL operations do not constitute a fully automated system of train handling under the control of the OCC.

An RCO concludes:

> “Anyone is dead right when he rebuts the railroad propaganda that this [RCL] technology is mere signal-passing. Train handling means knowing the inertial forces working on your train and your train's braking capabilities, knowledge engineers gain with much more complete training and experience.”

Question: Can better training in techniques to modulate RCL speed and more experience help to control this hazard?

7.7 Limitations on the Use of Independent Brake and Automatic Brake

Train braking is accomplished by two different compressed air braking systems, the Independent Brake system and the Automatic Brake system (also know as the Train Brake). Independent brake systems operate only the brakes on the locomotive itself, and the automatic brake system applies the brakes on each car and the locomotive. Conventional locomotives have both kinds of brake systems and engineers can use each brake system separately or together, depending on the circumstances.

With independent braking, only the locomotive brakes apply to retard any coupled cars, so the total braking capacity is less than that of the automatic brake system. However, if the operator (locomotive engineer or RCO) knows the limitations of his rolling equipment’s braking capacity, the weight of the consist, and the effects of other factors influencing braking ability (such as track gradient, rolling resistance, rail surface conditions, and other factors) and operates within those limits, safe braking can be accomplished by using the Independent Brake alone. When the operator does not properly understand and operate within these limitations, the use of the Independent Brake alone can pose a hazard. Of course, this hazard is not limited to RCL operations, but it must be considered in a discussion of RCL hazards because most RCOs do not have the level of training and experience of conventional locomotive engineers. (See Section 12.0 Training and Experience.)

Furthermore, some RCL systems are designed to prohibit the use of independent brakes when the automatic brake system is used. This system can result in a reduction of braking capacity and further limit the degree of finesse that an RCO can use to control the speed of the RCL.

One manufacturer’s manual reads:

> "Whenever train brakes are applied the locomotive brake portion of the train brake application is automatically bailed off."

In conventional operations, the engineer has the option to allow the independent (locomotive) brake to both apply and release to varying amounts at his or her judgment.

Not every RCL has automatic air brakes cut in, as an RCO explains:

> “There is no control of the brake pipe in the cars (at least at [terminal name]). You brake with independent engine brake power only. I'm told that there are belt packs [RCDs] that allow trainline control of the brakes but they are not used here yet.”

An RCO notes regarding the limitations of independent air brakes alone on a heavy RCL cut:

> "The only way to stop quickly is to put the engine into emergency brake application via the belt pack. If you have a draft of cars that are mostly loads you might not stop in a timely fashion."

Furthermore, without an operable Automatic Brake System the train has no emergency braking capacity. The independent brakes on the RCL can be applied fully, however, when the automatic brake lever on an RCD is activated, even though the air brakes are not cut in on the attached cars.

7.8 Lack of Gauges for Automatic Brake System

RCDs are not equipped with the air brake gauges that are present in conventional locomotives; therefore, RCOs are deprived of air brake information allowing locomotive engineers to exercise finer degrees of control over the air brake systems on conventional locomotives. The gauges indicate brake pipe, equalizing reservoir, main reservoir, and brake cylinder pressures and sometimes a brake pipe flow indicator. (This last indicator provides information about the flow of air in the automatic brake system.) When moving a long, heavy train with the Automatic Brakes cut in and in use, the RCO cannot monitor the air pressure in the various brake system component with a simple glance at a dial as can his engineer counterpart. Some RCL proponents, including RCL designers, claim that with dial-in speed systems, the only time the RCO needs to operate the Automatic Brakes is to make an emergency stop. Many RCOs in the field have a quite different experience. They find that the OCC is not capable of recognizing all the complexities involved in controlling the speed of a heavy train.

An RCO put it this way:

> "the consequences of ceding braking decisions to the RCL computer, for example on a grade where the choice may be to reserve braking capability rather than regulate for a particular set speed."

See Section 7.5 for further discussion of the consequences relying on the OCC to control speed.

7.9 Automatic Brake Control Lever Can Be Moved Accidentally

Some RCOs report that the automatic brake control lever on some RCDs can be moved unintentionally, which could cause the train to stop abruptly, creating excessive slack action. A group of RCOs noted that:

> "The train brake lever on the side of the box [RCD] can be unintentionally pushed into EMERGENCY application because there is no resistance [indent] between FULL SERVICE and EMERGENCY as with a real automatic brake valve."

Other RCDs are designed to require a specific operation of an emergency brake lever to initiate an emergency stop.

8.0 RCL Safety Features That Can Cause Hazards

The latest generations of RCL systems have a variety of features designed to detect operational anomalies or conditions that can pose a hazard to RCL crews or movements. When the system detects such conditions the OCC, then, autonomously acts immediately to stop the movement of the RCL. Intended to safeguard RCL crews and rolling equipment, these features initiate emergency stops or full service brake applications. Unfortunately, times exist when abruptly stopping the movement of a train can itself cause hazards.

There are a large number of conditions which can trigger an emergency or full service brake application that brings an RCL controlled train to an abrupt stop. For example, activation of the previously mentioned Tilt Feature, failure to respond to an alerter alarm, loss of the communication signal between the RCD and the OCC, and improper execution to the pitch and catch between two RCOs are some of the conditions that will cause the RCL system to shut down and stop autonomously. Appendix H has a fuller listing of these conditions in operational contexts.

One of the hazards of stopping rolling equipment abruptly is that it can cause severe slack action. *Slack* is a term used to describe the unrestrained free motion of the cars in a train. If the cars bunch together or compress, the slack action is *Run-In* and the forces are *Buff* forces. If the cars stretch apart from one another, the slack is *Run-Out* and the forces are *Draft* forces.

If a locomotive suddenly brakes heavily while pulling a long cut of cars, Draft suddenly becomes Buff. The slack run-in has a potential to jackknife or derail the cars because of high Buff forces and, perhaps additionally, coupler angularity. Varying combinations of heavy and light cars can exacerbate the dynamics of slack run-in. Employees riding on cars can become dislodged because of the sudden high buff force.

If a locomotive abruptly brakes heavily while shoving a long cut of cars, Buff suddenly becomes Draft. Severe slack run-out has a potential to derail the cars or break apart the cut of cars because of high Draft forces. Sudden high Draft or Buff forces can dislodge employees riding on cars. Even relatively modest slack action has thrown RCOs from the sides of cars on which they were riding. This autonomous slack action could throw RCOs underneath or into the path of rolling equipment.

8.1 Emergency Stops and Full Service Brake Applications That Throw Trainmen off Cars

A railroader comments on a communications loss between the RCD and OCC that caused the OCC to apply abruptly the brakes causing a serious injury to train crewmember:

> "Another incident in 'VBN' caused broken ribs and lacerations when a helper [switchman] who was riding the point of a long cut of cars experienced a comm break. The [RC] locomotive responded as it had been programmed, and applied full independent and automatic brake. When the slack ran out, the helper was thrown from the end of the cars."

Another RCO reports a similar accident as follows:

> "There was a recent RCL accident on the 'RTU RR' involving an inexperienced RCO riding a '99' car shove and being thrown off when the air dumped [air brakes went into an autonomous emergency application]. Let's see. What does that beeping mean? What do I have to do to recover - oooops. Too late."

A third RCO reported regarding an OCC's autonomous stop:

> "One incident at 'XXX' (making a cut on the Main Line and attempting to shove about 40 cars into the yard) and another at the 'YYY' (shoving about 35 cars into the yard from the Main Line) resulted in both individuals being almost thrown off the hind car when the train suddenly stopped and they were unexpectedly exposed to the slack action."

How often can these unexpectedly abrupt stops occur, according to one RCO, quite frequently:

> "The cold weather has brought back the COMM LOSS which now can occur 10 times, 3 times, or not at all during a shift."

An RCO discusses the autonomous brake applications of the OCC, in a location where it is unwise to stop, as follows”

> "our problems with communication losses (or other reasons) for a sudden and unrequested shutdown of the RCL while in the middle of a movement. We still maintain that there are situations in rail operations where you do not want to stop but want to move as quickly as possible. If you are on the ground and in a safe position this is not a big problem. If you are riding a shove (controlling or not) or pulling out a cut of cars the only warning you get is a beeping alert and a visual cue from the box before the slack runs in or out. This can happen quickly and abruptly depending on the cars in question, the locomotive consist (they still behave differently) and whether you are using train [automatic] air."

The current generations of RCDs provide warning alerts or send voice-radio messages intended to warn RCL crew members that an emergency or full service stop is occurring. Do these alerts not forewarn and simultaneously protect? The answer is not that simple. The alert protection can be elusive.

An RCO group discusses this design issue:

> "Once again it's the matter of theoretical v. actual. I am sure that [MANUFACTURER] (or [ANOTHER MANUFACTURER]) engineers feel that they have designed away the problem in the vacuum of their own laboratories. But in the real world, there sometimes exists an embarrassing time lag between what's happening on the box [RCD] and what's happening with the RCL. You might be in the middle of a [task] before you get the alert. Then there is the problem of what do you do when the alert arrives. Do you immediately hunker down in preparation for the slack action or do you take the time to look down at your box in order to read and process and react to the LED display's message? What will you be doing when the slack runs out? It's easy to say that we are being alerted to this in a timely fashion but our

> experience has been that the stop can arrive suddenly and that people have complained about being severely jostled because of it."

Another RCO opines:

> "During a comm loss, the unit will not receive or respond to a command for up to 5 seconds. If a crew is attempting to spot an industry track, this may be an excessive amount of time to be out of touch with the locomotive. And if the operator is not aware of the locomotive's response to changing load, it could result in a personal injury or fatality."

8.2 Rollaway Caused by Inadvertent Stop on a Grade

A railroader comments regarding another autonomous penalty brake application by the OCC, with RCL equipment functioning as designed:

> "'HIJ' yard job [number and location] was shoving a cut of cars eastbound when the remote control operator lost communication with the locomotive causing it to go into emergency. The train then suffered a broken knuckle on [an] east car, allowing those cars to roll away and into the path of [a] train. The derailment left seven cars on each train derailed, including two empty hazardous materials cars on their sides."

The condition that caused this accident can be described as a latent hazard. The safety feature of this technology functioned as intended: unfortunately, under these circumstances, the technology caused the accident. Describing this accident as one not caused by the RCL technology is a matter of wordplay.

8.3 Inadvertent Stop While Dropping Cars Causes Collision with RCL

One technique frequently used to switch railcars is a "drop." To drop a car, the locomotive begins to pull the car; then, a crewmember pulls the cut lever to separate the rolling car from the locomotive. At that point, the locomotive accelerates to distance itself from the car. The locomotive, then, passes a track switch. Once it clears the switch, a crewmember immediately throws the switch to divert the following car onto the diverging track. In the following instance, an RCL condition occurred triggering the OCC to safety-stop the RCL, thereby causing the cars being dropped to hit the RCL. Here the fail-safe subsystem had actually operated to "fail-unsafely." See Appendix B. Definitions, Fail-safe.

As an RCO commented on this autonomously-stopped, "fail-safe" drop:

"The RCL lost radio-signal continuity, which results in either a Penalty or Emergency air brake application. Unfortunately, at that moment they were in the process of making a Drop. So, the RCL did what it's supposed to do [with radio-signal fault] - IMMEDIATELY STOP - which in this case was a rather poor automation choice."

In other words, the RCO says that the OCC, in its inexorable, autonomous logic, made a hazardous decision, as designed.

Another RCO comments regarding an undesired autonomous stop:

"There are times when dead in the water is the last thing you want to be. There are many recollections of incidents where an alert engineer was able to go fast and escape disaster. Cars rolling back out of tracks to foul the lead, unexpectedly meeting a train coming at you, racing to catch a car that got loose down the wrong track."

Hazards that can result from undesired autonomous stops include halting: on a grade crossing, in the area of a fire, near a hazardous material spill or other hazardous event, when in the path of uncontrolled runaway car(s), and when not in the clear of an approaching train movement.

8.4 Disabling the Tilt Feature – Reduce One Hazard, Intensify Another

To prevent inadvertent RCL brake applications caused by the activation of the Tilt Feature, or by an unforeseen communications loss between the RCD and the RCL, some RCOs have resorted to the practice of removing or shutting down the RCD while working on, under or around the railroad cars. If an RCO removes an RCD from his body for any reason such as cleaning a switch or removing debris from underfoot, this nullifies the protection afforded by the Tilt feature. This practice has been prohibited by most railroads and is discouraged in the FRA safety guidelines. However, recently some RCDs have been equipped with a feature that allows the RCO to disable the Tilt Feature whenever he or she pleases.

An RCO group reported, regarding an RCO working without his RCD on his body:

> "People who have to couple air on a whole track will take the box [RCD] off and leave it on the locomotive. Of course, if they encounter a situation where the cars have to be moved they must radio the Primary Operator and command him to perform the required task."

An RCO group reports:

> "Some here have begun to take regular breaks where they remove the vest and box [RCD] for awhile."

Regarding this extra-rules practice, an RCO informs:

> “It was clearly indicated to us during our [RCL] training that misuse of the vest/harness in such a fashion would be construed as a decertifiable offense, namely the disabling of a safety feature. I find this rather disingenuous when compared to the perfectly ‘legal’ disabling of the feature for 60 seconds at a time with no way to re-enable it without waiting for the extension to time out.”

Apparently not all railroads or RCL system manufacturers continue to view the protections provide by the Tilt Feature as a necessary safeguard. A recent kind of RCD allows one RCO to disable his RCDs while the other RCO continues to switch the RCL and its consist.

An RCO reports a conversation regarding this feature with another RCO:

> "He claims that in Denver they have been using the [MANUFACTURER] RCO equipment and have had the ability to DISMISS and turn one of the boxes off from the beginning. He mentioned the problem of the secondary [RCO] traveling too far from the RCL and

> provoking a lost communication shut down that requires him to walk back to the RCL in order to recover." Furthermore: "He also said that our Denver brothers were in the habit of moving the RCL around and working with it while the secondary was wandering around with his dead box."

This RCO comments on the previous paragraph:

> "This makes some sense as part of the [local] rule change directly addressed that problem and stressed the importance of keeping the DISMISSED box turned off while in STANDBY mode, apparently to allow recovery once the secondary operator was once again within range, not necessarily all the way back to the RCL."

Another RCO views the practice of turning off one of the RCDs as problematic:

> "The most interesting mode has to do with Secondary Operator Dismissal, a procedure that allows the Secondary to turn off his box and work without man-down or vigilance protection for extended periods of time. It effectively transforms the system from 2-box mode to 1-box mode and back again without having to relink in the cab of the locomotive. We are not sure who asked for this mode and what they intend its use to be. . . . This seems a step back, safety-wise."

Regarding the secondary operator dismissal operations, an RCO asks:

> "But the most important question and concern of all is whether this change introduces new risks to the operators. Given the agonizing that the FRA went through in their RCL GUIDELINES with respect to the design and implementation of a TILT indicator, a MAN-DOWN alert and the limited ability of an operator to give himself a TIME EXTENSION before the MAN-DOWN alarm is transmitted, how is this new ability to effectively turn off this protection for an unlimited amount of time justified?"

This RCO continues:

> "When we were being RCO trained we were told that leaving the OCU unhooked from our VEST at the bottom, in order to be able to bend over without setting off the alarm, was the equivalent of tampering with a safety device and a de-certifiable offense. In fact, at the beginning of Terminal implementation of RCO, when the trainers and safety captains and the first RCO class discovered that a secondary operator could give himself a TIME EXTENSION of the TILT feature and be merrily bending over working in various [fouling zones] while the primary operator was moving the locomotive, this was viewed as a serious SAFETY problem and the system was reprogrammed to prevent it. The later software modification that allowed both operators to TILT-extend at the same time still deactivated both TIME EXTENTIONS once movement was initiated. Since the beginning of the RCO experiment in the [location] it has been considered UNSAFE to allow any modification of the original TILT TIMEOUT period or to allow such a TIMEOUT while the RCL was moving. With this new modification we will have the ability to completely remove this very important protection for the secondary operator who may be required to operate in his own [fouling zone] while his locomotive is moving. Otherwise, what is the point of this change?"

The hazards associated with having one RCO on a two-person RCL crew disable his RCD are replicated in the practice of having only one RCD assigned to multi-person RCL crew. The practice described by this RCO was confirmed by a number of others:

> “Mr. [officer] seemed surprised to learn that they are running jobs with one Box-[RCD] equipped man and one without. He either didn't understand or pretended not to understand the matter of the still present voice communication link that has not been eliminated but simply transposed to other individuals and other locations. They are also now resorting to running flat switching and industry jobs with one box. One man only.”

A group of RCOs commented on an accident that resulted in an amputation to a utility employee who was working with an RCL crew but was not wearing an RCD:

> "Inside sources reveal that the brother was working as a utility man and was on the same track as an RCL assignment at the time of his injury. We think this speaks to the problem of one-man RCL jobs, one and two-man RCL jobs utilizing a non-RCL helper who may not even be RCL qualified, and the recent proposal in some places to allow the secondary RCO to DISMISS his box and turn it off for an indefinite amount of time, thereby deactivating all the safety features that were originally engineered into the system. As inconvenient and annoying as it is to wear the box all day, at least if you get into trouble and fall down, things will soon come to a halt, alerting your partner that something is wrong."

Question: Did the railroad or RCL equipment manufacturer formally assess the risks associated with conducting RCL operations with and without the protections afforded by the Tilt Feature and the fail-safe stop in response to a communications loss? Or was the design change instituted to promote the speed and efficiency of RCL switching operations? Furthermore, has any risk assessment been done by any party regarding a one-person RCL crew?

9.0 Remote Control Zone (RCZ) Issues

A Remote Control Zone (RCZ) is a section of track usually in a yard having RCL operations under special rules and procedures designed to protect against the intrusion into the RCZ of other operating crews, other employees, or contractors. In most cases, when an RCL is operating in an RCZ, its crew is not required to provide point protection (*point protection* is the practice of having a crewmember stationed at the end of the rolling equipment, or point, to observe the tracks are not obstructed and that switches are properly lined). However, some carriers' rules stipulate that the RCO is relieved of providing point protection when pulling a cut of cars. Most RCL rules include the requirement that a "Remote Control Area" be published in the timetable, and within this area a "Remote Control Zone" can be voice activated by an RCL crew. Appropriate signage in the field and special instructions designate the tracks of an RCZ. If a carrier does not establish an RCZ, then all RCL movements must have point protection. In short, a RCZ provides protection on a segment of track by prohibiting an engine, train, on-track equipment, or person to occupy or foul that track without permission from the employee, usually the RCO who has been designated to control the RCZ. After authorization for occupying or fouling the track, the involved RCOs must protect against such entry until it reports that it is in the clear of the RCZ.

Before activating an RCZ, the RCL crew inspects the tracks of the zone. RCZ tracks must be known to be clear of rolling equipment, persons, improperly lined switches and derails, blue signals, and other objects. Switches and derails must be properly lined. RCZ signs must be displayed only during the period of activation of the zone. Finally, the RCO-Foreman must notify the designated control office in the yard or area when an RCZ has been activated. The RCZ is under the command of this RCO-Foreman, who can give permission to other movements, employees, or contractors to enter of foul the RCZ. When the RCO-Foreman gives permission for other employees or contractors to enter his RCZ, his RCL crew must provide protection for these employees and contractors. Note: The rules of one carrier require only that before rolling equipment enters an RCZ, its crewmember must "attempt" to communicate with the RCO-Foreman in command of the zone or the designated remote control office.

Some RCZs are equipped with an electronic system that automatically detects the presence of an RCL and prevents it from going beyond the limits of the RCZ. This system is known as Electronic Pull-Back Protection (EPP) and it consists of a series of transponders (often called pucks) sequentially placed in the tracks, that detect and control the speed of an RCL passing over them. An EPP system is aptly described by an RCO, as follows:

> "'Puck' refers to the physical device [transponder] that is installed between the rails of a track and at intervals within an RCL 'pullback zone.' They are semi-buried between two ties and covered, in our case, with a piece of plywood so that you don't trip over them. When pulling back through an RCL zone, if the pullback protection has not been disabled (a matter of depressing and holding two buttons on the onboard computer[OCC] for a few seconds), when the locomotive passes over the first puck its speed will be limited to 10 mph. When passing over the next puck the speed will be limited to 9 mph and so on until the second to last puck slows things to 1 mph and finally the stop puck brings everything to a stop. Hopefully. Because [MANUFACTURER] also employs a backup system based on a "map" of the RCL zone and GPS satellites, sometimes the system gets confused. For example, when it fails to detect a puck when it expects one or when it passes over one that it doesn't expect. I guess its called a puck because physically it resembles a hockey puck."

Another RCO adds:

> "'PSP' [EPP] seems to be a label for the system of pucks-between-rails, sensing devices on locomotives, onboard computers using software maps and GPS backup data, and box [RCD] readouts that is, within the programmed limits determined by braking ability of the consist and maximum tonnage, supposed to stop the movement before the end of the remote control Zone. Although it is defined in the rules, it couldn't hurt to define it in a glossary as well."

Practical limits exist to the effectiveness of this technology that an RCO must understand and respect. An RCO explains these limits:

> "Given our experience here with the [MANUFACTURER] equipment, it would seem that the only ways go beyond the stop puck in a PSP zone would be to: 1. Manually override the PSP system and then mis-guesstimate the location of the locomotive when pulling out without point protection. 2. Manually override the PSP system and then, through improper train handling, fall victim to a bad combination of speed and tonnage, resulting in the inability to stop in time. 3. Exceed the tonnage rating for which the particular PSP zone and the particular locomotive

> consist (it's about braking power) are certified. If you do this the manufacturer cannot guarantee that the system will stop things at the stop puck. Although the bulletins defining these zones also indicate these maximum tonnages, nobody really pays attention to them. Who is going to total the individual car tonnages if they are even given on the list or even if the list is accurate (eg. no extra cars)?"

9.1 Pullback Protection Can Be Disabled without RCO's Knowledge

The Electronic Pullback Protection (EPP) in an RCZ shares some functional similarities with a modern train control system on a main track. Both use wayside electronic devices to determine the presence of rolling equipment on the controlled track. In both systems, these electronic devices send data-radio signals to the locomotive to control its speed and movement, and in both systems the locomotive has electronic receivers and microprocessors to read the data-radio signal and command the locomotive to comply with the speed and movement indications. One big difference between the two is that Federal regulations exist governing the maintenance, inspection, and testing of train control systems (both the wayside and on-board locomotive components) but for the EPP, there are no Federal requirements for inspection and testing. If there were the following situation might have been prevented. A railroader comments on a blind movement leading to an RCL accident where the EPP system was disabled:

> "It is the only track designed as an RC zone at the 'KLM', the only one with 'pucks', and the only track that can be used as a 'pull-back' track without someone physically being on the engine. The RCL (with no one aboard) ran passed the red Absolute Signal protecting movement onto the main track at 'UVW,' ran thru the power switch there, and continued eastward down the Main Track a ways. The RCOs were unaware of this (can't see it at night) and were somewhat perplexed as to why the cut of loaded cars they were handling only moved a little ways when they issued the command to the RCL to back up. The reason being, of course, that [equipment was] derailing in a general pileup on top of the run-thru power switch."

Regarding this above blind accident, a railroader explains how the indication on the RCL reporting pullback protection was false:

> "The reason the RCL failed to automatically stop when it ran over the 'puck' (indicating that it was erroneously leaving the 'KLM' and headed out [track number] towards the mainline) was because the Pullback Protection inside the [MANUFACTURER] computer had been disabled by someone [at an earlier date] (according to the diagnosis download). So since that time, even though the display in the cab indicated that the Pullback Protection was cut in, it actually wasn't."

Although there is no doubt that EPP is designed to be a safeguard, the fact that it can be disabled without the knowledge of the RCO in charge of the RCZ means that it is not a "fail-safe" system.

9.2 Radio Controlled Switches Thrown without Knowledge of RCO in Charge

Many rail yards today have remotely controlled switches used by operating using portable keypads. A crewmember punches in the identification number of the switch in the same way one dials a telephone, and a digital radio signal transmits to the appropriate switch for throwing to either the normal or reverse position.

Most remote control switches broadcast synthesized-voice radio messages indicating their positions to operating crews working in the vicinity. However, this safeguard, designed to alert crews about a misaligned switch, is not foolproof. Some railroads have installed locks on the remote control switches to allow crews to lock them into position to prevent other trains from entering the RCZ without the permission of the RCO in charge. Again, this protection has not always proven effective. The following commentary from several RCOs illustrates the hazards associated with radio-controlled switches within the limits of an RCZ.

An RCO says:

> "While working the 'XXX' Yard RCL switch job, we observed the following: After our lunch break we went to work with our 'activated' remote control pullback zone still intact. IE., no jobs had sought permission or entered the zone while we were eating. That means that the switches should have remained lined for our movement. We were going to go against a track and pull it out for switching. I had no intention of putting anyone on the locomotive as the zone was still ours. I never heard the radio toning commands but did hear that a switch that is within our RCL zone announced that it was now in the wrong position for our movement. The primary operator heard nothing. If I had not heard the announcement we would have made a trailing point movement through a wrongly lined switch and then shoved back."

Another RCO reports:

> "Now, twice in the last two weeks, a remote control job working at the 'RRR' Yard has pulled out into the activated remote control zone that they 'owned' only to find that the radio controlled switch was lined into [another location]. Fortunately, there was someone on the locomotive both times. But the job had the authorization to pull out without anyone on the point and the outcome could have been much different. Some of us think that we must keep someone on the locomotive at all times until this situation is remedied."

This RCO reported a third incident:

> "There was yet another incident with a remote control switch found wrong in a previously inspected and activated remote control zone."

Similarly, an RCO says:

> "A remotely controlled switch was thrown against our [RCL] movement the other night. We heard the announcement of its changed position in time to throw it back before running through it. No particular job in the neighborhood or reason for the action. We actually like these switches as they make our work easier, but there is the little matter of them not working in the cold weather (in which case they make our work harder having to hand pump them) and

> being thrown by agents unknown at inopportune times. Technology. A love-hate relationship."

An RCO comments, in this and the following paragraph:

> "While working as helper on a 2-man RCL switching job yesterday, we witnessed the following. We had, making use of one of the really slick remote radio controlled solar powered switches, just pulled out a cut of cars and shoved back and switched them all out. No more than 10 minutes had elapsed. No jobs had operated in our area, let alone requested permission to enter our activated remote control zone. Yet when we attempted to retrace our route and run the light units down to the yard office to take our beans, we found the remote control switch lined against us. How had this happened?
>
> "The only explanation was that someone had either inadvertently or purposely thrown the switch by remote control. We had not heard what the authorities here have assured us we would always hear, that being the radio toning in of the switch throwing command and the announcement that the switch was now lined against our movement. Neither I nor the foreman heard any indication that the switch had been thrown. Since the zone was active, we could have "legally" pulled out and shoved back without anyone on the locomotive to observe that the switch was wrong. It would have involved a trailing point movement and rumor has it that these switches are floppers so perhaps nothing would have happened except for slight damage to the hydraulic seals in the switch. The other [such switch] was found lined wrong in an activated [RC] zone in at least 2 instances. As I have said, this seems a minor incident, yet it is symbolic of and illustrates the risks involved with the prevailing philosophy from 'AAA' ('NNN RR' Headquarters) to Washington (FRA Headquarters): abandonment of the Cautionary Principle, progress at any cost and immediate implementation with only a postponed and possibly even subverted analysis of the ultimate expense. Let's implement and work out the problems as they occur. Cost effective. FRA doesn't interfere with the right of management to do what they think they do best . . . manage. A few grunts get ground up in the process? Well, they'd be dead meat even if nothing had changed. Gotta go forward. Progress is our god."

An RCO notes:

> "In my terminal there is a problem which is potentially dangerous: Our RCZs include within their boundaries remote-controlled switches. These switches are operated by radio commands. The problem is that anyone with a radio tuned to the yard frequency and within radio range can anonymously throw switches within the remote control zone, so that it is impossible for the yardmaster to guarantee the security of the RCZ. It is true that each switch has a lockout toggle switch, but the lockout switches are secured with an ordinary railroad switch lock, and there are a dozen switches. Also, most of these switches are not within sight of the RCO during a normal switching operation. Some authority should have sole possession of an effective lockout function."

Question: Can remote control switches be equipped with an initialization device that would permit an RCO in charge to link his keypad to the switch and become its sole operator while working in the RCZ?

9.3 Intrusion of Other Train Crews into RC Zones

Some RCOs expressed concerns about the difficulty of keeping track of those whom they permit to enter into their RCZ. Others note that RCZs on some railroads are more effective than on others at prohibiting the intrusions. As one group of RCOs reports regarding recording of movements in an RCZ:

> "The only recording that gets done here are the instances of 'activating' and 'deactivating' the Remote Control Zones. The yardmaster logs the zone number, status and time in some kind of log book. The RCO-foreman is definitely responsible for keeping track of who he has allowed to enter the zone and who has left. The rule states that only one other job at a time may be allowed in an activated zone. The common practice here even before the remotes was that the yardmaster would tell the crew that wanted to pass through an area to contact Job such-and-such."

An important difference between RCL and conventional operations is that blind shoves are not permitted in conventional switching operations but with RCL operations, blind shoves are allowed in RCZs. Some express no faith in RCZs and believe that protecting the point of the move is the only effective way to protect RCL movements. One railroader put it this way:

> “But any crew member who shoves blind almost deserves what they get if they foul their zone or go beyond the limits of their zone. There have already been several ‘near misses’ because no crew person was on the point of a move that either went outside of an RCO zone or better yet had two RCO crews in the same zone, not knowing that they other was there until somebody went to the point of a shove or pull.”

Control of a RCZ could be on one voice-radio channel while some yard movements are on another channel, thereby leading to an unauthorized entrance into an RCZ. A railroader explains that two hostlers were moving light engines and they:

> "called the Yard Master to ask if they could cross over and come back to the Roundhouse. The Yard Master fumed: 'You're in a remote control zone; how did you get there?' They had not heard from anyone that an RCL Zone had been established while they were in it. It may have been the mere fact that they were on channel '999' and the Yard Master gave the zone to the RCO's on channel '888' and did not bother to inform everyone else in the yard. This is a SERIOUS problem."

9.4 Adequacy of Railroad RCZ Rules and Procedures

The effectiveness of an RCZ to prevent rolling equipment and persons from unauthorized entrances into the working limits of an RCL crew depends on how well the zone is constructed and what kind of safeguards are in place. An RCZ should be designed so that the tracks contained in it can be easily identified by the RCL crew and others. Additionally, it should be possible to isolate easily the tracks in an RCZ to guard against intrusion. Finally, there needs to be adequate signage or marking to alert train crews and those working in the yard that an RCZ exists.

Reports indicated that some RCZs are well constructed, others are less so. A railroader notes:

> “These two RRs have totally different approaches to RCL and zones. ‘ABC’ spent about zip for safety, ‘DEF’ went all out. The ‘ABC,’ in ‘XYZ,’ has a remote 'area' that encompasses about all the yard and the yard leads. The remotes are even allowed out onto the mainlines. There are a couple of small signs to alert motorists but they are really too small to be noticed. There is some sort of new sign on the west end of the yard near ‘UVW’ for eastbound trains.”

Another RCO observes:

> “if an entire yard is designated an RCZ, then, there is no zone of Remote Control.

One RCO comments:

> "Some kind of RC Zone rule whereby you initially ascertain that your track is lined up and clear and then anyone who enters the zone or misaligns switches within it is at fault. This won't prevent mishaps, only ensure that someone other than the RCO is to blame."

Several other RCOs agreed with the sentiment expressed below:

> "an RCZ does not prevent all possible accidents in the zone. The RCZ does provide a fixing of blame away from the RCO and the carrier."

Railroads have also established rules that the yard crews should follow to establish protection when working in an RCZ. The effectiveness of these rules appears to vary. An RCO explains about the flux of rules for the RCZ:

> "On the matter of ascertaining that the activated [RC] Zone (the ownership of the Zone by the RCL job indicated by a notation in a book in the yard office) is clear and switches lined after allowing another job to pass through it and before being able to pullout without point protection, local management originally interpreted the term 'ascertain' to mean visually inspect. There is a rumor now that they really mean 'ensure' and that we can rely on the other job 'reporting in the clear with switches lined back.' This confusion may be partly to blame for the common practice of bending the rule and moving around without point protection when you can see the locomotive, for example. Or when operating in areas where there is no PSP [EPP] zone set up. Of course this doesn't justify overriding the system and then getting off the locomotive to help with the switching. Yet that is being done."

A number of RCOs have complained of imprecise rules and practices for operations in RCZs. An RCO comments:

> "The biggest stupidity of all is taking the perhaps useful concept of the ‘activated’ RC Zone, which originally assured the operator of not having to worry about complying with [the governing rule], and splitting it in two so that now you have one kind of activated zone where you don't need anyone on the locomotive, and another one where you do. Pretty confusing… The point of all this is to reinforce the argument that these (and many others) [RCL-related] rules are being cobbled together and interpreted by people who have little appreciation for what

> is going on out in the field. Rules are an important part of railroading but when they lose their logic and consistency then they just end up creating confusion and making it more difficult to work in a manner that makes everyone happy."

9.5 Lack of Awareness about RCZ Operations by Nonrailroad Personnel

RCOs report contractors and other nonrailroaders authorized to be on railroad property can be completely ignorant about the nature of RCL operations and the restrictions against entering or fouling the tracks in an RCZ without the permission of the RCO in charge. An RCO reports:

> “while he was checking his RCL when it was stopped, a contract fueler was fueling one of the two RCL units from his tank truck. The RCL's strobe light was flashing and signage for RCL operations was in place. When the RCO question the contract fueler about RCL operations, the man proved to be entirely uninstructed and was not notified about them.“

An RCO explains regarding nonemployees fouling an RCL zone and not having instruction about RCL zones:

> "On an RCL job we witnessed the following. A truck pulling a large trailer was attempting to make a U-turn between the [track] and the activated RCL zone we were using. It fouled the zone on two occasions while it struggled to turn around. We were pulling out but I was in position to see them. When I talked to the crew that was on the property to load [material] I asked them if anyone had explained the concept of RCOs, zones, etc. They were private contractors and totally unaware of what I was talking about. These guys weren't trespassers. They'd been invited on the property to work in a dangerous zone. Wouldn't you think a briefing on the dangers involved would be in order? Oh, I guess that's our job too. "

Many contractors are unaware that the cab of a moving RCL may be unoccupied. Unless briefed on RCL operations, the time-honored assumption was that a moving locomotive was occupied by a locomotive engineer. Similar concerns exist, however, for other railroad personnel, such as maintenance-of-way and signal forces who may rarely work in switching yards and who may not be familiar with switching rules and practices. Several RCOs separately voiced the following concern:

> “If railroad or contractor trackmen work to foul live RCL tracks in a yard and the involved RCOs do not provide point protection, an accident could result to these preoccupied personnel.”

Regarding training for working in the vicinity of an RCZ, we find the following press report:

> "POCATELLO - A Union Pacific van was struck by a remotely-controlled train in the Pocatello UP hump yard early Friday [4.30.05]. There were no injuries and the accident was on private property, so it was not investigated by local authorities.
>
> "'The people operating the train were watching the van, but they thought (the van driver) was just turning around,' said UP spokesman John Bromley. 'He swerved in front of the train and it struck the van'" (Petersen 2005).

Given the two agents directly involved in the accident, RCO and van driver, the central question here is, had the van driver been trained to work in the vicinity of RCL movements?

An RCO comments in the following two paragraphs on the above training issue:

> "As my encounter with an independent contractor fouling an RCZ illustrated, management has been derelict in their duty to keep these people safe. We have principle and precedent on our side here. If we cannot expect independent contractors to be trained in the rules, then they must be provided protection. After all, these are people who are invited on the property, unlike the unfortunate trespassers.
>
> "Don't think about this, but where the RCZ intersects with the public, the totally guilty trespasser or invitee may very well have an innocent passenger in their care. The trespasser invitee rules-violator may deserve to be mangled or killed, but the passenger, if damaged, must surely seek redress from the person who put them in harms way. Once again, the carriers are innocent. That was a close call but you know what they say about "close" hand grenades and horseshoes. It's a great system."

Question: To what extent do railroads adequately educate other railroad employees and nonrailroad personnel who do not routinely work in or around RCL switching areas about precautions required when working around RCL operations?

9.6 Visibility of RCZ Signs

RCZ signs notify train crews and other railroad personnel that a section of a yard is a designated RCZ and that the RCZ is activated. These markings can be effective if properly designed. RCOs have recommended that RCZ signs should have flashing or rotating lights mounted on them, which could be activated during activation of the RCZ. As a railroader points out, some railroads have adopted this practice, at least in some yards:

> “'DEF's' operations have the remote 'zones' clearly marked. They use just one lead for the zone and each point where the zone can be entered is marked with a flashing yellow strobe when the zone is activated. The point where the zone lead enters the main is protected by a derail to protect movement to and from the main.”

But not all RCZs are so well marked. Another railroader observes:

> “These two RRs have totally different approaches to RCL and zones. ‘ABC’ spent about zip for safety, ‘DEF’ went all out. The ‘ABC,’ in ‘XYZ,’ has a remote 'area' that encompasses about all the yard and the yard leads. The remotes are even allowed out onto the mainlines. There are a couple of small signs to alert motorists but they are really too small to be noticed. There is some sort of new sign on the west end of the yard near ‘UVW’ for eastbound trains.”

9.7 Operation of RCLs over Highway-Railroad Grade Crossings with Use of Remote Cameras

Direct human visual protection of grade crossings and footpaths is generally advocated by many RCOs and other railroaders. However, some railroads are experimenting with remote camera systems that permit an RCO to monitor, from a video monitor at a remote location, the movement of his RCL over a highway-rail grade crossing.

From comments of railroad employees, this practice raises a number of concerns:

- Does the video monitor screen provide clear and precise images of the area of RCL operation that do not distort, obscure, narrow, or shadow the view?
- Can the RCO clearly determine that all grade crossing warning devices are fully functional?
- Do the images allow the RCO to see sufficiently far enough down the approaching streets, sidewalks, and footpath to detect traffic and pedestrians approaching at various speeds?
- Does the view on the monitor allow the RCO to judge the distance of the RCL from the crossing and the time it will take to enter the crossing?
- Does the view on the monitor provide a precise perspective to allow the RCO to accurately assess the speed and distance of approaching traffic and pedestrians and determine their relationship to the RCL movement?
- Does the use of remote video monitors contribute to task overload of the RCO? Human factors experts have indicated that it requires a far greater portion of brain capacity when human beings interpret images on a screen than when they make direct observations.

A railroader comments that not all of these questions can be answered in the affirmative:

> "While observing these [on-screen] images during the day, the sun and shadows blur out almost the entire screen. It is extremely hard to make out the conditions of the crossing, let alone see what traffic is at or approaching the crossing. In addition to the problems with the screen, shadows cast by the [highway] overhead bridge at the location of the grade crossing creates an very large 'black' area that nothing can be seen in. The cameras are each aimed directly at the crossing and are zoomed to only show the area between the gates. An operator cannot tell if there is any traffic or pedestrians approaching or attempting to go around the gates."

Another RCO notes problems of reliability:

> "The 'AAA Yard' is still struggling with the issue of protecting the major crossing that is in the middle of their RCL Zone. A few weeks back when they removed the third [switch-] man that was riding the locomotive, determined to utilize the video cameras that had been installed earlier, we were hit with a sub-zero cold snap that 'froze up' the cameras. Apparently the equipment is not invulnerable to severe weather conditions."

The multitude of hazards associated with the use of cameras and remote video monitors to guide the movement or RCLs across highway-railroad grade crossings affects motorist and pedestrians even more than railroad personnel. FRA has expressed reservations about this practice, which needs to be most carefully evaluated.

9.8 Protecting Zones Adds to Duties and Responsibilities of RCOs

In the following case, the RCO who was in control of the Remote Control Zone appears to have lost track of how many movements he had allowed into the zone. In addition to the responsibilities of switching cars and running the RCL, an RCO in charge of an RCZ must take on the added duty of controlling the movements through their zones, a task normally handled by a yardmaster in conventional switching operations.   All of which can lead to task overload. A railroader discussed a collision that resulted from a lapse by an RCO in charge of an RCZ as follows:

> "The train consisting of a couple of locomotives and [X cars] was given permission by job '99' to enter [a] Remote Control Zone and proceed to the yard office where the outbound crew was to get on. They stopped at the yard office with their entire train still in the zone, without reporting clear, and handed the train over to the outbound crew. There was another light power move that was authorized to enter the zone and proceed [elsewhere]. This they did and reported clear of the zone. Job '99' then apparently assumed that there was no train occupying the zone and without making the inspection required by the rule proceeded to make an unprotected pullout. The unoccupied RCL coupled into the rear end of the train and pushed it a short distance. The RCL then attempted to move [in the other direction] but without success. There may have been more backward and forward movements attempted until a [officer], seeing what was happening, ordered the crew to stop and walk down and inspect the situation."

Regarding the above incident, this railroader notes further that the consequences of collision could have been much worse:

> "A train was near its departure time and its conductor notified his engineer that he would be bodily fouling between equipment. The engineer acknowledged and, as per the rules, centered his reverse lever and set the independent air brakes. His train then began to move! This was the second time within a short period that uncontrolled movement had occurred to the train. The reason for the uncontrolled movements of the train was that an RCL and its cars had been blindly shoved by its RCOs into the standing train. The train's conductor was not injured but he could have been.

Another RCO had this to say about the additional duties placed on the RCO In-Charge:

> ". . . particular part of the multi-tasking juggling act of the RCO that was dropped [unsafely reacted to] here was probably the 'yardmastering' job that is required of an RCO while operating in and directing traffic through his [RC] zone."

10.0 Human Factor Issues That Involve RCOs

The following section examines a wide variety of errors that can be committed by both the individual and managers in the organizations engaged in RCL operations. One question to keep in mind in examining each issue: is there something about the nature of RCL operations that fosters the occurrence of the error or affects the severity of its consequences?

10.1 Increased Tendency to Make Blind Shoves

Blind shoves can be implicated in more than half of the "human factor caused" train collisions reported to the FRA. Failure to protect the point, switches not properly lined, cars left in the foul, nearly all collisions reported under these FRA cause codes could have been prevented if effective point protection was provided during the train movement. Because this practice figures so prominently as a cause for conventional switching accidents, why single out blind shoves for discussion in a survey of RCL hazards? The answer is the added pressures for blind-shove and blind-pull movements in RCL operations.

Using RCLs with one-and two-person crewing working far out of sight from any direct supervision, the temptation mounts for RCOs to make blind shoves. In short, because of the reduced number of crewmembers found in RCL operations, a temptation is present to save the bodily effort and expended time of walked steps and, hence, to make the blind movements. As Badler et al. note: "People usually move in ways that conserve resources (except when they are deliberately trying to achieve optimum performance)" (Badler et al. 1993:13).

Even momentarily losing point protection can be hazardous. As the Transportation Safety Board of Canada explained regarding an RCL accident involving a damaging blind shove into a standing train: “The Board determined that the yard assignment crew momentarily lost point protection for their movement and operated it in an area that was not known to be safe.” All blind movements not allowed by the rules are errors of omission. If a rules infraction is locally condoned by management, then, the omission is by persons a higher organizational level.

One railroader explains the tendency to make blind shoves as follows:

> "Blind shoves increase the efficiency of yard and road switching operations greatly, and the rules ALL BUT FORBID MAKING BLIND SHOVES. Many accidents have resulted over the years from the practice, and the rules are tightened up a bit -- or at least the interpretation -- but they just can't seem to find it in themselves to remove that always popular, "when practicable" or "when conditions require". If you have to put a man on the point or ahead of the movement each time you shove a track, with a two-man ground crew -- with or without an Engineer -- and you're talking about A LOT OF WALKING to and fro!!!"

As a long-experienced Canadian RCO comments and confesses, a problem in RCL operations is:

> "The dangerous lack of point protection owing to not wanting to walk long distances: One factor that the people seemed to have let slip here is point protection. The company set down

> a rule that no trains may enter our lead until after calling us on our operating channel. So many people seem to think that this relieves us of point protection but NO! If something happens we are as much to blame as they are. Wish the workers here would have put man on point every time we had to back up and wait for said man to walk back up to lead end before switching resumed. Each time we had to back up, walk back and protect the point again. But like anything, too much of an inconvenience for us. I am guilty of this also."

A railroader asks a pivotal question regarding reducing walking and other shortcuts:

> "Does RCO [RCL operations] amplify the deadly potential inherent in corner cutting?"

An RCO comments:

> "Fail-safe functions that are designed to stop the [RC] locomotive in response to diminished conditions, such as low air pressure, loss of signal, or hand shaking and cross checking all contribute to loss of productivity. The result is pressure to take shortcuts and speed up the operation to complete the work. Based on experience, if an operator can't figure out a way to beat a bad design in a machine, he/she will do something else to complete their task." (Here "bad design" means time-consuming design.)

An RCO notes:

> "If a worker follows established rules and procedures, he will stay out of trouble. In truth, all rail workers face pressures to produce, which is a contradictory impulse to working slow, safe, and according to rigid and well-understood rules. The new workers are most susceptible to this pressure."

Moves that were legal under railroad operating rules in conventional switching operations with an engineer in the locomotive cab can be illegal and dangerous in an RCL with no one in the cab. A railroader comments:

> "Many times when setting over a cut of cars to another track when the joint is a considerable distance in on a track, one switchman will stay at the joint, the other will pull over the switch then send the cut back to the joint. With an engineer that move worked great, the engineer protected the movement ahead. With an RCO there is no protection ahead. But they continue to do what is easy and because it is faster the carrier tolerates the move."

Regarding blind shoves, a railroader comments on refusing to do so:

> "Even if the rule seemed to allow a blind shove (as RCL rules now do in an RCL Zone), one could make a stand on safety and refuse to perform the act. However, the carrier manager would probably say that he would take responsibility (such as Stanley Milgram's experimenter's did), and might insist that the switchman or brakeman would not be held responsible for damage done during blind shoves performed properly. With this, we are back to the defense of superior orders."

Thus, in a rules violation, a blind shove (and other rules violations) can be "performed properly."

On the subject of "proper" violation of the rules, a group of RCOs comments:

> "Failure to recognize a hazard is placed at the top of the list ahead of failure to look for one. Most of us are cautious enough to avoid shoving with abandon without careful consideration, but we are perhaps prone to think we have factored in all the possibilities and that we are truly IN CONTROL. Most will not shove blind without considering and checking off on all the possibilities (track length, number of cars, other jobs working in the yard) and without communicating to people who may be affected by the movement."

An RCO reports:

> "not providing point protection, an RCL crew ran onto a track for which they were improperly lined and ran past a red block, through a power switch, and out onto the main track. This was some time before a passenger train was due on that track. The RCO then changed the direction of the movement and piled up a half dozen cars at the consequently run-through power switch. With the right timing of events, a passenger train accident could have occurred."

On another matter, a railroader reports:

> "A collision occurred on [date and location] between a RCO Locomotive and a road switcher. The RCO was not providing protection when it rammed into the parked road switcher on the [location]."

Regarding a recent collision the RCO observes:

> "These two [Internet] links are from [location] last Friday. Remotes were pulling out a cut with no point protection. I saw the engine last night. Took a good beating."

Finally, the insightful comments of this railroader seem to imply that the habits developed from working in an RCZ may contribute to the tendency to make blind shoves.

> "If a crew establishes sufficient room to hold the cars, rarely does any other observation of the movement continue, for example until the cars come to a rest. Often, the computer calculation of room in the track is used to justify a blind shove. Sometimes, a blind shove is made to the point where it comes into view of a yardmaster or a camera that monitors the lead. In this scenario, fifty car lengths of a fifty-five car shove filling a track may be made without anyone watching the movement. Only when the movement nears the end of the track, does the movement come into the line of sight of the camera or a person protecting the movement from re-entering the lead. These issues are all problematic as this sort of operation migrates further and further from the confines of the core 'yard' tracks. As this philosophy migrates to include crossings or other areas where pedestrians have access to railroad operations, these blind shoves become ever more troubling. Such is the world of U.S. railroad operations in the 21st century."

10.2 Point Protection Must Be Provided for Pulling Moves

As noted previously, “point protection” is the practice of having a crewmember stationed at the end of rolling equipment, (on the point) to observe that the tracks are not obstructed and that switches and derails are properly lined. When rolling equipment moves without point protection it is called a blind move. Blind shoves, but not blind pulls, have been part of railroading since time immemorial. Blind pulls are unique to RCL operations because in conventional switching, the engineer in the locomotive is necessarily at the point to provide point protection when the locomotive pulls the rolling equipment. However, the motivation of individuals to perform these blind pulls and company supervisors and officers to permit them appears to be the same as for blind shoves. Given the increase tendency among RCL crews to make blind shoves, will the addition of blind pulls impact the safety of RCL operations? A number RCOs share their thoughts and observations on this issue.

An RCO notes regarding blind pulls, saving effort, and violation:

> “The blind pull [is] one of several potential problems. Leaving aside the question of innocent civilians maimed and killed by the blind pull, you can write all the rules you want, but if the RCOs are still subject to pressures to produce and their own human nature (let's just cut this corner - I don't want to take the effort to comply - we've gotten away with this so many times surely once more won't hurt, etc.) then you must expect to experience such accidents and worse. Get used to it.”

A railroader reports:

> “A remote control at ‘ABC’ yard was lined out to the main line at ‘DEF’ and ran by a Red Block and through the power switch at ‘GHI.’ The unit then backed up and derailed five cars blocking the main line. The crew thought they were lined down the ‘Z’ lead and since there wasn't anyone on the locomotive, there wasn't anyone to stop the unit. This could have been a potentially deadly accident since Amtrak ‘999’ was the next train that was to use the main line.”

Another railroader reports:

> “’ABC’ has had other RCO derailment [on day]. The local [RCL] switcher ran over a derail. The Brakeman has a [recent] date. Had there been an engineer on board there would not have been a derailment; the engine was facing the derail.”

A railroader reported a similar RCL accident:

> “The afternoon remote hump engine was switching out the [industry name]. Since no one was in the cab they did not notice that there was a derail in front of the engine. Put all six wheels of the [RCL] on the ground. They tried to pee test the guy in the cab but couldn't find him so they tested the ground pounders instead.”

On the “QWE RR”:

> "The crew pulled back with what they thought were ‘XX’ cars, but they actually had [more] cars. This resulted in the crew trailing through two switches not lined for their movement.

> When the reverse [changed direction] movement was made, the engine and one car derailed."

A railroader reports:

> "[Name] obtained the attached photos documenting yet another RCO collision at the 'VVV' terminal. The latest occurred yesterday and it is not yet know if anyone was hurt. The unprotected lead locomotive collided with an inbound train, overturning at least one car and extensively damaging locomotive 'XYZ 888.'"

On the “XYZ RR" an RCO reports:

> "A remote control job was pulling north through the ‘X’ crossover with light engines and struck another yard job operating in conventional mode, sideswiping ‘X’ loads of [freight]. The remote control job was pulling out of the south end of the ‘Y’-yard and assumed the other yard job was switching on the [name] track. The [RCO] was controlling the movement. However, point protection was not complied with. The remote technology was inspected and was found to function properly."

Regarding blind pulls, a railroader exemplifies:

> “An RC yard job with two units was pulling back a cut of cars and ran thru a rigid switch. The movement continued for some distance, then the command was give to ‘come ahead’, at which time the cars in the cut that were on top of the run thru switch started derailing. The derailing cars struck an unoccupied two-unit RCL on a adjacent track.”

Finally, a railroader comments about no longer having an engineer to protect a blind pull:

> “As one who typically works in areas where more than one movement is happening at any one time, I'm very concerned about the unprotected reverse [back up] movements that are made whenever RC operations are used. With no one on the RC locomotive, the groundman can only hope (pray?) that nobody or nothing is in the way when it's necessary to make a ‘blind’ movement.”

10.3 RCL Operation with One-Person Crewing

One of the possibilities afforded by RCL switching operations is the establishment of one-person crews. It did not take the railroad industry long to begin to implement this practice, although it does not appear to be widespread.

Not yet fully explored are the safety implications of one-person crews. No party has performed related risk or human reliability assessments. Clearly, the tendency to perform blind shoves and pulls becomes more likely in RCL operations where one RCO in the sole crewmember. The potential for increased fatigue among lone RCOs has also been raised. Experience suggests that the risks associated with other hazards might also intensify when RCLs are run by just a single person.

One RCO expresses the concerns of one-person crews quite succinctly:

> "We've had several one-man operation of remotes [RCLs], which seems dangerous. Sooner or later this will result in a accident." (Such operation was because of a temporary shortage of personnel.)

Another RCO notes:

> "On the matter of one-man RCOs, don't the FRA guidelines recommend the ability to locate the possible man down? The answer given here, by local experts, to the fact that the only GPS position indicated is that of the locomotive was that the second man 'up' will probably have a good idea where the man 'down' might be. Now if there is only one man on the crew that solution no longer applies. Being 50 or more cars from the locomotive, it could be 'hour' before they find you."

This RCO questions:

> "I may be wrong but didn't that RCO fatality in San Antonio[name] involve a one-man assignment? How can they get away with this?"

An RCO thought that regarding one-person RCL crewing:

> "One man operations for twelve hours could be too fatiguing."

Indeed, one-person operation might increase the fatigue experienced by RCO. The Federal mandated ceiling of twelve hours of service (plus any limbo time) could well be too long for a one-person crewmember to execute safety-critical switching tasks. As a report of the American Association of Railroad Superintendents reasoned:

> "These is also the consideration of dealing with higher pressure and stress of putting all the work on a one-man crew. . . . We also thought that looking into current FRA hours of service would be a wise thing to do. Twelve hours may be too long for one man or woman to be working alone." (Stoffer 1996:63)

To be sure, some fears about single-person crews transcend safety, as can be seen from the comments of this RCO:

> "1-Person RCL crew is their dream, I am sure [YUI RR] has 1-person RCL crews in [location, verified] and the borrow-outs from [location, verified] that were working here told us that RCO was implemented there and that all the jobs are now 1-person. There are paranoid rumors circulating here about that being the next cut-back, along with farming out all the industry work to non-union Rail."

However, not all RCOs are dismayed about single-crew operations, some invite the practice, whether it is authorized or not.

An RCO notes:

> "What we have been doing to speed things up a little bit is link up to 2 sets of power and work on opposite ends of [location]. We have been doing this now for about [X] months and obviously are getting the work done in [fraction] the time. I don't know for sure, but I'm sure if they were to find out, they would tell us that we shouldn't do this."

Another RCO explains the necessary technique of linkage:

> "With the [MANUFACTURER] equipment, whether using one or two boxes [RCDs], you can only link up to one RCL at a time. So in order to pull something like this off, you would have to link one box [RCD] to one RCL and the other to another. Then two men on one assignment could work all night, by themselves on both ends of the yard, which amounts to transforming one 2-man RCL assignment into two 1-man RCL assignments."

Another RCO, however, recognizes hazards associated with the single person RCO crew:

> "With two RCOs who are, on paper, on the same job, but who are actually operating as sole operators of two different RCLs, the safety connect between them is severed and if one gets run over by the other the survivor will have no immediate feedback that there is a problem and can continue to work for an indefinite amount of time."

10.4 Task Overload and Loss of Situational Awareness

Given the number of specific tasks required of RCOs, an opportunity exists to become distracted from the main objective to switch cars safely, even when handling relatively simple switching movements. A common concept used to explain the actions of many victims of severe switching accidents is “loss of situational awareness.” One way for an RCO to lose situational awareness is becoming distracted by a multitude of individual tasks that must be done to accomplish the overall objective of switching cars. Thus, “task overload” may lead to “loss of situational awareness.” (For Switching tasks, see Appendix F. For Situational awareness, see Appendix B.)

The following comment expressed the sentiment shared by a group of RCOs:

> "We have a lot to think about, like how we are going to make the moves to block the train correctly, is the list wrong, what is the footing like on the ground, where is the next cut (to name just a few examples). Now we have to think about what the locomotive is doing and who should be operating the box. I think this is information overload for us."

A railroader notes regarding RCL operations:

> "The bottom line is you're taking a switchman / trainman who already has his hands full dealing with switching cars, reading lists, planning work, trying to protect his butt to avoid injury, often working in adverse conditions (rain, wind, cold, dark), and are now adding operating a locomotive by remote control to his list of duties. At what point in time does this employee get to the point where he can't do anything safely because he's got way too much to deal with." He further notes: "Yes, the [RCL] technology is theoretically safe but when you load an individual up with excessive amounts of responsibility and duties something has to give. You get employees working out there with all these duties and responsibilities, add to that the constant harassment of managers looking for any rule violation they can find so they can ‘level the person up’, and you've got a recipe for disaster."

An RCO said:

> "The bottom line is the distribution of a limited amount of attention, and more importantly, whether that limited attention is being pulled and pushed in ways that will affect the safety of the operation. Sure you can, with practice, operate the locomotive while walking, talking on the radio, looking at other things, planning your next move, taking a piss, etc. But should you at least be looking at what the locomotive is doing?"

Another RCO adds:

> “The workload is increased quite a bit as you have to do all the stuff the engineer use to do (daily inspections, locomotive consist air brake tests, etc.), get your track warrants, train list (who keeps the engineer's copy now?) and you spend more time on the radio getting track & time, authority to enter the main track, signals and so on.”

Note: Unlike the copy in many announcements about RCL operations, RCLs are not confined to yards. Today, for flexibility in operations, most yard jobs work some of the time on main tracks.

One RCO summed it up this way:

> "The question is to what extent does such a divided attention impinge on safe movements. I'm going to wait and see. The risk factor here is not whether an operator is neglectful or inattentive. The risk is in where the operator's attention is directed."

An RCO reports, from another RCO:

> "A brother received a lecture and a [warning notice] (the receipt of [which] you must sign to admit you did wrong and will mend your ways). The charge was 'walking and looking down reading list.' We all thought it quite bizarre. (How could they see his eyes from 50 yards away, what about walking and looking up at cars or switches or the moving RCL, what about walking in the dark especially with the inadequate lighting that they have given us to use?) What is the actual rule he violated (oh, I know, failure to work safely)? He suggested this was an admission by management that with the box we now have too much to do safely."

On the situational issue, as an RCO writes, the RCO's problem is:

> "Having to do too many jobs at once, and not keeping one's mind on what you are doing."

Another RCO similarly reports:

> "As far as missed signals, this occurs because as my responsibilities have increased on my own duties, my attention is drawn to myself instead of where it should be, with the men in the field."

This RCO reports:

> "Mental overload: I am required to do too many difficult and dangerous tasks all at the same time."

This busy RCO complains:

> "Difficult to coordinate duties. Too many things to do. Must focus on one thing at a time."

Yet another RCO reminded:

> ". . . adding to the duties of the groundman, many of which are also doing the work of clerks, carmen, and yardmasters."

These added tasks often cognitively burden the groundman quite heavily. Furthermore, the conventional and RCL groundman has many tasks, as this RCO writes:

> "The thing [RCD] is kind of fun to use, but the loss of the other set of eyes makes the job more dangerous, and harder to perform. You are now divided between duties, running the motors [RCLs] and blocking tracks, throwing switches, answering the phone, [voice-radio], logging records, etc. You are forced to look away from the movement constantly."

An RCO comments:

> "I would much rather have a Hoghead in the seat as part of the team batting out 150+ cars an hour, vs. me trying to keep track of EVERYTHING plus 'running' the engine. That old saying goes... "jack of all trades, master of none", that fits right here!" ("Hoghead" is a common slang expression for a locomotive engineer.)

An RCO concludes:

> "Unavoidable is while operating my box [RCD] that my attention was divided between the movement of the cars and mastering the sometimes complex RCO functions needed to control a movement."

Regarding RCOs, a railroader summarizes:

> "What [will] the work lives of the new RCOs be like? These guys will not only be making less money then Engineers, but they will actually have MORE concerns, not less. They will have LESS control over their environment. They can see less and feel less. More Responsibility, less control equals more anxiety, more pressure, more worry. More weight on a single individual."

10.5 Multitasking

Related to the hazards of task overload, are hazards associated with multitasking. The difference is that the former concerns hazards that result from a loss of situational or ability to see the big picture. Multitasking hazards, as defined in this study, refers to hazards that arise form errors in carrying out the multitude of individual tasks that are required to accomplish the objective.

An RCO often has to handle a switch list and, when night signals are required, sometimes carries a hand lantern. This person might also be operating a voice-communication radio. At times, the groundperson might carry an ignited fusee (flare). These hand-held and manipulated items would be in addition to using the hands to manipulate the RCD. All these manual tasks, if multitasked all at once, owing to operational circumstances, could result in an error. Note: At least one carrier recognized the cumbersome nature of these multitask manipulations while carrying a standard lantern, when it furnished RCOs with a new pocket-clipped or miner's style halogen lamp, LED-based lamps, and other lights.

About multitasking on RCO reports:

> "to many things to hold to while doing the work."

Another reports:

> "Crew is expected to carry lanterns, radios, switch list, and use the portable radios. Safety is compromised."

However, not all RCOs feel so strongly about this issue. An RCO group commented on the kind of report by the last RCO:

> "The comment about riding with a lantern in hand is irrelevant as the lantern is seldom used in this context, or if it is, it can be manipulated and pointed in the required direction without sacrificing the 4-point stance (break for humor: an official criticized a hoghead recently for getting off the locomotive without using his '4-point stance' -- think about it)."

It appears that some concerns for RCL safety are relative to the kind of motor habits of a particular RCO.

10.6 Attention Capture

Operation of the RCD requires considerable attention on the part of the RCO. Not only must the RCO concentrate on how, when, and which controls to manipulate for properly controlling the RCL, but also he receives messages, warning alerts, and other feedback from the RCD, which, in many cases, must be understood and responded to in an appropriate manner. A number of RCOs intimated that their attention is often captured by the RCD. This phenomenon may lead to a loss of situational awareness and its attendant hazards. Although attention capture may be thought of as a subset of task overload and produce the same hazards, it is being treated separately in this study to identify its cause as the cognitive effort that the RCO must focus on the operation of the RCD. (For Attention capture, see also Appendix B. Definitions.)

An RCO comments as follows:

> "I noticed while operating my box that my attention was divided between the movement of the cars and mastering the sometimes complex rco functions needed to control a movement. This is unavoidable. The question is to what extent does such a divided attention impinge on safe movements. I'm going to wait and see. Clearly the more proficient one becomes on the box, the less focused attention its operation will claim. The risk factor here is not whether an operator is neglectful or inattentive. The risk is in where the operator's attention directed"

An RCO insightfully comments at length on attention capture in RCL operations, in the following six paragraphs:

> "The box [RCD] has us all trained to respond to its frequent and noisy alerts. Some of them are critical and must be dealt with or the operation will come to a halt. Some of them are

> informational only and yet one is compelled to discover just what the box is trying to say to us. Some of the [arresting of attention] involves helpful but not necessary feedback from the box that may or may not make our job easier. The speed readout is one example.
>
> "With [MANUFACTURER] we deal with a combination of audible and visual signals but the audible ones draw the attention to the visual. A few audible signals can be dealt with without looking down at the box. For example, because of the placement of the vigilance buttons at the outer edges of the box they can be found easily by touch and used to stop the countdown to a vigilance penalty application of the brakes. I find that I've already developed the bad habit of looking at the LED display anyway. Perhaps I want to discover how long the countdown has been going on (did I miss hearing it because of some other noise?) and how long I have to respond. Other audible alerts require a look at the box. Is it complaining because the wheels are slipping or the brakes are dragging or the electronic pullback protection has been manually disabled? Perhaps simply that a vigilance button is stuck.
>
> "And then there is the problem caused by the way they time-sliced the communications between onboard computer and the box. Sometimes you have to wait 10 or more seconds to read the info that you are really interested in seeing.
>
> "And then there is the problem of a sense of urgency to respond to the alarm telling you that you are tipped over too far. I've bumped parts of my body on various car parts or have gotten vest or radio cables hung up on cars while rushing to stand up and avoid a man-down situation.
>
> "The distinction between senses of hearing and sight is appropriate here. Hearing being more diffused or non-focused is probably a good choice for an alerting signal in a situation where an operator is focused on other things. Sight is described as being more focused and oriented toward a specific object or point. I believe one can train oneself to move and operate in the world with a more diffused, all-encompassing sight ("soft-eyes", a Zen-like state of mind and being, etc.) that affords one more protection against worldly hazards. But this is unlikely to be developed by mortals like ourselves and it is especially difficult if not impossible to maintain when there is reading and acquiring information from a visual display and then some kind of processing or decision making going on that is more based on RCL theory and what you have been told rather than years of experience.

"Is [arresting of attention] a problem during normal switching operations (without an RCL)? Not likely. The only distraction comparable to a squawking box would be a squawking radio and that can be generally be ignored and responded to at a later time unless it is an emergency broadcast."

10.7 Dangers of Riding a Car While Operating the RCD

If a Primary RCO rides with three-point contact on the side of a car while manipulating the RCD, the potential for error in controlling the movement increases because the RCL operator: (1) must manipulate controls on the RCD and manipulate other devices such as a portable radio; (2) might slip from but not release the supporting ladder, or stirrup, or grab irons; (3) might actually drop to the ground from his car-side stance but not fall; (4) might brush against objects and be knocked to the ground; or (5) might be distracted because of the need to maintain personal safety.

Some RCL proponents assert that the new generation of RCL technology contains a speed-control feature that allows the RCO simply to select a speed setting on the RCD and then hang on with both hands, while the OCC automatically handles the movement. However, the comments of numerous RCOs indicate that the operation of an RCL is much more complex, requiring the frequent modulation of speed and braking to safely and smoothly handle RCL switching movements. Operating an RCD is considerably more complex and safety critical than keying a voice radio. Operating an RCL and a heavy cut of cars under varying track and traffic conditions involve a number of cognitive tasks.

A Canadian RCO says:

> “Personally, I cannot see how it would be in the interest of safety to ride on cars carrying equipment that is being used to operate the engine. This is not to say it cannot be done safely in most instances but only that the risk associated with riding the car is increased by virtue of performing multiple tasks.”

The RCO not only manipulates so-called automatic and override controls as necessary for a particular operating situation, he must within at least every 60 seconds, press a vigilance button on the RCD.

An RCO group reported:

> "The operations [MANUFACTURER] that require two hands are applying the sand (must hold both vigilance buttons depressed for several seconds) and the unauthorized selection of display of speed on the box (must press both vigilance buttons and toggle the Time/Status switch.) You can also try and get creative and use the Speed lever and Independent Brake Override lever simultaneously to modulate your speed. We have been instructed to just ‘hook an arm around something’ to comply with the rule about 3-point stance. And no two cars are alike (let alone two tank cars). Tank cars can be a particular problem (even with a real 3-point stance -- two feet and a hand) when they start or stop suddenly. You almost need both hands firmly gripping something in order to avoid being swung around the end of the car. The point of all this is that, instead of un-encumbering us to allow us to maximize our safety, they are making it more difficult to hang on and to pay attention to what's happening."

Another RCO stated:

> "It's physically difficult and takes a lot of concentration and attention to hang onto equipment while operating a remote control box [RCD]. The [MANUFACTURER] Beltpack has the most-used controls, the reverser and the speed controller, on the right side. The independent brake override (which includes the emergency function, unlike in normal locomotive controls) and automatic brake controls are both on the left side. Vigilance has an acknowledgment button on both sides; either button may be used."

Regarding the matter of how much skill and attention an RCO devotes to controlling the speed of an RCL movement, an RCO has this to offer:

> "The computer initiated changes to the braking and throttle are too slow for my liking, so that I normally compensate by anticipating the engine's response without really waiting for it, and by frequently and rapidly shifting through various speed settings to get the result I want. I think this is the skill component of remote control operations. It is of course that aspect of RC operations discounted by parties interested in promoting the fiction that this technology is

> mere sign-passing. Conscientious rails want to work safely, sure, but many of us also have a craftworker's pride in doing a job with skill. The railroads have done a lot in recent years to eliminate opportunities to demonstrate our skill, but this is a common human impulse & will find an outlet in one arena or another."

In a concern with safety when an RCO rides on a car, some carriers now advocate a 4-point protection, i.e., using both hands and both feet to secure ones body. Regarding the safety of the 3-point versus the 4-point stance, an RCO group reports:

> "The 4-point stance is much safer than the 3-point stance when hanging on the side of a car."

Concerning the manipulating of controls on an RCD, an RCO group reports:

> "You definitely have to move to a 3-point stance to manipulate the levers/switches on the box unless you're fourth point is an arm 'hooked' through a rung or something else. Unfortunately, many ladder rungs do not allow this 'hooking' action as the space between rung and car is too narrow to accommodate an arm."

But not all RCO are concerned about riding cars while operating the RCD, as this RCO notes:

> "Since you pretty much need your hands to hold onto cars and run the pack [RCD] a lantern is out of the question so now we wear these little miner's lights that strap onto your hat or head. . . . Riding the side of cars is not bad at all. I was very concerned about this at first. You can pretty much run the pack [RCD] with your right hand and hold on with your left."

Some prefer to ride the car as a matter of convenience as this road RCO says:

> “If you are not allowed to ride the side of a car and operate an RCL [via an RCD]. However, then a mile shove into a yard track is gonna take an entire shift!” (Unless a second RCO operates the RCD.)

10.8 Inadvertent Movement in the Wrong Direction

An RCO could have his RCD's reverser in the wrong position and move his RCL in the wrong direction. If the RCO does not (or cannot) observe his RCL, this error can result in a move of some distance, perhaps leading to an accident. In any event, an RCO, if distant from his RCL could take some time before slowly adjusting slack so he can see his cut move. An engineer in conventional operations immediately receives the kinesthetic “feel” of a wrong-direction move and can immediately stop it. Usually, he does so before the locomotive has moved more than a few inches. (See Appendix B for Kinesthetics.)

An RCO comments:

> “One [RCO] thinking that he was moving forward and was actually in reverse shoving out the end of a track.”

An accident report finds:

> "RCO foreman placed the direction switch into reverse position and began walking away from the RC locomotive. He should have placed the direction switch into forward position to move away from the adjacent locomotive and watched the locomotive more closely. CSXT 1224 struck the occupied locomotive that was stopped on the same track at approximately four m.p.h., causing neck and lower back discomfort to the engineer in the cab."

An RCO notes:

> "At least twice, newly trained [RCL] operators have moved engines at low speed in the wrong direction and into the side of cars on adjacent track fouling them."

Another RCO observes:

> "When very far from the end of his cut, an RCO can move it in the wrong direction. This is especially so at night or in fog."

In conventional switching operations, a locomotive engineer is present to catch mistakes regarding the direction of movement. An engineer reports:

> "In my personal experience, quite commonly I'm told to 'Come Ahead' when the ground employee actually means to say 'Back 'em Up', or vice versa. I'm sure you can see how this simple mistake could lead to an injury or fatality. In situations like this, when I have reason to believe the ground employee has given me the wrong command, I ask 'Really?' (when working by radio), or simply don't move (when working by lantern signal). That's all it takes to jog the groundman's memory, and he'll correct his mistake."

Another engineer says:

> "The most common problem I run across is being told to 'Come Ahead' when they really mean back up, or vice versa. It happens at least once daily, sometimes multiple times, and is because the engine is sometimes turned north, sometimes south. I catch this error 99.999% of the time, and we're able to prevent a wrong-way movement. With beltpack, that safeguard is missing. The beltpack is completely agreeable with whatever it's told to do. It never questions or argues. This, IMHO, is a MAJOR safety concern, as someone could get crushed as the movement moves in the direction opposite of what was anticipated."

An RCO notes:

> "And now the number one risk of murder and mayhem in RCL operations - the mistaken movement of the locomotive in the wrong direction. We warned long ago that this would be a big problem. When we were only car-handlers we had much to think about and often told the engineer to 'go ahead' when we really meant 'back up.' The engineer more often than not caught this mistake as making no sense in the context of the ongoing work and asked for a clarification. Now the only protection against this is another rule: RCL movement cannot be initiated unless a crew member can see the moving equipment. Will they in fact look to see that they are moving in the correct direction? It would be prudent. But experience indicates

> otherwise. There is just so much to do now, so much to think about. And believe it or not, most here want to do a good job and get the work done.”

10.9 RCL Keeps Shoving/Pulling after Derailment or Obstruction -- RCO Lacks Kinesthetic Sensation and Traction Power Information

Shoving through a derail and derailing cars, otherwise derailing cars, and shoving through a switch lined against a trailing point movement is usually, at first, an unknown event to an OCC of an RCL, i.e., until cars start to pile up off the track and thereby stop the movement. In a number of reported RCL derailments, the movements did not stop even after a derailment or collision occurred. The problem appears to stem from the fact the RCO is usually not in the RCL cab and thus has no “kinesthetic sensation” or feel of the movement. In conventional switching operations, a locomotive engineer is stationed in the locomotive and can feel when the train is no longer rolling smoothly. These kinesthetic sensations can include acceleration, deceleration, and velocity stasis; variable pressures of slack run-in and run-out; smell of hot metal from heavily used locomotive brakes; spinning powered wheels on locomotive; sliding locomotive wheels; and the feeling of resistance when starting a heavy cut of cars.

An RCO describes the lack of kinesthetic sensation this way:

> "When on the ground, you do not have any ‘feeling’ as you would controlling the movement from the engine, and it makes for some pretty hard joints [couplings] at times."

Also, the locomotive engineer in conventional switching operations has the benefit of an amperage meter which shows how much electrical current is flowing to the locomotive’s traction motors to power the movement. When a train encounters an obstruction or additional rolling resistance because of a derailment, the locomotive's traction motors automatically begin to work harder and draw more electrical current. Thus, through a combination of feel and the information provided by the amperage meter, an engineer can usually instantly tell when his train has derailed or encountered an obstruction.

The RCO, on the other hand, has no view of the amperage meter and no kinesthetic sensation of the train’s movement. Thus, it can take a considerable amount of time before an RCO becomes aware that an accident has occurred and takes appropriate action. Furthermore, the OCC does not always have information that derailments or collisions occur. With quite slight variation, the OCC maintains the speed selected by the Primary RCO, until the RCO changes this speed. But, with resistance to motion from a derailment, collision, or other unwanted event, this constant speed regulated by the OCC can result in the OCC increasing the power to the traction motors. Such OCC action can exacerbate the effects of the accident as the OCC literally “mindlessly” pushes onward with increasing tractive power into increasing damage. Because of the lack of awareness of the RCO and the inability of the OCC to respond appropriately, there have been a number of instances where the severity of RCL accidents increased because neither the RCO nor the OCC had information that an accident had occurred and the RCL continued to push onward.

An RCO explains regarding an OCC's autonomous unwanted continuation of a shove after a collision or derailment:

> "The locomotive could run up against an obstacle, or could even pull a cut of cars with a derailment down in the string. It would keep adding throttle amps attempting to attain the set speed until it was unable to move. Only then would it interpret a problem condition, cut throttle, apply brakes, and transmit a 'locomotive movement failure' radio alert, requiring further action from the RCO."

Another RCO reported what happened to an engineer on a standing train when an RCL,

> "hit standing train was thrown about in his cab."

The observations of the RCO above are more than hypothetical concerns. There have been reports of small collisions and derailments turning into large ones because RCOs apparently could not feel the increased resistance of their trains' movement (which) and kept increasing the throttle. A railroader reported:

> "RCL at [location]--a car in bowl ran out other end as trim job was
> pulling down lead. Impact derailed car. RCL operator had just began movement and assumed he had a real cut of cars so went to max throttle. 22 cars later his RCL could not pull any more. Brakie was riding out on engine and saw cars overturning."

A railroader reported:

> "Watched a RCO derailment yesterday at [CCC]. It was kinda weird. Ice and snow was all over the place and I guess switch points did not fit up properly and the cars split the switch. But the weird thing was that when they hit the ground the RCO operator speeded up and then when they really got to derailing he speeded up again. Then as they were about to turn over he plugged it [put the movement into emergency braking]. I guess he could not feel it [the movement] dragging him down as an Engineer would have so he just needed more speed. Two set of trucks were laying near the tracks with about 10 cars derailed with some leaning on their sides. No one hurt."

A railroader noted regarding a blind RCL movement that hit a standing train three times in succession:

> "Now, with proper supervision and the 'feel' of the movement that an Engineer would have had, that surely would not have gone on to a major mess. If nothing else, a 'view' from the cab would have stopped it. Simply put; You can't 'feel' the movement of the cars from a beltpack, but seated on an engine ... yes! You really do. And, for the most-part you know when something's 'not right'."

Another railroader said regarding this same triple-hit RCL accident:

> "The two parts I like is how the RCO's three times 'rammed' the cut of autos (the old phrase 'Third time's the charm' comes to mind), and that [railroad's] spokesperson stated that the accident could've happened if an engineer had been onboard. Yeah...right."

Another railroader observed:

> "We had an RCL accident at 'ABC' recently, where, in a blind shove onto a main track, the RCL kept on shoving its long cut into a standing train. The RCL's computer overcame the resistance of the train and kept on shoving after the collision." And another railroader says regarding the same accident: "We are getting the details. It appears the train was hit twice. This is understandable given the fact that the microprocessor [OCC] that replaced the engineer would have likely put more power to the shove to overcome the resistance of hitting the train. Now that is one spaced out engineer!"

RCL manufacturers have attempted to design safeguards to minimize this tendency of the RCL to increase power after an accident, but it appears that an OCC is not nearly as adept as a human in discriminating between resistance caused by the train weight and track gradient combinations, and resistance caused by a derailment or collision.

An RCO explains:

> "The RCL attempts to maintain the set speed in the Circumstance of encountering a resistance in a shove. If it cannot move, then it disengages the throttle, sets brakes, and transmits a "locomotive movement failure" radio message."

As this RCO bears witness, the OCC takes time to distinguish the level resistance caused by a derailment:

> "When cars in middle of drag in yard without air derailed, engines [RCL] kept pushing causing about 7 or 8 cars to derail until someone visually noticed."

A railroader opines:

> "We have several accidents that have been made worse because of the [RCL] technology's design flaw where speed is 'governed' regardless of reason for resistance to movement."

Another RCO explains the actions of the OCC this way:

> "On the [RTY RR] ([ABC] Terminal) operating with [MANUFACTURER] equipment, we were told during training that once the box [RCD] was set to a fixed speed the locomotive would try to attain that speed no matter what the resistance. This has been our experience. I have been successful at shoving tracks with too many handbrakes or too much air by means of stretching out the slack and then shoving at a high setting. You also have to apply some sand or you might get wheel slip or an axle generator fault that has to be reset."

10.10 Inability to Detect Wheel Slip

An RCO comments that only sometimes, usually on straight track, can he detect the spinning of the driving wheels on his RCL:

> "I did see the wheels spinning on the first move of the day while pulling 25 [heavy loads] on straight track."

A railroader comments regarding kinesthetic sensation:

> "There have been incidents in RCL operation where the RCO is so far away from the locomotive that he/she is unaware that the wheels of a locomotive are spinning and burning holes in the rail so deep. Since the RCO is not on the locomotive, he/she is not getting the tactile feedback which a locomotive engineer always gets via the seat-of-the-pants."

A railroader (engineer) comments on kinesthetic sensation in the following two paragraphs:

> "If we are switching a 3,000 foot cut of intermodal equipment, it requires that I control the power and braking functions of the locomotive differently than if we were switching, say, twenty box cars. I do this based on a number of things: Weather; rail condition; vertical and horizontal curves; weight of the cut being switched; specific locomotive response (and they all respond a little differently). My **experience** combined with my **physical presence** on the locomotive, which allows me to observe by sight, sound and feel (the ol' 'seat of the pants' railroading), are the key factors that prevent derailments and accidents. As a specific example, when we are switching through crossovers, I modulate the acceleration and braking to prevent coupler buff forces from jackknifing or derailing the cars. Another specific example is when stopping, I modulate ('feather') the locomotive brake to prevent wheel sliding. That's important not only to prevent flat spots on the locomotive wheels, but it's been proven than a sliding wheel requires at least twice the distance to stop as a rotating wheel.
>
> "By design, none of these functions are available to a groundman using RC. The typical 'Belt Pack' has eight preset throttle functions and five preset locomotive brake functions. There is simply no possible way for the groundman to know how the locomotive is responding to his RC commands until those commands propagate to the location where the groundman is standing. That location can be quite a distance from the locomotive, and depending on the distance and circumstances (number of cars, grade, etc.), the propagation delay can be lengthy. A few seconds delay can mean the difference between preventing an accident, or not."

10.11 Unexpected Movement of the RCL -- Unintentional Operation of the RCD Controls

There have been reports of unexpected and unexplained movement of an RCL. In most of these cases, the RCOs assumed they must have unintentionally activated some of the control devices on their RCDs. However, it may be possible that additional factors caused some of these unexpected movements.

It was previously noted in section 6.2 that on some RCDs, the reverser lever can slip into neutral thereby negating two of the protections prescribed in a three-point protection procedure to protect against unintentional movement of the RCL. We also observed that on some RCDs the vigilance button can become stuck, thereby reducing the two-step process to initiate movement to a one-step process. In this section, we discuss accounts of accidental operation of the RCD controls. In reviewing the accounts of unexpected RCL movements, one cannot help but wonder if a stuck vigilance button, faulty reverser lever, or some other malfunctioning control device might have been an antecedent to some of the mishaps.

In the case of the unexpected abrupt stops of the RCL, it appears certain that the unintentional operation of the wrong control device at the wrong time can precipitate such an action. Regarding the unexpected movement of an RCL, an RCO had this to say.

> "I was lining up two long drawbars when I heard the bell on engine go off [sound]. Engine was approx. 4 cars away. I immediately removed myself from between the cars thinking I had actually tripped the bell. I looked down at my box and my selector lever was in 10 MPH and the cars, at the same time as I looked down, began to move. I immediately put it to stop. Somehow, and I have no idea how, I must have knocked the reset button and the speed selector button causing a movement." (Or could the vigilance [i.e. reset] button have been stuck in the on position?)

Another RCO reports a similar incident, at length:

> "A brother who was working recently on an RCL assignment reported the following: He was the primary operator and wrongly agreed to help a utility man by attaching an EOT [End-of-Train Device] to the end of a train he had doubled up. The train had neither locomotive attached nor crew assigned. His RCL was on the same track, behind him and separated by the required distance. In the process of wrestling with the EOT to attach it, he apparently moved the REVERSER switch out of neutral, pressed a vigilance button, and moved the speed control lever. He happened to look back in time and saw his locomotive moving slowly toward him." (Or could the reverser have slipped out of neutral and into reverse unnoticed?)

An RCO sums up the possibility that a faulty control device could contribute to the unexpected movement of an RCL, as follows:

> "The 3-step setup for disaster illustrated above is surely remote and unlikely to happen. Or is it? I recently worked with an RCT [RCD] that had a defective REVERSER switch. I finally noticed that the box would switch itself into reverse without actually moving the switch out of the centered position. A mere bump was enough to do this. On top of this we have a situation where we have been trained to continually press the vigilance button in order to avoid the annoying alert. Even if a person was not fiddling with the button, and even with the 'stuck vigilance button' software fix that has been implemented, it is possible to find oneself in a 'pressed vigilance button' mode for a moment and if that moment is when one is handling an EOT or more probably, adjusting a hard-to-move drawbar, buttons and levers will get moved because the box is hanging in the wrong place. Instead of soiling a shirt or jacket while adjusting the drawbar, you may just get coupled up."

As noted previously, unexpected abrupt stops of the RCL-controlled movement can pose a significant hazard. The following are reported instances were the abrupt stops were triggered by the unintentional operation of a control device on the RCD.

A railroader reports:

> "At approximately [time], two yard employees working on a RCL (remote control locomotive) yard job were riding a loaded open center beam bulkhead flatcar containing bundled plywood while protecting the point of a shove. Both employees were riding the point

> on either side of the car in the stirrup position. The employee operating the RCT (remote control transmitter) inadvertently activated the ‘pitch’ button on the control box causing the locomotive to fully apply the independent brake. This caused a rapid deceleration of the equipment. When the employees heard the slack running out, they each braced themselves by placing a portion of their bodies between the bulkhead and the lading. As the slack ran out, the lading on the car shifted toward the bulkhead, pinning both employees.”

An RCO writes:

> ". . . while throwing the switch, the [switch stand] handle caught the reverser toggle switch [on the RCD]. This is considered an illegal reverser change and the RCL stopped but was not in the clear." (A collision followed.)

An RCO reports regarding the design of an RCD and its consequences:

> "On the matter of boxes[RCDs] being turned off, I worked with a portly brother yesterday and he was constantly turning his box off by accident when he moved around in the cab of the locomotive or when he was getting on or off the motor. [MANUFACTURER’S] sizing and positioning of the on/off switch on the front of the box surely ranks as one of the all-time design screw-ups. Even a normal sized user is always bumping into things. "

One manufacturer modified the design of one of its RCDs to reduce the incidents of unintentional operation of the controls. Here is what an RCO reports:

> "The 'HHH' boxes [RCDs] have been refurbished and redesigned. Now all the switches on the top of the box are high-standing metal toggles. This has required that addition of little plastic fins (like a shark's only rounded) on the outer edges of the box. They prevent the new VIGILANCE toggles from getting bumped or damaged but [they] also seem to catch on things as you move around on the locomotives."

But another RCO offers a contrary opinion:

> " By the way, the 'fins' on the [MANUFACTURER] boxes do not in any way prevent the accidental moving of SPEED CONTROL LEVER or INDEPENDENT BRAKE LEVER. Their only function is to prevent damage to the now protruding VIGILENCE TOGGLES. The risk of bumping a VIGILENCE TOGGLE and then a SPEED CONTROL LEVER is still very real. The 'fins' only prevent a side-to-side movement, not a back-and-forth movement, which is the way the VIGILENCE TOGGLE is designed to move."

Question: To what extent is the proper functioning of the RCD ever examined by regulatory or investigative agencies when investigating an RCL accident? Is the RCD impounded? If so, how long after the accident does this occur?

10.12 Automatic Radio Messages -- Effect on Railroad Radio Communications

Some railroads have rules that admonish employees against transmitting a radio message while another radio message is being broadcast. The obvious intent of this directive is to prevent interference of a radio transmission that may be important to the safety of a movement or other railroad related operation. However, RCL systems (and some remote-control track switches) frequently automatically broadcast radio messages to transmit safety critical warnings or other messages to RCL crews. Unfortunately, these remote control systems are incapable of timing their broadcasts to respect the radio broadcasts of others who may already be transmitting a message over the same radio frequency.

On the other hand, for some types of RCL operations, the overall amount of radio transmissions may be less than in conventional switching. The elimination of radio communications between the locomotive engineer and the ground crew can, in some circumstances, more than compensate for any additional autonomous transmissions of the RCL system.

Numerous reports were received on this issue but the range of opinion was diverse. The effects of RCL operations on the capacity of railroad radio frequencies appears to vary greatly, depending on the location and nature of the switching operations. Thus, any attempts to mitigate hazards associated with the increase of decrease in radio traffic must truly be site specific.

10.12.1 RCL Operations Can Increase Radio Chatter

A railroader notes that railroad rules admonished train crews against "stepping on" (obliterating) the radio transmissions of their fellow employees, but RCL systems do not have the ability to follow all railroad rules:

> "The [RC] locomotives report their status on the same radio channel, stepping on switching moves with impunity and endangering anyone close to making a joint [coupling]. So much for, among other things, 'listening' a sufficient interval before transmitting to determine the channel is not already in use! Ah, more rules will need to be modified to 'make room' for the new [RC] technology."

A railroader explained for a busy yard:

> "If you want to get really frustrated by radio garbage, you ought to see what's happening out here. 'The ABD RR' has decided that here in 'JKL' Yard we all need to be on the same channel so we don't run into each other. Even though we have [several] yard channels available, if you choose to use one of these to make a move you may risk a citation and will most assuredly move up a LEVEL toward losing your job. Add to this the fact that these [officers] decided to use the [MANUFACTURER] remote control system, in which the locomotives report their status on the same radio channel, stepping on switching moves with impunity and endangering anyone close to making a joint. We have 5 or 6 RCL engines per shift here, so you can imagine what it sounds like when these recorded messages tell us to recover the air or that we have made an improper reverser change. Now, we also have to call out a signal aspect and indication on the radio when making such moves as hostling power or making a shove on the main." ("Stepping on" is rail jargon for a second radio transmission interfering with one already in progress.)

An RCO has this to say:

> "To make [the] RCL operationally feasible the terminal has established remote control zones within which point protection is not required. Within these zones are radio linked switches,

> which report their status via radio every time they are queried or thrown. (and don't forget throwing the switch involves transmitting a tone sequence over the radio.) So not only are yard crews stepping [talking over]on each other's radio transmissions, so are the so-called hydra switches. Often the car department will throw one of these switches by hand--one end of a crossover--to provide protection while they are working a track. That generates an error message: '[XYZ Johnson] Yard. Switch 9. Switch out of correspondence. Stop and inspect.' And this error message is transmitted frequently whether or not engines are operating near it. Also the remote control locomotives report their status via radio. Computers didn't create the paperless office; killing the engineers didn't stop obnoxious voices on the airwaves."

Some railroads have acted to minimize hazards associated with excessive radio chatter by installing digital radio systems. These allow each RCL crew to have its own radio channel on which to work.

For operations where there are less switching activities, the railroads rules prohibiting employees from "stepping on" another's radio transmissions, appear to suffice, as this RCO observed:

> "The matter of being 'stepped on' [talked over] by another radio communication is an efficiency problem but not a safety problem here, as virtually everyone I work with will simply ask for a clarification, indicating that the transmission was 'stepped on' or interfered with in some manner. People are quite reluctant to act on a garbled or partial transmission. They are very vocal (even on the radio, which is verboten) about giving the Yardmaster (the one who does most of the 'stepping on') some guff about not monitoring the airwaves before beginning one of his lengthy monologues."

10.12.2 RCL Operations Reduce Radio Chatter

As an RCO working at a distant industrial location said:

> "One of the biggest benefits of RCO [here, remote control operation] is the cut-down in intracrew communications. I switched out about 150 cars last night using a switch list and said very little on the radio to my foreman. It is nice to work in peace and quiet without the endless chatter on the radio." (This was for a crew quite experienced for the switching location.)

Another RCO said on a similar subject:

> "I also like doing more detail work with RCL than with an engineer. For example, spotting [X] tracks. 'Bring 'em back 1 car, 20 feet, 10 feet, 5 feet, easy, easy, that'll do, oops, overshot, ahead 2 feet easy, good, good, that'll do...shoot, missed it again, give me a pin....' All this can be done with a box with only profanity uttered but no radio chatter."

10.13 Intra-Crew Communication Errors

One of the highly touted safety benefits of RCL operations is the elimination of communication errors between a locomotive engineer and his ground crew. Some RCL proponents reason that because RCOs perform the functions of both the engineer and the ground crewman, such communications, and by extension, such communication errors are virtually eliminated in RCL operations.

Reports from the field, however, indicate that the amount of reduction in intracrew communication may be considerably overstated. Likewise, the degree of risk attributed to communication errors between conventional locomotive engineers and their crew may have been greatly overstated. The following comments from RCOs provide an indication about the nature and extent of intra-crews communications that take place in RCL switching. This is followed by a brief analysis of FRA statistics regarding the extent to which miscommunication between the locomotive engineer and ground crew has been a factor in serious switching accidents.

Regarding the first issue about intra-crew communications, an RCO had this to say.

> "In the course of giving commands to the [Primary] RCO (via [voice-] radio) and making several joints, I noticed there was no improvement over conventional engineer operations and, in fact, the process was slower and more tedious. More importantly, the same potential for miscommunication exists in this type of scenario as more than once I had to repeat my instructions to the RCO (who had stopped the movement account he either didn't understand my command or could not clearly hear my command over the radio). As you know, one of [MANUFACTURER'S] marketing claims is the total elimination of communication errors between the locomotive engineer and the person on the ground. I would think this proves the same potential for communication errors exist with remote control as with conventional locomotive engineer operations."

A railroader explained regarding a Secondary RCO fatality:

> "The operator of the pitch and catch operation [the Primary RCO] was not on the point of the movement. That should have been the deceased. The operator was the conductor who was kicking the car that eventually killed [name]. This practice nullifies the railroad and supplier argument that errors such as these are eliminated because the point of control is being done by the person with closest vision to the work."

An RCO comments on this matter:

> "The [RCL] side swiping accident that occurred is officially being explained away because of faulty radio communication. So, we are moving back into the realm of more and more critical radio communications. I thought we were trying to eliminate this source of potential error by going to the remotes [RCLs] ? Oh well."

Old habits often die hard. Excessive reliance on voice-radio communication from an RCO on the point to a distant RCO who controls the switching move, instead of pitching control of the RCL to the RCO on the point, can be from habit. Perhaps this matter might be addressed with more thorough training, although experience is also critical. The sentiments expressed by the following RCOs were echoed by a number of others.

> "Many times, while working with a 'box hog' who won't relinquish control of the RCL, the Secondary Operator finds himself using radio or hand signals to communicate to the Primary

> Operator who runs the locomotive. Sometimes it is just laziness that keeps people from pitching and catching when they should. This practice is widespread."

Another RCO explained:

> “Once again the desire to eliminate a relatively trivial pitch and catch procedure is probably the reason. Even if you believe that a man on the locomotive relaying radio messages about the condition of the track ahead is enough to comply with [Rule] GCOR 6.28, you are again dealing with the voice communication link that the carriers and manufacturers are so proud of having eliminated.”

A number of RCOs also indicated it is not unusual for only one RCD to be available for a two-person crew. In some instances, only one RCD was available, in other instances an RCD would breakdown during a shift and the two RCOs had to complete their switching duties with the one remaining RCD. In such instances, frequently, the two-person RCL crew must rely on voice-radio communication or hand signals to perform in the exact same manner as conventional switching crews, to perform their switching duties

It appears the amount of intracrew radio communications remains substantial in RCL switching operations. Attention can now be turned to the question regarding the degree of risk associated with communication errors between a conventional locomotive engineer and his ground crew.

A locomotive engineer can be susceptible to two types of communication errors leading to a switching accident. First, the locomotive engineer can fail to receive a hand or voice-radio signal from a crewmember to initiate or stop the movement of the locomotive and any attached cars. Second, the engineer can respond inappropriately to the hand signal or voice-radio communication, for example he can move forward when the crewmember requested a reverse move, or he can accelerate when he should decelerate. To get a sense of how of these locomotive engineer errors might occur and cause an accident or casualty, one can review the results of FRA’s Switching Operations Fatality Analysis (SOFA) reports which analyzed all switching fatalities between January 1992 and June 2004, inclusive (SOFA 1999, 2000, 2001, 2004, 2005).

All SOFA materials for 2000 and earlier concern conventional switching operations and pertain to train and engine service employees. Materials beginning in 2001 additionally concern RCL operations with their Remote Control Operators (RCOs). In the twelve and one-half year period from January 1992 through June 2004, 128 switching fatalities occurred. In 18 of 128 fatal accidents (14 percent), communications was found to be a factor. However, in only two of those cases did the locomotive engineer fail to respond properly to a movement signal or initiate the movement without receiving the proper movement signal.[2] Thus, the possible extent of this problem appears to be much smaller than is often alleged.

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[2] Most of the other communication issues involved shoving moves that were properly initiated by the locomotive engineer and crew; however, at some point the crewmember stopped giving a car count before the movement was completed in violation of railroad operating rules. Under these circumstances, the movements should have been stopped after a prescribed interval according to railroad operating rules, although it is not known whether stopping the move would have prevented the fatalities.

An RCO thinks this reason is a straw man (a weak argument or position).

> "This question [reason] involves the proverbial "straw man"; the potentially awful risks associated with garbled and misunderstood voice and/or visual communications. Let me suggest that in my 30 years of railroading I've never experienced nor even heard of a case of a hoghead taking the signal given by a member of another crew or moving when he shouldn't have because he mis-heard or mis-read the signal given. I've seen hogheads respond correctly to unintended signals (conductor error). I've heard of sleepy or spaced out hogheads moving erratically or for no reason. But these individuals are well known and the rest of us work accordingly. Most hogheads here are quite aware of the context in which they are working, they recognize voices and the visual presentation of their crew members. Mostly it's us conductors who routinely transmit, 'Back up Job 99' when we really mean 'Back up Job 88' because we have been working Job 99 for the last week or we have been hearing a lot of radio communications involving Job 99. Most of the time the huggers are smarter than we are and don't move when the voice is different or the movement doesn't make sense. They generally ask for a clarification or transmit their own sarcastic message (eg. "Huh??????)."

A railroader comments:

> "One of the (many) interesting things about the whole Remote Control debate is the claim by the carriers and the manufacturers that it will save lives because there's no more engineer to 'misunderstand' the instructions he or she receives from the ground employees. I've only been working for the railroad since [over 30 years], but during that time I've noticed the only occasions where there's a misunderstanding of the type referred to in this claim is really not a misunderstanding at all. It happens when the ground employee tells the engineer, either by radio communication or lantern signal, to proceed is the direction OPPOSITE of the one desired, because the ground employee becomes confused (or forgets) about which way the locomotive is facing."

10.14 Braking Heavy Train Consists with Independent Brakes Only

In yard and industrial areas, moving and switching freight cars without connecting their automatic brakes is a common practice. It saves a great amount of time because switching crews do not have to connect the air hoses between the cars and wait for the air pressure to build up in the train line (air brake line that runs the length of the train). Additionally, cars cannot be cut off in motion when the automatic air is cut in. When the automatic brakes are not operative, the locomotive's independent brakes provide all braking. With independent braking, then, only the locomotive has a braking force for its attached brakeless cars. Accordingly, the total braking capacity is considerably less than that of the automatic brake system. As noted in section 7.7, independent braking alone is perfectly acceptable provided the RCO is trained, experienced, and knowledgeable about the use of the RCL braking systems and their limits. When this understanding is inadequate, it can be especially hazardous because, by not connecting the automatic brake system, the RCO is deprived of an emergency brake system. Of course, the same hazards are present when heavy movements are switched conventionally without connecting the automatic brakes, but typically conventional engineers receive more training in the operation of train braking systems. (See Section 12.0 Training and Experience)

Section 7.7 discussed the practice of relying on independent braking in RCL operations because of the limitation on certain types of RCL systems. In this section, the practice of relying on independent braking to switch heavy RCL movements appears to be a matter of management policy.

An RCO comments:

> "I believe that if remotes were used to handle a certain amount of cars at one time, say 25 loads, then they would work fine. Where I work, the company wants you to handle 60 loaded tri-levels at one time without air---and that is crazy, and beyond dangerous."

An RCO notes that after independent braking:

> "I've seen several cuts drift 30 car lengths or better after the intended stopping point."

An RCO explains:

> "In my opinion, remote technology is fine if there were enforced regulations minimizing the number of cars that can be handled at one time, however with the company wishing for employees to handle enormous cuts, these remotes can best be referred to as several accidents standing in line, just waiting to happen."

10.15 Increased Fatigue Because of Stress of RCL Operations

Fatigue is an issue that warrants attention throughout the railroad industry. The National Transportation Safety Board has estimated that fatigue is believed to be a contributing factor in as many as one-third of all human factor caused transportation accidents. Fatigue may be an especially significant hazard in RCL operations. It is possible that the performance of complex and physically demanding RCL switching tasks, along with the added responsibility for conducting skilled RCL train handling tasks, may make RCL operations more stressful than conventional switching operations. Increased stress can lead to increased fatigue. A railroader has this to say about fatigue:

> ". . . After a crash, again and again, we always see the same thing. Officers from the carriers, and now union investigative teams arrive at the scene, to 'ascertain the facts', as to what could have possibly caused this tragedy. They always come to the same conclusions; absent signal failure, it was crew error! I always respond; 'no kidding'! Lets talk about 'fatigue' having been at the root cause of the error. No one, and I mean no one, wants to talk about fatigue, causing reduction in reaction times; or impairment of judgment (ie microsleep), or all the other things we now know about adverse effects of fatigue in the transportation industry. Only: 'what rule did they violate?' . . . "

Another railroader comments:

> "Somehow, someday, I hope this information [on fatigue] is used to address the problem of fatigue on our nation's [railroads]; in a 'meaningful' way. I really think that management today in railroading, never having worked on [trains or switch engines], really doesn't understand the depth and scope of the problem. . . . Which is in fact, an understatement of

> the situation, as I see it; from 30 [plus] years working 'on the railroad' as opposed to any lesser time they have working 'for the railroad.'"

11.0 Ergonomic issues

A prominent feature of RCL systems is that the RCD must be attached to the RCO. This is accomplished by a specially designed vest to which the RCD is attached. The evolution of RCD designs clearly indicates that manufacturers have given thought to ergonomic issues. The current generation of RCD is less than half the weight of earlier designs, with some models weighing four and one-half pounds with the battery installed. The RCD's are attached to the vests with breakaway attachments to prevent an RCO from being dragged under rolling equipment should the RCD become tangled with this equipment. Despite the ergonomic improvement, RCOs continue to report some ergonomic concerns.

11.1 Weight of RCD, Radio, and Lantern

A number of RCOs believe the weight of the RCD, especially when added to the weight of the portable radio and lantern, posed a burden. Many RCOs expressed agreement with the following comment:

> "First of all, the [MANUFACTURER] box with a battery weighs 4.30 lbs. There would be no point in carrying it around without the battery yet the 3.5 lbs weight was what we were told and what it was marketed with. (The box (with battery) plus the [voice-radio] handset (with battery and required microphone) plus the vest with metal ribs (the only one anyone can tolerate) and a couple of the clip-on lights they issued us all weighs over 9 lbs.) I have experienced discomfort in the neck/shoulder/upper back area after wearing the box for 8 hours. You might think that being trained to stand and work upright is a good thing – better posture and less strain on the back when throwing switches, coupling air hoses, etc. I've noticed my knees are now taking a beating and complaining with various snaps, creaks and pains. It's a bother to get old. There are lots of other actions and movements that we make every day at work that don't involve forceful effort and that can be done quite comfortably and safely while bending at the waist."

11.2 RCD Causes Back and Neck Pain -- (newer reinforced vests improve weight distribution)

A far more prevalent complaint was that the RCD causes significant back and neck strain, especially when worn for long periods of time. There were many complaints about this matter, only a sampling of which are presented as follows.

As one RCO said:

> "Yes the pack is under 10 lbs. but that doesn't mean that it fits comfortably. I find that the box more or less hangs down and pulls at the back of my neck, making me walk with my back slightly bowed, reason why I walk this way? Because if the box pulls down and has the slightest angle to it, it sets off the man down alerter which means as soon as you hear it go off you better straighten up or go into emergency (about 3 seconds). And yes I have adjusted the straps tight, there is just no way around the damn thing pulling down my front, not to mention

> moving around with the box while getting on or off the engine. So after contorting your body in this manner you DO get some back pain after a while."

An RCO notes problems of:

> "mostly back strain and neck strain, which had never occurred before use of RC."

The following is a small sampling of many complaints from RCOs regarding neck and back pain:

> “I'm finding after working a shift that I now have much stiffness in my back, shoulders, & neck that I didn't have before."
>
> "Pain in the neck (literally); lower back pain; stress.”
>
> “I almost never need pain killers but I have to carry a couple of Motrin, etc. to get thru the shift.”
>
> "3 of us have had lower back pain; when reported to the trainmaster as feedback his reply is, 'Do you want to go to the clinic?' i.e., you have a reportable injury or keep your mouth shut."
>
> “I think the mental & physical aspects wear you down and is a time bomb waiting to happen.”
>
> “I [now] have back problems. I never took two days off on the railroad. But now, I need both days for the pain to go away.”

Other RCOs report that back and neck pains have diminished or ceased completely when they stopped wearing the RCD:

> “pain in the stomach area. nausea. tenderness. After box is removed, symptoms decrease somewhat.”
>
> “I've had the good fortune lately to be able to work jobs with engineers. (My back is thanking me.)"

A former RCO who has transferred to road (non-RCL) work says regarding strains from carrying RCD equipment:

> "The scope of work is greatly reduced. I never feel sore, exhausted, rundown, etc. The constant pain in my lower back from carrying the box [RCD] around is gone. Even working a local is a relaxing break from a yard job. I love the pace of things here and I have no intention of donning the box [RCD] again."

A newer, more rigidly designed vest seems to distribute the weight of the RCD on the shoulders and relieve the neck and back pain experienced by some RCOs. An RCO reports:

> “The harness style vests caused neck and shoulder aches- have been replaced with the internal frame vests and have had no further aches.”

Similarly, another RCO comments:

> “Initial vests distributed with RCD's were inadequate and caused neck and back aches, however new vests that are rigid and distribute weight on shoulders rather than neck have improved any aches and pains.”

Some RCOs report pain in their sides, which appears to have been induced by one carrier’s requirement for the use of a particular style of portable radio. An RCO reports:

> "We are required to wear a radio handset in a holster with a microphone. The original setup caused the antenna of the handset to be pressed against my side/back and after a month I experienced pain/discomfort in the kidney area. It was a constant pain that I experienced for about 2 weeks until I decided to screw their rules and use the handset without the microphone. I only transmitted when the thing was in my hand. After a few days the pain went away. I don't know but I do know that I will do what I have to do to avoid such discomfort in the future."

Another RCO explains:

> "After having developed a continuous dull aching pain in the area of my right kidney where the mandated holstered and microphoned radio handset's antenna was positioned, I first moved the unit to the other side and then took off the mic and was holstering and unholstering the radio as needed. This brought immediate relief and now the pain is gone. I have subsequently, in an effort to keep from drawing attention to myself reattached the mic to the handset, but have been trying not to use it."

11.3 Catching Vest, RCD, Radio Microphone Cord on Equipment or Obstruction

Despite the breakaway features on RCD vests, their have been some reports of individuals becoming entangled in rolling equipment. Also, portable radio cords can catch on moving equipment causing a hazard.

An RCO reported:

> "A brother here got his RCT [RCD] vest 'hooked' on some moving equipment and instead of 'breaking away' it dragged him some distance until he was able to 'undress.'"

An RCO reported:

> “At a low speed derailment, man [RCO] riding side of car snagged his vest on something causing box to land upright on ground, cars still moving for a while. Man broke collarbone but could have been killed.”

An RCO reported an RCO's RCD vest caught on moving equipment and the man was dragged about three car lengths. The RCL was not hurt, however.

An RCO reported:

> “an RCO dismounting from a car had his RCD hit part of the car, causing the man to fall to the ground and become injured.”

Several RCOs have commented that their particular railroads allow wearing no ring on an ungloved hand while on the job. This is to prevent snagging the ringed finger on something, especially on rolling equipment in motion. Yet, the RCOs must wear an RCD vest/harness on the job, a device more liable to the ring-prohibited snagging. Said an RCO,

> "If my little ring is a safety problem why isn't my big vest a bigger problem?"

The possibility of becoming entangled with moving equipment or other objects is not limited to RCD vests, RCOs have reported similar problems with portable radio cords. An RCO says:

> "The other day, while wrestling with a recalcitrant pair of air hoses and almost timing out several times without being able to couple them, I stood up quickly to prevent the 'Man Down' message from being broadcast and succeeded in getting the microphone cord hung up on some part of the pin lifting assembly. Not long after that, I caught the same cord on a locomotive door handle while trying to exit the cab. Neither of these incidents were life threatening but they illustrate the potential problem of encumbering one who is working in an environment filled with moving and unforgiving objects."

An RCO reports:

> "I would still opt to work with an engineer because the physical discomfort level and the associated hassle of wearing the stuff. I feel better and safer when able to move around unencumbered. I have even stopped using the microphone with handheld radio. In some ways the mic is a convenience because you don't have to holster and un-holster the radio and it is easier to hear what's being said to you. But that darned microphone cable keeps getting caught on things."

11.4 Climbing Ladders and Riding Cars with RCDs

Climbing ladders mounted on railroad cars and riding these cars while hanging onto the ladders or onto handholds represent a particular challenge. Wearing an RCD increases the angle that an RCO must lean away from a car, thereby increasing the strain on the hands, arms and shoulders. Also, RCDs and vests can become snagged on some ladders and handholds. An RCO group expressed this thought about hanging on to the side of a car with the added bulk of an RCD:

> "Remember that the 3-point stance is now modified by the necessity to hang out and away from the car consequently putting more stress on the supporting arm."

From an RCO:

> "With an RCD mounted on your waist, start climbing up and down ladders. Tell me if you think this is a problem. Dismounting locomotives is a problem. Getting off some kinds of cars is a real hassle when the rungs are not where you would expect them to be. (Think everything is standardized? Check it out.) You can twist and turn to get a look at where you are stepping, but be careful of TILT."

Regarding the manipulating of controls on an RCD, an RCO group reports:

> "You definitely have to move to a 3-point stance to manipulate the levers/switches on the box unless you're fourth point is an arm 'hooked' through a rung or something else. Unfortunately, many ladder rungs do not allow this 'hooking' action as the space between rung and car is too narrow to accommodate an arm."

Another RCO reports:

> "[RCO Z] says that he was having trouble all day long with the snaps that hold the remote control unit [RCD] (a [MANUFACTURER] model) in place. Every time one of the snaps came loose the remote control unit would slip a little causing the tilt feature to activate on the unit. This can be very irritating as the unit will start talking to you when it is not level and eventually will put the engine in emergency if not dealt with in a timely manner. While [Z] was dismounting a railcar that day the snap came loose and his attention was diverted for a moment and he missed a step and fell from the equipment. [Z] sustained injuries to his shoulder, back, and ribs because of the fall. He landed in the gauge of an adjoining track and luckily there was no activity on the track."

11.5 RCD Blocks View of Feet

From an RCO:

> "A significant complaint about wearing the box is that you cannot see your feet. This might seem trivial, but try it out. Hang something around your neck or affixed to your waist which obstructs your view of your feet."

From an RCO group regarding seeing the feet:

> "This is a problem. Walking is a potential problem if you don't study the terrain ahead of you. Someone here stepped in a hole and fell down just the other day."

Here we have not only a human-machine interface but also a human-workplace interface. Rail yards can be covered with stone ballast. Railroad employees must constantly step over rails and rights-of-way are magnets for debris, especially when working around industrial tracks. In other words, a railroad right-of-way is seldom a paragon of industrial hygiene. Having the ability to see where one is stepping is an important issue for crews engaged in switching operations.

12.0 Training and Experience

The issues of RCL training and experience may be paramount with the railroad industry for some time. Training and experience cannot be separated as critical for operational safety. Based on projections of the US Railroad Retirement Board, in June 2004, the railroads estimated that they would have to hire 80,000 new employees across six years, and 140,000 in ten years, or about 13,000 annually. (anon. 2004a) Thus, railroads will be flooded with inexperienced employees, in a workplace having fewer employees than traditionally to mentor the waves of neophytes working in a potentially catastrophic setting. (See Training and experience in Appendix B.)

A number of the RCL-related hazards discussed above could be mitigated if RCL crews were better trained and had the opportunity to gain more experience. Experience comes with time, but as has been seen, sometimes an accident comes first. Also, experience, without proper training has a negative tendency to reinforce bad habits.

Many RCOs expressed the belief that more and better training is needed. Railroads commented about the importance of RCOs needing to gain experience. Training concerns expressed by the RCOs included, insufficient training time, failure to train in the most demanding type of service the RCOs will be expected to perform, and poorly qualified instructors. Training alone, however, might not compensate for the advantages an engineer receives from his observation of his gauges and other indicators. (See Appendix G for a comparison of typical training programs for RCOs and locomotive engineers)

Moreover, not all young persons tolerate the stressful demands of railroad service. A well-placed railroader notes one consequence of this intolerance by new-hires:

"RRs are having a hard time retaining newly hired employees. [VBN RR] is hiring almost continuously around here." Another railroader comments on the great hiring needs: "One other factor in play here, is the carriers' (this includes [XCV RR]) willful decision not to hire and train enough conductors and engineers to replace those retiring, attrition, and for new business that they knew was coming."

Accordingly, in the coming decade, the railroads will have to hire more than 140,000 "student" neophytes to retain 140,000.

Thus, the carriers will be flooded with inexperienced employees, in a workplace having fewer employees than traditionally to mentor the waves of neophytes working in a potentially catastrophic setting. Traditionally, supplementing formal training was the informal transfer of knowledge from the veterans before they retired. With reduced crew sizes on switch engines and trains, the number of such veteran employees and their opportunity to transfer knowledge have diminished in concert. At one time, these crews had five and sometimes six members, whereas, today, we find frequent two-person crews, as the railroads look to reduce this size to one person.

12.1 Insufficient Training Time to Practice Switching with an RCL

At the urging of FRA most railroads, after proposing a shorter period, agreed to provide at least two weeks of training for new RCOs. Nevertheless, a common RCO complaint was that RCL training courses were too short. Railroads also assert that an RCO is free to ask for additional training if he believes he needs it. Despite these assertions, the amount of training remains an issue with many RCOs. In their narratives, subjects noted that training sessions were too short, there were not enough instructors, and training resources were insufficient (i.e., not enough RCDs). Of course, individuals learn at their own pace, and not all RCO’s felt that more training was necessary.

12.1.1 Training Course Too Short

An RCO comments on training:

> “2 weeks of training for me was NOWHERE NEAR ENOUGH! Engine controls should belong to the engineer, not me!”

An RCO comments:

> "The new workers are being rushed through training, and given too much responsibility too soon. The most capable new worker cannot absorb the complicated procedures associated with the new technology, the layout of a large number of unfamiliar yards, the inertial characteristics of car cuts of a variety of weights, lengths, and speeds, the individual braking characteristics of the locomotives he uses, and simultaneously navigate the social integration problems deriving from being the new person on the block. Increase that pressure if there are race, gender, or cultural factors."

An RCO reports:

> "There was a little incident here involving our box [RCD] student who is actually a prodigy of sorts in comparison to other new hires and who consequently got certified after only about 20 minutes of observation by the [officer] (what's the rule on that?) He was training on a night flat switching job and cornered [sideswiped] a hazardous tank car that had slowly rolled back out of a track it had been switched into."

An RCO reports:

> “The training program does a terrible job of training on the Train handling and air brake rules, as well as the FRA rules that apply to RCL. We covered ‘Authority’ in less than 5 minutes, and train handling in 4. As long as a job stays in the yard, and handlings short cuts, the only real consequence is inefficiency. But, in unfamiliar circumstances, guys can get into trouble fast.”

An RCO writes:

> "Subtract long lunch breaks & coffee breaks and long periods of inactivity because leads were blocked and congested and I estimate I only received 3 or 4 hours of actual hands on operation” [in one week].

An RCO concluded regarding RCOs and their training:

> “We'll all eventually get the experience I suppose, but the training regimen does not exist, and the real safety risks ensuing from this ignorance are ignored by the railroads.”

An RCO commented:

> "The 'MNO RR' is heading for disaster with this combination of too much technology and too little training."

At least one railroad appears to recognize the need for additional RCL training for newly hired employees with little or no prior railroad experience as this road RCO reports

> "There were [X] of us in the RCL class. We all had 1 week of classroom/field training. After that if you have been with the railroad for more than a year you get 5 days of training on your job with an instructor. If you have been on the railroad for less than a year you get 10 days with an instructor. This is basically par for the course from what I have seen. The railroad always seems that they are lacking in the training department."

Another railroad recently began to require 30 student trips for a student RCO. This provides far more hands-on "box time" than the previous 40 hours on-the-job training. As an RCO explains:

> "The program here is 30 on-the-job starts training with the box [RCD] for new hires. I recall that our training took two weeks."

12.1.2 Insufficient Number of Qualified Instructors

Some RCOs have expressed concern that a student-RCO, while operating an RCL, is not always under the direct and immediate supervision of a qualified RCO instructor. This is an FRA requirement for the training of student-engineers and student-RCOs. Subjects have reported that the instructor-RCO is not in the immediate *close* proximity of his student (or sometimes two students) and, at times, might be riding on the opposite side of the same car from the student or be not riding when the student is riding. If an instructor is not in the immediate close proximity of his student, how does he, first, comprehend and, second, stop performance of an error by the student?

An RCO reports on too many RCO students of too few RCO instructors:

> ”As far as the field training is concerned, there were 4 people per instructor so the 40 hrs was really split between 4 people."

An RCO commented on inadequate amounts of hands-on RCL training:

> ". . . and one of the trainees in the first class, confirmed the situation and, dismissed it as no problem because he himself 'had to spend most of his training in the yard watching others attempt to learn how to move the engine.' At that point someone suggested that 8 students might be too many for only two RCLs."

A railroader comments on an RCL accident in which the Instructor-RCO and the Student-RCO operating the RCL were on opposite sides of the cut of cars being handled:

> "He [the student] got off on the INSIDE of the curve in the 'RST.' The RCO / Foreman got off on the OUTSIDE of the curve; thus he could not physically see the RCL after it disappeared around the curve. The student, being on his second day, was probably clueless."

12.1.3 Insufficient Number of RCDs

Some RCOs complained of training classes where there were not enough RCDs available to allow all of the student RCOs to practice RCL operations throughout the training period.

Regarding two student-RCOs on one job, with a normal two-person crew, an RCO says:

> "then one trainee gets no box time [RCD handling] while the other is controlling."

An RCO comments:

> "In short, with two students on an RCL job, the hands-on training time is cut in half from what it otherwise would have been."

Another RCO states:

> "The 'GHJ RR' hiring frenzy is resulting some interesting situations. Several times now we have had two students on our job, one a boxer [having an RCD] and the other boxless. Makes for even more difficulties in trying to plan the work if you are the foreman. I'm not sure how that is supposed to work."

Another variation on the theme of insufficient number of RCDs during training is reported by this RCO:

> "The quality of the classroom training was fairly decent (instructed by a [foreign railroad] retiree) with over 15 years of rcl use. However, he used a [MANUFACTURER] box and had never used the [ANOTHER MANUFACTURER] box we were being trained for. I understand that all the managers were trained on the [FIRST MANUFACTURER’S BOX] as well. A lot of good that does for us."

With the great number of new hires on all the class-I railroads, currently and in the next several years, we could see a continuation of this situation.

12.2 RCOs Not Trained to Perform Most Demanding Type of Service to Which Assigned

Most RCO training involves handling moderate size cuts of cars in yard switching. In actual service, however, RCOs report having to move entire road trains or long, heavy cuts of cars with the automatic air cut in, a task for which they have not been trained. One railroader said:

> “With the on-the-job experience handling trains, for which they had no training, the RCOs were now thus qualified."

Here we find self-training, on the job, by trial and error in rail switching. (See Training and experience in Appendix B for deficiencies of such practice.) FRA regulations require that anyone who operates a locomotive, including an RCO, needs training for every class of service he will perform. Some carriers instruct their RCOs that they can request training for a class of service for which they do not feel trained or adequately trained. However, such a voluntary request for additional training puts the onus and pressure on the RCO-requester. How likely is an 18 to 20 year old student-RCO, new to railroading, about to say, "I need more training?"

An RCO comments:

> "FRA has placed the onus for determination of 'qualification' on the uninformed operator. Remember the Arabic proverb--He who believes he knows and knows not is a fool... FRA and the railroads are making fools of the unqualified RCOs." (Actually, it is the railroad's responsibility to determine whether an RCO is qualified.)

Question: To what extent does FRA monitor newly qualified RCOs to determine whether they received training on the most demanding type of service they will actually perform?

12.3 Lack of Qualified RCO Instructors

It has long been known, from experimental evidence in industry that formal training of trainers concerning teaching is of inherent benefit to proper instruction (Maier 1946:225-228). Some RCOs complained that their trainers for RCL operations had insufficient training and experience in RCL operations. Such trainers did not understand all that was happening in RCL operations, could not answer the more involved RCL questions, had no experience with local conditions, had no experience with the groundman's craft, and had no experience with the consequences of certain kinds of RCL moves. This last included moving long, heavy cuts, with and without the automatic air cut in. Other complaints from student RCOs include, trainers did not have teaching skills, trainers telling the students to keep out of the way while they work, trainers only permitting students to make simple moves, and yardmasters expecting trainers to get the switching work done. (For conceptual discussion of these problems, see Training and experience in Appendix B.) No one is a "natural born teacher," no matter what the currency of this fiction.

An RCO notes:

> "Most RCOs who train students receive no instruction on how to be trainers and nothing about what to include and what to stress in their training of an RCO."

An RCO comments on inadequate training coupled to inadequacies of the trainer:

> "One of the field trainers was a [ZXC RR] human resources employee, and apparently he was a switchman [seniority date]. When we got more into spotting cars and were having a hard time stopping on a dime, we asked him to show us how it was done. His response to us was, 'You guys will get the hang of it.' Later he admitted to [us] that he had never used the remotes while performing his job but only during the training that they put him through."

One RCO contrasts RCL training with the training for conventional engineers by stating:

> "Engineers are not trained by instructors needing more training and having almost no experience with what they are teaching the engineers."

A railroader said:

> "Apparently these managers think that conductors just sit and ride and the job requires no knowledge or skill. **I mean what the heck, they sent RCL trainers and such out here that have never worked a day on the ground as a conductor.**"

On some carriers, hands-on training of student RCOs is now done in the field by an RCO crew. The crew has been given no training on how to train students or what the content of the hands-on training should be. An RCO comments:

> "We are now 'training' the new RCL new hires 'on-the-job'. The old rule of thumb, 'If they ask you to do something that you have not yet done, ask for a trainer' is pretty much irrelevant. We are the trainers. Some of these guys [the students] can't tie their bootlace while wearing a beltpack. Some can handle big cuts with train air. Go figure. The point is, we are having them do the sorts of things they will be doing when they are set up [as an RCO]. But there is no emphasis (other than what we instill in them) on their right to refuse to do things that they haven't yet been trained in."

Another RCO who is required to train student RCOs reports:

> "We have helped eliminate the RCL TRAINERS. We are providing the on-the-job RCL training for new hires while trying to get the work done and keep the management happy. It's not working out too well. There are conflicting messages. Our prime directive is to train these people to work safely. But we have to get the cars switched and the trains made up. Things are backing up once again resulting in more pressure to get the work done. Yardmasters are telling people not to let the students [trainees] run the box [RCD]. It's a mess."

Perhaps the most damming assessment of the quality of RCL instructions came from this RCO:

> "The training program was a joke. It has consisted of 6 classroom days, 2 of which nothing was done. By nothing I mean no equipment or no instructor. We sat around and talked about fishing, vacations, cars, and etc.... Somewhere in the middle we got a 50 question hostler test, and at the end a 50 question RCL test. They spoon fed us the tests-nobody fails. 'Course nobody learned anything but the answer to #42 was yes. Then we had 5 days on the job training with switchmen but no instructors."

Closely related to the lack of qualified instructors is the lack of supervisors who understand and are qualified in the operation of RCLs.

Some RCOs have noted:

> "the operating officers and supervisors who oversee them have had no or only superficial training in RCO tasks and RCL operations and about RCL physical systems and the components of these. Thus these personnel have no or limited comprehension of RCL operations. Operating officers and supervisors often do not know the limitations of RCL performance and of what an RCO can do or safely do."

A new RCO was,

> "told by a supervisor to take his RCL out a few miles out on the main track and bring in a freight train parked there. The RCO coupled his RCL to the road locomotive of the train but could not figure out how to release, test, or use the automatic air brakes. He had not in any way been trained to do so. He voice-radioed the supervisor about his problems and was told to uncouple his RCL and come back to the yard with it alone. (Did the supervisor understand what was involved with his request to bring in the train?)

As an RCO says:

> "How can they [officers and supervisors] supervise us, if they do not know what they are supervising or what we are doing out here?"

12.4 Insufficient Instruction about the Operation of RCL Technology and Operations

Another issued raised about RCL training was insufficient instruction about the nature of the technology and about switching itself. Obviously, experienced switchmen, conductors, and brakemen were not concerned about the latter.

A railroader comments:

> "I think it would be very fair to say that the safety of the [RCL] equipment seems to be directly related to the amount of time the carrier is willing to devote to training the crews on how to use it."

An RCO, generally satisfied with RCL operations, notes that RCOs' greatest hazard is:

> "Someone not understanding how the equipment works." This RCO feels that RCL operations would be enhanced: "If more people understand RCL and the rules the [that] govern the use of the equipment."

Several RCOs reported insufficient time for training in the nature and functions of the automatic air brakes system. As one RCO said:

> "I'm still dazed by the quick lesson in modern airbrake systems. And I think I knew a little about this. Enough to surreptitiously move an engine if I had to. Mr. [officer] claimed at the end of the class that we now know as much as any locomotive engineer about this stuff. We got him to admit that we are in fact taking on many of the responsibilities of the locomotive engineer. But whenever I turned the discussion to issues of train handling he slipped and slid and avoided the question."

An RCO comments:

> "New hires are going to go thru class be promoted to conductor and rco trained before they know how to switch cars- it's going to be very overwhelming for them."

A railroader reports an RCL accident that the railroad attributed to insufficient training:

> “And on one of those web sites I sent you awhile back, there's a photo of a [XYZ 999] at [location] that's buried up to the frame after being run off the end of the track. No discipline assessed in that incident, as management's position was ‘the cut was heavier than the RC crew thought it was’. Gimme a break.”

Here, then, we have a managerial acknowledgement that these RCOs were not adequately trained and knowledgeable about local gradients with relation to tonnage and braking characteristics and limits. Also, it is an obvious admission that RCL operations are not fully automated and require a considerable degree of skill on the part of the operator.

12.5 Lack of Experienced RCOs

Formal classroom and in-field instruction are important parts of effective training but such instruction alone is no substitute for experience.

An RCO comments:

> “It is the new hires who are having the most difficulty adapting to this new [RCL] technology. The old switchmen already knew how to switch without thinking too much about it and can concentrate on the train handling aspect. What's going to happen when all the old heads leave and an[operationally] inexperienced managerial force is left to train the newbies?”

An RCO explained regarding a crew having a serious injury:

> "The person that was helping [name] has quit because he [had three accidents resulting in damage to equipment] all with remotes. The guy had minimal training as a trainmen (5 weeks) and then went right in to RCO training."

A group of RCOs caution regarding the potential for a lack of experience for an entire RCO crew of two:

> "Of course, our RCL assignments are still 2 men. Of course, there is the real possibility, given the current manpower shortage, that 2 of these new hires will end up on the same job. And, possibly, with an RCL student. It's madness. That's our story and we are sticking to it. Of course no one is listening to us."

This group's caution is being realized in the rail world. An RCO provides the following report about inexperienced RCOs:

> “An RCL moving a long, heavy cut ran out of a yard, past a stop signal, through a power switch, and into a train on the main track. Eleven cars derailed and one of the two coupled m-u RCLs toppled. The two RCOs did not provide point protection for their movement. The two RCOs were new employees, one having less than two weeks as an employee. Nevertheless, the two were assigned a student-RCO to train.”

Lack of experience may have played a role in a fatal RCL accident reported by The Idaho State Journal: It involved a utility employee riding an RCL movement at Union Pacific's Riverdale, Utah yard (O'Connell 2005):

> "RIVERDALE, Utah -- A 38-year-old Union Pacific Railroad switchman was killed early Monday [April 11, 2005] after he apparently fell under a freight car being pushed by a remotely-controlled locomotive. . . . it was the victim's second day of work at the Riverdale switch yard after a transfer from Salt Lake City. Riverdale is located about 30 miles north of Salt Lake City. The man had eight months of total experience with the railroad . . .." (While the victim was not an RCO, the question remains did he receive any training about working in RCL operations)

Regarding lack of sufficient experience for a pair of aircraft pilots Wiegmann and Shappell comment that this pairing "can be traced back to <u>unsafe supervision</u>" (2003:48). The rail parallels to this case of supervisor's error are obvious. Two newly trained RCOs in a collision of their RCL into a train apparently lacked the combined experience to work together unsupervised. They certainly did not possess sufficient experience to train a new student RCO.

At least one carrier recognizes the importance of experience: An RCO comments on this recognition:

> “Now, we have a class of RCL operators who are licensed to operate RCL but only as a helper with a ‘qualified’ foreman.”

An RCO says:

> "Our original and current position on this [experience] is that, whatever 'training program' carrier and UTU have agreed on, experience does make a difference. Theoretical discussion of braking and train handling is valuable but not, in the end, definitive. Even limited experience cannot make up for sufficient experience that results in an almost instinctive response to operational directives and situational surprises."

A railroader reports a near miss that easily could have turned into a fatal accident . . .

> “A train was near its departure time and its conductor notified his engineer that he would be bodily fouling between equipment. The engineer acknowledged and, as per the rules, centered his reverse lever and set the independent air brakes. His train then began to move! This was the second time within a short period that uncontrolled movement had occurred to the train. The reason for the uncontrolled movements of the train was that an RCL and its cars had been blindly shoved by its RCOs into the standing train. The train’s conductor was not injured but he could have been.

Concerning this near miss, an RCO, noted that lack of experience certainly appears to have been a factor:

> “A two man remote switching job was being worked by two new hires. Neither one had any railroad experience before hiring out and both had been ‘certified’ and given their RCO license within the last week.”

Question: Given the far-reaching effects that proper training and adequate experience can have on mitigating many of the RCL hazards that have been identified, does there need to *be greater regulatory oversight of RCO training programs? Should logs of training activities be kept and signed by each student-RCO?*

Part III

Recommendations and Conclusions

13.0 Strategies to Promote RCL Safety

13.1 Develop Baseline RCL Accident and Casualty Data Based on FRA Audited Accident and Injury Reports

FRA maintains an extensive database of railroad accidents, casualty statistics, and operational data. The data are provided by the railroads, which are required to report railroad accidents and casualties meeting a specific criteria mandated by Federal law. In its Interim Report to Congress, FRA used this data to compare the number and rate of switching accidents and casualties from conventional and RCL switching activities over a six-month period. The FRA requested the railroads to provide information about the number of switching miles for both types of operations so the data could be normalized. This preliminary data described RCL operations as having a 13.5 percent lower accident rate and 57.1 percent lower injury rate than conventional switching operations.

However, some rail industry critics question the accuracy of accident and casualty data whose source is the industry itself. The implication usually given by these critics is that local officers cover up the less severe accidents and casualties to protect their career records as managers. As Trevor Kletz points out in *Lessons from Disaster: How Organizations Have No Memory and Accidents Recur* , skepticism of industry generated accident data is by no means limited to the railroad industry. Addressing the motivation of those responsible for reporting industrials accidents, Kletz observes, "they consciously or unconsciously present themselves and their companies in as good a light as possible. . . . Try to look beyond the printed words" (1993:108, 138-140). However, he also recognizes the realities of our litigious society and notes that accident reports that are too candid and fully comprehensive invite legal problems and public relations nightmares (Kletz 1993:64-66).

RCOs and railroaders have expressed skepticism about railroad industry reporting of RCL accidents and casualties. This skepticism was summed up by a railroader who stated:

> “The FRA Blair [RCL] accident report is ‘laughable’ and shows the deficiencies of the FRA's data base. Although the codes available are fairly comprehensive, the actual report is prepared by the railroad and usually the information provided is based on an agenda to fix blame or mitigate a railroad's liability. They do not always reveal what actually occurs. Use of the narrative can go a long ways to address the shortcoming of the codes. The problem with narrative is they are not searchable requiring time consuming effort by someone who knows about the accident.

A similar opinion was expressed by this railroader:

> “However, this is an example of why the safety record of RC operations should not be taken at its face value, given that the carriers are the ones who investigate these accidents, determine their cause, and report them thusly.”

An RCO said, about another RCO who was injured on an RCL job:

> “I should note that, while we work for the [UIO RR] and their policy of firing employees who get injured on the job, they have been extremely nice with [Mr. Y,] in this instance. The official report on this [his] injury mentions **nothing** about remote control!"

A frequent criticism of railroad accident reports is the belief that railroads intentionally underestimate the damage caused by an accident so that it will not meet the FRA reporting threshold which is currently set at $6,700. This figure represents damage to railroad property. Railroads are *not* required to consider damage to non-railroad property nor damage to the cargo contained in rail cars when calculating the cost of an accident for FRA reporting purposes. Other critics are suspicious that underreporting of railroad accidents and casualty data also takes place by persons higher up the organizational ladder. In this vein, an RCO commented on accident-related information destroyed by a railroad:

> "My favorite quote from the NY Times was the one attributed to the 'OPQ RR' spokeswoman when commenting on the 12 boxes of destroyed evidence pertaining to the 'BCD' accident. 'We feel awful about that but people sometimes make mistakes.' Or something like that. Double standard, anyone?" (This was not an RCL accident.)

But a few subjects did not share the skepticism over RCL accident reporting, as reflected by the comments of this railroader:

> “The reality is that overall accident statistics in switching service have significantly improved since RCL was introduced. I have no reason to believe the stats are incorrect, since you can't easily hide fatalities or serious injuries, and those have dropped overall. It seems to me that while we don't have a lot of experience with using RCL in the US, the Canadian experience shows that there wasn't a high accident rate with the introduction of RCL, and that switching operations are at least as safe, if not safer, than they had been.” (Severe switching injuries have shown a slow but steady decline from 2000 through 2003; however, the number of switching fatalities grew over the last three years, from an all time low of six fatalities in 2002 to 11 fatalities in 2004, a level that slightly exceeds the average number of switching fatalities over the past 12 years)

Whatever the degree of skepticism about railroad accident reporting in general, that skepticism appears especially pronounced regarding the reporting of RCL accidents and casualties. Perceptions both shape and reflect beliefs, and it is beliefs that motivate human actions. Therefore, a widespread perception among RCOs and other railroad employees that the industry is not serious about identifying RCL accidents and hazards can only have a detrimental effect on employee attitudes toward RCL safety. Rank-and-file cynicism about an organization’s commitment to safety will, by necessity, diminish their commitment to working safely.

That cynicism is reflected in the comments of this RCO who recently observed:

> "While I was [location], my [crewmember] called me and said that they were dropping some cars (something we do everyday). Well while they were sawing back in the remote [RCL] lost comm and stopped. Needless to say the cars hit the locomotive and made it a convertible. From what my [crewmember] said, the first managers out there were looking for blood, saying they were gonna fire the whole crew. However, when the senior managers came out, it died down a little bit and heard them saying that because it was an RCL incident, it might have to be swept under the rug.

Another RCO reported:

> "Here in 'DEF,' a local chairman ran through a switch with an RCL movement and reversed and put cars on the ground. The accident never happened."

This RCO described an alleged cover up of an RCL accident this way:

> "This crew was drug tested but the [officer] told us that his counterpart who had inspected the damaged [RC] locomotives and taken the one out of service had received a phone call from his boss who had told him not to file an official report of the accident."

This RCO sarcastically described the attitude that no one is held accountable for RCL accidents this way:

> "We as RCO's don't need job insurance because the company protects us."

Another concern frequently expressed by RCOs and railroaders is that accidents and casualties caused by failures of RCL technology are misreported to FRA as "human error". A number of mishaps caused by an apparent failure of RCL technology were discussed in Section 5.0 More common are mishaps where the OCC, acting in the manner it has been designed, issues a command to the RCL that causes an accident or injury. A communication loss that results in an emergency stop which in turn causes the RCL to collide with the cars during a drop is an example of the latter situation. (These kinds of accidents are discussed in Section 8.0.) In these kinds of cases, actions of RCOs did not cause or contribute to the accidents. However, accidents that fall into this category are not being attributed to technological failure in the official reports. As FRA's Interim Report to Congress declared:

> "To date, nearly all of the FRA reportable accidents and incidents concerning RCL operations have been the result of human error and not RCL technology. As noted previously, there were no accidents or incidents associated with the technology malfunctions." (Interim Report - Safety of Remote Control Locomotive Operations, P. 8: May 2004)

However, the exoneration of RCL technology from accident causation is disputed by many whose views are reflected in the comments of this railroader responding to a question about how many incidents can be attributed to RCL equipment:

> “Apparently none, according to the FRA, the AAR, and the carriers. However, I've personally witnessed a lot of ‘hard joints’, and RCO's ‘joining the birds’, when their RCLs don't respond to braking commands.” (The jargon “joining the birds” means jumping off moving rolling equipment prior to a collision).”

While the FRA strives for get the industry to report accurately all accidents and injuries, the cynicism engendered by intentional underreporting or misreporting of RCL accidents can become directed at the agency. Such cynicism is palpable in the comments provided by this RCO regarding a fatality in an RCL accident:

> “Another victim of a rush to progress in the industry or a rules violator? Will the FRA spin this in order to ‘prove’ that the technology was not at fault? Notice the company line in the San Antonio Express-News account that admits the brother was working alone but that, ‘The system is designed for that. An employee working by himself in that situation is normal.’ Is that the FRA view?”

While the criticisms for railroad accident reporting in general are likely to remain as long as the railroad industry generates the vast majority of accident and casualty data, something can be done to generate baseline data of RCL accident and casualty rates with a fairly high degree of reliability. FRA could undertake a comprehensive audit of RCL accident and injury reporting. Auditing railroad RCL accident and casualty reports from a broad cross section to RCL operating environments would help provide a more accurate picture of RCL risks.

Given the significant degree of diversity in RCL operations, the audit should be conducted in selected divisions, terminals and yards, that cover the gamut of RCL operating environments. Some of these RCL operating environments include yards with extensive RCL service, small isolated yards, yards with RCZs, yards without RCZs, hump classification yards, flat switching yards, industrial spurs, secondary track, main tracks with RCL local freight trains, and RCL operations with different crew configurations (e.g. pitch and catch, multiple-person crews with one RCD, single-person crews). FRA should also audit the RCL operating data for these areas to allow for accurate normalization of accident and injury data.

FRA has developed an effective technique for auditing railroad injury reports. It sends a team of experts from FRA headquarters and regional offices to select railroad locations to compare the accident and injury reports with the records from the railroad’s Claims Department. When this technique was first employed in the late 1990s, underreporting rates were found to range from 10 to 30 percent. Once the FRA teams have completed the audits of the selected railroad divisions and yards, their data can be compared to the unaudited RCL accident and casualty reports to gauge their accuracy. Furthermore, by differentiating the various types of RCL operating environments, the agency can better judge the relative risks and benefits associated with each type RCL operation.

Others in the railroad industry have suggested the benefits of auditing accident and casualty data in the manner so described, as indicated by the comments from this RCO:

> "If the claims files could be opened and the injuries known along with the circumstances of their cause, the FRA could really begin to quantify the risks of RCL."

If the FRA is interested in comparing the relative safety risks between RCL and conventional switching operations, then, it would also be necessary to conduct similar audits of conventional switching operations.

13.2 Develop RCL Accident Investigation Protocols to Increase Understanding of Factors That Cause or Contribute to RCL Safety Risks

Accident data reported by railroads can never be the sole source of our knowledge about railroad risks and hazards because accident investigation are often hasty (owing to the need to restore rail service), railroad accident reports are necessarily brief and the information often lacks detail and context. Another quite valuable source of information about railroad hazards and risks can be gleaned from the accident reports of major accident investigations conducted by FRA. By reconstructing events and conditions leading up to and triggering an accident, much can be learned about the hazards and the measures to mitigate those hazards.

Unfortunately, because of the relatively recent introduction of RCL operations and technology into the U.S., there is little institutional knowledge within the industry about RCL technology and the finer points of RCL operations. Without this knowledge, it is difficult to conduct comprehensive and detailed investigations into the potential causes and contributing factors surrounding RCL accidents.

Government regulatory and accident investigative agencies should develop protocols to guide inspectors in the investigation of RCL related accidents and injuries. Possible investigative protocols might address some of the following topics:

- Teach investigators to understand the causes of the OCC's autonomous stops and other actions to determine if they may have caused or contributed to the incident.

- Investigate the condition and operation of the RCD involved in the incident, and poll other RCOs who work in the yard or vicinity to determine if there is a history of RCD problems.

- Verify the integrity of the RCD assignment process to ensure that only the authorized RCD(s) could operate the RCL in question.

- Investigate training of RCOs involved in an incident to determine the amount of training received, including the amount of operating time, and whether a qualified instructor was present. Also, investigate whether the RCO was trained on the most demanding type of service that he or she subsequently performed.

- Check OCC data logs, if they were created, and compare RCL data with locomotive event recorder data.

- Review RCZ rules and procedures. Also, investigate reliability of pullback protections, where in use.

13.3 RCL Stakeholders Should Work Together to Address RCL Safety Issues

FRA established a taskforce consisting of representatives from the Class I railroads, the American Shortline and Regional Railroad Association, RCL manufacturers, and the rail labor organizations that represent trainmen, locomotive engineers and RCOs to examine RCL issues. However, the group has only met twice and has not met at all since May 2003. Consideration should be given to establishing a standing committee or task force to systematically study RCL safety issues. The group could also explore strategies to mitigate RCL hazards.

By utilizing the diverse experience and knowledge of all the relevant RCL stakeholders, it may be possible to gain a more holistic view of RCL safety hazards and risks. Having representatives from the railroads, RCL manufactures, rail labor organizations work with FRA to identify RCL hazards, prioritize risks, and develop mitigation measures may prove to be one of the most effective methods to address many of safety issues that surround RCL technology and operations.

Diversity also breeds creativity of thought and action. Bringing together RCL stakeholders with differing interests and approaches to problem solving may foster innovative ideas to mitigate RCL safety risks. To be sure, each group will have its own agenda reflective of the organization’s core mission.   Railroads will look to increase productivity and minimize costs of RCL operations, manufactures will be concerned about market share and protecting proprietary information, and labor organizations will care about jobs, wages and benefits. However, safety is an issue that all stakeholders can embrace, since it can serve all of their interests.   FRA has ample experience in bringing together diverse railroad stakeholders to work together on safety issues. FRA’s Rail Safety Advisory Committee has used this approach to develop consensus based regulations since 1996. At least nine new or revised Federal railroad safety regulations were based on RSAC recommendations or ideas that came out of RSAC working groups.   Whether it is formed under the auspices of RSAC or as a standalone entity, a taskforce of RCL stakeholders working together to identify and address safety issues can be an effective way to promote and enhance the safety of RCL operations.

13.4 Special Attention Should Be Devoted to Ergonomic Issues

This recommendation is not a strategy, to improve RCL safety; rather, it is an important safety issue that appears to be so pervasive among RCOs that it warrants special attention.

Based on the numerous complaints from RCO about neck and back pain, concerns about RCDs and vests catching on obstructions, RCD controls that can be accidentally activated and other ergonomic issues, it is clear that continued attention needs to be devoted to ergonomic improvements. In some cases, effective hazard mitigation may require more than a new or improved design. Operational modifications, such as allowing RCOs to take breaks, limiting the duration of RCO work during a shift, developing exercise routines to help RCOs strengthen back, neck and shoulder muscles, and other measures may prove useful in mitigating ergonomic hazards.

This may be one area where the traditional railroad stakeholder groups may benefit from the help offered by ergonomic specialists.

13.5 Consider Adoption of Mandatory RCL Safety Standards

Serious consideration should be given to the promulgation of mandatory safety standards for RCL operations and technology. Whether this is done in the context of broader standards that address railroad-operating safety in general or as a more narrow set of standards that focuses exclusively on RCL safety, is a decision best left to the regulator. However, the point is that many RCL operations are conducted far outsides the parameters of the FRA's voluntary safety guidelines. Furthermore, railroads continue to stretch the envelope by using RCL in ways never contemplated by the regulators, for example, operating RCLs over grade crossings with the use of cameras and remote monitors.

Additionally, as RCL operations become more widespread, we may see a proliferation of RCL accidents and casualties. There is some evidence that this is already occurring. BNSF Railway Company reports that between January and September of 2004, the rate of RCL related injuries on its property was seven percent less than the rate of conventional switching related injuries. (Progressive Railroading: March 2005) That is a far cry from the 57.1 percent injury rate differential reported by FRA for the industry as a whole at the end of 2003. Although there is also evidence that some railroads are beginning to report RCL accidents more accurately. For example, one Railroader noted:

> “Interestingly, for about the first 6 months of RCL ops, the 'incidents' were mostly showing in the $6500 - 6600 range. ($6700 is the threshold for making it FRA reportable.) But now 'the bloom is off the rose', and the dollar amount is now typically higher. (For example, last week [XCV RR] bought [a factory] a new [item of equipment] to the tune of $'XX,XXX'). RCOs are now commonly charged with various rules violations and given discipline, instead of being told 'don't do that again'. And RCO 'human factor incidents' such as running into, off of, and over things has been on the increase."

As noted previously, switching operations account for more deaths and serious injuries among railroad workers than any other railroad activity. As is well known by human factors researchers and the FRA, new technologies, while lessening hazards from older technologies, often introduce new hazards. Although RCL operations may very well prove beneficial to the safety of switching operations, the technology also offers new challenges that have yet to be addressed, such as, the ability of RCLs to initiate, autonomously, abrupt braking applications.

It is interesting to note that FRA recently issued safety standards, developed over a period of several years,[3] for microprocessor based signal and train control systems. Many of the

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[3] In July 1994, FRA published its "Railroad Communications and Train Control. Report to Congress," devoted to considerations of Positive Train Control (PTC) and related matters. On September 30, 1997, the Railroad Safety Advisory Committee (RSAC) to the FRA accepted deliberation on three PTC-related tasks. These comprised, briefly: (1) prepare a descriptive report on the nature of and variation of PTC systems; (2) analyze and prepare recommendations on the feasibility of implementing fully integrated PTC systems; and (3) facilitate implementation of software-based signal and operating systems by discussing potential revision to the Rules, Standards and Instructions (49 CFR Part 236) to address processor-based technology and

new systems that will be covered under this regulation are designed as safety overlay systems, that is, they do not actually control the train. Instead, they act as a safeguard mechanism to slow or stop the train if the locomotive engineer makes a mistake and fails to operate the train within prescribed limits. However, RCL technology is truly a train control technology (all the more so in its quite frequent use on main tracks), the RCO controls every aspect of the RCL through a remote control system. In addition to many problems that are present in conventional switching operations, RCL accidents can also be triggered by problems unique to RCL activities, including RCO error, RCL technological autonomous actions and failures, or a combination of both. Any of these problems can lead to catastrophic accidents.

Of relevance to the previous paragraph, FRA issued regulations on March 7, 2005 promulgating performance-based safety standards for microprocessor based signal and train-control systems (see footnote 2). In the regulation, FRA intentionally declined to define the term *train control system*, stating:

> “FRA agrees and realizes that historically, there was an understanding among parties in the railroad industry regarding what constitutes a train control system. FRA further recognizes that evolving technology will change the nature of what is traditionally considered train control. FRA has decided that an attempt to craft a clear definition or even a laundry list of what systems or features are considered train control or components of train control systems may actually confuse the issue. Since the technology supporting these systems is continuously evolving any list would undoubtedly be outdated at its inception or shortly thereafter. The purpose and scope provision of this rule found at §236.901 clearly limits the rules application to ‘safety critical products.’ . . . given the difficulty of crafting a definition, FRA has decided to leave the term “train control” undefined."

While FRA chose not to define *train control system*, the subject of its regulation, the agency made the purpose and intent of the regulation crystal clear, by proclaiming in the rule text:

> "§ 236.901 Purpose and scope.
>
> (a) What is the purpose of this subpart?
>
> The purpose of this subpart is to promote the safe operation of processor-based signal and train control systems, subsystems, and components that are safety-critical products, as defined in §236.903, and to facilitate the development of those products."

In §236.903 FRA defined the term *safety-critical* as follows:

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communications-based operating architectures. The results of the first two RSAC tasks are found in "Report of the Railroad Safety Advisory Committee to the Federal railroad Administrator. Implementation of Positive Train Control Systems," September 8, 1999. On August 10, 2001, FRA published its notice of proposed rulemaking on "Performance Standards for Processor-Based Signal and Train Control Systems." On March 7, 2005, FRA published, its final, "Standards for Development and Use of Processor-Based Signal and Train Control Systems," Federal Register 70(43):11051-11108. Thus, on March 7, 2005, FRA completed the development work for PTC it had begun, generally, by July 1994 and, more specifically, on September 30, 1997. In all, the FRA's work on processor-based, safeguard and control systems for movements on main tracks and controlled sidings in PTC was done with extensive, exacting deliberation and due process over a considerable period of time.

> "Safety-critical, as applied to a function, a system, or any portion thereof, means the correct performance of which is essential to safety of personnel or equipment, or both; or the incorrect performance of which could cause a hazardous condition, or allow a hazardous condition which was intended to be prevented by the function or system to exist."

Given that RCL systems are a kind of safety-critical train control technology, ample rationale exists to apply the recent FRA safety standards for microprocessor based signal train control systems to RCL systems and their components.

In its RCL Safety Advisory, FRA stated that because of the relatively recent introduction of RCL technology into the U.S., it had decided to proceed prudently in issuing its guidelines. However, now that our nation's railroad system has seen widespread RCL operations for several years, prudence may call for a change in direction away from purely voluntary guidelines to mandatory safety standards. Some topics that should be considered for inclusion into RCL safety standards include:

- Standards for RCL microprocessor systems. Perhaps this may be accomplished by covering RCL microprocessor systems under the newly issued regulation for microprocessor based signal and train control systems. Thought should be given to covering Electronic Pullback Protection systems under this regulation.

- RCZ Standards. Develop rules and procedures for the establishment and operation of RCZs as a method to protect RCL operations. Also, standards for remotely controlled switches and derails that are used within these zones should be considered.

- Consideration should be given to requiring training in the rules and procedures of an RCZ for all persons authorized to be near an RCZ, including contractors. If contractors cannot be trained, an RCO-certified pilot should be provided for them.

- Railroad rules and practices for point protection should be examined to determine whether mandatory rules and procedures are necessary.

- The conduct of RCL operations outside of yards needs to be examined. In more than a decade of use in Canada, RCL operations remain largely confined to yards. Within only a few years, their use in the U.S. has proliferated well beyond the yard switching environment.

- Restrictions on RCL switching without Automatic Brakes is an important issue to examine.

- The practice of an RCO riding the side of a car while operating an RCD should be prohibited.

- Consideration should be given to requiring the installation and use of data logs on OCCs to determine messages received from the RCDs and the commands sent to the RCL control systems. Requirements for retaining the data in the event of a reportable accident or casualty could mirror the requirements for event recorder data. Given that RCL systems can make autonomous decisions that control the movement of the RCL, it is imperative that these autonomous systems can be closely monitored to detect flaws in design and operation.

- Training of RCOs, also needs greater scrutiny. Attention should be paid to the amount of training, the quality of the training and instructors, and qualification processes for RCOs. Although existing Locomotive Engineer Certification regulations cover RCO training programs, it appears many RCO training programs are less than effective.

- The mandatory use of Tilt protection and other RCL safeguards should be explored. With the recent development of allowing RCOs to disable tilt protection, this entire issue needs to be considered in a regulatory context.

- Fatigue is an item that warrants enhanced attention throughout the railroad industry. However, the stresses that can accrue from the performance of complex and physically demanding RCL switching operations and along with the added responsibility for conducting skilled RCL train handling operations make fatigue an especially significant safety issue that should be addressed.

- Consider mandatory reporting requirements for RCL accident, casualty, and operational data, to allow more thorough monitoring and analysis of RCL safety issues. In 2003, FRA introduced RCL reporting codes to identify accidents and casualties involving RCL operations. However, to normalize this data, railroads should be required to report the number of hours worked by RCOs and other RCL crewmembers and the number of RCL miles operated.

- Particular attention should be focused on the unique problems of Human-Machine Interface present in RCL switching operations. RCL accidents can be triggered by the actions of the RCO, the autonomous actions of the OCC, or a combination of the two. Once HMI risks are identified and analyzed, mitigation measures should be adopted.

14.0 Conclusions

RCL operations have brought about new practices and conditions that were unthinkable with conventional switching operations. One such example is the ability of the RCL technology to autonomously initiate emergency brake and full service brake applications. No longer is the braking function of the switching movement controlled solely by the human locomotive engineer or operator; decisions to stop a switching movement are now shared with RCL technology itself. It appears that the safety implications of this operation have yet to be understood fully or appreciated by the railroad industry.

Also revolutionary are the human-machine interactions brought about by RCL operations. Whereas the locomotive engineer is typically in full control of the movement of the locomotive in conventional switching operations, the RCO does not have full control of an RCL switching movement, but must share that control with the RCL control systems, especially the OCC. In some cases, the RCL control systems interpret and execute the commands of the RCO to operate the RCL. In other cases, the RCL control systems make autonomous decisions that control or affect the movement of the RCL. Once again, the RCL control technology does not function as a "robotic automaton" that makes and executes all the decisions that control the movement of the RCL. However, it is not a mere extension of the locomotive control stand; it does not permit the RCO to operate the RCL in the same manner that a locomotive engineer uses his controls and indicators to operate a conventional locomotive. Here too, there appears to be little understanding of the momentous safety implications of this revolutionary new human-machine interface for railroad switching.

With change comes challenge. To meet the safety challenges posed by RCL operations, at least three things are required:

> First, a better understanding is needed about how RCL operations impact the safety of switching and other railroad operations. Simply put, a concerted effort is needed to identify the hazards that can result for RCL operations. The collection of more comprehensive accident and operational data, better accident investigation protocols, and the systematic pursuit of RCL safety information from all relevant railroad industry stakeholders who have collected such information is needed to accomplish this daunting task.
>
> Second, a risk analysis of the RCL operations should be undertaken to understand and prioritize the severity of the consequences that RCL hazards may pose. This risk analysis should not be narrowly and selectively focused on human issues alone, but must include RCL technology and, most importantly, the interactions of RCOs and associated railroaders with the RCL systems (the Human-Machine and Human-Automation Interfaces). As this study illustrates, the belief that RCL technology plays little or no role in RCL accidents is widely disputed by those who work with and around this technology. Both the autonomous and authoritarian actions of RCL control systems and the possible RCL technological failures appear to have caused or contributed to RCL accidents. The problems inherent in a risk assessment involving a true HMI and HAI of RCL operations are, of course, significant, as outlined in appendices A and D.
>
> Third, efforts must be undertaken to mitigate known RCL safety risks. Of course, laudable attempts have already been made in this area. RCL operating rules and practices issued by the railroads and FRA's voluntary RCL guidelines are all actions intended to address RCL safety risks. As well intentioned as these efforts may be, the experience of the past few years shows that more needs to be done. The extensive proliferation of RCL operations on U.S. railroads exposed a number of prominent safety issues that have not been controlled either by railroad rules or voluntary federal guidelines. The time has come to consider seriously mandatory federal safety standards for RCL operations.

This study informs and supports all three of the aforementioned tasks. By cataloguing and framing RCL safety hazards reported by subject RCOs and other railroad personnel who are associated with RCL operations, this study helps provide useful information for hazard identification. By describing the consequences of some of the RCL accidents and casualties, this study can help serve as one starting point for risk analysis. Finally, by discussing complex circumstances and chains of causal factors surrounding some of the RCL accidents and casualties, this study generates a few ideas for future such studies and for mitigating RCL risks.

Appendix A. The Human-Machine Interface (HMI) and Human-Automation Interface (HAI)

1. Human-Machine Systems and the Human-Machine Interface

The twenty-first century dawned on a developing, fundamental restructuring of the American workplace. This was by computer control of the various kinds of production and the rendering of service (such as in railroad transportation). Some analysts consider this restructuring a second industrial revolution, effected by advanced microprocessors, electronic digital radio and wire communication, and computer programs for artificial intelligence, computer control, and related applications (Dechert 1966; Rose 1972; Piore and Sabel 1984; Burris 1993, 1998; Helenader, et al. 1997; see also Ellul 1967 [1954]; Goodman 1957). This second technological revolution is changing the world of work just as the external combustion steam engines of Newcomen, Watt, and the Stephensons did in the first revolution. RCL technology is one example of the current restructuring of human work and the division of labor. (Positive Train Control, PTC, is another example.)

Restructuring is not without its risks, however. Ever more inexpensive computing power means increased opportunities for microprocessor applications and, thus, latent failures in a technological system. Fostering rare but potentially catastrophic accidents are complex, hazardous technologies which have become more opaque to their operators and maintainers (Reason 1995:1709-1710). For example, in aircraft automation, we find "new classes of problems, which are due to failures in the human-machine relationship." Accidents and near misses "indicate failures to understand automation behavior" (Billings 1997:4). A concomitant of advanced automation is that operators become deskilled "in precisely those activities that justify their marginalized existence" (Reason 1990:180).

A veteran railroader comments, conservatively (realistically?), regarding technologies having computer control of rail operations: "Given the dynamic, Murphy's Law prone nature of railroading, I'm a skeptic when it comes to computer controlled applications to replace human experience, judgment and decision making."

Let us begin at the beginning. Our human biological preadaptations for technology shape human tools, including our bipedalism with locomotion-free arms, grasping hands with opposable thumbs, and stereoscopic color vision. In preindustrial societies, tools were direct extra-somatic extensions of our human physiology and anatomy, multiplying our biological power and work efficiency. Thus, an iron spearhead with its tapering, square cross section, enabled the Wayto hunters of Lake Tana, Ethiopia to adapt more successfully to the geographic environment by collecting energy in the form of hippopotami, protected by "safeguards" of slashing tusks and tough, thick hide (Gamst 1979, 1984b). Thus, an oxen-drawn, iron-tipped, scratch-plow allowed the Qemant peasants of Begemder, Ethiopia to multiply more greatly their collecting of energy, by cultivating grains and oil seeds, than other peoples could using just the hoe by hand (Gamst 1969). Every device, whether spear, plow, computer, RCD, or RCL, has an inherent imperative and limitation, from its design and procedures of use. Thus, the Qemant plow and the Wayto spear have limitations for productivity, no matter what the operator's skill and knowledge. Moreover, humans must use a particular device in prescribed effective ways for economically viable production. These comments hold for all technology, including an RCO using an RCD to control an RCL.

Human-machine systems, first, used preindustrial machines such as wind and water powered mills and ships having interrelated subsystems and components. Later were ever-more complex, fossil-fueled, industrial machines, in factories, on waterways, and on railroads. These later systems introduced new problems, including human errors and physical failures, having a scale previously unexperienced by humans. Accordingly, we had to manage and, later, regulate the design of the machines in a system and the procedures for interrelating and using them, as well as select, train, and supervise the machine operators, inspectors, maintainers, designers, and builders.

In preindustrial and early industrial human-machine systems, the machines were slow and limited in performance. Accordingly, the operator usually could "make do" and use his adaptability to restore performance. In Qemant plowing, the controls are a single wooden shaft of the plow and a whip, which cracks above but never actually touches the backs of the valuable oxen. Two natural displays are extant, the furrowing of the soil and the motion of the oxen-plow assemblage. In the limited human-machine systems, the operator has kinesthetic feedback as a natural safeguard. Given modern, highly complex systems, however, with the operator having multiple, abstracted parameters to integrate, problems often occur at the Human-Machine Interface (HMI). This is all the more prevalent when no kinesthetic feedback is present. (For <u>Kinesthetic</u>, see Appendix B.)

Classic studies of human-machine systems had the machines either under or largely under human <u>control</u>, as with the aircraft, terrestrial vehicles, and ships of World War II. Since the 1960s, however, we have pondered the allocation of control functions between humans and the machines they operate (Jordan 1963; Chapanis 1965; Corkindale 1967; Jones 1967; Card, Moran, and Newell 1983; Kletz, 1995, Amalberti 1999). With a machine ranging across its partial to complete computer control, To what extent can an operator, first, gather all necessary information for its operation and monitoring and, then, integrate, interpret, decide, and remember? As Eggleston notes, in some analysts' models of advanced human-machine systems, the human is not viewed as a constant operator but, instead, for some functions as an operator and for others he interacts with machine elements as a nonoperator (1987:118-119).

Until recently, study of human-computer interaction centered almost entirely on one individual interacting with computer applications relating to the division of work in an individual's tasks (Hollan 1999:379). The human was in control; the computer was his servant. Today, we can no longer conceptualize many computerized human-machine interfaces as having full human control, whether by an individual or a human team. The RCL is one such example and nonoverlay Positive Train Control (PTC) is another. Rather, the Human-Machine Interface is one of <u>dynamic</u> <u>interaction</u>. The interface leads to a complex system having not just linear causality but also interacting feedback and feedforward loops of circular causality.

In advanced technological systems, the operator is a member of a new kind of team making decisions in computerized systems. More exactingly, the team of active operator, latent designer, and active control computer share decision-making (Czaja 1997:23; DeGreen 1991). The manager implementing the system is also a latent member of this team. Designer and implementer decisions for the system limit the operator and control computer decisions. The question is, In the dynamic open environment of rail switching and main track operations, to what extent does and can the RCO know the limits of his decision-making ability? In other words, What is the boundary between RCO reliability and control computer reliability? Regarding operator and designer error, to the extent that a system is designed to be less prone to operator error, then, it becomes more prone to designer error. (See loci and levels of error in Appendix E.)

2. Automation and the Human-Machine Interface

With automation, the human-machine interface becomes one of redistribution of tasks from human to machine. As automation increases, the operator's role changes from controlling a system to allowing more computer control of the system (Endsley and Kiris 1995; Meister 1999:104). In systems with autonomous control computers, a cognitive dimension of human trust exists. When and why does the operator allow autonomous control and when does he assume manual control? Trust is contingent on an operator's ability to predict performance of the autonomous control and to comprehend overall system function, hence, dependability (Lerch and Prietula 1989; Lee and Moray 1992; Sharit 1997:322). Moreover, he often must quickly make decisions in what he experiences as an abstract rather than concrete situation, without sufficient or any kinesthetic cues and with feedback largely or only in symbolic displays or, perhaps, none at all. Lacking trust, in particular switching or main track running situations, an experienced RCO will manually control RCL speeds and braking rather than allow the control computer to select them. A question regarding the RCO is, How much necessary background experience in railroad operations must he have, and how much RCL training plus post-training experience does he require to trust knowledgably the autonomous control?

When a human operator interacts with an autonomous control system, he loses some occasions to practice needed cognitive and psychomotor skills. Furthermore, the direct relation between what he manipulates and what he senses occurring as a result may be degraded or even absent, including effects of reliance and complacency (Parasuraman, Molloy, and Singh 1993; Riley 1996; Sheridan, Gamst, and Harvey 1999).

Central to any system having safety-critical automation from microprocessors is assessment of the interaction of controlling human(s) and controlling computer(s). Who or which controls a system under what dynamic circumstances and how much is the human operator informed about control? Adapting from Klaus Christoffersen and David D. Woods (2002) on the subject, problems can exist, generated by the uncertainties of interfaces of human operators and computer-based automated systems, i.e., a <u>Human-Automation Interface</u> (HAI). This is a critical part of today's steadily developing and enveloping <u>Human-Machine Interface</u> (HMI). (For <u>HAI</u> and <u>HMI</u>, see Appendix B. Definitions.) In what ways do these problems of interface exist in Remote Control Locomotive (RCL) automation? What we must question is, How close is a particular subsystem of automation to the limits of its competence? Furthermore, although designers intend automation to reduce human cognitive and physical workload, Does it ever increase either of the two and, if so, under what circumstances (cf. Harris, Hancock, Arthur, and Caird 1995)? And under what circumstances, do operators cut out or override the automation teammate and resort to human action?

3. The Human-Computer Team in the Human-Automation Interface

We must rethink, in human and social factors, the question, What comprises the "team," “crew,” or “partnership,” in a work process? What functions have latent-team-member designers allocated to the human and to the computer agents? (Broadly, an agent is anything that produces an effect, but the term is often limited to animals with advanced cognition. Here, computers can also be agents.)

In complex automated systems, the direct operating team consists of human(s) and control computer. For such systems, increasingly, a human communicates with as well as operates a machine. Automated systems have been implemented which are more autonomous and authoritarian than previously, while giving the human operator inadequate feedback (Billings 1997:4). In these systems, What are the limitations of the role of the operator in executing control actions? The machine in the system is not a passive but an agent-like device functioning at high levels of autonomy and authority. This machine can autonomously operate without an immediately preceding operator input and can authoritatively override operator intention. Thus, an RCL's control computer can autonomously initiate an undesired and dangerous stop of a long, heavy movement. Such operating can engender novel responsibilities and events for the operator. These events can include sometimes-serious problems of breakdowns in interactions of the human and the control computer. Root causes of the events go beyond just the operator at the point of control and reach up to include the limitations set by the designer-suppliers and the manager-implementers of a system. Implementers of a system could find unexpected consequences because their system did function as a team player (Norman 1990; Sarter and Woods 1995, 1997; Sarter, Woods, and Billings 1997; Mitchell and Sunström 1997).

The key question with automation autonomy in a system is, How does it interact with operators and how might it enhance or degrade their performance? Does autonomous computer control shape the actions and thoughts of operators in ways unforeseen by its designers and managers who implement it (cf. Parasuraman and Riley 1997)? To what extent, if any, do inadequacies in the HAI foster accidents and near misses? Does the placing of automation between the RCO and his RCL, at times, remove him from the elements of operation?

Regarding operators, the human-computer partnership seems headed toward more computer and less human agents. The present report, however, does not treat issues of job loss owing to automation. Thomas Sheridan defines one aspect of advanced automation, i.e., (human) supervisory control, as one or more human agents setting initial conditions for, adjusting as needed, and receiving information from a computer that closes a control loop. Supervisory control can include the control computer acting on new information independently from the human supervisor, after his blanket previous authorization (1997:1295-1296). Sheridan notes, greater supervisory control leads to less direct human control and fewer jobs. That is, "the trend is toward fewer people per team, and eventually one person will be adequate in most installations." Thus, cognitive interaction with computers will replace interaction with other people (Sheridan 1997:1323). A feeling of alienation and abandonment of operator responsibility could well result as the control computer becomes greatly autonomous and the human supervisor lacks the understanding of how the control computer functions as it does (1997:1324). In all, in advanced automated systems, the number of human operators declines while they shift tasks from active to supervisory control of the machine.

Let us attempt to encapsulate this issue of the operator's control-computer teammate and its automation with an example from the aviation industry. In icy weather on October 31, 1994, a twin-engine, ATR-72 turboprop airliner was in a holding pattern at 9,200 feet for Chicago O'Hare. Not comprehended by the pilots, ice built up on the wings. The computer of the autopilot automatically compensated for the buildup and increasing unairworthiness of the aircraft by extending wing flaps to keep the flight under control. Eventually, the ice became so thick that the autopilot could no longer solve the problem of maintaining flight and it automatically disconnected. Thereupon, the plane rolled over and quickly dove into the ground, killing the 68 person onboard. A human-factors problem arose: How, in seconds, could the pilots recover from their teammate computer's unanticipated failure at automated problem solving? A new hazard of control automation had been thus exposed, expensively and tragically so. The NTSB found that contributing to the accident were overarching errors of managers in the French Directorate General for Civil Aviation and the US Federal Aviation Administration, in not taking actions that ensured continued airworthiness under icing conditions (NTSB 1996). What happened was the automation surreptitiously compensated for weather occurrences (icing) up to a point. When the automation could no longer cope with the occurrences, it suddenly handed the problem back to the pilots, who could not, then, cope in a few seconds. The pilots were undoubtedly unaware of the problem or of its gradual development.

If an operator does not receive sufficient information from the control computer to proceed in an appropriate manner, the automation's safeguards could become depleted and an accident could occur. The operator might not have time to assess adequately the hand-over situation or the operator might not effectively be able to handle the system, already moving beyond the point of human control.

Since about 1900, authorities have investigated many thousands of aircraft accidents. Nevertheless, aircraft are continually involved in a heretofore-thought-improbable chain of events leading to realization of a hazard. Regarding RCLs, the historical duration and the number of transpired operations on US railroads--thus for which accidents are possible--are greatly less than for aircraft. Nevertheless, for this quite short period of possible data gathering and study, one focus of human reliability and risk assessment has to be the uncertainties of interface of the controlling human(s) and the controlling computer(s).

4. Issues of the Human-Automation Interface

In all kinds of operations in numerous industries, the HAI problems of interface discussed in the previous two sections exist, in part, because of the absence of a true human-centered orientation to automation (Billings 1996). A human-centered orientation is advocated by many for the aviation industry (e.g., Kotaite 1999). In other words, problems occur because designers do not view fully the natural human and artifactual machine agents as an operating team. (Here, a group of human[s] and computer[s] working in a coordinated effort.) Adding a sometimes autonomous machine to the work interaction of humans and machines is like adding another member to a work team. (The autopilot on that ill-fated turbo-prop was a sometimes autonomous and authoritarian agent and not fully a team member.) "For automated agents to become team players, there are two fundamental characteristics which need to be designed in from the beginning: observability and directability" (Christoffersen and Woods 2002:10).

Generally, discussion of the problems of human-computer interface/interaction is twofold (Norman 1990). One polar school posits that the problems result from human limitations: with still greater automation, we can end or at least greatly lessen the problems of human error. Here, designers and managers feel the operator does not properly employ the automation. The other polar school posits that certain systems are too greatly automated: the human operator cannot, therefore, adequately interpret and control them. That is, human observability and directability of the automated system are impaired. This school is sometimes accused of being Luddite in nature, that is, basically against automation. In short, the first school often assumes that the joint human-computer system fails to perform adequately because of human error. "However, if one digs a little deeper, they find the only reason many of these joint systems perform adequately at all is because of the resourcefulness and adaptability that the human agents display in the face of uncommunicative and uncooperative machine agents" (Christoffersen and Woods 2002:10). To what extent is this true for the Remote Control Operator (RCO) and his RCL? This is a question that must be studied for the various teams of operating railroader(s) and control computer(s).

Christoffersen and Woods (2002) note that we do not have a polar problem of human error versus computer fault. Instead, we have a problem of breakdown in coordination between humans and computers and related technology (cf. Woods and Sarter 2000). Humans and automation comprise an inextricable composite system. Indeed, viewed in terms of human and social factors, we cannot consider most human work activities apart from the technologies supporting these endeavors, be they the capabilities of a Wayto's four-sided spearhead for killing a hippopotamus, the effectiveness of a Qemant's scratch plow for tiling land, the limitations of freight-car couplers for pulling an amount of tonnage, or the interactions of a flight crew in flying an aircraft with a glass cockpit. (A glass cockpit has computer display screens and control of many tasks).

A reason for failure of automated technology in complex environments of work is a designer's assumption that automated activities can replace human ones with overall system operation remaining unaffected. The cognitive and motor demands of work are not the sum of individual human efforts but, instead, the sum of interactive efforts of a group of human and machine agents. Increasing the complexity of control from and the autonomy of machine agents necessitates a parallel increasing of the feedback from machine to its human interactors (Christoffersen and Woods 2002:3).

"Human agents need to be able to maintain an understanding of the problems from the machine agent's perspective" (Christoffersen and Woods 2002:6). This understanding must not be buried in opaque automation or neglected or glossed over in training. Can such understanding be achieved in the FRA-required minimum 80 hours of training given to an RCO? Is training concerning the HAI adequate for the "students," just "off the street," with little experience in railroad operations, including switching?

The machine agent has a fixed repertoire of tactics for solving a problem. Thus, when at the Canadian Pacific's Agincourt hump yard, an RCO exceeded certain parameters of grade, speed, braking, and track resistances, his RCL's control computer did not warn him or prevent him from reaching that speed and could not automatically stop his movement. Here a particular subsystem of automation reached the limits of its competence. As the RCL supplier CANAC assessed regarding the Agincourt matter: “Furthermore, the LCS Unit [RCL] was never designed as a robotic automaton but as a Remotely Controlled Locomotive. The LCS [RC] Operator is still ultimately responsible for the consist movement." Thus, “Having demanded a full 100% Independent Brake output, the MCU [OCC] could do no more.” CANAC concluded: "Therefore, the Grade Force exceeded the available Brake and Rolling Resistance Forces" (CANAC 1996).

At Agincourt, the RCL’s computer could not solve the problem of stopping and, as with the turbo-prop's autopilot, did not warn of its failure of ability to solve prior to allowing an uncontrollable runaway. Instances such as that at Agincourt pose the twin questions of, In the HAI, who is in control, RCO or OCC, and when? A second pair of questions is, What and when does the human learn about an inability to control a movement by an RCL’s OCC?

Regarding the automation on its RCLs, CANAC instructs: "Speed Control reduces the judgment requirements that the operator must make of speed and therefore reduces the skill set requirement of the operator" (CANAC 2001:2-26). Here, the OCC autonomously executes actions without immediately preceding specific human commands. To what extent does this instruction conflict with the following CANAC instruction? "Care must be exercised when making speed selections in tight areas" (CANAC 2001:2-27). Compare also the first CANAC statement in this paragraph with CANAC's: The RCO “is still ultimately responsible for the consist movement." Undoubtedly, what is involved here is the RCL system does not simply require less knowledge and skills but, instead, requires different knowledge and new skills compared to conventional operations. RCOs must learn not only the capabilities but also the limitations of the automation RCL system. RCL technology creates new knowledge and attention demands compared to conventional locomotive technology. The RCOs must understand fully the effects of their own initiations on their RCDs. Gaps and misunderstandings in an RCO's mental model of the RCL system could result in degradation of his system awareness (cf. Sarter, Woods, and Billings 1997: 1928-1930, 1942). (See System Awareness in Appendix B.)

Reduction of skills can lead to operator complacency because of trust in automation (Billings 1996; Sheridan, Gamst, and Harvey 1999). Here complacency is an operator's satisfaction from a false sense of trust assumed as he relies on subsystems of or all of an automated system. Concepts closely related to complacency are reliance and over-trust. The reliance effect refers to the tendency of an operator to "over-rely (rely more than the system designers or managers intend)" on automation in doing work such as in RCL operations (Sheridan, Gamst, and Harvey 1999:5). The issue is, the automation is highly reliable but can fail, sometimes with slight or without warning. Designers of advanced human-machine systems create a sustained-attention task where a human must continuously monitor for rare events. "Complacency may therefore be more indicative of the need to rethink the human-machine architecture" (Sarter, Woods, and Billings 1997:1934).

A question for RCL operations is, To what extent does this reduction of task skill reduce responsibility of the operator for control of the movement, including under operational circumstances at the edges of the operating range and of the environment? In other words, What are the boundaries between human and computer responsibilities and, does the human have sufficient observability and directability for handling the RCL? So long as an RCO is responsible for outcomes and can lose his federal certification (and livelihood) as an RCO, he must have effective authority and realistic ultimate control over how the range of problems is solved (cf. Christoffersen and Woods 2002). The devil is in the details of how to achieve this authority and control.

5. Examples from the Field of Human-Automation Interface Problems

The examples presented in this section 5 are mostly natural experiments unfolding in ordinary day-to-day switching operations. A natural experiment involves a field situation in which a clear change has occurred. An accident and near miss are two related kinds of clear changes. A researcher does not conduct a natural experiment; they constantly occur around us. The researcher analyzes the results of a "naturally" occurring change, which could be brought about by human and/or computer agents or other entities (Bernard 1988:63-65).

We find problems generated by the uncertainties of interfaces of human operators and flawed computer-based automated systems. In one yard, installation of the wrong processor chips resulted in uncontrollable RCL speeds. Here we find human errors by the installer and mechanical supervisors and perhaps by the supplier but sufficient data about overarching levels of error are not available. At another yard, processor chip failure resulted in the RCO being unable to control the speed of his movement. In both instances, without sufficient feedback to the human operator, the OCC ran away with its, thus, hazardous control. In the second instance, we find human error by the supplier, at least. We can posit that a similar misinstallation of “good” chips or installation of failure-prone chips could occur again, with a similar realization of hazard, including into an accident.

Apart from processor chips is the issue of address duplication in the digitally coded telemetry furnishing the control link between an RCD and an RCL. No problems of this kind have surfaced in the present research for RCLs but have for the related and older Distributed Power (DP) operations, which see in Definitions section C. A railroader comments regarding DP addressing: "This [DP] equipment is manufactured by [supplier name]. There are several layers of security to prevent accidentally linking or controlling one unit with another, including [list of physical safeguards], and ROM chips that are 'supposed' to have a uniquely coded address. About 'X' years ago, two DP trains were departing 'FGH' and one unit started being controlled by the other train. Short version of the story is that [the supplier] coded the same address into two separate locomotive units. 'OPA RR' went ballistic and demanded a recheck of each of the units in use, and I seem to recall they found one or two other sets that were duplicated." This physical system failure was from a probable root cause in suppliers' error(s).

As an RCO explains regarding linking a pair of RCDs to an RCL: "I believe there is continual 'handshaking' [there is] between the controller [RCD] and the on-board computer, like with a modem, so that the [RC] locomotive determines pretty quickly when one of the controllers is turned off. When that happens--even if one of the linked controllers is not controlling-movement stops until the communications issue is resolved." (For Handshaking, see Appendix B.)

An RCO explains: "With [MANUFACTURER], after you have linked the first box [RCD] via the infra-red signal between it and the onboard computer, a question appears on the latter's LED display -

- DO YOU WANT TO LINK A SECOND OCU? -- or something to that effect. Depending on whether you push the YES or NO button on the onboard computer console, you end up with either 2 or 1 OCUs [RCDs] linked to the RCL in question."

With a fault in the RCL equipment, loss of communication between the RCD and OCC, certain other faults, or the tilt feature times out, then, the OCC cuts tractive power and applies air brakes. This autonomous reaction of the RCL's OCC could result in unanticipated slack action. The slack action could throw an RCO from a unit of rolling equipment on which he is riding onto the ground. Alternatively, the action could cause the RCO to be disengaged partially from his safe, desired 3-point or 4-point stance on a car side. A 3-point stance is required when manipulating a control or answering an alarm on the RCD with one-hand while holding on to a car side with the other hand. Both feet are securely positioned. Modest slack action has thrown RCOs from their perches on the side of a car in the movement they control or one they do not control. An RCO with a 3-point stance was subjected to an OCC's autonomous stopping action and the consequent slack action threw him from the car side, fortunately, clear of the movement. This autonomous action could also have thrown him partially into the path of the movement. The movement continued for two car lengths before coming to a stop, entirely controlled by the OCC but the mechanical braking force of the RCL limited this control.

Computer control often cannot compensate for the reduction, by policy, of the force of an RCL safeguard. On some carriers, the managers' reducing the mechanical braking force on an RCL that will use locomotive air brakes alone in switching tonnage cuts of cars necessarily reduces its retardation rate, possibly fostering a hazard. The RCO must use his judgment for this reduction in the force of the braking variable.

A good number of RCOs have commented that the OCC can make an autonomous stop that is hazardous given a particular context. One RCO comments regarding an undesired stop: "There are times when dead in the water is the last thing you want to be. . . . Cars rolling back out of tracks to foul the lead, unexpectedly meeting a train coming at you, racing to catch a car that got loose down the wrong track."

A railroader comments on autonomous slack action: "Another incident in 'VBN' caused broken ribs and lacerations when a helper who was riding the point of a long cut of cars experienced a comm break. The [RC] locomotive responded as it had been programmed, and applied full independent and automatic brake. When the slack ran out, the helper was thrown from the end of the cars."

An RCO comments regarding the OCC's autonomous stops: "If you are riding a shove (controlling or not) or pulling out a cut of cars the only warning you get is a beeping alert and a visual cue from the box before the slack runs in or out. This can happen quickly and abruptly depending on the cars in question, the locomotive consist (they still behave differently) and whether you are using train air. There was a recent RCL accident on the 'RTU RR' involving an inexperienced RCO riding a '9X' car shove and being thrown off when the air dumped [air brakes went into an emergency application]. Let's see. What does that beeping mean? What do I have to do to recover - oooops. Too late."

CATRRON RCL equipment is presented, in texts, as a "heads up" method of operation. That is, it gives audible warnings to the operator regarding certain important conditions that are safety related, e.g., activation of the tilt-man-down feature and of a full service brake application owing to a loss of the communication link. The question remains, Does the "heads up" nature of warning alarms always penetrate both the background noise in the openwork environment and the potential preoccupations of the RCO? (See Appendix B, Situational awareness.)

An RCO explains: "The locomotive could run up against an obstacle, or could even pull a cut of cars with a derailment down in the string. It would keep adding throttle amps attempting to attain the set speed until it was unable to move. Only then would it interpret a problem condition, cut throttle, apply brakes, and transmit a 'locomotive movement failure' radio alert, requiring further action from the RCO."

Regarding detrimental OCC autonomy, an RCO recognizes, "the consequences of ceding braking decisions to the RCL computer, for example on a grade where the choice may be to reserve braking capability rather than regulate for a particular set speed."

An RCO explained that another RCO was making a drop when his RCL experienced communication failure and the OCC, as designers intended, immediately killed tractive power and applied the air brakes. The car cut off in motion in the drop then collided with the stopped RCL which could not run in the clear of this car as it was intended to do by the RCO. It its safety logic, the OCC made an unsafe decision.

A railroader comments on what could be seen as a loophole in the RCL safeguards: "The 'GHJ RR' had a fatality involving RCL that was at least in part, the result of equipment failure. The foreman was controlling the movement while the helper was lining switches ahead of the [RC] locomotive [and its cars]. The movement stopped, and the helper's secondary OCU [RCD] indicated a comm break. The helper was unable to contact the foreman by radio, and [who] found that he [the helper] had been run over by the cut of cars he had been controlling. When he [the helper] fell, he hit the on/off power switch on his OCU [RCD], preventing it from initiating a man-down alarm and emergency stop. The carrier quickly said the foreman should have been more aware of his surroundings, and issued a safety bulletin to other carriers." (Blame it on the RCO? RCL equipment not involved?)

Another railroader comment on this tragic accident: "Evidently when [name] went down (fell, slipped)? His remote box was turned off by the fall. I was told that he fell directly onto the box and this somehow turned it off. His partner [the foreman] asked him what the problem was because he knew that his box was shut off. When he went to investigate it was too late. The free rolling draft of cars had already had hit him. They powers that be said that this made the remote 'safer' than conventional operations because they knew right away that there was a problem due to the fact that his box was turned off and the other operator knew this right away. Yes, but what about one-man remote operations?"

A worn RCD can cause an autonomous stop by the OCC. An RCO says: "The other day another [worn] box was decommissioned because it was causing COMM LOSSES."

A railroader summarizes regarding some aspects of OCC autonomous control: "The software simply cannot anticipate grades or adjust to changing conditions as well as a human can. Speed regulation is specified at plus or minus 1 mph, however in reality, 3-4 mph variations are common. At times, the locomotive will seem to be unresponsive to commands sent from the OCU or Beltpack [RCD]. In the incidents I am familiar with, this was the result of either a comm loss or the locomotive attempting to adjust to an increased load. During a comm loss, the unit will not receive or respond to a command for up to 5 seconds. If a crew is attempting to spot an industry track, this may be an excessive amount of time to be out of touch with the locomotive. And if the operator is not aware of the locomotive's response to changing load, it could result in a personal injury or fatality. For example, let's assume an operator couples into a cut of three cars that have air or handbrakes applied. The movement stops, and the operator forgets to place the speed selector lever in stop position before going between the cars to release a handbrake or adjust a drawbar. At some point, one of several things will happen: In 50 seconds, the alertness monitor will begin to sound, and in 10 more seconds, it will stop the movement. Within that 50-second window, the amperage on the locomotive will continue to build until the unit is able to move the cut of cars, possibly running over the operator in the process. At least one of the system vendors, [supplier], had a software check that would unload the unit if it did not move within 30 seconds, however I think that check may have been removed."

A problem can exist with a control computer's lack of artificial intelligence regarding certain moves, such as moving in the wrong direction. Human error cannot always be negated by the RCL system. When the RCO transmits, with his extraneous error, a signal for direction of movement to his RCL that is the opposite of what it should be, the RCL cannot correct that error. The RCL's OCC has no judgment about such human action, occurring out in the field. Given the vicissitudes of rail switching, the direction of movement constantly changes beyond the ken or the lockout of any RCL software or firmware. On this point, an RCO said: "The reason I'm mentioning this is because with Remote Control, the RCL will never (repeat, NEVER EVER!) question whatever command it's given. It'll to exactly as it's told 100% of the time." (For <u>Lockout</u>, see Appendix B.)

An engineer gives a complementing report: "In my personal experience, quite commonly I'm told to 'Come Ahead' when the ground employee actually means to say 'Back 'em Up', or vice versa. I'm sure you can see how this simple mistake could lead to an injury or fatality. In situations like this, when I have reason to believe the ground employee has given me the wrong command, I ask 'Really?' (when working by radio), or simply don't move (when working by lantern signal). That's all it takes to jog the groundman's memory, and he'll correct his mistake."

RCOs report various unwanted autonomous applications of the brakes by the OCC, including: "A bug that they claim will take [duration] to remedy is one that stops you dead in your tracks if you pull out past the [designation] puck and stop and reverse movement before passing the [designation] puck. The system goes into emergency and requests that the Primary Operator recover but this is impossible without walking to the RCL and disabling the pullback protection [plus] an annoying delay of about 4 seconds before the locomotives [RCL] obey a command to move and then an annoyingly rapid acceleration."

Regarding RCL hunting, an autonomous characteristic produced by the OCC, as RCO reports: "Other improvements include a worsening of the hunting behavior when pulling out into an activated ["puck"] zone."

In all, an RCL system's autonomous and authoritarian actions and this system's physical failure resulting in autonomous action could be seamlessly hidden and thereby rendered opaque to the operator. It is useful to distinguish human communication by any means from control communication generated by machines. This is especially so when control communication is autonomous and opaque to the operator. (For autonomous and authoritarian, see Appendix B, <u>Autonomous control</u>.)

Appendix B. Definitions

The following definitions concern items from RCL operations and technology and their encompassing overall railroad operations and technology. Additionally included are concepts from relevant research conceptualization and methodology.

Accident: An accident is an unplanned end of a chain of events resulting in an unwanted loss. (For loss, see Hazard and Loss.) An accident's cause can be from human error, physical failure, geographic occurrence, each singly or multiply, or some combination of these three kinds. Buried primordially deep in the culture history of our Western ideas about "accidents" is a bias against attempting to find root causes of such events. The very word accident, the shorthand label for these ideas in our culture, is fraught with semantic ambiguity and excuse making, despite its nearly universal use in the literature on work safety, including in transportation. (The Latin root of the word is accidere, that is, "to fall upon," as a tree branch falling by chance upon one's head.) Work accidents, beyond being nonfortuitious, may usefully be viewed as errors systematically produced during the work process. Moreover, work accidents are business problems evading the control of managers and the direction of involved government regulators. These, then, are human errors on the organizational and regulatory levels.

A near-miss is like an accident in its chain of events. In an accident or near miss, from one to all safeguards could be overcome, but no loss consequently occurs in a near miss. See Near miss and Safeguard, below. An accident scenario is a sequence of events resulting in an accident. Similarly, a near-miss scenario is a sequence of events resulting in a near-miss.

Railroad accidents are not always immediately visible. When a freight car has been coupled too severely, the lading in one or more cars could be damaged but invisible until a customer unloads unusable lading. This is a double loss, to the customer and to the customer-compensating railroad. Additionally, the steel of a car's coupler could suffer internal fracture damage apparent only after a failure in the future, perhaps delaying a freight train.

Agent: Broadly, an agent is anything that produces an effect, but the term is often limited to animals with advanced cognition. Here, control computers can also be agents. At times, used with reference to an Object, which see.

Alerter feature: A safety feature in which an alerter pushbutton or toggle switch control, or other non-alerter control, must be manually moved at set time intervals. Otherwise the tractive power is killed and the air brakes apply in a penalty application.

"Alibi": Railroaders' jargon for an excuse offered for an unwanted event such as an accident. It can be a plausible explanation. As a railroader wrote, "A job briefing is good right after an accident, so that we can all get our stories straight." In the railroaders' worldview, "alibis" exist on the levels of their own rank-and-file and on up the organizational hierarchy and examples of such are recounted. As Trevor Kletz notes: "After an accident senior people sometimes say, 'If I had known that was happening I would have stopped it.' That is no excuse" (2001:332).

Architecture, computer: Both the design and study of the interrelations of the elements of a computer system. It is sometimes divided into the instruction architecture of software and firmware and the device and circuitry architecture of hardware.

Artifact: Any patterned physical product of human work, thus, a material entity of any kind modified or made/manufactured by humans. Kinds of artifacts range across stone hand axes, spears, plows, buildings, roadways, mills, vehicles, radio transmitters and receivers, computers, power plants, manufactured chemicals and fuels, and so forth.

Attention (also cognitive) capture: The disproportionate concentration an operator could give to a task because of its visual salience and also its importance and consequence. In other words, after visually fixating on a cue or set of cues, an operator does not allocate enough perceptual and cognitive faculties to other cues from the physical and sociocultural environments. That is, under attention capture, an operator is less likely to process non-fixated visual cues and other information. This is because attention is necessarily selective, with a focusing on one stimulus likely suppressing a consideration of others. To the extent that such visual capture diverts an operator from reacting to the other visual cues, situational awareness could be considerably compromised. Such compromise could be heighten with challenging or stressful operations. Attention concerns focusing perception on a stimulus or restricted set of stimuli from the environment. The selective parts of perception function to allow an animal to focus at one moment on particular aspects of the environment while excluding to varying extents other aspects. A human is only sometimes entirely or partially aware of the elements engendering his perception of only a minute fraction of the total environmental stimuli. Perception is the complex of processes providing consistency to the sensory inputs to the brain. Attention capture especially occurs with the viewing of displays. Literature on the aviation and aerospace industries especially discusses attention capture. It is sometimes a category of Attention Failures, along with inadequate visual scan patterns, inadvertent activation of controls, and incorrect steps in sequencing a procedure.

Automation: Is the substitution of capital for labor. More specifically, it is the use of self-regulating machines to do work automatically, replacing human effort to varying degrees. Automation not only eliminates human work but also changes human work under some amount of it. Sensors automatically monitor system performance and states and send signals and other communication to the system for regulating the work process. To whatever extent a system is autonomous, artificial intelligence makes decisions for machine performance. Automation has a number of characteristics including all or some of, automatic operation (today's railroad grade crossing gates), combination of work devices and functions (cruise control on certain passenger trains), using closed-loop feedback subsystems for regulating a work process (automatic train control in transit systems). In practice, automation is neither a cure-all nor use of a demon mechanism.

Autonomous, control system: An automated system can be to varying degrees or entirely autonomous, where it functions independently without control by a human operator. Thus, the system independently executes actions without immediately preceding specific human commands. In advanced automated systems, the human operator shifts tasks from active to supervisory control of the machine. Such system might also be to varying degrees or entirely authoritarian in not providing adequate or any feedback to the human operator regarding his supervisory freedom for independent judgment and action. For an operator, seamlessly hidden and thereby rendered opaque to him could be an automated system's autonomous action and, additionally, its physical failure resulting in autonomous "fail-safe" action that cannot not guarantee operational safety. Autonomous authoritarian systems are often tightly coupled. See Fail-safe, Tightly coupled. Christoffersen and Woods hold that the central issue is not the levels of autonomy and authority but, instead, the amount of coordination between the human and machine components of an automated system (2002).

Base-case scenario: Is the nominal scenario, wherein selected parameters are set to their nominal values. (Some analysts say every parameter but in large complex systems not all parameters might be judged worthy of inclusion or even recognized as extant.) A nominal value is a par or recognized value, say, of a failure or error rate, set at the time of placing in service of a system, subsystem, or component. The nominal value is sometimes referred to as the best value. See also Worst-case scenario, Parameter.

Blaming the victim: A defensive practice for reducing monetary and other costs by denying responsibility, or some part of it, for a loss to a person. The practice stems from a policy distorting and disorienting public reaction about responsibility for an accident and creating a strong, sometimes legal, barrier to full understanding. Full understanding is vital for accident prevention. The practice, in short, is one of victimization and the necessary blocking of learning and consequent thinking regarding particular information. Many organizations have specific defensive personnel who are victim blamers, wielding a range of organizational safeguards for minimizing costs and consisting of procedures, documents, and fixed statements.

Blind movement: Includes blind shoves and blind pulls. A blind shove is a pushing of cars with any locomotive for which the point (leading end) is not either protected or seen to be on a clear, safe path. RCL operations introduce a new procedure and concept in railroading, the blind pull. A blind pull is a pulling of cars with any locomotive for which the point (leading end) is not either protected or seen to be on a clear, safe path. The rules for RCL operations attempt to eliminate blind pulls (and, sometimes, blind shoves) by establishment of an RCZ.

Interestingly, by rule a railroader cannot make a blind shove of, say, 30 cars, except where permitted by rule. He, however, can decide to pull the (uncoupling) pin and detach these same cars and let them rollaway freely. This is not a blind movement under the rules.

"Box," the: Railroader jargon for a Remote Control Device.

Catastrophe: This report uses the widely employed definition of "mishap severity" from MIL-STAND-882-D. "Catastrophic. . . Could result in death, permanent total disability, loss exceeding $1 M[illion], or irreversible severe environmental damage that violates law or regulation" (USDOD 2000:18).

Cause: An event resulting in an effect, which see, below. See also, Event and Dependency, below.

Cause/causal chain: A cause and effect sequence of events where an action either contributes to a following, intermediate event or terminates in a final or end event. In a lengthy chain, one action leads to another event, which changes conditions, which lead to the next event in the chain, and so forth. Preceding events in a chain are sometimes labeled those further "upstream." A causal chain could have root cause(s), then, intermediate causes, and, then, end in a final triggering event.

<u>Cause(s), contributing</u>: Alone will not cause an accident, near miss, or error.

<u>Cause, root</u>: Is the most fundamental/basic and "upstream" aspect of causation that can be identified for a final or end event. The main purposes of analytic tracing to a root cause of an unwanted event is to develop corrective or mitigating actions to protect the health and safety of workers, members of the public, and the geographic environment or to develop a business efficiency.

<u>Cause, triggering/direct</u>: The cause that immediately resulted in a final event, such as a physical failure of a component or an operator's error of omission. Also called <u>immediate cause</u>.

<u>Coded Digital Radio Communication</u>: Radio communication exists between a body-mounted RCD and its electronically mated OCC on an RCL. This communication is coded, to select precisely among which OCC and RCDs communication is conducted. Communication is in digital form. Digital data comprise a series of discrete numeric values. The code is a set of rules for interpreting a series of bit patterns for these data. OOCs and RCDs each operate on a unique digital address.

<u>Communication</u>: Transmission of a giving or exchanging of information by voice, digitally coded radio or wire signal, written alpha-numerics, graphics, colors, sounds, positions, shapes, and other means. Aural communication has two kinds, signaling with tones (bells, buzzers, whistles, horns, etc.) and with human or synthesized speech. In railroading, we find control by human and synthesized voice communication; digital codes transmitted electronically; color lights; semaphore arm and light positions; pigmented and shaped surfaces; track circuits for interval spacing of trains and other purposes; air pressure; whistle, bell, and buzzer sounds; alphanumeric designations such as a letter <u>D</u> on a derail switch stand, “END CTC” on a fixed sign, and other means. In some assessments, it is useful to distinguish human communication by any means from control communication generated by machines.

<u>Communication loss (COMM LOSS)/ Communications interrupted between RCD and RCL</u>): Communication loss could be divided into two functionally different faults. First, is the loss in which the coded digital radio communication between the onboard computer and the controlling RCD is interrupted for more than 5 seconds. Such communication loss/interruption results in a loss of tractive power and a service air brake application. (A tilt timeout results in loss of tractive power and an emergency air brake application. See <u>Tilt</u> in this appendix.) Second, is the micro loss in which such interruption of communication lasts for less than 5 seconds). In other words, the RCO can lose communication with his the RCL for 4 seconds at a time without experiencing a penalty air brake application, as in the loss for 5 seconds or longer.

<u>Consist</u> (noun): (1) Any assemblage of rolling equipment powered by a locomotive. (2) Any combination of units making up a locomotive under the control of an engineer or RCO.

Control: A control is a device transmitting control information to a machine system, subsystem, or component. The control allows an operator to affect the state of a machine. Apart from computer inputs and voice activations, controls are the usual manner of an operator sending instructions to a machine.

Conventional: Here, the customary non-RCL operations using a locomotive engineer to operate a locomotive with the ordinary controls at his workplace in the locomotive cab.

Conventional Crew (CC): The crew of a CYL consisting of three and sometimes four members, who do not use RCL equipment, as follows:

> Locomotive engineer: The person who runs a locomotive, with the ordinary controls at his workplace in the locomotive cab. and handles the attached train or cut of cars.
>
> Engine foreman: In operations by switchmen, he is the crewmember in charge of a yard locomotive, under the rules. He is sometimes called yard conductor.
>
> Helper: In conventional operations by switchmen, the second (and any third) crewmember is the engine foreman's helper, also called pin puller (and for any third switchman, called field man).

At times, the CC has two members, a locomotive engineer and an engine foreman.

Conventional Yard Locomotive (CYL): A locomotive, usually of the diesel-electric kind, used in yard service and not equipped with or not using RCL equipment.

Crew: As found in railroading, a team i.e., group (two or more persons) working in coordination under a designated leader: engine foreman, conductor, locomotive engineer, section foreman, bridge & building foreman, etc. Crewmember interactions allow the informal reciprocity of operating information, including subtle exchanges, and the building of teamwork coordinations (knowing where a teammate will be and what he can be depended on to do). In these and other ways, each crewmember accretes a repertoire of operating knowledge, both rules and skills based. Regarding the team in commercial aviation, it is being recognized that "safety depends more on teams than individuals, and that team synergy can be learned" (Pariés 1999:20).

Crew Resource Management (CRM): A term and related body of concepts developed in aviation and now somewhat applied in the railroad industry. In railroading, CRM concerns enhancing communication and coordination among flight crewmembers and among these and other interacting personnel (in traffic control, maintenance, flight attendant tasks, other flight crews, etc.). Effective CRM reduces poor communication and interactions and reduces near misses and accidents. In aviation, CRM includes the quality of the training and supervision and grades into "company resource management." It comprises effective use of all human, information, and equipment resources for efficient, safe operations. CRM is not a one-time only intervention or a set of admonishments to crewmembers but something for which special formal training is required and which is maintained continuously. Despite CRM's roots in accident reduction from "pilot error," clearly it has a broader scope. Particular CRM attention has been given to crews in automated aircraft

(Risukhin 2001:19, 59-60, 181-182, 279-281; see also Wiener 1993; Kern 1997; Helmreich 1999).

Cut: Two or more cars coupled, with or without the air brakes operative. Here, these cars are "cut/cut off" by use of a cutting/uncoupling lever.

Data-radio: A one- or two-way radio used to transmit or transmit and receive coded data (binary impulses).

Dependence n. /dependent adj.: A causality relation between two phenomena where a change in one results in a change in the other. See Cause, above.

Discipline: 1. In employment, generally, discipline is a characteristic of an employee resulting in his voluntarily acting in accordance with safe and efficient standards for work. The concept is thus self-discipline. 2. More specifically, in railroading, discipline primarily means disciplinary action by management, sometimes at the behest of governmental regulators. This is enforcing discipline in the sense 1 by punishment or correction but, ideally, it should have instructive and correctional functions. Prior to any discipline taken against a union employee, management holds a formal, transcribed investigation, with union representation of the employee. In recent years, the employee can waive the right to such investigation, usually in return for lighter or no punishment. See also Plea bargaining.

Dismissal of the Secondary RCD: For dismissal operations, the Primary and the Secondary RCOs of an RCL must complete a deinitializing procedure affecting the Secondary RCD only. (See Initializing and Linking.) If the procedure is successful, the Primary RCD will display "SEC. RCT DISMISSED." ("RCT" equals RCD.) For the Secondary RCD to be "reacquired," the Secondary RCO must, first, make a request via voice-radio to the Primary RCO. Then a procedure is completed to "reacquire" the Secondary RCD. If the procedure is successful, the Primary and Secondary RCDs will display "SEC. RCT REACQUIRED."

When his RCD is in dismissal status, the Secondary RCO must keep his RCD in its powered off mode while in standby mode. Otherwise, if the Secondary RCD moves out of range of the Primary RCD, the Primary RCD could experience a COMM LOSS and this might not be recoverable on the Primary RCD until the Secondary RCD moves back into the range of data communication. When a Secondary RCD is in dismissal status, various safety protective features of the RCLS are not available to the Secondary RCO, such as tilt-man-down and vigilance protection. See: Remote Control Device (RCD), Tilt Protection (Man Down) Feature, Vigilance Feature.

Distributed Power (DP): Allows control and monitoring by an engineer from his lead, controlling locomotive of the power and braking for a number of locomotives placed at separate locations, to the rear, in his train consist. Two-way, coded, digital-radio communication exists between a head-end DP radio and its electronically mated counterparts on each remote locomotive. Each locomotive in a DP train operates on a unique digital address. The DP engineer manually or automatically transmits control signals via the coded radio telemetry data to each remote locomotive he operates. A DP road engineer no longer has to rely on voice-radio signals to and from an engineer on a helper locomotive assisting on a grade.

With DP, the engineer can handle long, heavy trains more safely than by non-DP methods. Distribution of power and braking throughout a train results in quicker and smoother starting and stopping of a train, reduces train transit time, and allows trains of great tonnages otherwise not feasible. DP reduces in-train forces--preventing the buckling of a train and the lifting off the rails of a light car and lessening damage to lading.

Older DP required that an engineer manipulate multiple sets of controls, for the lead and remote locomotives he operated. Newer DP equipment allows the engineer to use one set of controls for operation of his lead and remote locomotives. Here the engineer operates using the function keys of a “summary screen's” throttle and dynamic brake controls. Both older and newer DP can be operated either automatically in a synchronous mode or manually in an asynchronous, “independent control” mode. Thus, when enabled in independent mode by his settings on the head end, the engineer can operate his remote DP locomotive(s), as he commands, separately from his lead locomotive. Hence, he can be beginning to balance, under dynamic braking, his lead locomotive on a downgrade, while shoving under full throttle power with his remote locomotive, still on an upgrade. Study of DP finds some of the same issues as with an RCL, including chip malfunctions and control via coded radio signals. Formerly, the name for DP operations was remote control locomotive operations.

Drop (also, running/flying switch): A switching move in which cars trailing a locomotive are uncoupled as a cut (which see) while in motion and allowed to roll freely onto a track other than the one on which the locomotive continues to run. Care must be taken that the governing track switch operates freely, the hand brake to stop the cars operates, and the locomotive accelerates enough to avoid being hit by the following cars. If the drop is made too slowly, the cars could “hang up” and stop over the governing switch, thereby trapping the locomotive on its track, causing its coupler to face a car side and not face a car end with a coupler. Precise coordination of tasks and timing are essential for a safe, efficient drop.

"Early quit": Railroad jargon, during shift work as on an eight-hour switching job, for being allowed to quit and go home early after finishing a designated number of tasks specified by a yardmaster or other authority. Rushing to receive an early quit has caused accidents in the past, including damage to freight-car lading. It is an example of what Perrow discusses: "Operators are often subject to production pressure, . . . which encourage and even necessitate overriding procedural safeguards" (1983:530). Railroading's "early quit" results not from unilateral managerial pressures but from informal, local labor management accords, mutually beneficial. See "double loss" in Accident.

Effect: Anything contributing to shaping an outcome. See Cause, above.

Efficiency testing: In-field tests by railroad officers conducted to determine if employees are following operating and other prescribed rules and practices. Test failures usually result in the imposing of discipline on the failed employee(s). See Discipline.

Electronic Pullback Protection (EPP): A generic label used in this report for a system having various proprietary names. It uses GPS and/or tag-readers to provide location of rolling equipment, pull-back protection for an RCL movement, and other functions such as sounding RCL horn and bell and activating grade-crossing warnings.

Event: A real-time happening of any phenomenon, including a human error, physical failure, or geographical occurrence.

Event recorder: A stand-alone optional device, with appropriate software, for electronically collecting, storing, sorting, and replaying a designated number of hours of specified data streams of parameters in operations for the RCL on which it is housed. Because this data is downloadable, it can be taken by law enforcement personnel and discovered, if extant, in lawsuits. With some event recorders, railroad officers at a central office can monitor the data, for example, to see if the yardmaster in a certain yard keeps his RCLs moving.

Event, reportable: An event to be reported according to specified authoritative criteria. The FRA has criteria for the reporting of railroad accidents and other events.

Fail-safe: This often-used term is a referent in design, a planned arrangement of components in a system. This referent means that, if a system, subsystem, or component fails (stops operating, or, at times, operates to a design designation of less effectively, reliably, or tolerably than planned), the item goes to a more restrictive condition. A common popular and incorrect view or connotation of fail-safe regards a device, having a capability to fail without harm to property, persons, or environment. Given a complex, heavy, and mobile machine, such as a locomotive and attached cars, a fail-safe design does not prevent continued undesired, even unsafe, function of a system for some period of time. Going into a fail-safe state, accordingly, does not insure an automatic instantly going into a safe operating mode in the event of a failure of a system, a subsystem, or component, and it cannot guarantee eliminating a hazard fully or immediately by automatically reacting to a failure. To the contrary, a so-called fail-safe subsystem of a device could operate to fail-unsafe. A system's diagnostic corrections subsystem when going to a more restrictive condition cannot always insure safety.

In other words, the more restrictive condition in fail-safe design does not necessarily insure safety. For example, steam locomotives and tank cars have several (redundant) safety (pressure relief) valves atop the boiler or tank shell. The valves automatically self-actuate by an increase of internal pressure beyond a design maximum. Such safety valves have not insured that the boiler or tank car shell does not rupture, sometimes in a violent explosion. In RCL operations, for one fail-safe example, if radio communication is lost between the RCD and the OCC, the OCC brings the locomotive to a stop automatically with a penalty brake application. Such a fail-safe, automatic stop, however, does not mean that the stop is completed instantly before property damage, human injury, or unauthorized fouling of track by rolling equipment occurs. Accordingly, a statement such as, an RCL is designed as fail-safe and if communication is lost between the OCC and the RCL the RCL automatically stops, must not provide any sense of automatic safety in operation.

Fail-safe is an old concept in railroad design, e.g., for automatic block and cab signal systems controlling the safety-critical spacing of movements on main tracks. Here the validity of the concept stems from using system components having well-established failure modes, with a safe condition resulting from a failure of a component. Thus, a signal designer labels such signal systems as vital, i.e., they will have the most restrictive indication that a particular signal can display if components fail. But this is only under certain design conditions. (A false clear signal is always possible under certain conditions, with a track relay for a signal stuck in the closed, or picked-up position, e.g., where the signal is wired incorrectly to falsely display a clear indication or where a mechanical impact to a signal causes it to falsely display a clear.) One could argue that the design is, nevertheless, vital but that, in the rail world, an intervening human error or physical impact defeated the vital characteristic.

Accordingly, even a relatively simple, over-a-century-old system such as for automatic block signals can fail unsafely and is not always vital, to a fail-safe state. The validity of fail-safe concept is even more in question for large-scale systems, especially those with microprocessor components. Here we do not need an initiating human error or physical impact. The almost-infinite number of failure combinations of such systems could well mean that the concept now has no validity. Perhaps, designers must abandon the traditional determinism of fail-safe and vital, having their experiential, observational underpinnings, and resort to the probabilism of risk assessments, having their weaknesses of subjective, judgmental underpinnings.

Failure: The end of a physical system's, subsystem's, or component's ability to function correctly. Failure can be anticipated or unanticipated; gradual or sudden; from wearing out, stress beyond component design capacity, or stress within component design capacity. An acceptable failure rate is a definition of a component's useful life.

Fault: A defect in a component causing a failure.

Feedback: A process wherein factors producing a result are affected by the result. See Loop, closed, open.

Fouling, bodily: This relates to a physical area which a human body enters (fouls) on a track on which rolling equipment is or could be present. (Here, to foul is in the related senses of to be in the path of, to become interspaced or entangled with, and to collide with or be collided with.) The fouling puts a human in danger of injury or death. On some carriers this physical area is called the Red Zone. The FRA refers to it as the zone of danger.

Function (microprocessor): The operation specified in an instruction. (This operation is not to be confused with Operations, railroad—which see.) An operation is an action defined by a single instruction. An instruction is data causing a microprocessor to execute an operation, specifying the locations or values of all operands. An operand is the element in an operation from which the result is produced through defined actions. A result is the outcome of an operation performed by an operator on one or more operands. An operator in an operation is the element defining the action to be performed on the operand. (This operator is not to be confused with Operator, human—which see.)

General railroad system of transportation: The term applies to all of the standard-gauge railroads in the US. They are under the jurisdiction of the Federal Railroad Administration (FRA). It does not apply to plant railroads inside of a bounded installation such as a factory, quarry, or distribution facility, and to urban rapid transit railroads, the two not being part of the general system.

Generator: A rotating machine which changes mechanical energy into electrical energy. The main (traction) generator on a diesel-electric locomotive receives power from the prime mover, a diesel engine which comes in sizes varying from 600 to 6000 hp. The main generator delivers, through connections in a high voltage cabinet, direct-current electrical power to traction motors geared, one each, to the locomotive's axles. The diesel engine also drives a smaller generator and alternator not used for traction. Some newer locomotives have an alternator producing alternating current for traction, instead of a direct-current main generator.

Generator (or alternator) field: A magnetic field in which the generator or alternator armature rotates. Without this field no electrical power can be produced; hence, a locomotive cannot be powered for movement.

Global Positioning System (GPS): A radio navigation system from earth satellites operated by the US Department of Defense. In furnishes highly accurate data for three dimensional position, velocity, and time. At any time, four global positioning satellites are above the horizon anywhere on earth. Precision is provided by an atomic clock on each satellite

Ground, on the: As in the common railroaders' "on the ground," means anywhere off rolling equipment, which is on the track.

Groundman: A collective term for switchmen, brakemen, conductors, engine foremen (yard conductors) and utility operating personnel assisting a crew, now including those who are RCOs. On some railroads, locomotive engineers are RCOs.

Hacker and hacking: A hacker is an individual or group who hacks, i.e., has both publicized and unpublicized unauthorized access to a computer and its applications and data. A hacker can be successful in penetrating the security safeguards for a computer or system of computers. Hacking could result in the shutdown of a railroad communication and/or signal system and thereby disrupt the flow of trains and other rolling equipment on main tracks. It is not known if a saboteur-hacker, such as a terrorist, can subvert such systems to cause loss of physical property or harm to humans. (To hack original meant to change or add to programming code, while outside the business organizations of the software industry. These benign hackers have developed much software in the public domain.)

Hand signal: Any signal given manually be an operating railroader including with bare or gloved hand or while holding an illuminated lantern, lit fusee (red of yellow flare), or flag. Codes exist for hand and lantern signals, although most such signals are outside a formal code. Colors for flags are also coded. Hand signals are continuous in that during a movement under control of a hand signaler, he (at night, his lantern) must be continuously in sight. Under the rules, his disappearance from view for any reason is a stop signal. Conveying the same information during the same kind of movement by voice-radio is discrete (discontinuous) signaling. Under the rules, the signals are spoken at prescribed fixed intervals, but, in reality, these spoken signals are often radioed at greater intervals.

Handshaking: In computer operations, handshaking controls flow of information between two linked microprocessors. It is an interface in electronic communications before a transmission, where a signal is requested and received and, after transmission, usually acknowledged. Handshaking eliminates ignored and overlapping signals between electronic devices. Here, between or among electronic systems, subsystems, and components, an interface is the common boundary and electronic-circuitry linkage of such units.

Hazard: A condition (process or state) that could lead to a loss, thus it is a potential. (See Loss.) A hazard could be a being, energy, mass, toxicity or duration of time that, if not controlled, could result in a loss. More specifically, hazard is the overlap in time and space of a potentially loss causing agent and a potentially vulnerable recipient. Risk is a probability of occurrence of a loss owing to realization of a hazard. Many analysts extend this last definition by positing, risk is the severity of the consequences of a loss times the probability of its occurrence. They thereby create a desired metric, however, subjective or arbitrary the assumptions were in assessing both the severity and the probability. The loss has to be defined regarding a reference point: the loss of what kind for whom? ("Your loss fills my desire for 'progress.' Let's get on with urban renewal.") What is considered a loss by one sector of a society might not be so viewed by another sector. If risk is predicated on a potential loss and the definition of a loss is culturally relative, then risk cannot always be an objective measure. Perhaps it can never be an objective measure. See also Accident, Severity, and Loss.

In the terms of everyday speech and common dictionary definition safe and safety mean freedom from danger. Almost nothing is danger free, however. Hazard is almost always a potential regarding objects, animals including humans, and procedures. A hazard could be extant without any knowledge, or if knowledge, recognition of it. Analytic considerations of hazard involve making judgments, from a particular social position, about the amount of risk that is acceptable. This relates to severity of a loss to particular sectors of the public and particular geographic environments.

He/him/his: Designates a person regardless of sex.

Human-Automation Interface (HAI): See Appendix A, on this topic for a discussion at some length.

Human Factors Analysis and Classification System (HFACS): As related to RCL operations, the present report provides a broad, exploratory classification for human errors and for physical failures. With further refinement the present classification could be adapted to the Human Factors Analysis Classification System (HFACS), having great utility and discussed in the second paragraph below (Wiegmann and Shappell 2003). The exploratory classification and its encompassed narratives begin to address the near-insuperable problems of mapping the intricate, complex reality of railroad operations and of rail switching in particular. The open-environment, rail world is not readily mapped and is quite difficult to model. Any classification of a complex subject matter is inevitably arbitrary, and information in taxa necessarily must be of varying lengths.

Our report classifies and presents results from one approach to Human Error Identification (HEI), indicating what could go wrong from the human perspective. Errors could also occur in combination with the Physical Failure Identifications, which we also present, and/or with occurrences in the geographical environment (somewhat covered throughout this report). The reported HEI presents many errors but is not intended to be exhaustive.

Scott Shappell and Douglas Wiegmann tellingly explain regarding accident taxonomy, "most accident reporting systems are not designed around any theoretical framework of human error. As a result, most accident databases are not conducive to a traditional human error analysis, making the identification of intervention strategies onerous. What is required is a general human error framework around which new investigative methods can be designed and existing accident databases restructured" (2000:i). They find an answer to their quest in The Human Factors Analysis and Classification System (HFACS), a comprehensive taxonomy for identifying and analyzing error. HFACS holds promise for its adaptation to railroad accidents.

The HFACS model is all the more compelling because at the base of its conceptualization is the heuristic modeling of James Reason outlining multiple causes of accidents, especially those "upstream," latently lurking at societal levels higher than the operator on the point. The utility of Reason's model reflects one test of time; it has been widely used for fifteen years. (For Reason's conceptualizations, see Appendix E. The Foci of Human Error.) Other analysts have developed useful, realistic models of chains of multiple causes in accidents (Bird 1974; Adams 1976).

Accident data and other information are collected for a number of reasons, including: in accident analyses, regarding liability matters, for achieving managerial goals, for business disciplinary actions, for regulatory assessments, and in private and public policy formulation. Numeric data can establish correlations between variables associated with accidents. These data, however, cannot determine causality between the variables (Stoop 1997).

Human-Machine Interface (HMI): The HMI could be considered as an abstract plane across which operator and machine exchange information. HMI, then, involves study and application regarding factors of interaction between human operator(s) and a machine including human, perception, decision-making, information-processing, capabilities and performances, task procedures, reactions to equipment layout and design, and integrations of physical stimuli and learning experiences. Hence, the designation HMI is often indistinguishable from human factors. A human's interface with a machine could be with one to some degree autonomous. See Autonomous, control system, Human-Automation Interface.

Specifically, HMI is a human's interaction with a machine through controls, displays, and data input devices. When an RCO does a task involving direct contact with a device, such as an RCD, the components of the RCD that he manipulates and/or observes are his HMI, for the task duration.

Human reliability: See Appendix C, section 5.

Incident: See near miss.

Interoperability: Generically, interoperability is the capacity for a particular kind of equipment to operate safely (and, perhaps, also efficiently) across all the firms of an industry using such equipment. This operational capacity includes maintaining a designated minimum of standard designed functions and standardization of the human-machine interfaces.

Initializing means to set at an initial state, ready for operation. That is, initializing sets all the values of a program (and any related indicators) to their initial settings.

Initiating event/ triggering event/immediate cause: An event that sets off a hazard regarding an accident or incident. An initiating event need not be hazardous in itself. The consequences of the event are hazardous.

Jargon (railroaders'): Railroaders' jargon or lingo (also linguistically labeled slang, argot, and cant) is an identifier and basis of solidarity among these "rails." They, in part, distinguish themselves from the "civilians" in the world outside of "the property" (the railroad) by their own specialized talk. My "Espee skipper" (conductor) friend and anthropologist, Lou Kemnitzer, notes that rail lingo is not just in articulate speech but also in hand signals and gestures (Kemnitzer 1973). A "snake" (switchman) with whom I used to "bat out MTs [empty cars] on a shotgun lead while running a midnight goat" could hold a long, complex conversation with a "dinger" (yardmaster) using only hand signals and signs, while this "YM" talked back from his tower via yard loudspeakers. "Rails" smile derisively to one another when any new railroader, not yet "cut in," misuses their argot of tribal membership. On my first day, I was taught, sternly, we never "drive" an engine, but instead "run, handle, or pilot" her, and any "drivers" involved are solely her powered wheels.

"Job insurance": Railroader jargon for insurance purchased from insurance firms specializing in providing income replacement for a railroad employee disciplined with suspension or firing from railroad employment.

“Joint”: Railroader jargon for a coupling of rolling equipment. (“He made a joint with the car.”)

Kick: A switching move in which cars are accelerated by a locomotive before they are uncoupled and allowed to roll freely into a designated track, while the locomotive decelerates or stops.

Kinesthetic (adj.) Kinesthesis (noun): This term refers to the human sensations of movement, tension, and position perceived through nerve-endings in the muscles, tendons, joints, and skin. Kinesthetic sensation is sometimes called intrinsic feedback. Kinesthesis, then, is an internal sense conveying information about bodily position and movement. These kinesthetic receptors of the human body form a feedback loop telling the brain, in part, the extent to which the operator's instructions to a machine are being executed in the manner the operator desires. Aircraft pilots, automotive vehicle drivers, boat operators, heavy equipment operators, and locomotive engineers receive such kinesthetic stimulation. If the movement of a machine, such as an RCL, is something physically apart from the operator, such as an RCO, the Human-Machine Interface is almost entirely informational, in some symbolic, abstracted form. Then, little or no kinesthesis obtains. (See Human-Machine Interface.)

A level of kinesthetic stimulation at which a difference can be detected is the threshold, or limen, between two stimuli, and the level at which a stimulus can just barely be discerned is called the absolute threshold. Operator awareness and use of thresholds, absolute and otherwise, is part of the learning curve beyond minimal competence into proficient (highly skilled/adept/expert) competence. In other words, the amount of previous experience influences perceptual judgment of kinesthetic sensations. A kinesthetic set is gradually accumulated/experienced by a human, that is, a kinesthetic stimulus cannot suddenly arrive as a "bolt for the blue" onto a completely uninitiated human. It must be gradually learned and maintained through experience.

The kinesthetic feedback cues for a locomotive engineer--but not possible for the operator of a remote-control model airplane, model boat, or model train or an RCO not located on a locomotive--include various feelings (equals sensations). These include acceleration, deceleration, and velocity stasis; variable pressures of slack run-in and run-out; smell of hot metal from heavily used locomotive brakes; feeling of resistance when starting a heavy train; detection of driving wheel slip and spin on the unit occupied; feeling of "picking up the drivers" (locking wheels during braking and sliding them flat) on the unit occupied; and so forth.

An RCO reports regarding RCO kinesthesia: "When on the ground, you do not have any ‘feeling’ as you would controlling the movement from the engine, and it makes for some pretty hard joints [couplings] at times."

Kinetic energy (KE): Energy (capacity for doing work) that an object has because it is in motion. KE is given to an object when it accelerates; therefore, all objects in motion possess KE. KE derives from the mass (m) of an object and its velocity (v) in the formula KE = $\frac{1}{2} mv^2$, convertible to $\frac{1}{2} (W / g)v^2$, where W is weight and g is gravity. On any impact, an object’s kinetic energy is converted to other forms of energy such as heat, light, and sound (and some could remain as unconverted mechanical KE). A 150-ton locomotive shoving a 2,850-ton cut of cars (or a total of 6,000,000 lb) at 15 mph (or 22 ft/sec) on level straight track would have a KE of 45,375,000 ft lb. Here KE = $\frac{1}{2}$ (6,000,000 lb / 32 ft/sec^2) (22 ft/sec)^2 = 45,375,000 ft lb.

Latent factors and errors: For James Reason's concept of, see Appendix E.

Learning: An RCO’s learning, as with everyone else, results from experience, including broad education and specific training, and practice. It results in relatively permanent changes in behavior, such a learning how to drive a car. A learning curve is a graphic representation of human performance thought to result from learning. Because a number of factors including motivation affect learning, which is not directly observable, no strict generalizations or hard measures can be formed about learning. Performance is observable and can be measured in some of its aspects. Learning is but one of a number of variables entering performance.

In learning, we develop learning sets, i.e., viewpoints and plans for handling similar kinds of learning. A learner is thus oriented and adapted to particular patterns of stimuli to be learned. In short, the learner learns how to learn and become increasingly able to handle particular kinds of patterns of stimuli. Thus a railroader learns not a series of single, discrete operating rules but, instead, selections of interrelated rules for application to concerns having variably overlapping patterns. During training and experience, a railroader develops learning sets which become more efficient over time. Learning builds upon past learning; thus, the learning component of individual performance becomes more effective over time. Effective occupational learning initially must be based upon sufficient formal training and periodic updating and refresher training. Throwing a manual or sheaf of general orders at a railroader is not a substitute for initial training and retraining. This provides the terms, concepts, and procedures that form mediational (serving as a medium for conveying information) elements allowing for more effective future learning and a more profound grasp of what is learned. See also Experience.

LED (Light Emitting Diode): A p-n junction diode emitting light from direct radiative recombination of electrons. What is seen is the energy from emitted photons. LEDs make useful low-voltage displays. (A p-n junction is the place where two semiconductors of opposite polarity meet.)

Linking: The initializing of a RCLS is called linking. In linking, the paired RCDs and the RCL exchange stored electronic information for recognizing the correct addresses and not recognizing any others. In the more recent linking technologies, infrared transceivers are used for this exchange. A menu-driven display on a panel of the OCC provides sequential prompting to the RCOs for the information transfer. First the primary and, then, the Secondary RCO completes the linking. Data thus transferred includes the digital addresses of the particular RCL, which has a unique identifying number, and the two RCDs, the Primary and the Secondary. The programming of a Secondary RCD places limits on the amount of control information that can be transmitted by it. However, the Primary or Secondary functions of paired RCDs can be exchanged in the field by the two RCOs, with the pitch and catch function.

In some instances, if so desired, the Secondary RCD is not used. Then, it is not part of the initializing process. This action produces RCL operations with only the Primary RCD, by the sole RCO. See Transceiver. See Initializing. See pitch and catch in Remote Control Device.

Live track: A track on which a movement of rolling equipment can be made at any time in either direction.

Locomotive: Here, a locomotive means a unit of rolling equipment capable of developing tractive effort and propelled by any form of energy. An RCL could be a single-unit or a multiple-unit locomotive controlled from one RCD. (I would prefer to use the term in the rules, engine, but the fixed term for the subject of this report, Remote Control Locomotive, forces the terminology in this report. To do otherwise could engender ambiguity and confusion.)

Locomotive, light: A single- or multiple-unit locomotive without any other rolling equipment coupled to it.

Lockout: A safeguard device or computer program used for preventing access to or prohibiting the activation of a device or computer program. See Safeguard.

Loop, closed, open: The paired concepts relate to a system having an input (feedback) function, an intermediate control function, and an output (feed forward) function. If no direct link exists between the input and output functions, then, the system is open. If output influences input, them the system is closed.   Where an operator has full control in a man-machine system, he is the intermediate link. Closed loops do not necessarily function immediately. When an operator applies the air brakes to stop a long, heavy movement, it could be a minute or more before he can observe discernable deceleration and still more minutes until the stop. Without immediate feedback, the operator could overcorrect his intended action. For computer control, the basic definition just given was expanded to include information used by a system to monitor and adjust its operation. In the behavioral science, kinesthetic feedback to the operator is an important determinant of successful outcome in many kinds of operations having motion. See Kinesthetics. In learning, information feedback to the operator informs of the correctness of an action. Thus, when an engineer or RCO responds to an alerter alarm, he knows his response was correctly executed when the alarm stops. In social science, feedback includes any input from the total environment, including persons, affecting action. Thus, in switching, when a person giving hand signals to guide a movement disappears from sight, that is a signal to stop

Loss: Includes injury and death to humans; damage to property and environment; and harm to business and government procedure, well-being, reputation, and good will. See Mitigation.

Machine: A device with fixed and/or moving parts for producing work, mechanically, electrically, chemically, or electronically.

Mean time between failures (MTBF): Is the average time a system, subsystem, or component will function without a failure and is expressed in hours. MTBF is a much used reliability statistic. It can be derived from empirical testing or from statistical calculation of past failure rates.) See Failure.

Mitigation: Is rendering the loss consequences of a hazard less severe, if the hazard is realized. See Loss. Mitigation is not prevention (to eliminate happening by a previous action). For example, for driving at night in rural Australia, I mitigate by renting an auto with "roo bars," i.e., steel bars on the front to lessen the damage if a large kangaroo suddenly materializes by hopping in front of my car. I could prevent by not driving at night, or at all.

Model: A representation of a system or subsystem and its interrelated parts.

Motion, after effects: A visual perception by an observer from viewing a steadily moving stimulus, such as a train. After shifting the view to a stationary stimulus, say, stationary railcars, the observer perceives it also to be in motion but in the opposite direction. Here motion is "seen" where there is no physical motion. Railroad operating work has a special case of this phenomenon. When an observer rides on a moving platform such as a locomotive, railcar, or road vehicle close and parallel to a railroad movement, moving in the same or opposite direction of the observer, his estimation of the speed of his platform is distorted. (When I ran a locomotive on a track with a movement running next to me on a parallel track, the speed of my movement was difficult to judge precisely, the more so when decelerating and accelerating in switching. An apparent visual disorientation greatly affected my skills.) This phenomenon in railroading is partially induced by vision and partially from the real motion of the riding observer. It is an illusion of movement having practical and serious consequences.

Move (noun): Any action by an operating railroader or railroad officer resulting in a movement of rolling equipment. ("The move he made was to have the locomotive come ahead.")

Movement (noun): Any number of coupled vehicles of rolling equipment in motion or stopped.

Near miss: For operational safety, an assessor must comprehend not just accidents but also near misses. Not studying near misses means that we neglect chances to prevent future accidents. Near misses are sometimes also called incidents but some literature differentiates between the two concepts. Here, we lump the two together. A close call is a recent synonym for near miss. A near miss is an event that did not lead to a loss but could have done so. That is a near miss is a near accident. In a near miss, its chain of events has a great potential for an accident and its consequent loss. Some or all of the safeguards in a system were penetrated but no loss resulted. For example, an RCO could infract the rules by running his RCL movement past a wayside red (stop) control signal for a few car lengths. If no rolling equipment was in the span of these car lengths, then, no loss could occur. If equipment were standing right beyond the signal, however, a collision with a loss to property would have occurred. Because a near miss does not enter into questions of legal liability for a loss, their information gathering and analysis yield a noncontroversial avenue for understanding human error and its potential for loss.

In short, a near miss is an accident that could have but did not happen--this time. Three-Mile Island is an example of a near-miss for a meltdown of a nuclear reactor. Chernobyl is an example of an accident with a nuclear reactor. A near miss can range from one in which only a few safeguards were defeated to one where catastrophe (which see) escaped realization by only a few seconds or inches. A near miss can be as instructive as an accident for risk analyses. Lack of accidents for a particular technology do not demonstrate operational safety and effective management when near misses occur.

Near misses provide for proactive as opposed to the usual reactive action for accidents. It follows that in analyses regarding safety, near misses as well as accidents must be studied for full comprehension of hazard. Given that near misses are more frequent than accidents, they have data for more exacting assessments than from accidents alone. This is particularly important in industries such as commercial aviation, nuclear power, and railroading having an exceedingly low frequency of accidents.

Normal accidents: Sociologist Charles Perrow's conceptualization of some kinds of accidents (1999). He finds accidents and their possible consequent catastrophic loss are inevitable in complex, tightly coupled systems. In brief, given the nature of these systems, accidents will occur, no matter what the precautions taken by management. These accidents are "normal." Normal accidents are not isolated events but problems in a system necessitating systematic attention. Local, narrowly focused reactions will not suffice. "Fixing" an operator or team of operators will not suffice.

Object: A reactive or nonreactive physical thing that a person or control computer detects or recognizes, sometimes an object of regard, some thing a person control computer attends or recognizes. At times, used with reference to an Agent, which see.

On-board (the RCL) Control Computer (OCC): The on-board control computer and decoder of an RCL is usually several microprocessors interfaced for maintaining RCLS integrity. One of these is the control microprocessor having input/output functions. Thus, the OCC ordinarily is a set of computers.

A standard yard or road locomotive is equipped with an OCC linked by wire to an on-board radio. The on-board radio, depending on which supplier, either receives from and transmits (as a transceiver) to or else receives from an RCD. Radio operation is on licensed UHF channels. Thus, radio communication exists between an RCD mounted on the body of an RCO and its electronically mated OCC on an RCL. The OCC links by wire to a radio signal decoder, for receiving the coded radio signals from an RCD. Commands manually entered by an RCO on his RCD for radioing to the OCC are converted to electronic signals by the OCC. Through electrical circuits to transmit the electronic signals, the OCC links to locomotive air brake and electric traction controls. The default function of an OCC is stop, whether the RCL is moving or already stopped. The RCO must manipulate the controls on his RCD to effect movements by his RCL.
Note: The FRA calls the OCC a Remote Control Receiver (RCR).

Operations, railroad: The intertwined procedures executed in fulfilling the business plans for a complex railroad organization.

Operator, human: The operator of any machine or device in any industry, not limited to an RCO. A person who effects something with a machine or device.

Parameter: Either a constant or else a variable, characterized by the range of the values of the elements in its set. Either is often used as a referent to determine other variables.

Penalty application: An automatic application of air brakes caused by locomotive operation at values outside of a prescribed setting or procedure or because of a fault in the RCLS.

Performance Shaping Factors (PSFs): Are a complex of elements affecting an operator in an operating system and often divided into those internal and external to the operator. Interaction of PSFs can have positive, negative, or little discernable affect of operator performance. Rasmussen posits three levels of human performance, skill-based, rule-based, and knowledge based (1982). PSFs can be useful in human error identification. If error or consequent accident data are sufficiently detailed, then, the PSFs can be scrutinized.

Internal PSFs involve an operator's learning, his training and experience regarding the task undertaken. They also include his current ability for the task, including, skill and knowledge levels, biological condition (any fatigue, etc.), and emotional state (any personal problems, etc.) External PSFs span the entire environment of work. Bahr usefully divides external factors into three aspects (1997:152-155). Situational conditions are company-wide or facility-wide, including shift schedules and time off the job. Task and equipment characteristics relate only to a specific task or piece of equipment, such as shoving cars or an RCD. Job and task instructions influence how an operator is instructed and expected to do a task, such as what a railroad employee, according to the rules, is trained (or not trained) to do and what local authorities allow him to do. Especially important are "the equipment design and written procedures or oral instructions" (1997:153). To these three PSFs, Bahr adds a fourth, stressors, which can be psychological (task load, task speed, high-jeopardy risk, fear of failure, boredom, distraction, etc.) and physiological (fatigue, pain, discomfort, temperature extremes, atmospheric extremes, disruption of circadian rhythm, etc.)

Plea-bargaining: A process not only predominating in sentencing in the US criminal justice system but also becoming common in railroad discipline. On a railroad, this involves negotiation between the accused employee and the company prior to a formal investigation and its written record, as required by union agreement. The accused pleads, and signs, guilt for a lesser charge in exchange for having the greater charge dropped. Then, no investigation is held. In this reciprocity in discipline, the accused receives a lesser punishment and the railroad reduces the costs of its disciplinary and record system.

Point Protection (PP): A shielding from danger in which the point (leading end) of a shoving or pulling movement is either protected or seen to be on a clear, safe path. Thus, either the point or the path is protected. Accordingly, when rolling equipment is moved and conditions require, a crewmember provides PP either by taking a position on the leading unit of the rolling equipment or by being in a place, to see that the track to be traversed is clear of persons, physical obstructions, and defects. It is useful to think of the category inadequate point protection, of which no point protection is a subcategory.

Procedure, work: The sequence of steps for an individual or team to follow to produce work.

Process industry: A process industry has either continuous of batch processing of material and energy for a product created through chemical or other physical conversion. Examples are the chemical petroleum, and electrical generating industries. The highly automated process industries have a far lower number of safety-critical, human interactions than we find in rail switching. Rail switching consists of numerous, manual, discrete, contingent acts in a highly variable geographic and operational environment. Except for the nature of the universal automatic couplers, power switches where extant, and the recent introduction of RCLs, flat yard and industrial switching, today, has most of the tasks found in switching in 1880.

"Puck":   In an Electronic Position Detection (EPD) system or Pullback Protection System (PPS), a "puck" is a passive transponder-sensing device installed between the rails of a track at intervals within an RCL pullback zone. (See Transponder.) It is partially buried between two ties. When pulling back through an RCL zone, when the RCL passes over the first puck its speed will be limited to 10 mph. When passing over the next puck the speed will be limited to 9 mph and so on until the next to last puck slows things to 1 mph. The final stop-puck brings everything to a stop. For most systems using pucks, GPS-monitored backup for RCL location and display on the RCD of a "manual override" are used. Operating rules require that an RCL move with such a manual override have point protection.

The puck pullback protection can be cut out for operational purposes, for example, having to make a legitimate move past the stop-puck. Cutting out is done by depressing and holding for a few seconds two buttons on the RCL's onboard computer console. After the moves beyond the stop-puck are completed, the pullback protection must be restored.

Radio Repeater Station (RRS) for RCL operations: An RRS is a specially located transceiver receiving and retransmitting signals between an RCD and an RCL’s OCC. A repeater is a stationary radio amplification device and is at a point that is in radio-line-of-sight with three other points, the Primary-RCD and the Secondary-RCD and the RCL controlled by these RCDs. The RRS extends the range of an RCD when operated in a yard or other area. Without an intervening RRS, the range of an RCD to its OCC is about one mile, with an RRS, about two miles. (A transceiver is a device in one housing alternately transmitting and receiving radio signals.)

"Rail": In railroad jargon, an experienced and able railroad employee, often restricted to those who crew trains and engines and switch cars, sometimes excluding those in office buildings. See "Student."

Railroader: Here, for analytic purposes, this term excludes Remote Control Operators, so that I can segregated for their RCL experience the reporting by such employees. The term includes (1) any other (non-RCO) operating railroader: those crewing trains and engines and switching railcars, including brakeman, conductor, locomotive engineer, switchman, switchtender, and utility man assisting a crew. It also includes (2) any railroad operating first-line supervisor and officer, including (titles vary): rules examiner, train dispatcher, chief train dispatcher, yardmaster, general yard master, road foreman of engines, trainmaster, terminal superintendent, and higher level officer. I lump together classifications (1) and (2) to provide full anonymity for supervisors and officers whose views on particular matters might be known in a context outside of the present report. I use the label railroad employee(s) when necessary to lump together RCO's and railroaders.

Recover/ recovery, human: A human regaining of control without which a loss could occur. Recovery is usually by returning to an original, pervious state prior to human error, physical failure, or geographic disturbance. Partial recovery returns to a state near a previous state. Recovery could prevent a loss and partial recovery could mitigate severity of a loss. Decreasing the number of actors in a team decreases the collective ability of the remaining actors to recover. See Severity.

“Remote, a/the”: Railroader jargon for a Remote Control Locomotive. (“He was operating a remote.”)

Remote Control Locomotive System (RCLS): An RCLS is a method of controlling an RCL from a remote location and/or from in the RCL cab by means of an OCC and an RCD mounted on the body of an RCO. The minimum RCL equipment, then, is an RCD and an OCC and its linked on-board equipment. An RRS could be a third item of equipment in an RCLS. The radio link between an RCO's RCD and the OCC must be maintained for at least 5 seconds (3.5 seconds for some equipment). Otherwise, the RCLS will initiate a "fail-safe" action, that is, apply the air brakes and kill any power throttle use. The RCD transmits 3 messages per second to the OCC. If the OCC does not receive a valid coded radio message from the RCD within the prescribed timeout duration (5 seconds), then, a full service brake application occurs. OCCs, RCDs, RCLs, and RCOs are components of an RCLS. RCZs and RRSs can be additional components of an RCLS.

If an RCO falls down (tilting the RCD more than 45 degrees from the vertical), if radio communication between the RCD and the OCC is interrupted, or if the RCO fails to manipulate the controls (or activate a reset safety button) during a period of 60 seconds, after an audible warning the RCLS automatically executes an emergency air brake application.

Remote Control Device (RCD): A body-mounted, battery-powered console having controls and visual and audio indicators for radio communication with the OCC on an RCL for the purpose of controlling and monitoring the RCL. RCDs operate as single or paired units. The two RCDs of an RCL crew are designated as A and B. Depending upon the supplier, either one-way (transmitting) or two-way (transceiver transmitting and receiving) radio communication exists between a body-mounted RCD and its electronically mated OCC on an RCL. The RCD is body-mounted by a vest of belt. The RCD must be fastened at all four of its corners to the vest or belt, to insure the functioning of the tilt protection feature. The rechargeable battery of the RCD has a power life of about 12 hours. A power ON and OFF button connects and disconnects the battery from the RCD and thereby turns the RCD on and off. The RCD gives a LOW BATTERY warning and shuts down when the battery is discharged.

A vigilance button is mounted on top of each side of an RCD. Either button must be pressed for 1-2 seconds, in response to an alert tone from the vigilance-timer. This button also functions to acknowledge warnings from the RCD and, when continuously depressed for over 2 seconds, to apply sand in the direction of RCL travel. The vigilance function is required on the primary-RCD only, when the Primary-RCO selects a speed other than STOP.

With two RCOs, the RCLS permits control of an RCL to be passed back and forth between the Primary and Secondary RCOs, by manipulation of the RCD. This is called a pitch and catch (also called shared) of the function of the RCL-controlling radio signal. Only the A or the B RCD can control the RCL at one time. Using a defined procedure, the Secondary RCO accepts a pitch of control from the Primary RCO. Use of the RCLS with two RCOs requires effective two-way voice-radio communication between the two. These two RCOs can be located one-hundred or more car lengths from one other.

The BELTPACK kind of RCD is equipped with an electronic messenger. When activated by the RCO, this messenger provides an audible “talker” indication of the status of certain RCL operating statuses or requirements through the RCO's portable voice-radio.

Note: The FRA labels the RCD a Radio Control Transmitter (RCT).

N.B. The word beltpack has assumed a generic status, often not capitalized in this use, for all RCDs whether or not the Beltpack of the copyright trade name. Thus people in the railroad industry and members of the press sometimes use beltpack to mean any RCD from any supplier.

The RCD is a locomotive appurtenance requiring daily and other inspections and tests as specified in 49 Code of Federal Regulations, Part 229.

Remote Control Locomotive (RCL): An RCL is often defined as a locomotive controlled by a method, using an RCD, executed from a remote location. However, the RCO can control as well from inside the cab of the RCL. The essence of remote control, then, is not any remote characteristic but, instead, the kind of controls manipulated--RCD controls versus conventional controls. Thus, an RCL is a locomotive equipped to be operated by an RCO using an RCD. As a railroader notes regarding RCL operations: "'ASD RR' is running almost every switch engine job in the yard as if it were conventional. That is, most of the time, [one of two] RCO[s] is stationed on the locomotive to protect the shoves and pull backs."

As a railroader comments on the RCO manipulating his RCD while in the cab of his RCL: “Well, that's been happening ever since they first started using Remote Control.“ For someone to think this would not happen would be naivety about the nature of railroad operations. Just think about a long RCL pull in snowy weather in below zero temperature with an added strong wind chill.

Only certified RCOs and employees being trained in RCL operations are permitted to operate RCL equipment. Before taking control of an RCL, the RCO(s) must make the required tests to see if the RCL responds to RCO commands. A locomotive in RCL mode must have a warning tag at the conventional locomotive controls, saying that the locomotive is in RCL mode. All of a railroad's operating, air brake, train handling, safety, and other rules remain in effect for RCL operations, except when changed by additional RCL rules.

Remote Control Operator (RCO):
N.B.: The fixed railroad term Remote Control Operator (operator of a remote control locomotive) must not be confused with the fixed term Control Operator (employee assigned to operate a CTC or interlocking plant or authorized to grant track permits).

> RCO, Primary (RCO-P): Is the operator operating an RCL via an RCD. In RCL operations with only one RCO, then, that person is necessarily the Primary RCO. A Primary RCO can control all functions of his RCL and pass the control ("pitch") of his RCL to the Secondary RCO.
>
> RCO, Secondary (RCO-S): Is an RCO having an RCD not controlling an RCL.
>
> RCO-Foreman (RCO-F): As in conventional operations by switchmen, the crewmember in charge of a yard locomotive, under the rules, is the yard foreman, also called yard conductor. Thus the RCO in charge of an RCL remains a yard foreman. The foreman could alternate between being the Primary and Secondary RCO.
>
> RCO-Helper (RCO-H): As in conventional operations by switchmen, the second (and any third) crewmember is the engine foreman's helper, also called pin puller (and for any third switchman, called field man). Thus the RCO helping remains a helper. The helper could alternate between being the Primary and Secondary RCO.

RCO-"Lookout": Some RCO operations have a third switchman or brakeman who is not an RCO-Secondary or a utility man temporarily assigned to assist an RCL crew. This permanent RCL crewmember rides the RCL and serves as a lookout for "civilians" in industrial switching areas, sounds the RCL air horn at crossings and other places, and generally provides the visual protection of an RCL pulling movement including at crossings, in place of the removed engineer. This third RCL crewmember has various formal and jargon labels. I use "lookout." As an RCO explains: "We have a 3 man crew [the RCO-Primary, RCO-Secondary, and a "Lookout."] The ['Lookout'] blows the whistle and lets us know if crossings are clear."

Note: An RCO could also be a locomotive engineer, as, for example, on the Montana Rail Link, Florida East Coast, San Diego & Imperial Valley Railroad, and Pacific Harbor Lines. An RCO could also be a road conductor or brakeman, as when an RCL operates in a territory contractually designated for road crews. Thus, we could use the designations RCO-E, RCO-C, and RCO-B. Any of these three could then either be or alternate between RCO-P and RCO-S. Furthermore, some officers and first line supervisors are certified as RCOs, although they do not ordinarily work as such.

Remote Control Zone (RCZ): Point protection is not required in an RCZ activated by an RCL crew, except that some carriers' rules stipulate that the RCO is relived of providing PP on pulling (RCL on lead end) movements only. Most RCL rules include the requirement that a "Remote Control Area" be published in the timetable, and within this area a "Remote Control Zone" be verbally activated by an RCL crew. The tracks of an RCZ are designated by appropriate signage in the field and special instructions. If a carrier does not establish RCZ, then all RCL movements must have point protection. In short, a RCZ provides protection on a segment of track thereby not authorizing an engine, train, on-track equipment, or person to occupy or foul that track without permission from the employee designated to grant such permission. After authorization for occupying or fouling the track, the involved RCOs must protect against such entry until it reports that it is in the clear of the RCZ.

Before activating a RCZ, the RCL crew inspects the tracks of the zone. (Thus an RCZ might not be activated at a particular time.) RCZ tracks must be known to be clear of rolling equipment, persons, improperly lined switches and derails, blue signals, and other objects. Switches, and if required derails in the derail position, must be properly lined and locked. RCZ signs must be displayed only during the period of activation of the zone. Finally, the RCO-Foreman must notify the designated control office of the activation of the RCZ. The RCZ is under the command of this RCO-Foreman, who gives all permissions for entering or fouling the RCZ by employees or contractors. When the RCO-Foreman gives permission for other employees or contractors to enter his RCZ, his RCL crew must provide protection for these employees and contractors. Note: The rules of one carrier require only that before rolling equipment enters a RCZ, its crewmember must "attempt" to communicate with the RCO-Foreman in command of the zone or the designated remote control office.

Some RCZs use transponders (which see) to control the track occupancy and speed of an RCL.

Risk: Risk has no external existence outside of our collectively carried, learned culture. Even though hazards (which see) truly abound, no risk is objective. Moreover, the subjectiveness in a risk assessment does not occur at just one or two critical junctures but, instead, occurs continuously in multiplying effects throughout the analyses. We can only ask, Is a concept of risk useful and, if so, in what ways and to whom for what reasons? The group(s) subjectively controlling the models, procedures, and data selection for assessment of risk formulates answers to questions about important societal issues. Such control of analysis fosters political and economic control in modern society. One must not come away with a view of risk analysis constituting an impregnable, indisputable body of explanation and assurance.

Questions posed by the very existence of risk assessment and management in our society include the following. How valid and reliable are scientific assessments of risk? How do we equitably allocate risk across the various sectors of the public of a society? How do we bound and deal with uncertainties in risk? And what constitutes "safe enough" and "acceptable" regarding risk?

Risk could be defined as the degree of probability of a loss of a thing valued by some humans and the amount of this loss within a particular duration of time. (Probability is some kind of measure, often a numeric expression, of an amount of belief. Thus, I am more likely to be struck by lightning than by a meteorite.) Initially, we can posit that risk is some kind of measure of exposure to some loss. We will modify this standard definition as we progress, inductively, in our consideration of "risk." Loss has a subset of danger or jeopardy to person, property, and habitat and this subset, in turn, has a subset of death to persons and destruction of property and habitat. Risk, then, is fostered by uncertainty regarding the consequences of a hazardous event. Risk could be thought of as a measure of exposure probability to hazard.

Risk thus has two aspects, the probability and the size of its consequences. The Western (our) concept of risk is more subtly and intricately complex than all this, however. In the physical sciences and engineering, risk is grounded in quantification of probabilities and outcomes. In the social and behavioral sciences, risk goes beyond these two procedures and includes its qualitative aspects and especially its relativistic meanings and foundations.

To think broadly, in each human society, risk is a network of social relations and beliefs guided by cultural prescriptions and proscriptions ("thou shalts" and "thou shalt nots") encompassing some thing in hazard. This "thing" could be a process of nature (e.g., storm, drought, flood, or vegetation blight), an object (e.g., leopard, cobra, enemy, or weapon), or supernaturalistic cultural construction (e.g., spirit; magical threat; witchcraft; or impersonal, amoral manistic force). Different human societies (sociocultural collectivities of people) have various social networks depicting particular things as risky. Americans tend to see all snakes as hazardous, whereas Australian aborigines see them as scarce, prized food. The Amhara and other Ethiopians folk classify the giant African python apart from all snakes. We are told, this zendo (Amharic, monster) is the color of the land and can swallow large animals and humans whole.

A society, not an individual socialized in it, both creates and maintains, with changes over time, its networks for determination of risk. Because risk is a sociocultural creation, it is subject to sociocultural limitations regarding its application to things in the world. Accordingly, as a social conception of risk changes over time, so do its referents. Speakers of Old English (Anglo-Saxon) feared the risk of monsters such as the people-eater Grendel ("Fie, fie, fo, fum"), and they believed in the risk management of monster-killing heroes such as Beowulf (Anglo-Saxon, Bear-wolf).

Eschewing the orthodoxy that risk is objectively derived from probability and amount of loss, risk, then, is a form of value-laden negotiation concerning a particular issue of hazard in a given society or subsociety. The negotiated give and take that constitutes risk is part of a political, administrative decision-making process. Risk requires subjective, usually partisan, judgment for such decision.

"Robot": Railroaders' jargon for an RCL.

Rolling equipment: Any railroad car, locomotive, or other vehicle capable of moving on its flanged wheels over railroad track. Formerly in railroad terminology: rolling stock.

Rules, the: The railroad operating and related rules.

Safeguard: Any device, computer program, procedure, or person that protects against loss. Thus, safeguards can be physical, procedural, or human. The human cognition is a multifaceted safeguard, at times guarding where the physical and procedural kinds cannot provide protection. An important human safeguard is the ability to recover (which see, above) after an error or physical failure. See Lockout.

Securing an RCL: When an RCL is left unattended (as during a meal period or at the end of a shift) varying railroad rules require that the RCL be secured. Tasks in such securing include: turning off the RCD, thereby causing a full service application of the air brakes; manually cutting in the independent air brakes and applying them on the RCL; tying down the hand brake; and turning the isolation switch to ISOLATE position, thereby preventing generation of tractive power. In short, a secured RCL is put into its conventional mode. Unattended should indicate, when the Primary-RCO is out of the immediate proximity of his RCL and, thus, is unable to immediately monitor and react to an unauthorized movement of his RCL.

Severity: The amount of effect that a human error, physical failure, or geographic occurrence has on a system, subsystem, or component.

Situational awareness: Refers to an individual being conscious of the full set of circumstances forming the context for his action(s). It includes the gathering, integration, and assessment of information from the environment, based on the individual's experiences and knowledge. It also includes projections of this information into the future to develop, sometimes alternative, plans for action. The awareness might involve either a correct or a mistaken assessment that a situation is a familiar one for which little or no projection for future action is necessary. To maintain situational awareness, an operator must frequently evaluate his operational environment, his operational actions, and the operational actions of others affecting his actions. The evaluation includes not only the current operating events but also their potential consequences. All of the information for a correct situational awareness might not be available to the operator because of environmental background noise or light, various kinds of operational distractions, geographical environmental occurrence, and other factors. See Experience.

Paul Craig, introducing his book on situational awareness in aviation, explains that it is "a trait that experienced pilots had and inexperienced pilots did not have." Pilots lacking situational awareness are considered "fat, dumb, and happy." "Fat" means that the pilot has many technological advantages, including automated ones, that can be easily taken for granted. "Dumb" refers to a pilot unaware of what occurs around him. And "happy" means the pilot is in danger without knowing it. (2001:3-5).

Some writers find it analytically useful to distinguish among several levels of awareness, e.g., from unconsciousness through highly sensitive and attuned alertness to events, persons, and objects in the environment. Higher levels of situational awareness are more than simply knowing what is going on around you. They comprise acute perception of and acting on conditions of machine operation and the encroaching factors of human and object interactions. It is known in aviation that "low-time" (little experienced) pilots have less situational awareness and get into trouble more than experienced pilots. Situational awareness can deteriorate during periods of low workload having little stimulation from the environment, during times of task saturation with rapid flow of stimuli from the environment, with fatigue, and with concern over personal issues. See also System Awareness, below.

Slack: The unrestrained free movement in rolling equipment. Slack can run in and run out, a potentially hazardous event, given sufficient force. Run-in is the movement of coupled rolling equipment to a state of compression. Buff is a term used to describe coupler compression forces. Run-out is the movement of coupled rolling equipment to a state of tension. Draft is a term used to describe coupler tension forces. Tension/stretching of coupled rolling equipment is a term describing the opposition of two outward forces, draft, along a single axis.

If a locomotive suddenly brakes heavily while pulling a long cut of cars, draft suddenly becomes buff. The slack run in has a potential to jackknife or derail the cars because of high buff forces and, perhaps additionally, coupler angularity. Varying combinations of heavy and light cars can exacerbate the dynamics of slack run in. Employees riding on cars can become dislodged because of the high buff force. Car resistance because of applied hand or air brakes and track resistance as on curves and through turnouts can create a dragging effect that parts the cut of cars. Coupler angularity occurs with buff forces when car slack is bunched, resulting in cars being forced out of alignment, sometimes to the point of derailment. This angularity increases with combinations of long and short cars.

If a locomotive suddenly brakes heavily while shoving a long cut of cars, buff suddenly becomes draft. The slack run out has a potential to derail the cars or part the cut of cars because of high draft forces. Employees riding on cars can be dislodged because of the high draft force.

Snow brake: When activated, this feature keeps a constant, light, independent, air brake pressure against the locomotive wheels. The friction from this pressure results in heat, which melts buildup of snow and ice on the locomotive brakes.

Student/"student": In railroading this term has a central denotation and an extended one also having a connotation. 1. Formally speaking a student is any one in a railroad training program, such as a student RCO, engineer, conductor, or switchman. 2. By extension, in railroaders' jargon, "student" means any employee in about the first year of continuous employment who is not yet experienced enough to be task proficient and "be trusted." Thus, the jargon "student" can be a referent of condescension and even derision grading into contempt. ("What do you expect from a 'student'?") See "Rail."

Subject/ Subject of research: A human participant in a study.

System: Many writings emphasize the concept of system to remind and to begin logically with the notion of interconnectivity. A system comprises interconnected elements which affect one another. The systems concept works best for physical systems (these are well bounded), less well for biological systems, and least well for social and behavioral systems. Too many variables obtain in the last two for full comprehension. An analyst could conceive a social system as having a number of subsumed subsystems (subsubsystem, subsubsubsystem, and so forth), with the components being individual humans. Each human occupies social positions or statuses each having an appropriate role, defined by culture and enacted with reference to the networked interacting statuses of others. A person's summative generic status and role are each a composite of the multiple, sometimes conflicting, specific statuses occupied and roles enacted: husband, father, son, nephew, cousin, professor, departmental chairman, graduate dean, congregant, civic volunteer, hobbyist, sport fisherman, amateur chef, union officer, army reservist, and so forth.

A closed system is considered as isolated from the environment. An open system is not isolated. That is, it comprises a set of elements forming a connected whole which is not a bounded, sealed entity. In other words, the set is not demarcated to consist of a finite (hence, predictable or knowable) number of interacting elements. In the open railroad system, because of later-occurring, varying numbers of unpredictable, impinging conditions, a final state cannot be predetermined by initial conditions, say, a train's consist, tonnage, authorized speeds, track occupancy authority, and crewmembers' experience. Different initial conditions can result in the same final state, and the same initial conditions can result in different final states.

No system of technology used by humans excludes the involved humans in their HMI. A classic exemplification of system is a number of pieces of equipment designed to fit and work together with a common purpose in view. Such systems include their associated personnel: "People are used or involved in every equipment system, because equipment systems are always built for some human purpose. They exist to serve some human need." Additionally, people want, design, build, maintain, monitor, supervise, and operate systems. In short, "all equipment systems are man-machine systems" (Chapanis 1965:14-16). Accordingly, Chapanis defines an equipment system as follows: "a man-machine system is an equipment system in which at least one of the components is a human being who interacts with or intervenes in the operation of the machine components of the system from time to time" (1965:16).

The human factors of a complex system concerns hardware and personnel subsystems but the distinction "is by no means clear-cut" (Chapanis 1965:17). Investigators have long recognized that considerations of equipment systems, necessarily, grade into social organizational theory including all of its methodologies and techniques of research. The social as well as the behavioral realm, then, is an integral part of systems-relevant criteria" (Singleton 1972:118-121). Moreover, an equipment system cannot be understood apart from the larger system (suprasystem) in which it is embedded (Meister 1999:119). The suprasystem is a sociotechnical environment: again, the technology and the sociocultural are inseparable in the real world. Furthermore, "To become a system, the human-technological subsystems must be organized into relationships of increasing complexity." At each level of social action in the hierarchy of organizational complexity, behaviors and social interactions vary according to function. A switchman does not have the same amount of control as does the vice president of operations, or a regulator, or a legislator (Meister 1999:90). In other words, a hierarchy of human controlling actions exist from the individual operator on up the business organization and into interacting organization of all kinds. Murrell summarizes aptly: "It is a major purpose of research into systems that the functions of man and equipment should be carefully balanced in order to obtain the optimum result, and for this purpose the various capabilities and limitations of peoples should be taken into consideration" (1979 [1965]).

System awareness: An operator's including a team member's internal, subjective consciousness of an operations system, its subsystems, and components and his alertness to stimuli from them. See also Situational Awareness, above.

Task versus Responsibility: A task is a piece of work, often having sub- and sub-subtasks. More specifically, a task comprises a human's acts using equipment (including tools) and procedures to change inputs into outputs for a purpose. Prehistorically and historically, the task can be entirely controlled by the human or, in recent times, also to varying extents controlled by a computer. (See Human-Automation Interface.) A responsibility is an accountability, explainability for one's acts, including tasks. Example: in railroading, one must either have authority to occupy or foul a main track or else provide flag protection for occupying. This is a task-responsibility pair. Various subtasks exist for several kinds of the broad responsibility of providing flag or other protection for track, other structures, and rolling equipment that pose a hazard. No flag protection is permitted for entering an established RCZ. Example: a movement of crew 2 cannot enter under its own flag protection a RCZ of crew 1 because the movements of crew 1 are essentially blind as provided by the rules.

Three-point contact: A bodily position while on rolling equipment requiring contact by either two hands and one foot or two feet and one hand. Four-point contact requires both hands and both feet.

Three-point/step protection: A procedure for protecting personnel going on or between or fouling stationary rolling equipment. The persons rendering and receiving this protection must affirmatively communicate when initiating and terminating it.

Tight coupling: Refers to closely linked dependent events in a system. Interactions of subsystems and components are not always apparent. These masked interactions can result in realizations of hazards. A part of Charles Perrow's conceptualization on normal accidents, which see.

Tilt Protection (Man Down) Feature: This is also called the man-down feature. When an RCD detects a tilt condition in excess of 45° past its vertical axis, the feature is activated. An audible man-down alarm is then broadcast, with a synthesized voice, from the locomotive voice-radio over an ordinary yard, two-way, channel. The frequency of the locomotive radio must be tuned to that of the designated office that monitors the man-down distress call. The call contains the locomotive initials and number ("XY 999") and whether the RCO of RCD A or B is down.

In the tilt of the RCD of more than 45° after 1 second, an alarm sounds and after about 4-5 seconds the air brakes go into emergency application and the man-down alarm is broadcast. This occurs unless the tilt extension feature is activated. The man-down feature remains activated until an RCO recovers the RCD from the feature. Recovery is that from an emergency brake application.

Tilt Time Extension: Tilt Time Extend extends the allowable tilt time. If the RCO anticipates having to tilt the RCD on his body for more than a few seconds, pushing the Time button extends the allowable tilt time to 60 seconds. This tilt extension cannot be sequentially repeated, that is, added to.

Tilting, to tilt: A new verb in railroading, meaning the RCO leans over, 45° past the vertical or more.

To throw an RCO from a unit of rolling equipment: The fall could be to unobstructed ground, against a trackside object such as a switch stand, debris, or adjacent unit of standing or moving rolling equipment, or under the wheels of the unit of rolling equipment being ridden.

Training and practical experience: Here, regarding work, we distinguish between formal training experience (formal learning from media; instructional devices; classroom, laboratory, and conference activities; simulators; programmed instruction, including computer assisted; on-the-job practice; etc.), which is necessary, and practical experience (learning on the job from work events), which is also necessary. Practical experience is logically a characteristic of amount of firsthand familiarity, ranging along a continuum, beyond the point of just being qualified or certified from formal training alone. Practical experience involves exposure to practice in events. The characteristics qualification or certification can precede and exist apart from any amount of subsequent practical experience, which could be little or none.

In brief, practical experience could be considered a personal involvement with or observation of occurring events. At work, it is the effect on a person of all that has happened to him on the job. Generally considered, practical experience is the total of knowledge from events accumulated by a person. At work, it is a subset of such knowledge related to a particular domain, as in railroading, aviation, power-plant operations, a sport, an art, teaching, managing, etc. Practical experience relates to the real, material world, outside of a person's mind, and not to personal subjective encounters such as seeing "pink elephants" when drunk or other hallucinations as when "high" on nonalcoholic drugs. See Situational awareness.

Any work training is part of a learning process made more complete by experience. Effective training, especially involving work safety, cannot be a hit or miss, ad hoc procedure, differing in teaching method and content from trainer to trainer. The main objective of training is to change behavior as efficiently as possible. Hence, "the importance of an understanding of the principles of learning to any training endeavor becomes obvious" (Bass and Vaughn 1966:4). The foundation for training is learning and thus involves learning theory (Goldstein 1974:91-135; McCormick and Tiffin 1974:223-273). Training can be defined as a person's learning of skills, responsibilities, rules, practices, concepts, and attitudes leading to change in performance, including in another setting.

Gaining some experience on the job can be part of a formal instructional program. However, "on the job the primary function is production, not training-- which, under the circumstances, must take second place" (Bass and Vaughn 1966:87). Moreover, among the disadvantages of on-the-job training: "Training may be casual, unsystematic, and poorly planned. . . . There is a fair chance that the trainer is a poor one in comparison to a professional instructor." Additionally, "The trainee has to learn while under the pressures of the job demands, at a pace set for already-trained workers" (Bass and Barrett 1972:359). As Goldstein expands upon these disadvantages: "Unfortunately, most on-the-job training programs are not planned and, thus, don't work well. Too often practicality is the main reason that this form of training is chosen. . . ." The trainer might not be capable of training and might feel that his added task of training is an imposition on his time. "Under these conditions training takes second place to performance on the job" (Goldstein 1972:142) It has long been known, from experimental evidence in industry that formal training of trainers concerning teaching is of inherent benefit to proper instruction (Maier 1946:225-228).

As M. Wright et al. explain regarding UK railways: "Competence, and implicit need for experience, is recognized by the railway industry to be a vital aspect of safety management. . . . It [experience] is part of what distinguishes the competent person from the trained person." For these researchers on the subject: "Experience is construed as a measure of whether the individual has recently had sufficient exposure to, and practice of, the range of tasks to acquire the skills and knowledge to complete those tasks to the level noted in competence standards. . ." (2004:ii, iv). Furthermore, "practical experience is a standard means of bridging the gap between existing and intended performance, particularly amongst staff who are newly appointed" (Wright, et al. 2004:iii). Moreover, "Higher levels of minimum experience are required for more safety critical posts tasks" (Wright, et al. 2004:iv). The Wright report concludes: "The conclusions are that experience does have an impact on safety. . . (2004:i, viii).

Experience has always been considered by the railroads as a key variable in safety, quality, and productivity. Thus, in providing instruction for job briefings, the Union Pacific instructs how work assignments will be done: “Abilities and experience of individuals. Make sure that each crew member is able to do their assignments (experience, mental state, and physical condition)” (Union Pacific, “Revised System Special Instructions” April 6, 2003:81).

Transceiver (Radio Frequency): A device or circuit containing both a transmitter and a receiver. Radio Frequency (RF) is any frequency of electromagnetic radiation or alternating current ranging from 3 kilohertz to 300 gigahertz. (These values comprise the internationally agreed radiofrequency bands.) An electronic device operating in this frequency range is a radiofrequency or radio device.

Transponder in RCZ): Transponders are electronic devices imbedded in the track structure of pull-back tracks (and used elsewhere for other purposes). They regulate the speed of an RCL movement along a track to ensure that it will stop before the end of the RCZ. Each transponder is read by an interrogator mounted on the RCL. As the RCL passes a transponder, its information is transmitted to the OCC on the RCL, which adjusts the speed as necessary. A transponder is a combined transmitter and receiver, automatically transmitting a signal upon receiving a defined triggering signal. This trigger, often a pulse, is the interrogating signal. See Puck.

Trend analysis: An examination of trends, i.e., the general direction or tendency of conditions, events, opinions, etc. Specifically, an examination of historical trends used for extrapolation in prediction of future directions of such entities. Identification of trends assumes an established trend is more prone to continue than to reverse. Trend analysis is used in transportation for particular safety forecasts, e.g., regarding fatalities, collisions, kinds of mechanical failures and human errors, etc.

Vigilance feature: When the Primary RCO does not change the status of any control on his RCD within 50 seconds, the RCD emits an audible warning, which must be reacted to within 10 seconds. The Primary RCO, then, must press either of the two vigilance buttons on the RCD. If the Primary RCO does not press the button within an overall duration of 60 (50 + 10) seconds, thereby resetting the protective vigilance feature, a penalty full-service brake application occurs. To operate the RCL, the Primary RCO, then, must do a recovery from a full-service application. The vigilance feature activates only when the Primary RCO selects a speed other than STOP on the RCD.

Voice-radio: A two-way radio used for spoken communication among members of a crew, between different crews, and between a crew and a supervisor and other person.

Wayside signal: A signal with a visual display at a fixed location alongside the track. Some examples are color-light block and interlocking signals, signs with alphanumeric information ("END CTC"), switch stand targets, and lights on detection devices.

Worst-case scenario/assessment: In a worst case, selected parameters are set to their worst values. (Some analysts say every parameter but in large complex systems not all parameters might be judged worthy of inclusion or even recognized as extant.) The very worst-case scenario would be of something improbable or so infinitesimally remote that it is unlikely ever to occur. An example would be a strongest force tornado lifts a lighter-weight tank car of chlorine from a rail yard where it sits uncoupled to other rolling equipment and drops it into a downtown business district in the middle of an extra-busy workday, where the consequently ruptured tank shell emits chlorine gas killing over a thousand people. This hypothetical example is not credible: its probability is improbable, i.e., "with a probability of occurrence less than 10^{-6} in that life" (USDOD definition 2000:19). A worst case must be credible (a subjectivity to be sure). A "marginal, critical, or catastrophic" (USDOD categories 2000:18) rail accident in the record since 1945 in North America is a credible hard anchor for a worst case in that industry. Note the semi-arbitrary date cutoff here. We could include documented near misses of these three categories as well, because many analysts read a near miss as a near accident. See also Base-case scenario and Parameter

Appendix C. Ethnographic Method and Reporting

1. Background

The data sections of this exploratory report for mapping human reliability consist of ethnographic accounts with contextual analyses, gathered from Remote Control Operators (RCOs) of Remote Control Locomotives (RCLs) and related railroaders, who include other operating personnel and officers. We present these persons' experiences and observations on RCL operations and related matters in their own first-person narratives. Such narratives provide access to information and resultant insights not directly observable. RCL-related narratives include views on the operating rules and practices, managerial supervision, FRA regulation, etc. The narratives, as recounted, are, thus simultaneously, a primary source and an archival item. High-powered microprocessors and digital electronic communication allow the automation of many work tasks. In this report, the focus is on RCOs and the computerized machines with which they interact and control to varying extents. An underlying report question is, To what extent can we require that operators such as RCOs always take proper control action in a highly automated, dynamic, open, work environment? (See Appendix A. The Human Machine and Human Automation Interfaces.)

The Transportation Safety Board (TSB) of Canada concluded the following after its investigation of an RCL accident. "As this accident and others (TSB reports R96T0080 and R96W0246) have demonstrated, LCS [RCL] operation involves safety risks unique to this method of control" (TSB 1955). Moreover, some RCL manuals have items labeled "warning" and "caution" regarding use of RCLs, reinforcing the TSB conclusion. The warnings and cautions concern possible injury or death to RCOs and damage to equipment and property under particular RCL circumstances. Thus, the suppliers of RCL equipment are cognizant of the hazard in use of their materials and procedures. The present report contributes to providing information for a regulatory agency's understanding of the underlying safety conclusion on RCL operations voiced by the TRB.

2. Identifying Subjects of Research and Their Narratives

This report reproduces all quotations from subjects of research in the their original words, between double quotation marks, with any emphasis in capitals, underlining, or bold type retained as in the original. Railroads historically and currently discipline their employees for discussing or otherwise providing information from work to outsiders, with the exception of those legally empowered to request such information. Personal and railroad identities are kept strictly confidential and, therefore, thoroughly masked in these quotations, including identification of personal, railroad, yard, and location names and job, train, and engine designations. Such masked labels are given in brackets with a replacement such as [officer], [name], [XYZ RR], engine [999], job [88], and so forth. At times masked labels will be in single quotes within the double quotes of a direct quotation from a subject of research, thus, "It was on the 'ABC RR' that this happened." Such bracketed and single quotation-marked replacements are not codes, i.e., the ABC or the XYZ Railroad does not stand for a particular actual railroad whenever these letters are used but could be used in various places for, say, a number of different railroads. At times, we add an explanatory word or two in brackets, e.g., “the box [RCD]” or “he [the RCO].” When information comes from a public report or a public news item, then, identities remain unmasked as in the original public document. Some general ideas on operations provided by subjects of research we classify under various section numbers and are not in quotation marks.

All information supplied by the subjects whether or not directly quoted, is in serif type, as in this sentence. The information written by us or by other writers not railroader employees is in sans serif type, as in this sentence. Because we put all direct quotes from subjects in "double quotation marks," where a subject writes double quotation marks, we change these to 'single quotation marks.' To facilitate understanding of what various technical researchers mean when their writings are cited in this report, as much as possible, their words are quoted directly rather than paraphrased. Accordingly, there should be no ambiguity about what they said on the precisely cited pages of a publication or report.

3. Ethnographic Method via the Internet

The information providing the substance of this report is ethnography. It came mainly from US railroad employees but a few Canadian railroad employees are included, and so labeled. (See Railroader in the Definitions Appendix B for the kinds of these employees.) These subjects of research provided self-reported written information mainly via the Internet but a few sent paper comments. Their provided information consists largely of narratives on problems and near misses plus some accidents. None of the many spoken comments given are included in this report. Information reported in writing is more measured, self-restrained, and often more developed than something thrown out briefly in conversation but, perhaps, not representative of the broader, more permanent view of a respondent. Moreover, the recipient of information via the Internet is not influenced impressionistically by how the sender of the information looks, sounds, or is attired. The electronic medium blurs the distinctions of sociocultural reaction attendant to our age-old, face-to-face exchanges.

Information and communication technologies using the Internet as a medium engender new kinds of social networks and novel communicative capabilities. Such emerging Internet communities provide a new cyber field research for sociocultural anthropologists and other sociocultural and behavioral scientists. US Internet communities range from small groups engaged in intensive discussion of an arcane domain, e.g., railroad operations; to advocacy groups, e.g., for particular railroader causes; to gatherers and sharers of information provided by Web pages of organizations, e.g., of railroads, rail suppliers, rail labor unions, railroad regulators, and posters of rail information; to ad hoc networks tapped by informal conveners, e.g., a researcher and his loosely bounded networks of railroaders. These railroader networks have some amount of homogeneity and share an arcane language of discourse comprising occupational jargon, rail technological terms and the esoteric information they label, and occupational words and concepts. These rail networks are simultaneously communities of practice (Lave and Wenger 1991) and of interest (Brown and Duguid (2002). Howard Rheingold foresaw Internet communities fostering citizen-based democracy and allowing the average person to bypass the customary, powerful, filtering media of communications (1993). In their writings via the Net, the subject railroaders bypass all filtering agents. M. L. Dertouzos saw, "a hopeful vision of a future built on an information infrastructure that will enrich our lives . . . by improving the ways we live, learn, and work and by unlocking new personal and social freedoms" (1991:62). Across the past decade or so, the visions of Rheingold, Dertouzo, and others have not unfolded fully. The Internet, however, does permit inexpensive, fast, easy, and permanently recordable communication among persons active in a particular domain and between experienced researchers and their subjects of research in a domain.

The explosive, all-pervading development of the World Wide Web has radically changed the way we communicate and distribute information. Supporting this development is the quite simple Human-Machine Interface (HMI) of mouse pointing, clicking, and pulling down menus, making e-communication and its storage efficient, low-cost, lightning-fast, easy to do, and pleasing. The burgeoning social network from e-mail and its attendant patterns of norms, values, and etiquette have created great connectivity among persons who formerly did not communicate with one another (cf. Sproull and Kiesler 1991), and e-mail has allowed expression by distant persons formerly not present for exchanges of information (cf. Finholt, Sproull, and Kiesler 1990). In short, on a scale heretofore undreamt, we find computer-mediated communication among persons in an electronic network of remote sites. Thus it is with the subject railroaders of this study and the instructive ethnographic narratives from their "native" insider viewpoint that they provide for this report. (Here native refers to a person indigenous, not to a locality, e,g., Boston or Timbuktu, but to an industry, railroading.) Samuel Wilson and Leighton Peterson explain: "Indeed, anthropology is uniquely suited for the study of socioculturally situated online communication within a rapidly changing context" (2002:450). Anthropologist David Hakken, for one researcher, has demonstrated this conceptual and methodological suitability (1993, 1999).

The unifying occupational jargon/argot/cant/slang of railroad employees is extensive and is marked with double quotes in this report, e.g., "rail," "student," and "sandhouse." For a brief bibliography and explanation of railroad jargon, see Gamst 1980a:3, 137-142. (See also Jargon in Definitions appendix B and Kemnitzer 1973.)

A number of shifting Internet communities of railroaders exists, bounded electronically instead of by face-to-face interaction. The communities have ties from a blending of communication and computer technologies largely imperceptible to the user and which afford worldwide connectivity (Nickerson and Landauer 1997). The communities could be formal groups with open or closed but activity-bounded memberships. Or the communities could be persons not consciously cooperating or even knowing one another. They, however, collectively develop a corpus of information for a gatherer of their information, not otherwise extant and made available. Every increment of their information increases the utility of the corpus. All of these kinds of communities exist for railroader employees contributing to this report.

Today, some railroaders of all kinds but especially operating railroaders communicate with one another via person-to-person, person-to-group, chat-group, and bulletin-board messages on the Internet. An ever-increasing few railroaders are blogers who self-publish their views and other information on their Internet blog site. Blog is short for weblog and this automatically formatted genre is somewhat different from print journalism (Friedman 2004; Kirkpatrick and Roth 2005).

Before the advent of inexpensive personal computers and the Internet, information (often called by railroaders "sandhouse" or "sandhouse" gossip) would slowly percolate from division to division on a railroad and across to connecting railroads. Today, for a rail accident or event in Maine, for example, railroaders contemplate and discuss it almost instantaneously across the US and Canada, sometimes with threaded chains of messages, including accident photos, from scores of persons. Moreover, this discussion tends to be informed because some discussants have firsthand access to the events or information being discussed via the Net. ("It was at 2:36 am, Sunday, on the number 2 main track, at mile post 99, and 18 cars derailed. No personal injuries. I'll post more as I learn more.") Furthermore, because other railroaders check and critique much of the information provided on the net, the provider of a piece of information or a comment makes painstaking effort to insure accuracy. Additionally, because in almost every narrative, the railroad-employee narrator was not involved in the accident or near miss he discusses, a tendency toward self-serving "alibis" does not exist. For the jargon "Alibi," see appendix section B.

The technology of the Internet provides a unifying social link of communication, and at times of solidarity, and a means of disseminating facts and ideas for many railroaders.   "Old heads" learn new tricks. On matters apart from the present study, Gamst even receives e-mail and its attachments from former railroaders in their 80s who, in rail jargon, have long since "pulled the pin" and "taken the rocking chair" yet remain well "cut in."

We gratefully acknowledge the myriad inputs of information from the innumerable subjects of research contributing to this report. All of these persons necessarily remain anonymous.

4. Ethnography

The concept ethnography has two referents, a method of research and its findings or results. Results of research include the present report. As an Internet method, Gamst maintains an electronic social network of railroaders, across the US (and around the world, for that matter, for example in the UK, Germany, Austria, Sweden, Czech Republic, Australia, New Zealand, South Africa, Eritrea, Ethiopia, and Canada). This network allows a new technique for gathering information in social scientific research. This novelty is not just in the speed and ease of gathering information and even of holding exchanges of views and material, but also it is a means of obtaining esoteric material difficult to gather by traditional techniques. It is a true method of quick ethnography (Handwerker 2001), given the caveat of prior long-term involvement with the domain of research. Accordingly, the method is fruitful for sociocultural anthropology and consultancy (Stewart and Strathem 2004). Nicholas Bahr notes in a different context of conducting research: "We would be foolish not to take advantage of the cheap price of personal computers and the proliferation of local and wide area networks" (1997:184). In the present study, use of Internet subjects of research and their computers is an application of Bahr's advocated use.

Regarding the present report, the gathering of the ethnographic information did not come from a period of emersion among subject railroaders on a particular railroad division or other unit (e.g., as in the rail ethnography by Cottrell 1939, 1940, 1951; Rodnick 1941; Spier 1959, 1963; Gamst 1961, 1963, 1980a, 1989b, 1990b; Kemnitzer 1977; Edelman 1997, 2003) or among subject workers in other industrial ethnographic study (e.g., Pilcher 1972; Applebaum 1981; Agar 1986; Darrah 1996). Instead, it comes from gathering across a much more broadly dispersed network, with subjects linked mainly via the Internet. The ethnographic approach, however, remains constant; the details of everyday life (here in the workday) are as important for comprehension as are the actions of managers, regulators, legislators, judges, and the explanations of their publicists, or the characteristics of institutions.

For a researcher's comprehension, the kind of ethnographic research conducted for this study largely via the Internet must be an adjunct to considerable firsthand experience and other exposure to the world of work being studied, here, rail switching as part of overall railroad operations. When researching via the Internet, the ethnographer must gain access, an issue for all such researchers (Feldman et al. 2003). Having long-term experience and results of research regarding the domain investigated, here that of railroading, is a solution to gaining access for the ethnographer: who I am and what I do.

As an ethnographer, Gamst has achieved this domain experience and other exposure, for 50 years, as a former railroad operating employee, university researcher of railroads around the world, and consultant to the railroad industry (comprising railroad carriers, rail unions, and rail regulatory agencies, in the US and abroad). The grasp of the railroad industry is the holistic one of an American sociocultural anthropologist (also called ethnologist). Gamst's operating employment began in May 1955; his first railroad research paper was in fall 1961 and first conference railroad presentation in 1963 (Gamst 1961, 1963); his research includes not just US railroads but those abroad, for example, from Germany to Eritrea (Gamst 2003d, 1996, 2003e); and consulting includes railroading abroad (Gamst 1992a, 1992b, 1993a, 1993c, 1995a, 2004b). Topics covered range across locomotive human factors (Gamst 1975a, 1975b, 1995a), rail signal color codes (Gamst 1975c), removal of the caboose (Gamst and others 1988),the genesis of US railroading (Gamst 1997a, 2001a), women in railroading (Gamst 1986a), fatigue (Gamst 1997b), the web of rules in railroading (Gamst 1983, 1990b, 1995c), modes of time and the railroader (Gamst 1993b), organizational culture (1989a, 1990a), industrial and labor relations (Gamst 1987, 1992b, 1993a, 2003), methodology of industrial ethnology, as developed for railroad research (Gamst 1977, 1980b, 1984a, 1995b, 2001b; Gamst and Helmers 1991), and information technology in railroading (Gamst 2000a).

Ethnography describes human sociocultural phenomena. Ethnography literally means writing/reporting about a particular people, here, the subject Remote Control Operators and conventional crews, plus other interacting railroaders in their social setting of work. An ethnographic approach, thus, can focus on a particular sector and situation in an encompassing society. Strengths of ethnography include its limited scope, on a particular kind of community; its concern with details and their interrelations; and a focus on everyday activities. Thus, it has the power to puncture overinflated statements (Kunda 1992:23).

Ethnography researches a specific social milieu to learn about its nature. Such research, in part, reports local knowledge. This knowledge is from the comprehensions and skills of persons native to a milieu, here, that of US rail operations. Local knowledge concerns not just operator' competencies but also operators' shared conceptualizations of work. Knowledge of this kind is not produced by experts on a particular domain, who, in whole or in part, might be uncomprehending or have biases regarding the local knowledge. Local knowledge, accordingly, is not an extra-contextual representation by others of native experience. It is arcane, i.e., not widely or, as in the case of rail operations, at all known in the encompassing society. It is knowledge from experiences and discussion of these experiences among "the natives." Above all, access to local knowledge allows the researcher of error and human reliability to see that the answer to the outsider's research question of into which box does that fit might be, no box envisioned by the study.

For operating railroaders their local knowledge anchors actions and reactions in their work lives and provides coherence and cohesion to their sector of society. Because collecting local knowledge can be time consuming, otherwise arduous, and monetarily costly, communication via the Internet is an apt solution to these three barriers. Expert (outsider) knowledge has a value of its own and should not be discarded in assessments. Local and expert knowledge must be balanced in assessments, an objective easier espoused than executed.

Stanney, Maxey, and Salvendy see ethnography as allowing examination of the influence of the work environment on system design (and operation). Such holistic examination does not see design as just a collection of evaluations of individualist units in isolation regarding user behaviors and tasks (1997:649). Ethnography facilitates learning the consequences of who designed and who approved the design of a device, layout, or procedure and for what range of design purposes. For example, who designed and who approved the location, protection, and functions of the vigilance button on an RCD for use in the rail switching environment? What human-factors research resulted in such design and its approval?

Modern ethnography becomes ever more intensive and profoundly probing. Thus, the contemporary ethnographer must stay abreast of a library of written and pictorial sources across disciplines and a stream of relevant kindred studies. Furthermore, the ethnographer's audience is no longer mainly academic but includes a readership having local knowledge and some political power (Brettell 1993; Sanjek 2004). This readership could value a study showing consequences of and reaction to technological change. Ethnographers with such readership know that they conduct research in an interdisciplinary context (Kuper 1994:116). Ethnography, as with other aspects of social science, has methodological discussions regarding limitations of presentations of realism's "truth" and of whose "truth" (Sanjek 1990a; Hammersley and Atkinson 1995; Wilson 2004). In short, How do we know what? I touch on this question throughout this report and on this matter see appendix E, The Foci of Human Error.

With the Internet, given several events of research interest at widely separated points A, N, and Y, the researcher does not have to travel to these places, for gathering information, at great cost and expenditure of time. Instant, Internet time conquers space and allows a research tempo not dreamed of only a few decades ago. Internet time is also quite flexibly efficient. Because many operating railroaders work other than from 8 to 5 and often in unpredictable, irregular shifts, seven days per week, the subject can provide information when he is free, free time often occurring on short notice to him. Via the Internet, the researcher can query key subjects, in a non-leading manner. Almost all subjects, however, volunteer information without being asked, once they learn via the grapevine that a researcher is interested in topic “X.” Accordingly, a volunteering Internet subject sometimes reveals aspects of a topic not known by the researcher. Serendipity reigns. Additionally, because the Internet researcher receives comments, first, reflected upon, then, written, and, often, edited by a subject, there is a greatly reduced chance for misinterpretation of the subject’s knowledge, as when writing these in the researcher's field notes (Sanjek 1990b). Instead, the subject writes Internet notes from the field. (The reader of the present report will no doubt be favorably impressed, as we were, by the lucid writing style and cogent development of material by many of the Internet subjects.) Of course, for an Internet researcher to have an in-depth comprehension of the material provided by the Internet subjects in the field, he must have strong background knowledge, from experience and/or research, of the domain studied, here, what Gamst has called for about 50 years, the rail world.

Beyond ethnography's three basic methods for collecting primary information, interviewing, observing, and reading documents regarding a system of operations (Bernard 1988:62), reports from Internet subjects of research are an additional source of primary information on work tasks and procedures for any kind of Human Reliability Assessment (HRA) and for other goals. As with interviewing, Internet reporting by subjects "is an indirect means of observation." Interviewing is perhaps the single most important action in which the ethnographer engages (Langness 1965:38, 41-42). Accordingly, Internet reporting can be a twin of interviewing.

The Internet subjects are Subject Matter Experts (SMEs) for an HRA and other research. In this report, the SMEs' domain is railroad operations with a focus on RCL operations. Two decades ago, Meister noted problems with HRA that are still extant, especially since methods and models were largely developed and applied in the process industries. Broad problems noted include "inadequacies of data sources, the many assumptions that must be made to use the HR methodology, and the subjective element in HR estimates" (1984:48). Moreover, regarding databases used in HRA, "Existing human error data banks are seen to be of little help to those who have tried to use them" (Rasmussen et al. 1987:3). The present report attempts to develop one kind of firsthand data sources as well as discuss the inadequacies (issues), both of method and assumption, in classic HR and related error concepts. (For Process industry, see Definitions appendix B.)

5. Human Reliability and Ethnography

Human reliability concerns the probability of a human, or human team, performing a task, or tasks, to function successfully, as specified, in all task sequences (Dhillon 1986:3). Ideally, Human Reliability Assessment (HRA) has two broad goals, providing a thorough description of human contribution to the total risk and, ultimately, to identify safeguards for reducing the risks. One source of a thorough description can be ethnography.

It is not simply a matter of physical failures, plus human errors, plus any geographic occurrences equal system failure. An interaction exists between the two (or among the three) in which human action can enhance or degrade a return to system's previous state (Gertman and Blackman 1994:2). Within its scope, this report contributes to describing some hazards in RCL operations. In modern society, assessments of risk constitute a wielding of power affecting everyday life, in general and within specific organizations. If hazard and risk assessment is to have merit for policymaking, then, its normative, social, and political aspects must be recognized and handled in analysis (Gamst 2000b, 2003a, 2005). (See Safeguard in definitions appendix B.)

HRA builds upon task analysis, a central topic in human factors (Luczak 1997) and to a lesser extent in social factors (Goldschmidt 1995). Analysts have discussed for some time just what task analysis comprises (Miller 1967). Yet, as in many procedures of the behavioral and social sciences, such analysis stems from number of conceptual and methodological sources, leading to many approaches and subordinate terms. A coherent, well-established task analysis must be developed for which reliability will no longer be an issue (Stammers 1995). Holger Luczak provides a comprehensive review of the topic, including on relations between task and error analyses (1997). (See Definitions appendix B, Task versus Responsibility.)

Some Human-Reliability Assessments (HRA) attempt to capture everything but fail to do so, especially in the realm of human behavior. The present report is not exhaustive and does not attempt to capture everything. Any HRA of complex, large-scale systems, such as those of open-environment railroads, is ambitious especially because it adds to the assessment the intricacies of human error (Kirwan 1994:4).

HRA has roots in studies of individual and group human performance in the behavioral, social, and managerial sciences. Assessors, accordingly, reach HRA through a number of approaches (Gertman and Blackman 1994:27-28). In discussing the methodology of contemporary human reliability analysis, Wreathall, Roth, Bley, and Multer recount that in researching human reliability we find a wide range of methods available. They explain, we are recognizing that most effective methods stem from data regarding the actual operating experience of the system being investigated and gathered over a wide range of conditions in the field (Wreathall et al. 2000:3-4). Ethnography is a way of tapping this operating experience. The system researched in the present report is that of Remote Control Locomotive switching in the context of overall rail operations. This study reports a large-scale use of computers (the RCL’s on-board control computer) in a highly mobile, socially interactive, outdoors, 24/7/365, workplace. Thus, the focus of this report is more sociocultural, organizational, and work environmental and less perceptual and cognitive (cf. Olson and Olson 2003:503-504).

Data for US RCL operations, outside of industrial plants and quarries not part of the general railroad system of transportation, are only recently being collected and not yet available in any appreciable amount. Hence, the method used for the information gathering in this report is an exploratory form of ethnography, i.e., collecting topic-focused, narrative information from a particular, bounded group of “natives”; writing a report; and presenting the report to relevant audiences. (For aspects of exploratory ethnography, see Robert A. Levine 1973:188-191.) The ethnographer’s explanation of, interpretations for, comparisons concerning, and conceptualization about descriptive ethnography is ethnology. Ethnology uses ethnography as a main source of primary information and the two enter into a comprehensive study in sociocultural anthropology and other fields (Gamst 1977, 1980b, 1984a, 1995b, 2001b; Gamst and Helmers 1991; Van Maanen 1996; Fetterman 1989, 1998). The method for the present study, then, is largely that of gathering and classifying Internet ethnography for analysis in preparation of the present ethnographic and ethnological report.

Appendix D. Risk Assessment and Its Uncertainties

1. About Risk

In life, we do not avoid known hazards but select among risks of such hazards (cf. Wilson 1979). Risk assessment (including analysis) and risk management are two separate but related domains of scientific basic and applied research and of government regulation and managerial application. The assessment and management of risk concern events having multiple uncertain outcomes. How do we conceptualize risk, that is, How do we form our ideas about risk and what influences us in this forming, both overtly and covertly? Is risk an unreducible concept or does it have traceable records of varying use? Risk and uncertainty, of course, are part of everyday life for humans in all societies, across time. For millions of years, societies of humans and other hominids ancestral or related to us faced hazards. These beings accumulated information about their total environment, the geographic and the sociocultural, so that they could plan for and attempt to overcome hazards. Such collective behavior became part of our evolving culturally, ever-more-effective adaptation, including risk mitigation, to the total environment. Such adaptation developed to the point that, of late, we adapt the geographic environment to us.

The central theme of this discussion of risk is that it is inherently subjective, in many accumulative ways. Risk has no external existence outside of our collectively carried, learned culture. Even though hazards (which see) truly abound, no risk reaction to hazard is objective. Engineers originally developed concepts of risk assessment and their models for physical systems necessarily having a limited number of variables. Assessment subjectivity is all the greater when individual behaviors and human social interactions, having seemingly infinite variables, comprise part of the system assessed for risk. Moreover, the subjectiveness in any risk assessment does not occur at just one or two critical analytic junctures but, instead, occurs continuously in multiplying effects throughout the analyses. We can only ask, Is a concept of risk useful and, if so, in what ways and to whom for what reasons? Is a request for a risk assessment solely to understand and bound risk or is it also an administrative attempt to provide cover for a project or product? The group(s) subjectively controlling the models, procedures, and data selection for assessment of risk formulates answers to questions about important societal issues. Such control of analysis fosters political and economic control in modern society. One must not come away with a view of risk analysis constituting an impregnable, indisputable body of explanation and assurance.

According to social scientists involved with risk--such as sociologists Anthony Giddens (1990) and Ulrich Beck (1992, 1995, 1996, 1999; Adam, Beck, and van Loon 2000), social anthropologist Mary Douglas (1985, 1990, 1992), and many others--a concern with risk has become a growing component of how modern societies reflect upon and govern themselves (see also Kaplan and Garrick 1981). Risk assessment is common in business and government organizations (Andrews and Moss 1993). The former uses it in strategic decision-making and the latter in regulation. The literature on the concept of risk, however, is myriad, often conflicting, sometimes confusing, fraught with ambiguity, supported by value judgments, beset with political acts, and sometimes presented with willful obfuscation. Risk assessment and management grade into accident analysis, safety design, safety training, and other related subjects.

Questions posed by the very existence of risk assessment and management include the following. How valid and reliable are scientific assessments of risk? How do we equitably allocate risk across the various sectors of the public of a society? How do we bound and deal with uncertainties in risk? And what constitutes "safe enough" and "acceptable" regarding risk?

We could tentatively define risk as the degree of probability of a loss of a thing valued by some humans and the amount of this loss within a particular duration of time. We will modify this definition, after we inductively review the concept. (Probability is some kind of measure, often a numeric expression, of an amount of belief. Thus, I am more likely to be struck by lightning than by a meteorite.) Initially, we can posit that risk is some kind of measure of exposure to some loss. We will modify this standard definition as we progress, inductively, in our course presentations. Loss has a subset of danger or jeopardy to person, property, and habitat and this subset, in turn, has a subset of death to persons and destruction of property and habitat. Uncertainty regarding the consequences of a hazardous event fosters risk. Risk could be thought of as a measure of exposure probability to hazard. Hazard could be a being, energy, mass, toxicity or duration of time that, if not controlled, could result in a loss. Thus, hazard is a source of loss, including but not limited to danger. More specifically, hazard is the overlap in time and space of a potentially loss causing agent and a potentially vulnerable recipient.

Beyond personal danger, the loss from hazard could be financial or social, i.e., a penalty payment on a contract not fulfilled or a diminishing of a business reputation. Loss could also be one of quality of a product or service, time, control of a procedure, or comprehension of social action. Risk is commonly expressed as the probability of an event multiplied by its cost within a particular duration of time.

In sum, risk includes in its conception a likelihood that a hazard[4] will become a loss. The loss from a hazard could be to humans physically or mentally, to habitat, to material property, or to incorporeal property including intellectual property and the good will and reputation of an organization. Risk, then, is a social context where an event takes place with a probability, a likelihood of occurrence. Risk thus has two aspects, the probability and the size of its consequences. The Western (our) concept of risk is more subtly and intricately complex than all this, however.

2. Thinking Risk

To think broadly, in each human society, risk is a network of social relations and beliefs guided by cultural prescriptions and proscriptions ("thou shalts" and "thou shalt nots") encompassing some thing in hazard. This "thing" could be a process of nature (e.g., storm, drought, flood, or vegetation blight), an object (e.g., leopard, cobra, enemy, or artifact), or supernaturalistic cultural construction (e.g., spirit; magical threat; witchcraft; or impersonal, amoral manistic force). Different human societies (sociocultural collectivities of people) have various social networks depicting particular things as risky. Americans tend to see all snakes as hazardous, whereas Australian aborigines see them as scarce, prized food. The

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[4] Hazard, incidentally, comes from the Arabic azzahr [literally, the die] an Arab game using dice, hence, involving chance. Shakespeare: "I will stand the hazard of the die." Modern "craps" is a simplified version of the older English game of "hazard."

Amhara and other Ethiopians folk classify the giant African python apart from all snakes. We are told, this <u>zendo</u> (Amharic, monster) is the color of the land and can swallow large animals and humans whole. A society, not an individual socialized in it, both creates and maintains, with changes over time, its networks for determination of risk. Because risk is a sociocultural creation, it is subject to sociocultural limitations regarding its application to things in the world. Accordingly, as a social conception of risk changes over time, so do its referents. Speakers of Old English (Anglo-Saxon) feared the risk of monsters such as the people-eater Grendel ("Fie, fie, fo, fum"), and they believed in the risk management of monster-killing heroes such as Beowulf (Anglo-Saxon, Bear-wolf). Recently, some Americans ethnocentrically feared the risk of the approaching Millennium (in 2001, not 2000; learn to count), that is, the period of one-thousand years during which the Christ will reign on earth. (An <u>artifact</u> is any human made or modified physical thing, from a flint arrowhead to a nuclear power plant; etymologically, something artificial, not natural.)

In the physical sciences and engineering, <u>risk</u> is grounded in quantification of probabilities and outcomes. In the social and behavioral sciences, <u>risk</u> goes beyond these two procedures and includes its qualitative aspects and especially its relativistic meanings and foundations. Nevertheless, today, <u>risk</u> is permeated by views taken from economics and its considerations of risk.

Usually, the possibility of risk is measured from 0 to 1: this is a statement of risk probability. Frank A. Haight, a leader in risk studies, provided some basic instruction in contemplating <u>risk</u>. First, a probability of zero, that is, zero risk, is only a numerical calculation. Zero risk does not mean an event cannot occur. Accidents occur at zero risk. And a probability of 1 does not mean the inevitability of an event. Second, we ordinarily confine a numerical calculation of risk to the unit interval (1 or less, e.g., .014). If a risk on Monday is p and on Tuesday is q, then, we calculate the risk for the two days to be $p + q$. If we used such formulation, then, we could wind up with a risk greater than 1 (Haight 1986:360). Kaplan and Garrick put it somewhat differently, we can reduce risk by safeguards, but as a matter of principle: "Risk is never zero, but it can be small" (1981:12). What about a documented history of zero occurrences of an event, say, of a catastrophic nature? "Zero occurrences of catastrophic events provide little help in ruling out the events" (Fairley 1981:203). (A <u>safeguard</u> against a hazard is any artifact, computer program, procedure, or person that protects against loss.)

Risk can be generic or specific. <u>Generic risk</u> is inherent in all plants (i.e., business buildings and grounds) and their components.[5] This risk could be miscommunication, insufficiently trained personnel, nondelivery of needed materials, weather event, and so forth. <u>Specific risk</u> is found in a particular plant and its components. In railroading, for example, specific risk could be a runaway car in a yard, hotbox, blocked or sabotaged train line, excessive brake-cylinder piston travel on a car, car brake "dynamiter" (causing an undesired emergency air brake application), sun kink in a rail, and lap of authority to occupy a main track. Risk can also be voluntary or involuntary. <u>Voluntary risk</u> obtains when an actor has full control over taking a risk, say, sky diving or bungee jumping. <u>Involuntary risk</u> obtains when an actor has no control over taking a risk. But the instances

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[5] A <u>plant</u> is a facility in the field such as but not limited to a: factory, warehouse, office building, railroad, airline, airport, pipeline, trucking firm, bus company, mine, granary, and seaport. It can be a component facility such as a railroads' rail yard, main line, train dispatcher office, or mechanical shop.

of such risk can be arguable, such as developing skin cancer from solar radiation; after all, common mitigations to this risk exist. Some would argue that degree of involuntariness is correlated with amount of personal wealth. The wealthier one is the more the affordability of risk mitigating devices and the greater the ability to move to a less hazardous setting.

In US society, three large economic mechanisms furnish incentives for reduction of risks. These are the costs from the market pricing of risk, government regulation, and tort liability before the courts for risky products and activities. Giant corporations go into bankruptcy from these costs. For one example, a landslide of asbestos lawsuits now clogs the courts. Over 60 firms have sought protection in bankruptcy because of asbestos exposure claims. Such companies include Kaiser Aluminum, Bethlehem Steel, Owens Corning, and Armstrong World Industries. Even an august, risk-assuming backup for these firms, Lloyds of London, balanced on the verge of bankruptcy by miscalculating risk. Hazards such as from asbestos, oil spills, or chemical contamination can assume multi-billion dollar liability for a firm. W. Kip Viscusi notes existing government regulation and tort liability should be sufficient for addressing market failures owing to risks. In reality, the risk event fostering liability costs often additionally creates demands for further regulatory intervention (Viscusi 1998).

Given our above, framing discussion of <u>risk</u>, we cannot think it is a clear-cut, agreed-upon concept. Often writers about risk and those using risk analysis proceed as if their concept of <u>risk</u> is understood by the reader or as if no other views about risk exist. The ways to study and conceptualize risk are under continuing discussion and reformulation, and even in dispute by many professionals in the risk business. Yes, risk assessment and management, just like any other business in the marketplace, has a community of practitioners and of persons interested in the subject for a wide variety of reasons.

Generally, as technology develops, its associated new hazards increase, with commensurate risks, even as it reduces or eliminates older risks. Given the revolutionary advances during recent decades in materials, electronics, and computation, it is physically possible to call for greater levels of performance and productivity in systems, both civil and military.

Western thought concerning risk, as with other ideas, continuously changes. In the late Middle Ages and thereafter, the Latin word <u>riscum</u> was applied, in maritime shipping, insurance, and other business, to the chance of hazard to ventures. This was done especially to ships engaged in commerce. (Also similarly formerly used in English were the words, from the Italian <u>risco</u> and <u>risgoe</u> and the French <u>risqué</u>.) The idea of risk excluded the thought of human fault and responsibility. Risk came from an inexplicable natural or fatalistic-God-intended event such as a storm. (Natural or Devine process depended upon one's learned viewpoint from one's cultural background.) Beginning in the Enlightenment of the 17th century, risk began to be discussed in terms of more objective knowledge of the world, through humans' rational thought and scientific inquiry and experimentation. Later, the practices of statistical sampling and reckoning and of probability-based life expectancy and theory developed to bring rationalized counting and thus an order to a seemingly chaotic world (Hacking 1975, 1990; Bernstein 1996).

<u>Risk</u>, as we previously noted, is usually expressed as probability times consequence. Kaplan and Garrick, however, caution that this expression is misleading, and they prefer

risk as probability plus consequence. “In the case of a single scenario the probability times consequence viewpoint would equate a low-probability high-damage scenario with a high-probability low-damage scenario--clearly not the same thing at all” (1981:13). This is something for us to contemplate regarding the muddles in the risk models.

Scientific risk theory often has a naiveté of supposed “hard” technical, data oblivious to the authenticity of the real world attempted to be modeled, such as a world of work, e.g., the rail world. Railroaders often complain about analysis in which the behavioral, social, and procedural complexity of their work is simplified, overlooked, and ignored to fit an elegant model of the analysts’ view of their world. For railroaders, their rail world comprises the natural geographic, technological, and sociocultural systems impacting and related to work procedures, which analysts attempt to model, mathematically or otherwise. The rail world exists in such a total environment.

All hazards must not be treated equally, with too great or too little a reaction to risk. As follows, we have a frequently used model from the US Department of Defense for categorizing hazards engendered by their severity and chance of occurrence.

Hazard severity categories (USDOD, 1983, "System safety program Requirements," Mil-Std-822C):

Description	Category	Definition
Catastrophic	I	Death, system loss, or severe environmental damage
Critical	II	Severe injury, severe occupational illness, major system or environmental damage
Marginal	III	Minor injury, minor occupational illness, or minor system or environmental damage
Negligible	IV	Less than minor injury, occupational illness, or less than system or environmental damage

Qualitative levels of probability of hazard (USDOD, 1983, "System Safety Program Requirements," Mil-Std-822C):

Description	Level	Specific Individual Item	Fleet or Inventory (define size)
Frequent	A	Likely to occur frequently	Continuously experienced
Probable	B	Will occur several times in the life of an item	Will occur frequently
Occasional	C	Likely to occur some time in the life of an item	Will occur several times

Remote	D	Unlikely but possible to occur in the life of an item	Unlikely but reasonably be expected to occur
Improbable	E	So unlikely that it can be Assumed occurrence may not be experienced	Unlikely to occur, but possible

Matrix of Assessment of Hazard Risk:

Hazard category frequency	I Catastrophic	II Critical	III Marginal	IV Negligible
A Frequent ($x > 10^{-1}$)	IA	IIA	IIIA	IVA
B Probable ($10^{-1} > x> 10^{-2}$)	IB	IIB	IIIB	IVB
C Occasional ($10^{-2} > X > 10^{-3}$)	IC	IIC	IIIC	IVC
D Remote ($10^{-3} > x >10^{-6}$)	ID	IID	IIID	IVD
E Improbable ($10^{-6} > x$)	IE	IIE	IIIE	IVE

Hazard risk index	Risk decision criteria
IA, IB, IC, IIA, IIB, IIIA	Unacceptable; stop operations and rectify immediately
ID, IIC, IID, IIIB, IIIC	Unacceptable; upper-management decision to accept/reject risk
IE, IIE, IIID, IIIE, IVA, IVB	Acceptable with management review
IVC, IVD, IVE	Acceptable without review

3. The Uncertainties in Doing a Risk Assessment

To begin, using Probabilistic Risk Assessment (PRA) is a preference of those responsible for making decisions about risk. In short, a PRA is conducted to aid in decision making for the safe operation of a plant or a part of it. It is sometimes labeled Probabilistic Safety Assessment (PSA). This kind of assessment has developed mainly since 1970 and is laden with uncertainties.

PRA provides comfort to those enculturated in the scientific-objectivist way of perceiving the world and how to grasp its reality. It is, however, as much an art form as science (Freudenberg 1988). Uncertainty-beset PRA beckons with a Holy Grail of certainty to policymakers who often cannot follow the mathematics, logic, and, above all, assumptions of its analyses. Uncertainty can be seen as having at least three basic sources: first, the inherent randomness of the real world wherein uncertainty cannot be reduced because it is characteristic of the assessed system; second, imperfect knowledge about matters knowable; third, mistakes (errors) in conducting activity in assessment (Suter 1990:204). One class of errors is mathematical. These errors stem from errors in: mathematics, programming, inputs, and computational techniques (Suter 1990:215). An underlying uncertainty exists in framing an analysis. This stems from the ways in which analysts interpret questions and judge their relevancy. Persons framing the kinds of questions asked in a study can control its findings. Once again, a significant uncertainty in risk assessment is its selective, sometimes political, undertones. For example, a risk assessment comparing paired elements of a new and an old kind of a technology will result in findings different than for an assessment all aspects of the new technology.

George Apostolakis, long on the forefront of the discussion of risk assessment, has some insights into the vagaries of PRA. Engineers and physical scientists are usually unaccustomed to moving from “objective” facts to subjective judgments, as required in PRAs. Added challenges for them are the realities of an actual system in the field and the fact of the rarity of major accidents. Because a PRA helps in making decisions for operating a plant, the decision problem has four broad elements of formal analysis. First, <u>structuring the problem</u> provides the foundation for further analysis to build models of the physical world and to find alternative paths for action. Second, <u>quantifying uncertainties</u> means introducing probabilities and calculating them. Third, <u>quantifying preferences</u> allows their expression in terms of utilities. Fourth, <u>making the decision</u>, i.e., choosing among alternatives, means maximization of the utility expected (Apostolakis 1990:1359). Each of the four elements encompasses uncertainties.

Something <u>uncertain</u> is questionable, doubtful, or vague. Vern Walker holds that some risk uncertainties are measurable and some are not. He developed a useful fivefold taxonomy of uncertainty inherent in causal information about groups (1998). Measurement uncertainty resides in any set of data gathered by using the variables we selected “scientifically.” Uncertainty is found in the reliability and validity of each datum we select.

For one example, in 1989, the General Accounting Office (GAO) investigated and found that the FRA necessarily relies on safety data provided by the railroads (USGAO 1989). "However, GAO found substantial underreporting and inaccurate reporting of injury and accident data by the railroads it visited, which raises questions about the overall effectiveness of FRA's safety program and the extent to which railroads have become safer" (USGAO 1989:3, also see 14-23). One datum uncovered by the GAO was that the five railroads it visited reported 2,176 missed workdays from 156 injuries, but the true number was 8,023 missed workdays (USGAO 1989:4). Another finding was that Amtrak did not report 32 of the passenger injuries from the catastrophic collision in 1987 at Gunpow Interlocking, Maryland of a passenger train into a standing freight locomotive (USGAO 1989:16). Private databases for railroad events could well suffer from the same shortcomings. Discussions of validity and reliability abound for such railroad “hard” data.

For a full risk assessment, for example, of the collision of two freight trains releasing hazardous chemicals, a number of factors must be included. What are the emergency responses provided for the train crewmembers? What are the emergency responses provided for members of the public along the right-of-way? How effectively did the railroad report the hazmat cargo? How effectively did the public emergency services respond and handle any hazmat cargo? If civilians must be removed from a derailment site caused, how effectively is this procedure handled? What provisions were made for housing and feeding them? These factors, then, largely concern actions of organizational and governmental officers.

Although risk analysis attempts to classify the possible consequences of identified alternative events, it seldom assists in identifying different objectives or in making transparent the cultural values and norms entering the analysis.

Because of the myriad known events, a PRA for some part of a complex industry is professionally labor intensive, time intensive, and monetarily quite costly. The organization or regulatory agency requiring a PRA cannot expect quick, inexpensive results. Given that a PRA is correctly calculated with its gathered information, unknown events could still make the final assessment an uncertainty to some unknowable degree.

In modern risk management, two main forms of coping exist, so-called prevention (actually, lowering the probability) and mitigation. Prevention of risk from technology is mainly by political regulation, however spotty it might be. “[W]e Americans have an almost mystical faith in the ability of regulatory agencies to find a way to make our lives safer without seriously degrading them” (Lewis 1990:69). Mitigation means making the consequences of a realized hazard less severe. The government’s FEMA mitigates the effects of natural disasters. Mechanical and electronic safeguards mitigate the consequences of an accident involving machines and humans and machines. Examples in railroading are the heavily buttressed full-width noses on road locomotives during a collision and the use of voice radios for communication in times of accident.

A third form of coping is by what could be called disclamation (denial or disavowal). Here an event involving a particular technology, or subsystem or component of it, is categorized by its organizational and/or regulatory proponents or defenders as not attributable or not directly attributable to the technology. Attributable means to think of as belonging to, or produced by, or resulting from some thing (including person). Directly means, being in a direct line with a thing, or without a thing coming in between, or being immediately responsible for an event. ("The accident is not directly attributable to new technology 'X' but results solely from operator error.")

With disclamation, a risk assessment can be self-serving. Two common strategies in assessing risk are blaming the victim and blaming the other. Thus, in the first instance, an automobile or tire manufacturer could protect its mechanically failed product and blame the accident-injured driver and, in the second instance, environmental groups could blame petroleum or timber companies for aspects of environmental change which the activists view as degradation. Kletz explains that, at a street intersection having a high number of accidents, it is cheaper to blame the drivers than to redesign and reconstruct the road (1991:30). Mary Douglas reasons that blaming the victim facilitates social control of persons, and blaming the other engenders group loyalty and solidarity vis-à-vis other groups. Both strategies serve to prevent a community from spliting with dissention over their formulations and perceptions of risk (Douglas 1985).

Scott Sagan concludes regarding disclamation: “the politics of blame: When a petrochemical plant explodes, a jumbo jet crashes, or an oil tanker runs aground, accident investigators round up the usual suspects: the control room operator, the pilot, or the captain who committed an error. It is extremely misleading, however, to place such a significant emphasis on 'operator error' as the cause of most accidents" (1993:278). "Pilot error has become an insidious dumping ground classification that is still attributed to more than 90 percent of all general aviation accidents and incidents" (Cohn 1994:xiii).

A large amount of risk management is done with the Probabilistic Risk Assessment (PRA), introduced above in at the beginning of this section 3. PRA constructs risk profiles/curves for a particular situation, such as for safely operating a nuclear power plant and for forecasting tomorrow's weather. Both have some amount of uncertainty. Uncertainty in PRA rests in part on the multiple outcomes and the consequences of these. Uncertainty relates to an unknown future event to which no measured probabilities are correctly attached. A risk profile/curve is a distribution pattern of a probability outcome pair (e.g., meltdown, no meltdown; rain, no rain). Risk management studies alternative chains of events and evaluates the risk profile for each, makes decisions for safety, selects alternatives to control risk, and makes the necessary corrections. Risk assessment is nominally more "objectively scientific," and risk management is "more subjective, societal, and political" (hence, culturally relativistic). Moreover, despite the nominally "scientific" nature of the PRA, its ingredients detract from its science and make it also culturally relativistic (Kumamoto and Henley 1996:1-7). As Hiromitsu Kumamoto and Ernest Henley explain (1996:7): "[T]he PRA is often compelled to use subjective likelihoods based on intuition, expertise, and partial, defective, or deceitful data and dubious theories." We cover experts in section 10.

Uncertainty in the risk profiles/curves stems from the fact that "the risk curve is far from exact because the [any] scenario frequency is a random variable with significant uncertainty. Risk curve variability is important because it influences the decision maker. . ." (Kumamoto and Henley 1996:535).   Risk curves, we should remember are not empirical but, instead, conceptual. Random might not be as random as we think it is (Kolata 1987).

Failures covered in the risk curve include hardware component failures, human errors, disturbances external to a plant, and expert evaluations including of acceptable design and construction.   Further, even the "hard" data on component failures is somewhat subjective. Usual data might include the number of component failures $\underline{m}$, the number of demands on the component, $\underline{n}$, and the time interval of exposure for the component, $\underline{T}$. Statistical uncertainty assumes that $\underline{m}$, $\underline{n}$, and $\underline{T}$ are constants. These data, however, are derived from plan and test data, all involving varying degrees subjective evaluation from subculturally relative backgrounds. The consequent uncertainties in $\underline{m}$, $\underline{n}$, and $\underline{T}$ produce significant effects on the parametric uncertainty. This is especially so with highly reliable components. The number of demands can be problematic in the uncertainty. If a system contains $\underline{r}$ redundant components, then, a single system demand results, on a component level, in $\underline{r}$ demands. Especially in generic databases, the redundancy parameter $\underline{r}$ is frequently unavailable.

A parametric uncertainty involves a quantity whose value varies with the nature of its application. Such a constant, having variable values, is used as a referent for determining other variables. The uncertainty in the frequency of failures of a component is deemed a parametric uncertainty when this frequency is an underlying variable in a frequency function for a loss scenario leading to an event such as an accident. Also this is because the uncertainty on the level of the component originates in the uncertainties in the distribution parameters for the component lifetime. Parametric uncertainties on the component level can transform into system-level uncertainties. (An accident scenario is a sequence of events resulting in an accident. Similarly, a near-miss scenario is a sequence of events resulting in a near-miss. Near-miss and incident are often used interchangeably and mean any event that could have resulted in realization of an accident but did not. From one to all safeguards could be overcome, but no loss consequently occurs.)

Study of near-misses is a safety tool. These events result in less emotional baggage, defensive reaction, and legal liability than does the recording and discussing of accidents. A near-miss, then, is politically more amenable to in-depth investigation than an accident. Moreover near-misses in their much greater frequency than the rare accidents provide the quantitative data useful in risk analysis. Recovery mechanisms regarding a near-miss can be reviewed for use as is and for strengthening (van der Schaff, Lucas, and Hale 1991).

Statistical uncertainty also exists, but will not be handled here. Generally, uncertainty on the component level declines as more data on failures and lack of failures become available. This presents a paramount problem for a genuinely new technology (say, nuclear propulsion for spacecraft or the nuclear powered locomotive once championed by the Denver & Rio Grande Western). For such new technology, by definition, the data are lacking or sparse.

Risk-curve uncertainty goes beyond basic parametric uncertainty to modeling uncertainties. These originate in sundry approximations made in constructing and assessing event trees and fault trees, assumptions made about kinds of distributions of lifetime of components, and the fact that the scenarios usually are not exhaustive and exclude significant initiating events. No method exists to ensure completeness of scenarios.

Uncertainty in risk assessment troubles political decision makers. Ricci and Molton explain that the governmental policy judgments on risks of health and safety often come under judicial review. “Science is not able to provide answers with the certainty that the courts have been accustomed to deal with in other areas. ‘Transscientific’ questions abound; answers are often provided by fiat” (1984:373). By transscientific is meant that standards for government regulation are based on the insufficient data currently available for making a fully informed factual determination. The fiats of policy judgments are then substituted for factual analyses. (Fiat: Latin, “let it be done.”)

Regarding risk regulation, we should bear in mind that as technology continues to evolve, almost exponentially in some of its aspects, previously unthought-of, relatively inexpensive, and highly effective safeguards against certain hazards could be developed. Also new hazards could be detected, thereby rendering current standards obsolete. An interesting example is that in 1903, the Brotherhood of Railroad Trainmen (BRT) presented news about radio communication to its members as a novelty (anon. 1903). Little did the BRT officers know that this technology would revolutionize railroading, both in transmitting data and in train, engine, and traffic control, not to mention RCLs. Thus, probabilities for loss from a hazard change over time and are not a constant and new hazards develop. (A standard is something established for use as a basis, often a rule, for comparison in measuring or judging some value.)

Beyond the issue of the cultural relativity of a PRA, as used in risk management, it additionally might not be complete and added risk could thus obtain. As Jens Rasmussen and O. M. Pedersen caution (1984:183):

> The result of the PRA is a calculated risk figure which, if accepted, covers the "accepted risk." If not accepted, the design has to be modified until acceptance has been achieved. Owing to incompleteness and errors during the PRA, an "additional risk" may exist, which is not included in the accepted risk.

Where does this additional risk originate? It could be in use of components, subsystems, and systems outside of the items studied, say, in plant A, for their failure rates or in items which are substandard. Other plants B-F may differ from A, however. Perhaps an actual plant in the real world does not match the limited PRA model representing such an infinitely complex entity. Sometimes the PRA modelers assume, with variable amounts of incorrectness, that their studied plant A follows an ideal industry practice according to the rules, practices, and policies put on paper by an umbrella industry association. Perhaps the plant does not operate in accordance with the assumptions of the PRA, e.g., the PRA modelers and analysts never understood railroading in its intricacies and its many contingent domains of everyday railroader knowledge, often with localized variations (see Appendix F). The analysts' model is both ideal and overly simple rather than realistically replicating real-world reality. The modelers also assume that, apart from the problem of the generally subjective judgments of the inputers of data to the base, the industry and regulatory databases reflect some semblance of reality. That is, the modelers do not allow for both the data-gatherers' specific inclinations to leave some organizationally disturbing data willfully unrecorded and the "cooked" data willfully distorted for individual career and corporate goals.

Judicial punishment and organizational displeasure are often in store for those who report all accidents, and for those who report an accident fully. As Andrew Hale explains regarding accident investigation (1997:7):

> Built into the judicial approach is a threat for those to whom the finger may finally point. They will have to pay, either as punishment, or to compensate others, and their reputation and future business or employment prospects will be damaged. There is a natural tendency for anyone faced with such a prospect to be unforthcoming, to limit themselves to statements which do not damage their position, to put the best gloss on their description of events and to act defensively under questioning. Event investigation and analysis in this paradigm becomes an adversarial activity, which shares many of the traits of detective work for criminal investigations.

"Unforthcoming" is an exceedingly polite way of putting it. This unforthcoming is more than just defending or covering an individual's own actions, however. Many organizations expect all employees to unite to protect the company's interests. This is interpreted to mean, reveal nothing to nonorganizational members, except for questions of law officers in the course of a particular investigation. Then, stick to recounting only the facts you observed.

Regarding accidents recorded in databases, William Fairley finds a broad uncertainty. A distinction exists between numbers of accidents actually occurring and the reported number of accidents. “We know in every field of data collection that the numbers of events reported to authorities and officially recorded by the latter may differ substantially from the actual frequency of these events” (1981:202).

Before it is collected, accident data can be distorted and rendered uncertain for a number of “good” reasons. The person at the point of control might not want to report his/her accident out of personal embarrassment for a “foul up,” out of fear of reprisal from managers, and from cooperation among fellow employees not to divulge kinds of accidents to superiors. A main motive for this last nondivulgence is to protect fellow employees from implication and punishment. Additionally, employees feel uncomfortable when questioned and dislike interrogation, in a police-like manner, by claims agents and attorneys working for the employer; thus, the less said, the better.[6] (“You can never tell just what might get you in trouble, later on. So, mum’s the word.”) Further, the employing organization has experienced that those with loses from an accident can sue for both compensatory and punitive damages. Any accident data collected by the organization, including detailed employee records of what happened, can be discovered in pretrial proceedings and used against the defendant organization. Being organizationally prudent means rather than illegally withholding accident information, do not collect it in abundance in the first place. Such prudence flies in the face of developing valid and reliable databases for risk analyses.

4. The Validity of a Risk Assessment

Kristin Shrader-Frechette calls attention to the problem, among others, of “bibliographical incompleteness,” to give it a polite label, in gathering information for risk assessment. Her prime example concerns the Yucca Mountain nuclear waste repository (1997). For example, a National Research Council report (NRC 1995) provided technical bases for standards to protect public health regarding high-level radioactive waste disposal at Yucca Mountain, Nevada. Yet the NRC report overlooked in its deliberations and citations to literature a Department of Energy report (DOE 1992) on the subject. A panel of fourteen distinguished geologists and earth scientists wrote the DOE report and it appears to challenge some of the conclusions of the NRC report (Shrader-Frechette 1997). The point raised here is not who is right, the writers of the NRC or DOE reports, but why did the NRC experts exclude without comment the conclusions of the DOE experts? Further, Shrader-Frechette questions the imbalance and underrepresentation of certain expertises (viewpoints) on the NRC panel (1997). (See also: Slovic, Layman, and Flynn 1991.) Specifically, focusing on risk uncertainties, the DOE panel report concludes (DOE 1992:B2):

> It is the opinion of the panel that many aspects of site suitability are not well suited for quantitative risk assessment. . . . Any projections of the rates of tectonic activity

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[6] On the "ASD RR," as they continued running to their terminal, a crew of a long, heavy freight train reported by radio to the train dispatcher a fire high up in the wooden eaves of a tunnel on a steep mountain grade having sharp curves. The company procedures for response to such an event, in remote terrain, took about four hours. Meanwhile, the tunnel fire flared and the structure collapsed severing all transportation on the line for a considerable time. The railroad managers fired the train crew for not stopping their train and extinguishing the tunnel fire, a task for which they said they were neither trained nor equipped. As crewmembers explained to me, "If we just kept on going and reported nothing, we would not have been fired. A tunnel fire, after we went by? Imagine that."

> and volcanism, as well as natural resource occurrence and value, will be fraught with substantial uncertainties that cannot be quantified using standard statistical methods.

A Rand Corporation Study for the Congress, not surprisingly, found: "The government is too dependent on work from groups with direct interests in the results, including manufacturers, operators, and regulators. . ." (Wald 1999:A21). Said Cynthia C. Lebow, a Rand analyst leading the study, regarding the "party process" by which expert individuals and organizations are invited as parties to assist the NTSB in its investigations: "the party process is essential in many respects because the safety board is never going to be an enormous agency, and it will never have the staff and technical capability to design an aircraft or operate an airline." Regarding the overt biases of the parties, however, she said: "you have to recognize that in this day and age, those guys are coming in with multiple agendas." Furthermore updating training, or any training, for NTSBers is almost nil (Wald 1999:A21). Not only do the parties have overt biases, so do the subjects of research. Human subjects introduce errors into data in two ways. Their responses can be innocently incomplete. (I didn't know he meant that.") And the responses can be knowingly false. ("I would not tell them about <u>that</u>.")

Regarding the above, "the plant in the field does not match the limited PRA model," the following sometimes obtains. The amount of historical data for a new technology or for an old technology in a new operating environment can be scant. One analytic crutch to make up for this shortcoming often is to use the abundant data from the nuclear power industry (which will not be cited here) (Shrader-Frechette 1985, especially p. 150-151). Nuclear power plant operators, in a process industry radically different from the railroad industry, however, work in their shirtsleeves in a climate-controlled physical environment--safe from heavy moving equipment, the vicissitudes of the weather, and unstable footing-- while sipping on a cup of coffee and chatting about the ballgame with a co-worker. (Gamst's late father in-law was a power plant operator, whom he visited at work.)

The power operator's response to an indicator change or need to manipulate a control, then, is, for example, not the same as for maintenance-of-way trackmen operating heavy vehicles on a busy railroad right of way, or for switchmen and trainmen handling freight cars while amongst the interconnecting live tracks, or for signal maintainers dodging trains while conducting their tests, maintenance, and repairs. What, then, is the valid benefit in risk analysis of using information from the nuclear power industry for analysis of dissimilar industries?

What risk management attempts to do is conform to a (correct) set of conditions for safe operations of a plant as defined in the PRA and calculated to be of acceptable risk. Rasmussen and Pedersen caution further, however (1984:183):

> The major part of the human decision-making and administrative functions involved in operations management is not accessible to formal analyses with the present state of PRA. Errors of management may, however, be significant sources of common-mode errors and are therefore important candidates for risk management by feedback control.

No definitive conception of or methodology for risk exists. Therefore, what constitutes acceptable risk must always be a culturally relative (i.e., comparative) matter imbedded in a particular specific culture, say, French-Canadian, Anglo-American, German-Swiss, Japanese, Zulu, or Qemant or, highly significant, a subculture of such a culture. Judging one culture or subculture by the norms and values of another is an ethnocentrism. And so is assuming our own norms and values are also those of another group in our own society. ("They think and act just like us." Indeed!) In ethnocentric views, our own group's norms and values and consequent behavior are uncritically regarded as unquestionably superior to those of other groups, who, if they are to "measure up," should therefore accord with what we desire and do. Thus, Americans put money into missions abroad, to change the norms and values of "benighted" cultures about which they have no knowledge. And, thus, here at home, American policy makers put public funds into projects to change behaviors and lifeways about which they have little or no knowledge. Carl Cranor notes that risk assessment "is permeated with normative presuppositions. Recognizing the normative aspects of risk assessment greatly affects how we use it and what we should expect from it. . ." (1997:123).

Not just the assessment and management of risk but also the ranking of risk involves culture-laden judgments having winner and loser consequences. Rankings of risk and risk-reductions strategies depend on questions of the ethics aspect of culture and not of science, to determine just which risks are considered, how a risk is measured, how the different dimensions of risk are weighed, and how uncertainty is treated. Accordingly, the differences will result in just whose welfare is protected and whose risky activities are curtailed (Fischhoff 1995).

To act as if all members of a society desire what policy makers and experts have calculated to be best for them is an ethnocentrism. Baruch Fischhoff, Sarah Lichtenstein, and Paul Slovic explain about our culturally-based choices concerning risk (1980:ii-iii) (see also Fischhoff et al. 1978, 1981, 1984):

> That choice depends upon alternatives, values, and beliefs that are considered. As a result there is no single all-purpose number that expresses "acceptable risk" for a society.
>
> Values and uncertainties are an integral part of every acceptable-risk problem. As a result, there are no value-free processes for choosing between risky alternatives. The search for an "objective" method is doomed to failure and may blind the searchers to the value-laden assumptions they are making . . . .
>
> Not only does each approach fail to give a definitive answer, but it is predisposed to representing particular interests and recommending particular solutions. Hence, choice of a method is a political decision with a distinct message about who should rule and what should matter.

Risk, then, is more than just the degree of probability of a loss and the amount of this loss, as noted in our introduction to the concept. The concept also involves political negotiation and consent or coercion about the probabilities. Consent, however, is frequently contested in assessment of risk. Often the consent obtained is not informed.

A culturally based theory of risk assessment, including perceptions of risk, then, must consider the wielding of social and economic power in relation to the kinds of risks deemed acceptable. What parts of society and its culture engender the various, sometimes privileged, outlooks about hazards? That is, Why are certain kinds of hazards chosen for just how much concern? Each specific culture, and each of its subcultures, has its own selection of perceived risks. Shared cultural values and norms foster both group apprehensions and assumptions not to have apprehensions about other things. (N<u>orms</u> are the enculturated prescriptions and proscriptions, i.e., shared expectations, for social action and include the rules of social behavior.) For subcultures of safety in US transportation, see NTSB 1997.

In his now-classic article on risk, Chauncey Starr (1969) explains:

> "involuntary" activities differ in that the criteria and opinions are determined not by the individuals affected by a controlling body. Such control may be in the hands of a government agency, a political entity, a leadership group, an assembly of authorities or "opinion-makers," or a combination of such bodies. Because of the complexity of large societies, only the control group is likely to be fully aware of all the criteria and options involved in their decision process.

Thus, each social assemblage of values and norms elevates some hazards to high peaks and submerges others. This is a part of our cultural paterning a social order for things in our universe. To order things, we classify some as important, some of degrees of less importance, and some as unimportant. Different societies and subsocieties are culturally biased toward finding and addressing different kinds of hazards. Because we cannot be omniscient, social life means we must both order and rank in priorities all of our biases, i.e., inclinations and partialities. Otherwise, we would be immobilized by indecision. Understanding these value and normatively ordered biases enables us to examine the bases of our analytic conclusions of and policy decisions for risk.

Decades ago, Kaplan and Garrick reminded that, "risk is relative to the observer. It is a subjective thing—it depends on who is looking." All risk is perceived and no risk is absolute. "So, qualitatively, risk depends on what you do and what you know and what you do not know" (Kapaln and Garrick 1981:12). The <u>you</u> stands for the individual carrying the collective conventions of a particular group and cannot mean individualistic unpatterned guidance for behavior. In all, regarding risk, social groupings form the patterned perception of it. Risk does not reside in the unpatterned, private views of an individual, rational or irrational.

A problem exists in the biased nature of the data used in risk assessment and management. The many sources of bias in data from, among other things, individual self-interest, organizational protectiveness, regulatory lack of definition, comparability of data, methodology, conceptualization, lack of data precision, social position of actors, and cultural background of actors have been reviewed. The corrections of these many intricate sources of error in the data used are necessarily manifold and fraught with conflicts of procedure. Undoubtedly, the data for considerations of risk cannot be completely purged of error in their creation and of consequent uncertainties

In all, despite claims for scientific objectivity, we can view <u>risk</u> pragmatically as a variably culturally relative set of ideas and methods for an ordering of reality in the world. This ordering allows a sense of security that earthly hazards have been or can be coped with.

As an ordering of reality, risk is part of a people's worldview. More specifically, risk is a set of interrelated learned patterned views, developed by different groups in a society and among which individual's choose opportunistically. Convention, however, bounds the choices, which are not freewheeling from free will.

Finally, for those readers who are somewhat skeptical about risk assessment and its management, as the Ethiopian Qemant do concerning risk, stand, face east, hold upward your cupped hands as if you will receive something from above, and repeat: "Getoch Mezgena, ye-Adera new." ("Lord Mezgena my-God He-is.") You are not a Qemant and, anyway, you do not understand the ideas underlying this procedure, you say? Does the following, instead, give you confidence and a perception of security? "The regulatory agency has provided great reduction of hazard and uncertainty through scientific risk assessments." Feel better? Is it all a matter of relativistically enculturated belief? Can we disregard risk analysis of hazards, however?

Appendix E. The Loci of Human Error

The category of human error is overly relied on for simplistic, often self-serving, and anti-scientific statements about causes of accidents and near misses. It is a hoary catchall category having incorrect implications that causes with such a label are uniform, when they are diverse. The category is an example of the buck stops there but almost never here.

The underlying analysis presented in this appendix E, not in any way unique, is that an individual is rarely the only cause of an error or resultant accident. In modern human-machine systems, an individual error comprises a complex of interactions among humans on various overarching societal levels and interactions with ordinary and computer-control machines, as well as with the geographical environment. In this appendix, abstractions such as errors from the work, organizational, or social environment are treated as errors from individuals on various societal levels. The operator and his machine cannot be validly separated in any analysis of what is necessarily a human-machine system, within a system of overarching levels of human inputs.

1. The Nature of Error

Human error is widely discussed in the literature in the behavioral and social sciences and engineering yet, as recognized by most analysts, its conceptualization has considerable range of variation (Singleton 1984; Rasmussen 1986:149-169, 1990; Amalberti and Wioland 1997; Prabhu and Prabhu 1997; Wiegmann and Shappell 1997, 2001; Callentine 2002). Several decades ago, most analysts had a residual category for accident cause called human error. In was a convenient wastebasket for attribution of accidents to Chimera of a uniform, undifferentiated cause. "Fixing" the individual "culprit" was the one-size-fits-all-accidents remediation.

In this report, differentiated among are <u>errors</u> caused by humans, on all societal levels; <u>failures</u> in physical systems, subsystems, and components; and <u>occurrences</u>, possibly leading to a loss from elements of the geographic environment, such as wind, storms, rain, snow, hail, dust, heat, freeze, humidity, glare, darkness, and so forth. The significance of an error depends on the severity of any loss it creates. A railroader might err in pushing the wrong selection button on a soda-dispensing machine or in running his movement having great kinetic energy past an absolute stop signal having rolling equipment immediately beyond it. (See also <u>Severity</u> in appendix B.)

Physical components such as relays, valves, and steel fastenings have quite delimited inputs and outputs and thus dimensions of failure. The structural failure of a metal component is something about which engineers have no difficulty agreeing after analyzing with well-developed techniques. Nowadays, severe failures of large metal structures such as bridges result in an exacting forensic engineering delineation of physical causes (Petroski 2004). Similar delineation does not exist for the catastrophic errors of a human actor, behaving in ways influenced by myriad dynamic and dependent inputs and sometimes changing desires for outputs. As Wiegmann and Shappell explain, even the matter of operator fatigue is a quality not readily agreed upon by analysts. Its assessment involves not only the operator's recent personal history such as when he went to bed and for how long but also any dependent factors such as experience, tempo of work, and duration of work. For such reasons, in accident reports, human factors causes are not actually causes but, instead, brief descriptions of errors and accidents. (2003:15). (See Catastrophic, Dependent in appendix B.)

Severe geographic occurrences are not always the root cause of loss. Natural disturbances can be made worse by humans, sometimes into a mega-catastrophe. For example, in 1984, both Ethiopia and neighboring Kenya experienced natural, periodic, severe drought. In Communist Ethiopia, having a Stalinist-style, extreme central planning, a famine resulted with many tens of thousands of deaths from starvation. Drought deaths did not occur in Kenya. The political leaders of Ethiopia, not nature, caused the unnatural famine (from Gamst's research in the Horn of Africa). So-called Acts of God, and "freak accidents," are often excuses made by those in public and private authority who do not develop or mobilize resources to mitigate or prevent recurrent occurrences, of small and large scale. (See Cause in appendix B.)

A working definition of human error could be: A human action or inaction exceeding a prescribed limit of allowable adequacy. Error may or may not result in a loss. Loss includes injury and death to humans; damage to property, environment, and business and government procedure; and diminishing of business and government well-being, reputation, and good will. Error is usually recovered in time to prevent loss, and error could have dependencies intertwined with other events. (See definitions appendix B, Dependent.)

One should not facilely blame human error on "the system" or "the organization," both faceless constructs and useless conclusions. On all levels of any social system, living humans execute actions, including errors. As Meister explained a third of a century ago: "System-induced error, therefore, describes errors made by personnel which result from inadequate design of the overall system" (1971:23). Moreover, "a major cause of user [human] error is the error 'built into' the system during its development by inappropriate design practices" (Meister 1971:21). The higher level of human error also obtains for inadequate management, by live managers of a system or organization. Kletz adds, "institutions and technology have no minds of their own and cannot change on their own: someone has to do something" (2001:4). Of course, an analyst could usefully posit system and organizational pressures, as well as those from the price-making market and from formal and informal politics (i.e., from government and from one's membership groups). These are faceless pressures.

Focus on the individual reflects an underlying pattern of values and norms in Anglo-Saxon culture. We consider society as an aggregate of individuals as we deemphasize any saliency of collective actions and responsibilities. As Michael Piore explains: "We as a society are committed to individualism. We try to understand society as an aggregate of its individual members and the economy as a collection of individual producers and consumers. . . . We . . . reject social theories predicated on the idea that human beings understand themselves only as a part of cohesive groups" (Piore 1995:7, 24; 1996). Indeed, how can we comprehend an individual's actions (and thoughts) apart from his role network of social relations and the guidance of his culture, which provides the scripts and cues for enacting roles? Individual behavior is bounded in its "freedom."

"The system failed" is the mother of all excuses and eschewing of any human culpability. A system is merely a conceptual abstraction for encompassing and comprehending information. A system error stems from the errors of persons responsible. A social system is a social organization, or suborganization, having a social structure designed and managed formally and informally through overt and covert human actions and inactions. Socially interacting incumbent persons populate any human-related system with reference to its particular cultural norms, values, etiquette, and goals. The copout of "system failure" prevents any consideration of the natural levels of error in a system. It is often a management and sometimes a regulator excuse. Imbedded in social systems are human-machine systems.

Perhaps, as Tom Dwyer holds, all accidents that managers in a business organization cannot control (and cannot attribute to system error) they classify as the error of an individual on the point of action. Thus, actors further up the organizational hierarchy become defined as nonactors. "Through such processes victims are blamed. . ." (1991:303).

Sarter, Woods, and Billings, note that experience with highly automated systems confirm that automation has an effect on error. Error involving automation is not system error, however. The impact of automation is different and more complex that anticipated. Automation does not just reduce but also changes workload and errors. Advanced automation seems to lead to change of a qualitative and context-dependent nature, instead of quantitative and uniform in nature. Accordingly, unexpected error problems arise from automated systems not designed for cooperative team interactions with humans (1997:1927-1928).

Just what is the nature of human error, and just who is capable of erring? In the conceptualization of Ernst Mach, human errors are just human behavior and not distinct from other behavior. In his influential Erkenntis und Irrtum (Knowledge and Error), Mach says “Knowledge and error flow from the same mental sources; only success can differentiate one from the other” (Mach 1905:84). Now that's flying at his Mach 2, or better: human error cannot be differentiated fundamentally from ordinary human behavior.

In other (Machian) words, knowledge and error represent two aspects of the same phenomenon. To have knowledge means to be sure that what has been expressed is without error, i.e., actually correct. What we think, speak, and act have different amounts of success. Here success includes correctness, i.e., freedom from error. Such success we can understand by its contrast with the mischances that menace an assertion of knowing something. Railroad employees, like other humans, necessarily make errors in understanding and reacting to the world in their thoughts and actions. A large source of error is from knowing information customarily successful, for action in, say, frequent situations B through F. The railroader applies this information to novel situation G, inappropriately because of familiarization with now irrelevant (extraneous) procedure and with dissimilar experiences from past situations B through F. He thereby produces an error. The knowledge for use in situations B through F and for erring in situation G has the same source. The difference is the Machian success.

Wagenaar and Groeneweg illustrate an aspect of the Machian explanation in their analysis of 100 accidents at sea, which "shows that human errors were not as such recognizable before the accident occurred. Therefore general increase of motivation or safety awareness will not remedy the problem" (1987:587).

To err, then, is human because erring is part of our ordinary cognition. Error is an inevitable aspect of human existence. It is part of our learning process. Logically, an operative's error cannot be something that the risk or safety manager can entirely root out. Accordingly, as professor Mach would have agreed, we have our minds full in attempting to fathom human error, and this is especially so if we futilely stick to the old assessor's tale that a consideration of human error should focus on the individual at the point of control. ("Blame it on the RCO.") The present report assesses particular human performance as a basis of assessing associated risks. Analysts usually do not consider malevolent human behavior willfully intended to bring about loss in a system as error, and it is not considered error in this report. (See also violation at the end of section 5, below.)

In 1967, Alan Swain developed the concept of Performance Shaping Factors (PSFs) for identifying any factor influencing performance of a human (see PSFs in appendix B). PSFs external to an individual are largely under the control of management and generally can be classified as follows. External PSFs include: inadequate workspace and work layout; poor environmental conditions including noise level, temperature, light adequacy; inadequate human engineering design including for selecting, sequencing, and moving controls; inadequate training and job aids procedures including not receiving adequate job information, practice, or written instructions; and poor supervision including inadequate feedback about errors and overworking through demanding work schedules. Internal PSFs are those within an individual and brought to and developed during employment by him. Given adequate training by management, the internal PSFs have less impact on human reliability than do the external. An important internal PSF is experience: "Practice and skills acquired in training and on the job increase proficiency and decrease the number of errors." The state of reaching proficiency depends on the amount of experience necessary for an occupation (Miller and Swain 1987:223-224). A redcap handling baggage requires far less experience that an RCO or an engineer handling heavy tonnage cuts of cars in public environments. (See appendix B for Experience.)

2. Error Causality

To consider who is involved in an error-caused accident delves into the very heart of the logic of cause and effect in our sociocultural system. When we contemplate who made the human error resulting in an accident, according to the nature of the event, we can range from the individual to the all-embracing society. This section focuses empirically on US railroads. The conceptualizations have wider applicability. A social system's parts are dynamically interrelated; therefore, we cannot understand these parts in isolation from the entire system.

Analysts have questioned the very utility of the concept of "cause." Concomitant variation might be more apt. Because our folk, "common sense" concept of "cause" is so intertwined with our experience, we are convinced, erroneously, that we understand it. Scientific concepts of "cause," as predicated on the required "necessary connection" between a cause and its effect, dissolve with deep analysis of this subordinate concept: we can demonstrate only that "effect" follows (has covariation with) a "cause." These ur-ideas David Hume explained in the 1700s. Hume held that, logically, "Ultimate [causes] are totally shut off from human curiosity and enquiry." Much earlier, in the 1200s, St. Thomas Aquinas laid this analytic foundation stone in Western thought, when he reasoned that any given "cause" has a chain of antecedent causes. More recently, Bertrand Russell found "cause" a "relic of a bygone age." Is the concept of cause a folk prejudice?

Since the beginnings of the modern behavioral and social sciences, analysts have known that the concept of causality as an analytic tool usually involves complexities far beyond the layman's folk or an apologist's defensive views that a single "cause" event results in a single "effect" event (e.g., Cohen and Nagel 1934; Churchman 1948). John Stuart Mill, at the dawn of the age of modern science, held that an event can result from a number of causes. Modern analysts emphasize a multiplicity of determining conditions, which collectively allow but do not ordain the occurrence of a result event. Analytic recognition of the multiplicity of contributory causes to a final event allows search for alternative conditions leading to this event. "[W]hile common sense leads one to expect that one factor may provide a complete explanation, the scientist rarely if ever expects to find a single factor or condition that is both necessary and sufficient to bring about an event. Rather, he is interested in contributory conditions, contingent conditions, alternative conditions--all of which he will expect to find operating to make occurrence of the event probable but not certain" (Selltiz et al. 1961:80-81). I would say "possible" instead of "probable."

Accordingly, following an ancient theme in Western analysis, we can hold that only rarely do accidents have just one cause or just one individual as a cause, as US railroad investigatory practice has ordained for 175 years. One current railroad policy for empowering the employee turns all error cause back on the individual. Regarding the prevention of error through empowerment of the individual railroader, a railroader explains: "Yet, as the carrier emphasizes, ad nauseam, 'I am responsible for my own safety' (on the back of the SSI and Timetable). If I perform an unsafe act, it is because (they would argue) I chose to do it. The employer is not responsible because I chose to perform the act, even though the Empowerment Policy says that I 'am empowered to refuse to perform any unsafe act.'"

Because of the intertwined antecedents of most accidents, finding a primary cause can be problematic. In short, accidents usually have multiple causes. Cause can be quite intricate, even regarding events not appearing intricate. Nevertheless, many, managers, researchers, assessors, consultants, and government regulators of railroads mistakenly attempt to learn <u>the cause</u> (a false singularity) of a rail accident. For an assessor to say that he has found an error after an accident investigation is about as helpful as an auto mechanic telling a person with a disabled car that, “There is something mechanically wrong with this car.” Finding that a railroad accident is caused by a human error (usually the man on the point of the operation) is a rather naive result of inquiry (Gamst 2004a, 2005, In press a).

In all, most accidents and near misses are the final result of a chain or chains of multiple causes. When a link in the chain of events leading to an accident or near miss is broken, that event is prevented, at the place of the break. In studying just the immediate cause, i.e., triggering event, of an accident or near miss, we might prevent the same kind of event from recurring. If we study the chain(s) of precursor--Reason's "upstream"--cause<u>s</u> of an accident or near miss, we can prevent several kinds in a set of such events from recurring. Put in a slightly different perspective, in discussing the value of searching for the root cause of an unwanted event, Wilson, Dell, and Anderson explain that fixing just the more immediate causes and any apparent causes in a chain of causation could allow the recurrence of the event. With a triggering immediate cause, the temptation is to go no further because now the analyst has a "smoking gun." When the root cause of the event is identified and treated, "the recurrence can be prevented" (Wilson, Dell, and Anderson 1993:9-11). As Wiegmann and Shappell conclude: "Ultimately, causal factors at all levels in the organization must be addressed if any accident investigation and prevention system is going to succeed" (2003:49).

Root cause analysis does not stop with the error of an operator at the point because it could well find earlier causes further "upstream" in problems of: equipment, procedure, design and design approval or regulation, training deficiency, other management issues, or other issue external to a business organization. (See USONSPS 1992 for a catholic text on root cause analysis covering the just-enumerated causes. See appendix B for the various Cause entries.)

The last of this chain of causes can be the act of a human (Reason 1990, 1995, 1997), such as a train dispatcher, conductor, roundhouse machinist, trackman, locomotive engineer, RCO, yardmaster, superintendent, and so forth. For railroading, it has long been recognized that it takes a particular alignment of circumstances (a breaching of all procedural and physical safeguards) to multi-cause an accident: “[T]he railway disaster of modern times is the more poignant and tragic because some . . . unlucky combination of circumstances can still defeat the best laid schemes, the finest organization” (Rolt 1955:12-13). As Alphonse Chapanis taught his students four decades ago: "Accident statistics compiled by insurance companies on home, street, railway, and industrial accidents are full of causes, such as carelessness, faulty attitude, and inattention. Although labels such as these appear to tell us something, they really don't." All of us are inattentive at some time. Accordingly, a finding of inattentiveness provides no clue at all regarding accident prevention (Chapanis 1965:8). This viewpoint has broadened to become a near truism in human factors and social factors (Chapanis 1996).

For decades, we have known the investigator must, "forego the temptation to place the burden of accident prevention on the individual worker" (Johnson 1980:42). It is all too human, and emotion rewarding, to fashion a so-called (singleton) human-factors outlook for blaming the scapegoat at the bottom of the chain of command, at the point of control. In US railroading, the tradition followed is blame it on the “pin puller,” “hoghead” (switchman, locomotive engineer), etc. And it is an easier, less problematic task to find a simplistic, singular cause rather than an intricately interwoven one, often reaching up the chain of command. Railroads have used and still use to a large extent adversarial investigations directed toward finding a rules violator so that he can be disciplined. (See Plea bargaining in appendix B.) Railroad managers customarily "fix" an individual employee instead of their behavior-channeling system.

As Trevor Kletz notes regarding the individual: "Sometimes people are blamed because those in charge wish to deflect criticism from themselves on to a scapegoat" (1991:167). Also, "We do not want to blame ourselves and it is easier to blame those below us that those above us." Further, "when someone says that an accident was due to human error he usually means an error by someone at the bottom of the organization who could not blame someone below him" (Kletz 1993:108). What fool of a investigator on a railroad would implicate the company's general officers? Further, regarding why accident statistics say that over 50 percent, often 80 or 90 percent, of accidents are from human failing Kletz notes: "Accident reports are written by managers and it is easy to blame the other person" (1991:169).

The customary investigatory outlook focused on the behavior of one railroader, or the occurrence of one event, obstructs the search for systemic causes in the encompassing organizational and regulatory bodies of the industry. Causes include deeds of omission, commission, and extraneousness. Causation might end in a work act but reaches back to failed, managerial practice, rules formulation, training, work organization, and engineering decisions, mostly under executive-branch regulation, generally guided by the overall federal government. An individual's error, then, might involve errors executed in the overarching system. Of course, an accident having causation at a particular level of error does not necessarily have causes in a higher level. Jens Rasmussen calls for a reconsideration of the customary error focus of assessors, on behavior fragments labeled as error. Instead, we must also look at factors in the encompassing organization for analysis of complex real life phenomena. This is especially so with developments in work brought about by linkages in advanced information technology (Rasmussen 1990).

In summation, errors could be viewed as usually systemic, with causation(s) ranging anywhere or entirely across the full societal system. The error chain could happen alone or in conjunction with physical failures and/or geographical environmental occurrences. Most errors are inconsequential but consequential ones could cause a loss, if not recovered. James Reason explains: “the commission of unsafe acts is determined by a complex interaction between intrinsic system influences . . . and those arising from the outside world. . . .” Furthermore, Reason instructs, “systems accidents have their primary origins in fallible decisions by designers and high-level (corporate or plant) managerial decision makers. . . . Fallible decisions are an inevitable part of the design and management process“ (Reason 1990: 206, 203).

3. Uses of Error Analysis

Using Reason’s insightfully heuristic analysis probes beyond the individual and the organization: “Human-machine mismatches . . . being the result of prior decisions in the upper echelons of the system. And these, in turn, are shaped by wider regulatory and societal factors” (1997:226). Reason's heuristic model of error "present the people at the sharp end as the inheritors rather than as the instigators of an accident sequence" (1995:1710). Before we can understand individual human error, then, we must comprehend all of any contributing levels overarching an individual’s initiating action. For example, at the Hinton, Alberta head-on collision of a freight into a passenger train, we find cascading errors of the involved Parliament, regulatory organization, railroad organization, and labor organizations (Foisy 1986).

Use of the concept of error should note its division into those potentially consequential and those inconsequential, that is, having no possible loss. An initiating event for a consequential error could be a rules violation, whether, willfully done as part of collectively accepted local practice (for local management’s operational shortcuts), willfully done as an idiosyncrasy for operator's gain (reducing effort, saving time, increasing remuneration, etc.), ignorantly done (“I did not know that rule”), or inadequately enacted by commission (action too little, too much, too late, too early, out of allowable sequence, ineptly performed, or some combination of these). An initiating event results in a potentially consequential error, when all of the safeguards for a system have been breached. Safeguards (which see, below, are also called barriers) can be procedural (at a red block signal with a number plate, a train must, first, stop, and, then, "whistle off" and proceed at restricted speed), physical (a derailing device on a track), or human ("I'm in doubt here; so, I'll stop the movement."). Usually no one action causes error, but preventing one action in a chain of events could stop performance of an error at the point of control.

Logically and for results, an analyst needs to ascend the hierarchy of error causation to chart any hierarchical chain of error resulting in an initiating error event. Only in the upper levels of organizations, and higher, do we come to grips with basic kinds of error. At the highest overarching level are human errors generated by leaders of a state society including its component institutions. Here we find human errors engendered in government by the legislation of legislators, judicial rulings of judges who flesh out through interpretation the skeleton of legislation, and enforcements of governmental executives often through regulators of regulatory agencies. Next, we descend to the level of error from modern organizations. Errors in organizations stem from the actions and inactions of managers on all levels, from the board of directors to first-line supervisors. Workers in teams are near the bottom of the levels of error causation. At the very bottom, we find the individual worker. His error is ordinarily not in isolation but shaped by errors from actors on the higher system levels. (For culture as used in this report, see Gamst and Norbeck 1976.)

Tom Dwyer explains, in Western societies subjective reactions often color the reality of work accidents, which are an "invisible phenomenon." The number of workers killed or injured in accidents can exceed the number of persons killed or injured by criminal assaults. The criminal assaults, however, receive the headlines. Also, in the US and New Zealand for example, more workdays are lost from accidents than from strikes. Yet, industrial accidents are implicitly treated as "unfortunate" and strikes are denounced by many (1991:6-7). Charles Perrow explains that, in industry and the military, "the social structure favors the choice of technologies that centralize authority and deskill operators and . . . it encourages unwarranted attributions of operator error" (1983:521).

As Reason explains regarding these supra-individual levels of error-making: "Only in the upper levels of the system can we begin to get to grips with the 'parent' failure types--the processes that create the downstream 'problem children'. If these remain unchanged, then the efforts to improve things at the workplace and worker level will be largely in vain" (Reason 1997:121). Since about 1970, the search for causes of accidents has slowly extended outwards in scope and backwards in time, to discover increasingly remote, often multifactoral precursors *(*Hale 1997:7). This report is a contribution to such extending.

In Reason's concepts, most active (immediate) errors of individuals or teams can be viewed as the consequences of latent (dormant) errors/conditions from an overarching (his "upstream") level. Latent errors are remote in time and space from the operator on the point who makes an active error. Identifying an active error is ordinarily only the start of the investigation of cause for an accident. As Reason concludes: Latent errors/conditions "arise from strategic and other top level decisions made by governments, regulators, manufacturers, designers and organizational managers" (1997:10). Latent errors can weaken system safeguards. Reason summarizes: "In aviation and elsewhere, human error is one of a long-established list of 'causes' used by the press and accident investigators. But human error is a consequence and not a cause. Errors . . . are shaped and provoked by upstream workplace and organizational factors," (1997:126) and, of course, regulatory factors, he notes (1995:1710). Latent factors can be from "deficient tools and equipment" (1995:1710). Although many unsafe active acts occur, very few penetrate all of the safeguards to result in a loss.

Use of a systemic explanation of error permits organizational and regulatory learning for safety and efficiency. Blaming the person on the point of an operation does not afford such learning opportunity. Hale explains: “Organizational learning requires that event analysis traces the causal factors and determinants of an event further back into the past than before, and further up the chain of management control. At each step it needs to ask whether those responsible for hardware, people, rules and procedures, communication and organizational structures had taken suitable decisions to select, prepare, instruct, supervise, monitor and improve them. Such questions lead into the heart of the safety management system. . .” (Hale 1997:9).

For broad learning, analysis of the roots of an error cannot not stop with an individual error or a physical failure. A complete root causes analysis moves as far up the chain of responsibility as necessary to include all of the roots. Root causes (usually a plural concept) are the most overarching or "upstream" events for an accident: their correction should prevent repetition of the accident. Root causes usually flow through intermediate causes to a triggering/end cause/event. A triggering event is usually a manifestation of a root cause further upstream, behaviorally, socially, physically, or all inseparably. The analytic representation of an accident's causes in a formal logic tree is a subjective process because many reasonable patterns are possible for its depiction in a diagram but only some are selected.

Often, for reasons of limiting the scope, either for ease of closure or political pragmatism, analysts make a conscious decision not to trace back to ur-roots of cause. This action is an invoking of a subjective closure rule. Thus limiting the scope does not lead to effective results for business efficiency and safety or for regulatory actions. In considering a regulatory agency's invoking of a closure rule, we should realize that as a bureaucracy, the agency takes on a life of its own, functioning as an instrument of power (Perrow 1986:5-6; Heyman 2004:488-494). As the Environmental Protection Agency notes: "Root cause analyses should focus on an exhaustive and diligent identification of all causal factors to properly identify long-term solutions" (USEPA 1999:45).

Nothing presented in this report advocates abandoning study and analysis of individual error and near miss to promote safety. The point made is that individual-oriented study alone usually fails to see the broader error forest of overarching earlier levels because of narrow focus on error trees of recent actions on an individual level. As an RCO notes: "In my own near-miss experience, I was on the [RC] locomotive, pulling a long heavy cut and trying to pull as close to the fouling point as possible. I had some experience with that, but I made bad decisions, saw that I wasn't going to get stopped in time to avoid a fouling movement, and applied the emergency brakes via the box [RCD]. Then I sat [in the RCL cab] helpless as the movement slid to within inches of a collision." As a railroader notes regarding an accident involving a small loss of property: "Investigation revealed that one of the local managers was attempting to instruct an unqualified engineer on the operation of the unit, and accidentally throttled up the DP remote causing it to surge or lunge."

4. Reflections on the Nature of "Error"

Reducing the active part of the complex of human error chips away at the tip of the accident-causal iceberg. But because of our penchant for feeling accomplishment by such facile chipping away at individual human error, we continue to do so. In any event, contemplating the latent errors is arduous, time consuming, might get one “dehorned” on the job, and could stir up a political hornets nest.

Usually, error is not merely attributable to the point-person in a chain of events leading to that error. By focusing on an individual’s behavior, the correction for error becomes restricted to personal remediation. Accordingly, in this myopia of individual behavior, practitioners believe error correctable largely by admonishments, discipline, advising, training, and behavior modification, to condition error-free individuals for future situations. However, regarding personal remediations as the correct-all for operator error: “The evidence from a large number of accident inquiries indicates that bad events are more often the result of error-prone situations and error-prone activities than they are of error-prone people.” (Reason 1990:129).

Quantified data collected from the common viewpoint and practice of blaming one employee, or one event, for an accident do not provide valid and reliable information for accident and risk assessment. Above all, for safety assessment of new rail operating technologies, arrangements, and procedures of work, use of past flawed accident data cannot support the well-established railroad practice of simplistically blaming just one employee or one event for an accident.

When pointing at error, we must realize that we usually look through the wrong end of the telescope. After an accident, investigators and journalists customarily point to individual error as the cause of the event. Individual error, however, is usually consequence, not cause. Because the generators of most error are usually further up the societal hierarchy, fingering the individual at the point of control must be the start of the inquiry into accident cause, not the end. Makers of safety-critical errors can be arrayed throughout a societal system. The higher in the system errors occur, the more widespread and repetitive the consequences for safety on the individual level. "Blaming it on the pin puller" is part of a hoary railroad managerial problem and not part of an investigative solution.

Despite claims for scientific objectivity in the range of concepts of error, we may view error pragmatically as a variably culturally relative set of ideas and methods for ordering reality. This ordering allows a sense of security that earthly hazards have been or can be coped with. As an ordering of reality, error is part of our society’s worldview, a cultural ordering of reality. Developed over time by various groups in society, error consists of sets of learned views, among which individuals can choose opportunistically. Culture restricts the choices, however.

Some analysts have long recognized that value judgments influence both the categorization of basic constructs and the "evidence" for them when encompassing sociocultural variables, such as risk, error, and accident (Lowrance 1975, 1976; Mayo and Hollander 1991). Error analysis, then, is not a kind of Immaculate Conception, not fouled by pressures in the real social world. It cannot be free from "extra-scientific" values. Because perceptions of and reactions to error are mediated through learned cultural constructions guiding thought, error depicts, assesses, and accesses some part of reality by culturally delimiting it. One's learning and its consequent development, by their conceptual inclinations, condition any formulation of error. At times, error perceptions and reactions are laden with the values of certain groups privileged in some way or who want to exert social control regarding an error matter. Further, managers and analysts within a business, union, or regulatory organization respond to the rewards and negative sanctions of that body, as well as to the conventions of their top management. (As a medium-level rail officer told me: "I want to hitch my wagon to his star.") In other words, error cannot be fully comprehended apart from norms, values, and political processes including those of control: "blame it on the RCO?"

The goal of scientific investigation is objective knowledge free from bias. But how can any person be free from the biases of his continuous enculturation? Any error investigation, then, is to varying degrees necessarily subjective, from an investigator's own experiences and expectations and from the experiences and expectations of the producers of concepts, designers of methods, formulators of assumptions, and gatherers of information used. Accordingly, the enculturated values, norms, and status of the error assessor guide his selecting of the matters chosen for study, conceptual framework, methodology, and questions he asks. Assessment outlooks and agendas also result in part from a person's social position in society (one's status). Our social position channels our focus on what is important and how important. Unequal social positions fostering different outlooks thereby obscure some of the social and physical environments from us. Such a position in social groups and networks channels what we comprehend, including to what extent, and the nature of our communication of this comprehension. Certain groups, for example, railroad managers or, somewhat separately, railroad regulators, with particular outlooks and agendas generate hypotheses and methods for handling error information. At times, various sectors of the public mobilize to apply pressure to an industry, its regulator, or those having legislative power over the industry. In short, error assessors cannot posit procedures mitigating error by venturing that their conclusions flow inevitably from "the hard data." Exactly what and whose hard data?

In all, error relates to ideas from politics and political control, especially regarding accountability, responsibility, and, eventually, blame in some form. Consequently, "blame it on the RCO." Why are some errors disregarded or minimized as such, and others reacted to with great regard and amounts of alarm? The answer is certain groups select, from their collectively held beliefs, particular errors among others for value-laden reasons germane to them. That is, genuine errors exist in the real world, but the value systems of various power-wielding societal subcultures mediate human contemplation, selection, and reaction regarding them. All positions on error have subjective cultural underpinnings.

It should be noted that some safety analysts delve into semantics and say "I am not interested in fixing blame, only in finding causes." Indeed. As Kletz explains, "The word 'cause' implies blame and people become defensive" (2001:4). After all, a dictionary definition of cause is a person or thing voluntarily or involuntarily bringing about an effect or result.

If error assessment, in itself or as a part of Human-Reliability Assessment, is to have merit for policymaking and managing, we must recognize not only the physical and procedural but also the political, social, and normative aspects of a technology used in work.

Discussion of error cannot be solely in the “scientific” domain because, in the final analysis, all such discussions are grounded in epistemology, always a cultural reflection. (See appendix B on Cause.)

5. Labels of Error, Violation, and Sabotage

Different analysts variously classify human errors on the individual level. Because conducting an assessment of human error on the level of the operator alone informs little about accidents and their reduction. Such assessment is a telling example of "a little knowledge is dangerous.” Moreover, however, elegant the error taxonomy, a particular error taxon can originate in different causations and different taxa can share some of the same causal elements (Reason 1990:11). Furthermore, in our development of error taxonomies: "With each successive level of classification, we move further from immediate surface 'data' and deeper into the realm of assumption and conjecture" (Reason 1990:12). Error analysts having an engineering orientation should not feel that any "exacting" error typology will allow them to find the Holy Grail of error assessment, quantifiable taxa. Humans and their behavior, from their highly variable social interactions and enculturation, are not artifacts, with their physically quite limited characteristics and attendant values.

5.1. The Guttmann-Swain Error Typology

A useful tripartite typology of error, of value is a classification of individual error developed by A. D. Swain and H. E. Guttmann (1983; Bahr 1997:152-155) and adapted for use in this report. The two main types are omission and commission.

1. Errors of omission, required acts not performed, includes nonviolation rules infraction;

2. Errors of commission, required acts performed too little, too much, too late, too early, in the wrong sequence, imprecisely, or not completely, includes nonviolation rules infraction; and

3. Errors of extraneousness, acts not required and done instead of or in addition to a required act, wrong acts, includes nonviolation rules infraction.

5.2. The Wiegmann-Shappell Error Typology

Another useful tripartite typology of error has been developed over time by several analysts. Rasmussen first posited three taxa of human performance, skill-based, rule-based, and knowledge based (1982). These taxa were expanded upon by Reason in his modeling (1990:42-44, 1997:68-82) and reworked by Wiegmann and Shappell (2003:50-54). In the third version of 2003, we have three basic kinds of errors. This third version is part of the Human Factors Analysis Classification System (HFACS) and is as follows:

Skill-based errors occur without much conscious thought. These are deficiencies during highly routinized tasks. Three subsets exist, attention deficiencies, memory deficiencies, and technique deficiencies--which might stem, in part, from innate abilities and aptitude. Errors of these kinds include, breakdown in visual scan (hand signal), task fixation (attention capture), inadvertent use of a control , poor technique , over-reliance on automation, failure to prioritize attention, task overload, forgotten intentions, failure to see and avoid, and distraction.

Decision errors are intentional behaviors proceeding as planned but the plan is either inadequate or inappropriate to the situation. Three subsets of these deliberate, conscious acts exist, procedural (rule-based) errors, poor choices (knowledge-based), and problem-solving errors. Procedural errors exist in rule-bound military and commercial aviation (and, similarly, exist in the railroading). Not every operating situation has a corresponding procedure to apply. So, sometimes a choice must be made, good or poor. Rarely, a procedure or response option does not exist. Then, a novel solution must be developed quickly. Errors of these kinds include inappropriate procedure/move, inadequate knowledge of systems or procedures, exceeded ability, and wrong response to emergency.

Perceptual errors occur when an actor's perception of the world differs from reality. Visual illusions or deprivations can occur in darkness, behind a barrier, and vision-obscuring or -distorting weather. The actor misjudges speed, distance, and other qualities. Errors of these kinds include, from visual illusion (motion, after effects), from spatial disorientation, and from misjudged distance, speed.

A problem with this typology is, although from a mode of transportation, it does not fit all of the PSFs found in railroading but it fits much better than error typologies and models from the process industries (which see, in appendix B). Are error models and typologies to varying extents industry-specific? An issue is the orientation of such a developed typology focusing on the operator on the point. This in an error typology originating in that of Rasmussen who thinks we could well eliminate the concept of error (1987). Wiegmann and Shappell, however, are advocates of and use James Reason's multi-cause model of accidents.

5.3. Violation, Sabotage, and Terrorism in a Typology

Various writers add the concept of violation to taxonomies of error. The following discussion is from Gamst's study of railroading. Violation, or intentional non-compliance, i.e., willful breach regarding authoritative rule, practice, or procedure. Violation might not be an entirely useful dichotomy, however, because it is based on intent, in the real world perhaps on a continuum with error rather than a different type of behavior. Certainly, if an intentional violation gradually becomes locally routinized, it, thereby, progresses along a continuum of degree of intent. Another thought, Is an act a violation if it breaches no formal rule or practice but violates common sense? How about, at the last interval, an employee puts his foot inside the coupler on the engine he is riding to open/adjust the knuckle just before it couples to a standing car?

Assuming its separateness from error, violation could be routine and part of a local informal accord. That is, they are well intentioned with a goal of increased productivity, for the good of the business and the involved employees. Making a blind shove instead of doing the required walking is a way of increasing productivity. As such, they could be tolerated or even encouraged by local authority (shortcuts across formal rules "to get the work done"). Accord violations differ in their genesis from violation with an overt contempt for the rule.

Some contempt violations involve conducting a task in a more adventurous way, "grandstanding," "hotdogging." Contempt violators intend the rules infraction but not always any consequent loss. A switch crew could kick a car with great velocity into a "hung up" load to move it into the clear of a lead track Thereby, they cause damage to the load which cannot be seen until the customer unloads his carload--of glassware.

The consequences of accord or contempt violation could be the same kind of accident or near miss. Either violation, as with errors, could have catastrophic consequence on a railroad, e.g., the collision of two freight trains or cuts with a release of poison gas from ruptured tank cars. However, the accord variety is a bending of the rules by those with a good knowledge of the rules' operational boundaries and, thus, having a lesser chance of accident than with contempt violation. Either kind of violating often stems from doing a physically (e.g., saving walking, time) or mentally (e.g., omitting procedural steps) easier way of working, in short, saving exertion. A good "rail" does not consciously take chances with others' safety but can take short cuts across the rules, with a personal, or collective, or supervisory judgment that such action is safe. (For some of the complexity and the range of violation behavior see Gamst 1989b. For the jargon "Rail" see appendix B.) As with errors, violations are not just behaviors of the man on the point of operations but also of persons on the various overarching levels. "The rules" of the corporate game, however, are not always as precisely formulated as the operating rules. Thus, a railroad's apical management could estimate that it will not need a large number of new operating employees in the next two years and, thereby, save on training costs but suffer from a self-induced crisis when it cannot crew all of its trains and engines during an increase in traffic.

Shappell and Wiegmann discuss a distinction between routine, similar to that just discussed, and exceptional, to a greater extent, violations (2000:5-6; Wiegmann and Shappell 2003). In railroading, these types are polar on a continuum and not dichotomous.

On railroads, routine violations are just that, they become routinized into informal and sometimes condoned local practice. With an informal local, shadow "code" of routinized violations the consequences can be wide ranging in rail operations. Reason holds that "many violations are prompted by procedural over-specification" (1995:1715), a point with which many railroad employees would agree. We cannot railroad without the specifications, however. By and large, the view dies not apply to the industry.

Regarding violation, sooner or later Bozo Texino's dictum obtains. The fictive "Bozo Texino," the ubiquitous alter ego of the "rails," chalks on the sides of boxcars: "You can get by with violating the rules every time/ Until the time you don't." This is the über-rule in railroading. It applies to officers, supervisors, and rank-and-file employees.

Accidents and near misses involving humans and rolling equipment on railroads are, of course, not new kinds of events. They have existed since the dawn of steam locomotion on railroads and were extant during the two previous centuries when livestock pulled the rolling stock along the track. For example, ca. 1830, the Baltimore & Ohio had an accident in which the (horse) driver of a rail-coach fell fatally to the rails. For another example, during the period of 1813-1833 on the 3.5-mile colliery railway from the coal pits at Middleton to Leeds, England, four of Blenkinsop's locomotive steam engines operated. By 1815, the four engines replaced the last of the previous horse power. The pioneering steam trains killed at least six members of the public, including persons saving time by attempting to beat the train to a point of crossing the track. With available post-accident data, it is frequently difficult to tell if a "civilian" hit by a train was attempting rail suicide.

Beyond contempt violation is sabotage, where the actor intends a loss through willful infraction of rules and laws. Such action is infinitesimally rare from a railroad employee. Sabotage has come from the malicious outsider's destruction of crucial railroad property. For example, as previously done, an outsider breaks a switch lock and misaligns a main track switch, uncouples a train at some mid-point and turns the angle cocks on the two parted cars to prevent any brake application, or removes spikes holding a rail in place. The outsider saboteur, however, might be only vaguely or not aware of railroad rules and procedures but would act mechanically logically to create property damage or other loss. Suicide by railroad could be considered a variety of sabotage. Terrorism could be a variety of future sabotage, perhaps catastrophic, on the largely unsecured railroads.

Appendix F. The Range of Variation in North American Railroad Switching

Note: Some human-factors literature deals not, as traditional, with an individual operator but with a team of operators, as in process industries such as a power plant or petroleum refinery. In such studies and also with individual operator studies, the analyst investigates layout of (fixed) equipment and workstations crewed with reference to these fixities. Among other things, in team studies, the analyst reviews amounts of compatibility among team members and the fixities. In switching, no fixities of rolling equipment or workstations exist. All are dynamic, in myriad, transient permutations. Accordingly, physical anchoring points in analysis are ephemeral.

1. The Open Physical Environment of Switching

Most human factors studies of a workplace discuss environmental elements such as levels of illumination, noise, and temperature as well as flow of fresh air, exhaust venting of any dust and toxins, removing floor clutter, the condition of restrooms, and the amenities of the cafeteria. Flow of work past machines and operators is analyzed along with the nature of firsthand supervision. None of these environmental elements apropos of fixed plants obtain in railroad switching's outdoor, all weather, mobile, 24/7/365, highly dynamic moving of heavy equipment on track, sometimes in thousands of tons per single movement. In a word, railroad switching is different.

Human factors applications also abound having physical barrier safeguards to prevent or lessen an accident in a plant. Gilbert Marshall discusses these barrier safeguards, in his "Principles of Machine Guarding." The safeguards include enclosure of a machine or its moving parts, interlockings where a body part cannot be inserted when a machine operates, and automatically imposed safeguards (Marshall 1982:341-369). These cannot obtain in rail switching because the essence of the work is to move, in the open, huge rolling equipment, singly and in varying numbers. As Kjellén notes regarding certain industries: "Traditional safety measures such as guards, will in many cases be unfeasible" (1987:172). Marshall also lists for discussion "fail-safe brakes" as a physical safeguard but says that "they can hardly be called guards" (1982:352). This is because when a so-called fail-safe brake fully stops all motion, a loss might have occurred within the stopping duration.

In North America, railroad switching occurs within the confines of a central or satellite yard of a terminal, from a main track both within and outside of main-track yard limits, and in settings of industrial yards and spurs apart from a terminal's central yard. Both road freight-train crews and yard switch-engine crews do switching (marshalling). Crews conduct switching every day of the year, around the clock. Thus, switching is in fair weather, subfreezing cold, torrid heat, intense wind, rain, snow, fog, and blowing dust, including in poor-illumination and pitch-black settings. At times, background noise can drown out sounds of rolling equipment. All tracks are "live," i.e., can have rolling equipment moving in any direction at any time by one's own or another engine and, accordingly, a track must not be fouled by one's body except when required by a task. Clearances between tracks are close and, at switches, narrow down to space not permitting presence of a human body. "Kicked" free rolling cars are usually quiet in their approach and thus railroaders sometimes call them "silent death." A single car's weight can range from about 23 tons empty to over 130 tons loaded and may move in "cuts" (drafts) of several hundreds to many thousand tons and in lengths of up to a mile, or more. Footing can be insecure, with rough crushed rock ballast, depressions in the ground, debris strewn between tracks, and possible icy and slippery surfaces. Configurations of locations to place one’s body on different kinds of freight cars vary regarding grab irons, foot stirrups, ladders, and platforms.

Operating railroaders must react to and attempt to control myriad kinds of events occurring, some intruding, into a railroad’s ubiquitous, open physical environment. In the sciences, a closed system is considered as isolated from the environment. An open system is not isolated. The railroad switching environment is an open system. As such, it comprises a set of elements forming a connected whole, which is not a bounded, sealed entity. In other words, the set is not demarcated to consist of a finite (hence, predictable or knowable) number of interacting elements. In the open railroad system, because of later-occurring, varying numbers of often-unpredictable, impinging conditions, a final state cannot be predetermined by initial conditions, say, a train's consist, tonnage, authorized speeds, track occupancy authority, and crewmember experience. Thus, a particular final state can be reached from different initial conditions, and the same initial conditions can result in different final states.

2. The Switching Tasks, an Overview

Many variably sequentially interacting and simultaneous tasks compromise a crewmember's situational awareness while on the ground switching. A crewmember responds to many cues, some gross, some subtle, and some for which he might not be fully or at all aware.

Switching tasks include reading and comprehending a switch list (of cars to be moved to a particular location); giving and receiving manual signals by hand, lantern, and fusee (flare); giving and receiving voice-radio signals; monitoring voice-radio traffic to help maintain situational awareness; hanging on to the side of rolling equipment; climbing on and dismounting from such equipment; applying and releasing car hand brakes; aligning track switches and derails; kicking cars; dropping cars; riding cars to a coupling; reading car identifying letters and numbers; judging the speed and closing distance of cars to be coupled to other cars, often while riding on the side of the lead car of a movement; observing close clearances and obstacles such as switch stands, rails, gates, and walls; safeguarding pedestrians and automotive vehicles in the vicinity; handling hazardous loads; knowing the location of other crewmembers and other impacted railroaders; thinking about particular chess-like moves in the efficient switching of cars; thinking about an overall schedule for the day's work to be done; assessing movements of other engines, road trains, occasional nonrevenue equipment such as roadway vehicles on flanged wheels, and fouling rubber-tired vehicles; always thinking about tasks with reference to the complex code of railroad operating rules; at rare times, being the person on the scene who has to attend to an injured or killed human, employee or other; and walking and standing in the dynamic, open switching environment. When no yardmaster is on duty in a yard, a conductor or engine foreman engaged in switching might also work as a footboard yardmaster. Then, he must direct, other movements such as trains and engines, including their rail traffic control, entering, leaving, or performing work in that yard, as well as monitor the voice-radio for any problems. When a Remote Control Zone is established, he must also provide protection for or respect that zone.

Switching tasks of one individual might be dependent on the actions of another person on the same crew, on a different crew, or of a railroad employee not on any crew, or, perhaps, of a nonrailroader, e.g., a "civilian" waving his arms violently near the tracks, falling across a track, or fouling a track with his vehicle. Thus an operator's error resulting in an accident or near miss could be, in whole or in part, from an error of commission, omission, or extraneousness or a violation by another individual or team. (For Dependence, see appendix B.) Accordingly, for every case, an analyst cannot simply decompose an accident or near miss into the actions and HMIs of a single railroad employee. The actions might be dependent upon the actions of another or others. Dependency could also be considered as an aspect of the open environment of railroad operations.

3. Human Interaction with Tasks and Physical Environment

(This subsection benefits from discussions with nuclear engineers who have assessed power plant and other nuclear reactors.)

In switching work, the potential events could be considered randomly or almost randomly occurring. Randomness is from the huge range of human interactions with the many above single task and environmental variables and with the interfacing combinations among these variables. Accordingly, with these dynamically combinative variables as initiating events for a switching error, no overall structure for potential events in the rail world can be readily ascertained to use in the calculation of probabilities of human error and dependencies related to an error.

In comparison, when studying human error and consequent risk regarding work with nuclear power plants, we find the physical environment is one of a secured, sequestered, highly managed and controlled, and industrially hygienic setting. Moreover, many possible operator errors and rule bendings and breakings in performance of tasks are “locked out” in the design of the human-machine interface and also recorded. For nuclear reactors, the number of combinations among human tasks and physical environmental factors is far more limited than for switching. Consequently, the number of potential kinds of error-producing events from performing human tasks and interaction with the physical environment are far more limited than for switching.

A railroader notes: “I am continually challenged when it comes to applying mathematical models to predict probability for human error in the railroad industry. The variables found in the railroad work are too variable to give me confidence in a result based on mathematics. I can see where plugging a number in somewhere along the equation to account for these uncertainties may address the concern. Knowing where and when to put the number in the equation is important to avoid skewing the result. The dynamic railroad environment does not lend itself to the techniques used in other industries.”

A railroader comments on the necessary local variations of switching practices because of particular local characteristics: "With both ends of the yard a 1% down grade, kicking cars in that yard meant revving up and getting a cut up to 15 mph, and then maybe the cars would clear in the track. Of course, they were just as likely to come right back at you at the same speed unless tied down with good handbrakes. After kicking one car, you always had to pull forward because of the grade."

Similarly, an RCO reports: "The RCL accident had everything to do with the more subtle aspects of car handling like which tracks do you have to watch closely because the cars will come back at you. I always point out these sorts of dangers to the students but then they give you that glassy eyed look that tells you they won't remember anything in the morning."

A railroader reports regarding an RCL roll out of cars: "[Job designation and location] struck two cars that had rolled out of an adjacent track. After shoving a cut into Track [1] to a spot on the west end, the crew cut off four excess cars and set them to Track [6]. While pulling out of Track [6] with the light engine, crew was riding on rear platform and did not see that the cars they had left in Track [1] had rolled out. The RCL struck the two cars while moving at an estimated speed of 8 MPH, derailing the robot and the two cars."

In all, railroad switching consists of a large number of frequent, cognitive and manual <u>active</u> interventions in the personally life-critical, operationally safety-critical work process. The interventions are not <u>passive</u> monitoring as frequently done in large-scale, automated process industries (cf. Moray 1997:1944-1949; Sharit 1997:316-317). Moreover, rail switching interventions are usually contingent upon and have consequence for similar interventions of others. (See <u>Process industry</u> in Appendix B).

4. The Ever-Present Potential for Railroad Catastrophe Including in Switching

America's railroad industry constitutes a highly dispersed, potentially catastrophic worksite, with respect to its movement of trains and engines and the switching of rail cars. This linear worksite branches for 169,000 miles across forty-nine states, and pierces through the heart of most communities of any size. Operating crewmembers directly perform the potentially catastrophic work on railroads. (For <u>Catastrophe</u>, see appendix B.)

Regarding the harmful results of railroad catastrophe, the U.S. General Accounting office reports, "thousands of people are evacuated from their homes as a result of the hazardous materials that are released during train accidents" (USGAO 1997:3). Between 1978 and 1995, about 261,000 persons were evacuated from their homes, nationwide, because of releases of rail-related hazardous materials. "Concerns remain about evacuations because the volume of chemical traffic increased by over one-third from 1976 to 1995," the GAO concludes (USGAO 1997:4, 36). As <u>Railway Age</u> editor John Armstrong writes regarding the issue of safety on railroads: "there's always a 'knock on wood' realization that a combination of events and circumstances can lead to a wreck of proportions sufficient to tarnish the best of records" (1982:32). John's experience led him to say that rail accidents come from a combination of events source, personal discussions).

The work of operating crewmembers is safety critical and involves mental and manual responsibilities and tasks for the mastering and safeguarding of movements on track of rolling equipment having great kinetic energy. The movements, although indeed potentially catastrophic, are only rarely disastrous because of these crewmembers' proper performing of tasks and proper fulfilling of responsibilities on the job. At its core, such safety-critical performing and fulfilling depends upon learned and maintained judgments and skills. Maintaining the experience-based judgment and skills for operating crews further lessens unacceptable catastrophic risk, thereby protecting railroader and public health and safety. For <u>Learning</u>, see Appendix B.)

Appendix G. Typical Locomotive Engineer and RCO Training

By labor agreement, training to become a locomotive engineer is open only to and mandatory for all post-1985 trainmen (switchmen, brakemen, and conductors). Training prior to becoming a student engineer (also known as a fireman-in-training) or prior to becoming a locomotive servicing engineer (also known as a hostler) is that for trainmen. This prior training is "licensed" by a railroad company by issuing a current rules card to the instructed trainman (rules, etc. passed). Then, he is eligible for student engineer training as need from business conditions (traffic levels) warrants. I find no standardized minimum required period of prior service, as such, as a trainman for training as engineer. However, the trainman's training can have a duration of 14 weeks, as in 1B, below. For some of the variability in duration of training, see 3C, Question, below.

Some railroads are considering reducing the training time for locomotive engineers.

The explanation, in 3, below, is for the FRA's "class of service" labeled "01-Train Service Engineers" (locomotive engineers) and is typical for various railroads. Discussion for level 02 for "locomotive servicing engineers" (hostlers), of locomotives without cars, and 03 for "student engineers" (learners) is included below.

1. Typical training for train service comprises:

1A. A 3-week (18-day) course in classroom, including 4 days of field training around live equipment. Next, 7 weeks on-the-job training. Then, 2 weeks classroom conductor training. Finally, 2 weeks of on-the-job training for conductor.

1B. After completing the 2 weeks of classroom conductor training, the student must complete, with a minimum score of 85%, a final exam of multiple choice questions. A student must complete a safety exam before the first field trip.

2. Typical training, as a student engineer, for locomotive servicing engineer (hostler) comprises:

2A. First, a 1-day classroom and field session to acquaint the student engineer with the locations and functions of locomotive components and servicing facility rules.

2B. A minimum of 6 8-hour student trips under an instructor engineer are required before the student engineer's testing for skills performance and for knowledge of the physical characteristics of the track over which he will operate. Finally, the supervisor of locomotive engineers conducts a ride check for skills performance.

3. Typical training, as a student engineer, for train service engineer (LE) comprises:

3A. First, the student must be certified as a student engineer or a locomotive servicing engineer.

3B. Second, at his work location, the student attends formal classroom training and, following this, on-the-job-training. This home-terminal training has an unspecified duration.

The total duration of "student trips," presumably both before and after training at a training center, however, lasts 4-5 months. After the home-terminal training, the student goes to the training center. On one railroad, the training center is on the campus of and is a part of the curriculum and faculty of an accredited community college. At the center, classroom and locomotive simulator training is for at least 15 days. Thus total training varies from 4.5 to 5.5 months.

3C. Daily instructional quizzes are given at the center. A multi-section final exam requires a minimum passing grade of 85% on each section. The sections comprehensively include: mechanical and electrical matters, wayside signals and signs, track warrants and bulletins, air brake and train handling rules, operating rules including for safety and hazardous materials and federal regulations, and locomotive simulator (on a modern locomotive simulator). Finally, the supervisory officer for locomotive engineers conducts a ride check for skills performance. The simulator may also be used for this purpose.

3D. Question: Is there a minimal time of service as a conductor before one can take promotion to locomotive engineer? This varies by railroad and by the manpower pressures on the railroad but one answer from a person who knows is: "The time frame was one year but lately one month can suffice." A second insider answer was: "Policy changed when they ran short of engineers. Will promote conductors immediately. Total process, date of hire to promoted engineer, 9 months!" An earlier response from a railroader on the 'ZXC RR' said that the railroad was short of road freight conductors. So, it used student conductors still in training to work as conductors on the road including over the 'BBB' mountain. On the 'AAA' mountain, an officer, from a "pool table" division being used as a conductor erred greatly in the required use of retainer valves on the automatic brake system. His train ran away downgrade but the engineer recovered before an accident occurred.

3E. Note: The contemporary training sequence for locomotive engineers is as follows but the promotion to Remote Control Operator (RCO) is not a requirement: 1, switchman/brakeman; 2, conductor; 3, RCO; and 4, locomotive engineer.

Promotion to RCO can be force-assigned on the junior-most men on the seniority list if sufficient senior men do not choose qualification as an RCO. When a trainman whose seniority (or lack of sufficient seniority) requires that he work as an RCO and he is not certified for this position, he may not work in any position, including ordinary switchman/brakeman, until he is certified.

4. One variety of typical training, for Remote Control Operator (RCO) comprises:

4A. First, candidate must be certified any one of the following: student remote control operator, student engineer, locomotive servicing engineer, or a certified train service engineer.

4B. Minimal RCO training can be as follows:

8 hours classroom instruction about RCL components and their functions and RCL operation, plus introduction to the body-mounted Remote Control Device (RCD) and RCL's Onboard Control Computer (OCC).

24 hours classroom and field instruction on related ground equipment, troubleshooting conditions and faults, and safe yard procedures including yard switching and train operations.

8 hours testing. Final examination must be passed with a minimum grade of 85%. Finally, a supervisory officer conducts a check for skills performance. The RCO is then qualified to operate an RCL safely and without direct supervision.

40 hours of use of RCL equipment to switch cars, move cars from point to point, and perform required inspections and tests. Hands-on operation in particular assignments is under supervision of an employee who has been appropriately qualified and trained, as determined by the railroad. As noted in the body of this report, this minimum of 40hours required by the FRA has been increased in some instances.

Appendix H.
Autonomous vs. Human Caused Braking in RCL Operations

The lists in this appendix come from CATTRON and CANAC manuals (Cattron 2002; CANAC 2001). An assumption made in classifying the lists is for CATTRON we consider its ACCUSPEED™ Locomotive Remote Control System and for CANAC we consider its Beltpack® II Locomotive Remote Control System, employing its Dynamic Speed Control.™

Note: In October 2004, the Canadian National sold its RCL business to its competitor the Cattron Group Inc., parent company of Cattron-Theimeg. The Cattron group has 57 years of experience in radio-frequency and industrial remote control applications. Across the globe, the Cattron Group has implemented over 10,000 railroad-related installations. Cattron's principal operating company is Cattron-Theimeg Inc., which produces remote control products for RCL operations, overhead cranes, and material handling. In April 2004, Canadian National had previously sold the rest of its former Canac Inc. subsidiary (anon. 2004b).

The RCL system is quite automated and has a good number of autonomously acting safeguards. Accordingly, the RCL's OCC creates more itemized/classified causes of severe slack action, in section 1 below, than does a human by manual acts, in section 2 below.

1. RCL-OCC Caused Autonomous, Possibly Severe Brake Applications:

1.1. CATTRON:

CATTRON uses an RCD and an OCC each of which contains a control Radio Frequency Transceiver.

A CATTRON RCD's warning sounds comprise the following. Two short beeps indicate that the RCD's display has an important status message. The paired beeps continue every 10 seconds until the RCO acknowledges with an RCD's vigilance push button. A steady tone warns the RCO that his RCD is in a tilt condition which if not properly responded to will cause an emergency brake application. The tone ceases after either the RCO returns to the upright position or the RCD has sent the timed emergency stop command to the RCL. A pulsing tone warns the Primary-RCO that the "vigilance" time of the RCD is about to expire. A hi-low siren warns the RCO that a service, full service, or emergency brake application is about to occur.

The CATTRON RCD has a 10-character LED display of alphanumerics, to inform the RCO of critical events. This display has both internally generated messages from the RCD and externally generated messages from the OCC, all regarding various operating conditions and requirements. Some messages are accompanied by audible tones from the RCD. Display messages include: TILT, VIGILANCE, OCU [RCD] COMM LOSS, EMERGENCY, INVALID DIRECTION CHANGE, INVALID DIRECTION DETECTED, SPEED (in mph), AUTO BRAKE (in psi), and so forth.

CATTRON's LED indicators change from red to green when the RCL responds to an RCO's command. These LED changes confirm the RCO's change of a control on his RCD.

1.1.1. ACCUSPEED is programmed so that after 3 seconds of control communication loss between an RCD and the RCL's OCC, a light air brake application is produced along with a killing of tractive power. If control communication is reestablished between 3.5 and 5 seconds, ACCUSPEED resumes its normal operation. Owing to possible severe slack action from such autonomous air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.1.2. ACCUSPEED senses when either the Primary-RCD or Secondary-RCD is tilted greater than 45º ±15º from the vertical and, after a prescribed period, autonomously sends a shutdown command to the OCC on the RCL. This command produces an "emergency brake application shutdown," kills the traction power, and, over voice-radio, broadcasts on the normal frequency of the local yard channel a man-down alarm having a synthesized voice. The RCO must return to an upright position within 5 seconds after a warning sound from his RCD to avoid activating the tilt feature. The warning sound occurs when the RCD is tilted beyond its limits for 1 second. Design does not allow an RCO to hold down the acknowledging button for a continuous period.

A man-down alarm is broadcast until acknowledged at the OCC or until 10 minutes have elapsed. The broadcast typically includes the RCL's identification, e.g., "ABC 999" and a message about which of the RCDs has entered a tilt condition (primary operator down or secondary operator down).

If necessary in the performance of tasks, the RCO can command a "tilt-time extend" to increase his task time while in a bodily tilted position. First, the RCL must be stopped and the RCD's speed selector lever must be in stop position. Second, the RCO moves the "time/status" toggle switch to the "time" position. Then, the "tilt shutdown feature" will be delayed for "X" seconds (the value of "X" is set by a railroad, typically 50 seconds). Design does not allow the RCO to command any time added to the tilt-time extension. If the RCO has not returned to an upright position before "X" seconds expire, the OCC produces a tilt penalty brake application, which is an "emergency brake application shutdown." This must be recovered later with suitable RCO actions. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

The tilt switch circuit uses a normally closed mercury switch, producing a safety stop if any part of the circuit fails.

1.1.3. Regarding vigilance, ACCUSPEED requires the Primary-RCO's activation of a control feature, within every 60 seconds, on his RCD. Should the RCO not change the state of any RCD function within 50 seconds, the RCD emits a pulsed warning sound for 10 seconds. Within the duration of this warning, the RCO must reset the vigilance system by depressing either of the two vigilance push buttons on his RCD. This vigilance feature is active only on the Primary-RCD and when a speed other than stop is selected. Failure to reset the vigilance system produces a "full-service reduction shutdown" including a killing of tractive power. This must be recovered later with suitable RCO actions. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

The pair of vigilance push buttons is multifunctional. Either resets a vigilance timer, acknowledges RCD warnings, and accepts a “pitch” of control function from the Primary-RCO by the Secondary-RCO. Further, if a button is depressed for longer than 2 seconds, while depressed sanding occurs in the direction of movement.

1.1.4. ACCUSPEED has multiple “watchdog” circuits. A “watchdog” circuit monitors another critical circuit to insure it has not failed. If such failure occurs, the watchdog circuit produces an action dependent on the function of the critical circuit. This action includes safely shutting down the RCLS and its RCL. (Watchdog monitors execution of software code, insures no undesired lock ups, and insures no errant commands.) Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.1.5. ACCUSPEED has an Automatic Safety Override (ASO) function. The ASO continuously monitors all output functions of critical relays in the Primary-RCD. If a critical output relay is active but has no corresponding control command from the RCD, the ASO disables that relay and thereby shuts down and stops the RCL. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.1.6. An ACCUSPEED RCL has a line-of-sight range of transmission from its RCD of about 1 mile. When a repeater is used a command transmission’s operating range is about two miles. (A repeater is a stationary radio amplification device and is at a point that is in radio-line-of-sight with three other points, the Primary-RCD and the Secondary-RCD and the RCL controlled by these RCDs.) If either the Primary or Secondary RCD moves outside of its operating range, the RCL shuts down. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.1.7. ACCUSPEED has a detection circuit for low battery charge. The battery is a standard, rechargeable 7.2 VDC, Nickel Metal Hydride, Ni-MH, type with a battery life of about 12 hours continuous operation. A power on/off push button on the RCD connects and disconnects the RCD’s battery power. The detection circuit determines when battery voltage has gone to full discharge, despite LED and screen displays of warning. When battery voltage falls to full discharge, the circuit automatically shuts down the RCD. Given other protective features on the RCLS, this action will stop the RCL. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.1.8. With ACCUSPEED, if an independent brake setting of “medium” or higher is commanded, for longer than 30 seconds, by the Primary-RCO with a speed setting of 4 mph or higher, the RCD will emit warning sounds, within 30 seconds. After this warning, the RCO must either decrease independent brake or decrease speed selector lever to specified settings. If the RCO does not take this action, the RCLS produces a “service application shutdown,” which must be recovered later with suitable RCO actions. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.1.9. With ACCUSPEED, if an automatic brake setting of “light” or higher is commanded, for longer than 30 seconds, by the Primary-RCO with a speed setting of 4 mph or higher, the RCD will emit warning sounds, within 30 seconds. After this warning, the RCO must either place the automatic brake in “release” or decrease speed selector lever to specified settings. If the RCO does not take this action, the RCLS produces a “service application shutdown,” which must be recovered later with suitable RCO actions. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.1.10. With ACCUSPEED, if the reverser on the RCD is used to attempt to reverse direction (intentionally or unintentionally) while the RCL is in motion, the RCLS commands a “full service reduction shut down” which must be recovered with suitable RCO actions. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.1.11. Separately, when a direction of movement opposite to that commanded by the Primary-RCO on his RCD continues for more than 20 seconds, the RCLS produces a “full service reduction shutdown,” which must be recovered later with suitable RCO actions. Thus we find a possible autonomous brake application. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.1.12. Any of several locomotive protective alarms result in an autonomous full service reduction and stop of the RCL. The alarms include high cooling water temperature, low crankcase oil pressure, low main reservoir air pressure, ground relay trip, and so forth. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.1.13. An internal fault of the OCC can result in an autonomous full service reduction and stop of the RCL. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.1.14. ACCUSPEED design allows an hour loss of signal from a GPS signal. If the OCC cannot re-establish communication with a GPS, through appropriate on-RCL equipment, the OCC autonomously applies a full-service shutdown of the RCL. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car. The lack of GPS signal can be overridden for up to 10 minutes by RCO manipulation of two control push buttons and observation of an indicator on the OCC on the RCL. This allows continued normal remote control operation for the time period.

1.1.15. Movement of the RCL is disabled until the OCC detects a full charge of the brake pipe. Until the full charge is detected, automatic brakes are kept in release (i.e., charging) setting.

1.2. CANAC:

CANAC uses an RCD with a control Radio Frequency Transmitter and an OCC with a control Radio Frequency Receiver.

A CANAC RCD's warning sounds comprise the following. Reset safety time-out warning, 3 beeps per second for up to 10 seconds. Tilt warning, continuous alarm for up to 4 seconds. Tilt time extend accepted, 1 beep. RCD failure, 3 beeps. Low battery shutdown warning, double beep every 15 seconds up to 5 minutes. Low battery shutdown, 1 beep every 4 seconds. If the RCO does not change the state of any RCD function within 50 seconds, the RCD emits a pulsed warning sound for 10 seconds, before full-service shutdown.

The CANAC RCLS produces many spoken talker messages listing problems and recommending recovery procedures. Toggling the status/timer switch on either RCD produces a talker message given the current status of the RCLS. Talker radio messages having a synthesized voice are broadcast by the RCL's voice-radio over the normal, local yard channel, for example, "dragging brakes," "brake recovery complete," or "illegal reverser change; recover service from Beltpack." An RCO and others receive talker messages over their portable radios, while on the ground and on rolling equipment.

Flashing LEDs on the brake selector indicators alert the RCO to particular warnings. The EMERG LED flashes during a tilt warning alarm or to indicate that an RCD commands an "emergency" air brake application. The AUTO-FULL LED flashes during a Reset Safety Timer alarm or when the RCD commands a "full service" brake application.

1.2.1. CANAC is programmed so that after a control communication loss, typically of 5 seconds, between an RCD and the RCL's OCC, a "full service" air brake application is produced along with a killing of tractive power. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.2.2. BELTPACK senses when either the Primary-RCD or Secondary-RCD is tilted greater than 45º from the vertical and, after a prescribed period, autonomously sends a shutdown command to the OCC on the RCL. Tilting the RCD more than 45º activates an audible alarm for 3 seconds. If the RCD is not restored to an upright position before the 3 seconds expires, the RCD sends an emergency stop command to the OCC, killing the traction power, and, over voice-radio, broadcasts on the normal frequency of the local yard channel a tilt time-out alarm having a synthesized voice. Ten seconds after an emergency tilt stop, if the RCD is not righted and recovered, a talker alarm for a "tilt-time-out" is broadcast once per minute for 10 minutes or until the RCD is righted. A continuous warning tone occurs when the RCD is tilted beyond its limits for 1 second. Design does not allow an RCO to hold down the acknowledging button for a continuous period. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

If necessary in the performance of tasks, the RCO can command a "tilt-time extend" to increase his task time while in a bodily tilted position. First, the RCL must be stopped and the RCD's speed selector lever must be in stop position. Second, the RCO moves the "time/status" toggle switch to the "time" position and must be held there until a confirming beep is heard. Then, the "tilt shutdown feature" will be delayed for "X" seconds (the value of "X" is set by a railroad, typically a total of 60 seconds). Design does not allow the RCO to command any time added to the tilt-time extension. If the RCO has not returned to an upright position before "X" seconds expire, the OCC produces a tilt penalty brake application, which is an "emergency brake application shutdown." This must be recovered later with suitable RCO actions.

1.2.3. Regarding vigilance, BELTPACK requires the Primary-RCO's activation of a Reset Safety Control (RSC) feature, within every 60 seconds, on his Primary-RCD. Should the RCO not change the state of any RCD function within 50 seconds, the RCD emits a pulsed warning sound for 10 seconds. Within the duration of this warning, the RCO must reset the vigilance system by depressing either of the two "Reset" push buttons on his RCD. This vigilance feature is active only on the Primary-RCD, when a speed other than stop is selected. Failure to reset the vigilance system produces a "full-service" air brake application including a killing of tractive power. This brake application must be recovered later with suitable RCO actions. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

The pair of "Reset" push buttons is multifunctional. Either resets a vigilance timer and accepts a "pitch" of control function from the Primary-RCO by the Secondary-RCO. Further, if a button is depressed for longer than 7 seconds, while depressed sanding occurs in the direction of movement.

1.2.4. BELTPACK monitors to insure that a number of system faults have not occurred. If a particular system fault occurs, an air brake application is made to a stop. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.2.5. If either the independent or train (automatic) brake control valves' feedback signals differ from an RCO request for more than 10 seconds, the RCLS assumes a hardware problem. Owing to possible severe slack action from consequent air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.2.6. A BELTPACK RCL has a line-of-sight range of transmission from its RCD of about 1 mile. When a repeater is used a command transmission's operating range is about two miles. (A repeater is a stationary radio amplification device and is at a point that is in radio-line-of-sight with three other points, the Primary-RCD and the Secondary-RCD and the RCL controlled by these RCDs.) If either the Primary or Secondary RCD moves outside of its operating range, the RCL shuts down. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.2.7. BELTPACK has a detection circuit for low battery charge. The detection circuit determines when battery voltage has gone to full discharge, despite LED and audible beeper warnings. A power on/off push button on the RCD connects and disconnects the RCD's battery power. When battery voltage falls to full discharge, the circuit automatically shuts down the RCD. Given other protective features on the RCLS, this action will stop the

RCL. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.2.8. With BELTPACK, if an <u>independent brake</u> setting of “medium” or higher is commanded, by the Primary-RCO with a speed setting of 4 mph or higher, the RCLS produces a service application shutdown, which must be recovered later with suitable RCO actions. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.2.9. With BELTPACK, if an <u>automatic brake</u> setting of “light” or higher is commanded by the Primary-RCO with a speed setting of 4 mph or higher, the RCLS talker will warn of this infraction over voice-radio before a penalty braking is applied. After this warning, the RCO must either place the automatic brake in “release” or decrease speed selector lever to specified settings. If the RCO does not take this action, the RCLS produces a service application to a stop, which must be recovered later with suitable RCO actions. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.2.10. With BELTPACK, if the reverser on the RCD is used to attempt to reverse direction (intentionally or unintentionally) while the RCL is in motion, the RCLS commands an “automatic stop” which must be recovered with suitable RCO actions. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.2.11. Intentionally left blank.

1.2.12. Any of several locomotive protective alarms result in an autonomous full service reduction and stop of the RCL. The alarms include high cooling water temperature, low crankcase oil pressure, low main reservoir air pressure, ground relay trip, and so forth. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.2.13. An internal fault of the OCC can result in an autonomous full service reduction and stop of the RCL. Beltpack autonomously applies brakes in “emergency” when the RCLS has a “serious fault.” Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

1.2.14. Intentionally left blank.

1.2.15. With BELTPACK, if an RCO makes a “minimum” automatic brake reduction, then releases, and next, reapplies the automatic brakes, an autonomous safety feature operates. The OCC reduces the brake pipe a further 5 psi to ensure braking. The RCO cannot make further application of the automatic brakes until the RCLS finds that the automatic brake system is sufficiently recharged. Any RCO attempt to make a further reduction of the automatic brakes causes the RCLS talker to speak “brakes depleted” and brake the RCL movement to a stop. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

2. RCO and Other Human Caused Possibly Severe Brake Applications:

2.1. Any one of several emergency-stop push buttons on the exterior of the RCL can be depressed resulting in an emergency brake application, from which the RCO must later make a recovery. Thus, we find a possible severe brake application and slack action produced by an RCL crewmember or a non-crewmember. Such brake application would usually be unanticipated to an employee riding on a car. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

2.2. Either a Primary or a Secondary RCO, intentionally or unintentionally, can command an “emergency” brake application using the using the independent brake override selector on the RCD. This braking can be unanticipated by the other RCO or other crewmember, such as a non-RCO utility man temporarily assigned to an RCL crew. Owing to possible severe slack action from such emergency application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

2.3. Either a Primary or a Secondary RCO, intentionally or unintentionally, can command a “full” independent brake application on the RCD. This braking can be unanticipated by the other RCO or other crewmember, such as a non-RCO utility man temporarily assigned to an RCL crew. Owing to possible severe slack action from such air brake application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

2.4. Either a Primary or a Secondary RCO, intentionally or unintentionally, can command a full-service automatic brake application using the RCD. This braking can be unanticipated by the other RCO or other crewmember, such as a non-RCO utility man temporarily assigned to an RCL crew. Owing to possible severe slack action from such emergency application on a long cut of cars, the braking could dislodge an employee from his position on the side of a moving car.

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About the Authors

Frederick Charles Gamst

From Sept. 1975 through May 2001, Gamst was professor of anthropology (social), emeritus thereafter, at the University of Massachusetts, Boston. He is adjunct professor of anthropology at the University of Wyoming. A.B., University of California, Los Angeles, 1961; Ph.D., University of California, Berkeley, 1967. He was on the faculty of Rice University from Sept. 1966 through Aug. 1975. Principal expertise is in **industrial and organizational social anthropology**; research foci on the railroad industry, in North America but also in Europe, Eastern Africa, China, Australia, and New Zealand. Gamst has published over 100 articles, chapters, proceedings, and shorter works; produced more than 100 reports and papers on the railroad industry and related matters; prepared numerous reviews; written or edited 12 books and monographs. Biographical information is in *Who's Who in the East*, *Who's Who in America*, *Who's Who in the World*, *Who's Who in Science and Engineering, Who's Who in American Education.* From the Society for the Anthropology of Work of the American Anthropological Association (AAA), he received Conrad Arensberg Award, 1995, for development of the anthropology of work, industry, and organizations. Honored, 2002, with a Festschrift session (100th annual meeting of the AAA) celebrating his lifework. He was departmental chair, 1975-1978, and graduate dean, 1978-1983, when graduate programs increased from 4 to 27 and graduate students from about 50 to 690.

His two most recent books are: 1997 *Early American Railroads: Franz Anton Ritter von Gerstner's* Die innern Communicationen (1842-1843); two vols., F. C. Gamst, ed., Stanford, CA: Stanford University Press and 1995 *Meanings of Work: Considerations for the Twenty-first Century*. F. C. Gamst, ed., Albany, NY: State University of New York Press. In the *Encyclopedia of North American Railroading*, he wrote "Railroad Occupations" and "Seniority," and in the *International Encyclopedia of the Social and Behavioral Sciences* "Work, Sociology of." He is a participant in: the Subcommittee for Railroad Operational Safety of the Transportation Research Board (TRB); three sponsored projects, on task and risk analyses for conventional cf. to Remote Control Locomotives (RCLs), on root cause analysis regarding RCLs, and on human-centered evaluation tools; the FRA's Working and Human Factors Groups for Positive Train Control (PTC). Gamst has 50 years firsthand experience with the railroad industry, as operating employee, university researcher, and professional consultant. His specializations are the social and industrial relations and organization of railroad work, including human error, risk, and reliability. Specializations involve research and applications into the development by management of railroad operations and work, including management's unilateral operating rules and practices; the development by management and labor unions of collective labor agreements, including bilateral work rules; and the impact of governmental regulation on these bodies of, hence, trilateral, rules. Other specializations in rail operations involve the human factors (ergonomics) and social factors of human-machine systems, work tasks, and work organization.

The professional consultations of Gamst include planning discussions with rail managers; assistance of carrier and union and labor attorneys, industrial relations personnel, and others in preparing scores of cases and presentations involving railroad industrial relations and operations; development of materials on industrial relations and operations for carriers and unions enhancement of employee-management relations; and surveys of railroaders. Clients have included Atchison Topeka & Santa Fe, Canadian Pacific, Chinese People's Republic Railways, Consolidated Rail Corporation, Eritrean Railway, Norfolk Southern, Massachusetts Bay Transportation Authority, St. Louis Southwestern Railway, Southern Pacific, Brotherhood of Locomotive Engineers, Federace Strojvudcu Ceské Republiky, Gewerkschaft Deutsche Lokomotivführer und Anwärter, Gewerkschaft der Eisenbahner Deutschlands, Rail & Maritime Transport Union (New Zealand), United Transportation Union, and consulting firms.

From May 1955 through end-December 1961 (six years and eight months), Gamst was employed in railroad road and yard engine service, making some 1,800 runs as an engineman. Since this period of direct railroad employment, he has conducted innumerable months of in-field research among personnel in the transportation, engineering/maintenance-of-way, and mechanical departments of railroads. His basic and applied research results, involving railroad and other industrial study, comprise the following: publications; presentations of papers at meetings including to railroad audiences (management, union, regulatory); preparation of technical reports on railroad operations, training, safety, risk, and industrial relations; delivering seminars; and participation in the development of the field of industrial and organizational anthropology, extant since 1931.

In 1987, for the American Association of Railroad Superintendents (AARS), Gamst co-chaired the committee studying the removal of the caboose. In 1991-92, for Brotherhood of Locomotive Engineers (BLE) Canada, he prepared 14 papers on the engineer's craft. Regarding railroaders' sleep and fatigue, in 1996, the AARS, invited Gamst to its 100th Anniversary Meeting, to give the conference's central address, on sleep, fatigue, and railroaders; to chair the fatigue workshop and present orally and write the workshop report on this subject; and to give a meeting's closing address, on the past century in railroading, with a focus on industrial relations. In 1996, for the United Transportation Union, he gave the researched presentations at a hearing of the Federal Railroad Administration (FRA), presenting on safety regarding one-person crewing and RCLs on freight trains. In 1997, he represented the BLE at a conference of the Canadian Railway Association on one-person crewing and RCLs. He participated in FRA RSAC meetings on PTC, 1998-2005 and, in 1998, gave an opening PTC presentation. In 1998, he delivered an opening paper, on the genesis (1795-1830) of railroads in North America, at the International Early Railways Conference. In 1999, he joint authored the FRA white paper, "Reliance and

Distraction Effects in PTC Automation." At TRB workshops, in 2001, he presented two papers on operations of One-Person Crewing and on RCLs and, in 2005, on railroader fatigue. At various conferences, he has presented papers on error, risk, and social interactions of technology in the railroad industry.

Gamst's professional specializations in the Horn of Africa (Ethiopia, Somalia, Eritrea, Djibouti, and adjacent Sudan), include over four decades of extensive basic research, applied work, publications, technical reports, and professional service including election and campaigning monitoring (in war-torn Oromia, of the 23 million Oromo). He studies interplay of the social organization, cultural patterns, and economy of agrarian peoples. Such research includes the Amhara, Falasha/Beta Esrael ("Black Jews"), and Qemant. He has studied the adaptations to change of one of Africa's few foraging peoples, the Wayto hippopotamus hunters of Lake Tana. And he has studied the Eritrean Railway and the Addis Abeba-Djibouti Railway.

George A. Gavalla

2005 marks the beginning the Mr. Gavalla's 30th year in the railroad industry. From the end of 1997 to the beginning of 2004 he was the Associate Administrator for Safety at the Federal Railroad Administration (FRA). As head of the agency's Office of Safety, he directed the agency's railroad accident investigation, safety inspection and safety enforcement programs. He also directed large scale comprehensive safety investigations on the major railroads in the U.S. to identify safety risks and implement safety improvement action plans. During his tenure, the railroad industry achieved the lowest levels of rail-related fatalities and injuries in its history, all rail-related fatalities fell by 19%, employee fatalities by 48% and grade crossing fatalities by 28%.

The Office of Safety enjoyed its most productive era for promulgation of new safety standards and regulations under his direction. Nine new or revised safety regulations were issued along with several proposed regulations, including the agency's first proposed performance-based regulations. FRA's regulatory process, was assisted the FRA Rail Safety Advisory Committee (RSAC), on which he served as Chairman. The 48 member RSAC consisted of rail safety experts representing 27 rail stakeholder organizations covering virtually every facet of the railroad industry, including freight, passenger and commuter railroads, rail labor organizations, suppliers and contractors and state and Federal safety agencies. As a Chairman, his role was that of a consensus builder to guide the committee toward consensus recommendations for new Federal railroad safety regulations.

Mr.Gavalla also championed a collaborative approach to improving railroad safety outside of the regulatory arena. He strengthened and refined the FRA Safety Assurance and Compliance Program (SACP), a program designed to bring railroad management, employee groups and FRA field forces together in safety committees to identify and address systemic safety issues and safety matters that fall outside of existing regulations.

While at the Office of Safety, Mr. Gavalla founded several important railroad safety initiatives. Recognizing that railroad switching operations were responsible for more railroad employee fatalities than any other activity, he convened a combined task force of industry and union leaders to work with FRA in reducing railroad switching accidents and casualties. Known as the Switching Operations Fatality Analysis Task Force, the group developed recommendations and promoted safety educational efforts among train and engine crews. The work of the SOFA Task Force helped bring about a 50% reduction in switching fatalities and an 18% reduction in switching accidents over a two year period.

Also, Mr. Gavalla founded the Office of Safety's Fatigue Mitigation program, appointing the FRA's first full time Fatigue Program manager to spearhead agency efforts to promote fatigue mitigation. He also helped found the North American Rail Alertness Partnership (NARAP) a group made up of railroad, rail labor, NTSB and Transport Canada representatives to encourage the development and implementation of fatigue mitigation programs in the railroad industry. In 1998 and again in1999, he helped draft fatigue mitigation provisions in two Administration rail safety bills calling for formal Fatigue Mitigation Plans. The bills were introduced in Congress but did not pass. In 1999, Mr. Gavalla was recognized by the National Sleep Foundation for his efforts to promote fatigue reduction in the railroad industry.

He was instrumental in FRA's efforts to publish the FRA Safety Advisory 2001-01, the agency's first formal safety guidelines for the use of Remote Control Locomotives. Prior to issuing the guidelines, he chaired an FRA safety inquiry into RCL operations and technology in June 2000 to learn about the latest developments in the RCL safety. After the guidelines were issued he convened a task forces of RCL stakeholder organizations including railroad and rail labor organizations to help oversee the safe implementation of the of RCL .

From October 1995 to October 1997, Mr. Gavalla served as Railroad Safety Project Coordinator for FRA. In that capacity he led a large scale, comprehensive safety audit of Amtrak which resulted in a 30% decline in Amtrak employee injuries. He also coordinated a safety audit of the Long Island Rail Road that focused on highway rail grade crossing safety. As a result of program improvements that resulted from the audit, LIRR grade crossing failures were reduced by 2/3rds.

While at FRA, Mr. Gavalla was a senior level agency liaison to the White House, and other Federal agencies. He has testified before Congress, the National Transportation Safety Board, and other federal and state agencies regarding railroad safety matters. He has met with and hosted numerous foreign delegations of railroad safety experts from countries including the Russian Federation, Australia, UK, India, Poland, Romania, Iraq, Nigeria, People's Republic of China, and Japan. He also led FRA trips to China, Japan and Germany to investigate magnetic levitation technology, shared use track by transit and heavy rail systems and railroad safety matters in general.

Prior to joining FRA, Mr. Gavalla worked for the Brotherhood of Railroad Signalmen (BRS) where he served as Director of Research and Grand Lodge Representative from 1991 until 1995. While a BRS representative he was a labor co-chairman of Roadway Worker Protection Advisory Committee (RWPAC), the first regulatory advisory committee at FRA and forerunner of RSAC. The RWPAC developed consensus recommendations to prevent railroad roadway workers from being struck and killed by train and moving equipment. The recommendations were eventually adopted into Federal safety regulations by FRA. From December 1984 to 1991, he served as Assistant General Chairman for the BRS, representing railroad signalmen in New England and New York State. During that period he successfully lobbied for mandatory state regulations requiring the testing, maintenance and inspection of highway rail grade crossing warning devices in his home state of Connecticut. These state grade crossing safety standards were a forerunner to Federal grade crossing safety standards.

From 1975 to 1984, he worked in the Signal Department of Consolidate Rail Corporation where he inspected, tested, repaired and built railroad communications and signal systems and highway-rail grade crossing warning devices on both freight and passenger railroad lines in Washington, DC, Maryland, Virginia, Pennsylvania and Delaware.

Since leaving FRA in 2004, Mr. Gavalla co-founded PVB Consulting, Inc., a full service railroad consulting firm. He has made multiple appearances and given numerous interviews on rail safety and security matters on CNN, 60 Minutes II, New York Times, Washington Post, the Los Angeles Times and numerous other news media outlets.