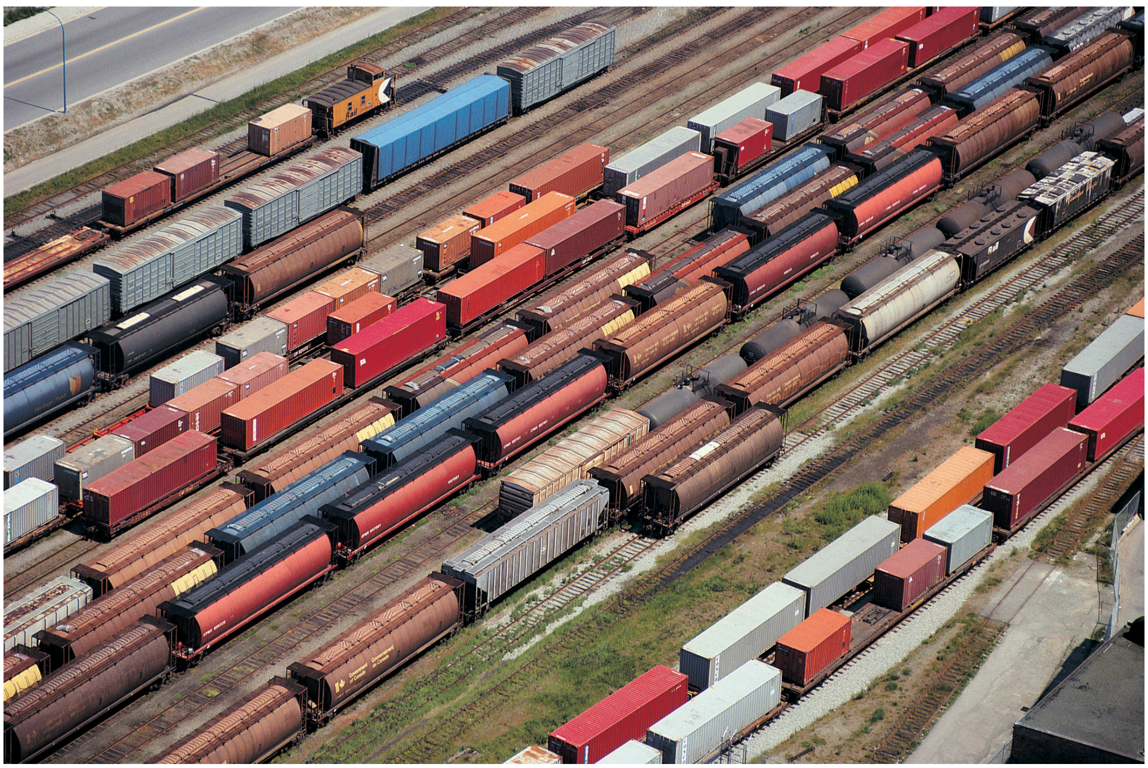
U.S. Department of Transportation

Federal Railroad Administration

Human Error Investigation Software Tool (HEIST)

Office of Research
and Development
Washington, DC 20590



DOT/FRA/ORD-07/15

Final Report
May 2007

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13. ABSTRACT (Maximum 200 words)
Human factors are a leading cause of train accidents and incidents in the United States. Human factors go beyond the crewmembers who operate the on-track equipment. They include management support and oversight, operating practices and procedures, technologies and facilities, and the work culture—in short, the socio-technical environment in which railroad employees work. The purpose of this project was to develop a software tool to help Federal Railroad Administration personnel, and the railroad industry in general, systematically consider human factors issues at all levels of the socio-technical environment (or system) when investigating the causes or contributing factors of train accidents, incidents, and close calls. This report describes the development and features of the Human Error Investigation Software Tool (HEIST). HEIST is a portable Tablet and Windows-based application that can be used in the field, a hotel room, or an office to support accident/incident investigations. HEIST data collection tools include a checklist of things to consider; operator, front-line supervisor, and manager interview guides; a human factors taxonomy and definitions; an interactive data collection aid; and an online accident/incident/close call summary form. Data classification tools include an interactive aid and practice module. A HEIST user manual was also produced under separate cover. The report concludes with some recommendations for future enhancements to HEIST, including implementation of a centralized accident, incident, and close call database, and preparation of a field test.

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in)	=	2.5 centimeters (cm)
1 foot (ft)	=	30 centimeters (cm)
1 yard (yd)	=	0.9 meter (m)
1 mile (mi)	=	1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2)	=	6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2)	=	0.09 square meter (m^2)
1 square yard (sq yd, yd^2)	=	0.8 square meter (m^2)
1 square mile (sq mi, mi^2)	=	2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he)	=	4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz)	=	28 grams (gm)
1 pound (lb)	=	0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb)	=	0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp)	=	5 milliliters (ml)
1 tablespoon (tbsp)	=	15 milliliters (ml)
1 fluid ounce (fl oz)	=	30 milliliters (ml)
1 cup (c)	=	0.24 liter (l)
1 pint (pt)	=	0.47 liter (l)
1 quart (qt)	=	0.96 liter (l)
1 gallon (gal)	=	3.8 liters (l)
1 cubic foot (cu ft, ft^3)	=	0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3)	=	0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm)	=	0.04 inch (in)
1 centimeter (cm)	=	0.4 inch (in)
1 meter (m)	=	3.3 feet (ft)
1 meter (m)	=	1.1 yards (yd)
1 kilometer (km)	=	0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2)	=	0.16 square inch (sq in, in^2)
1 square meter (m^2)	=	1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2)	=	0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2)	=	1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm)	=	0.036 ounce (oz)
1 kilogram (kg)	=	2.2 pounds (lb)
1 tonne (t)	=	1,000 kilograms (kg)
	=	1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml)	=	0.03 fluid ounce (fl oz)
1 liter (l)	=	2.1 pints (pt)
1 liter (l)	=	1.06 quarts (qt)
1 liter (l)	=	0.26 gallon (gal)
1 cubic meter (m^3)	=	36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3)	=	1.3 cubic yards (cu yd, yd^3)

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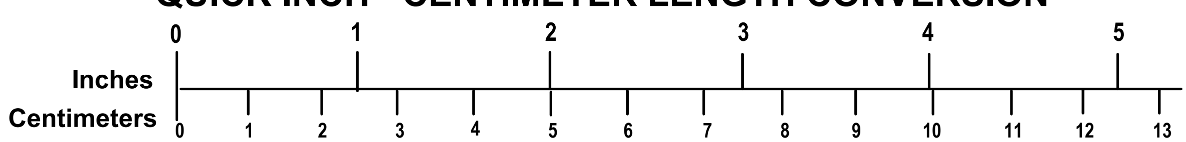
QUICK INCH - CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286

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Preface

Human factors are a leading cause of train accidents and incidents in the United States. Human factors go well beyond the crewmembers who operate the on-track equipment. They include local and senior management support and oversight, operating practices and procedures, technologies and facilities, and the work culture—in short, the socio-technical environment in which railroad employees work. The purpose of this project was to develop a software tool to help Federal Railroad Administration (FRA) personnel, and the railroad industry in general, systematically consider human factors issues at all levels of the socio-technical environment (or system) when investigating the causes or contributing factors of train accidents, incidents, and close calls. This work was based on earlier development work under a Small Business Innovative Research Phase I program, which identified user requirements and a human factors framework, and generated an initial concept of operations. The current research was performed under FRA Office of Research and Development Contract DTFR53-01-D-00029.

The authors would like to thank a number of individuals who assisted in the development or support of this tool. First, the authors would like to express thanks in particular to Dr. Thomas Raslear, FRA Office of Research and Development Human Factors Program, for sponsoring the research and providing programmatic support. The authors also wish to thank Mr. Ralph Elston, Mr. Theodore Bundy, and Mr. Patrick McFall, FRA Office of Safety, for their technical support, guidance, and critical feedback during the development and testing of the tool. The authors also want to thank Dr. Jordan Multer, Volpe National Transportation Systems Center, for collaborating on the update to the Human Factors Analysis and Classification System-Railroad taxonomy and associated definitions used in the Human Error Investigation Software Tool, as well as for providing valuable feedback throughout the project. Lastly, the authors wish to thank Ms. Susan McDonough, Foster-Miller, for providing administrative and programmatic support to the project and authors, and for reviewing a draft copy of the report.

Executive Summary

Human factors are a leading cause of train accidents and incidents in the United States. Human factors go well beyond the crewmembers who operate the on-track equipment. They include local and senior management support and oversight, operating practices and procedures, technologies and facilities, and the work culture—in short, the socio-technical environment in which railroad employees work. The purpose of this project was to develop a software tool to help Federal Railroad Administration (FRA) personnel, and the railroad industry in general, systematically consider human factors issues at all levels of the socio-technical environment, when investigating the causes or contributing factors of train accidents, incidents, and close calls.

This report describes the development and features of the Human Error Investigation Software Tool (HEIST). HEIST is a portable Tablet and Windows-based application that can be used in the field, a hotel room, or an office to support accident/incident investigations. HEIST is based on earlier development work that identified user requirements and a human factors framework and generated an initial concept of operations. The overall approach used to develop HEIST involved the following steps:

- Refining the concept of operations based on feedback from FRA Office of Safety stakeholders
- Developing a functional specification for the software
- Implementing the functional specification (i.e., developing the software)
- Debugging and improving HEIST using an iterative process
- Demonstrating HEIST to Office of Safety stakeholders and providing a brief user trial period to obtain Office of Safety feedback
- Updating HEIST based on Office of Safety feedback

A user manual was also developed to accompany and support HEIST.

HEIST was built using the .Net software development framework. It is designed to be used on a ruggedized Tablet PC that can be used in the field, but it can operate on any other computer running Microsoft Windows XP (i.e., another laptop or desktop PC). HEIST can be used in the field and/or an office environment to collect, analyze, classify, and report on accidents, incidents, and close calls.

HEIST data collection tools include a checklist of things to consider; operator, front-line supervisor, and manager interview guides; a human factors taxonomy and definitions; an interactive data collection aid; and an online accident/incident/close call summary form. Data classification tools include an interactive aid and practice tool.

Although the tool has been demonstrated to FRA Office of Safety stakeholders, it would be valuable to field test the software with FRA Office of Safety regional inspectors to obtain their feedback on usability and functionality before HEIST is distributed and used on a large scale. Furthermore, several enhancements to HEIST are suggested to increase functionality, including development of a HEIST analysis aid and implementation of a remote, centrally located database.

1. Introduction

1.1 Background

Although the number and percent of train accidents associated with human error have begun to decrease recently in the United States, they remain a significant portion—over one-third—of all U.S. railroad accidents, according to FRA data (see Table 1). Human factors often equates to blaming the crewmember(s) closest in time and proximity to the accident. Human factors and human error, however, go well beyond the crewmembers. James Reason, a leading expert in the field of human error theory, notes,

> …human error is a consequence not a cause. Errors…are shaped and provoked by upstream workplace and organizational factors. Identifying an error is merely the beginning of the search for causes, not the end. The error, just as much as the disaster that may follow it, is something that requires an explanation. Only by understanding the context that provoked the error can we hope to limit its recurrence (Reason, 1997, p. 126).

Table 1. U.S. train accident data, 2002-2006

	Total U.S. Train Accidents	**Human Factor Train Accidents**	**Human Factor Accidents as Percentage of Total U.S. Train Accidents**
2002	2738	1050	38
2003	3013	1227	41
2004	3375	1354	40
2005	3236	1253	39
2006	2834	1000	35
Source: http://safetydata.fra.dot.gov; data exclude highway-rail grade crossing accidents.			

A number of models of human error arose in the 1990s and 2000s, which explain organizational accidents as arising from a host of factors at all levels of the organization or system. Reason's Swiss Cheese model of accident causation is, perhaps, the most well known. The Swiss Cheese model posits that accidents, envisioned as a straight arrow or vector, occur when holes line up in the various layers of an organization in just the right manner to allow or enable the accident arrow to penetrate through all of the layers. Each layer represents a different level of an organization, and, more specifically, these layers represent various organizational accident barriers. It is when these barriers fail at all levels that accidents occur. Reason discusses these layers in terms of active and latent factors. Active factors are those decisions, conditions, or other aspects that are closest in time and physical space to the accident/incident. They have traditionally been most often cited as the cause of an accident/incident (e.g., a shop employee has a momentary slip of attention while grinding a wheel flange and injures his hand). Latent factors (decisions or conditions) often exist for years and may never be identified as a safety issue unless they are explicitly examined (e.g., an employee rushes to get the job done due to implicit or explicit pressure and skips a critical step in repairing a locomotive that contributes to an accident in the future).

Ideally, railroad accident investigators would search for and identify a broad range of operator, supervisory, technological, and organizational (i.e., upstream workplace) factors and conditions that contribute to railroad accidents. Often, however, this is not the case.

FRA investigates a variety of railroad accidents, including fatalities and other assigned accidents. FRA fatality investigations are thorough, but they are not necessarily systematic with respect to exploring possible human factors contributions. Headquarters and regionally-assigned FRA investigations address a range of human factors issues, but, again, they may not explore human factors contributing factors systematically. The U.S. railroad industry also conducts accident investigations on their own properties. The focus, however, is often on the crewmembers and those closest in time and proximity to the accident. Little, if any, examination focuses on the contextual factors that allowed the accident to occur. In general, the U.S. railroad industry lacks a cohesive theory of human error to drive accident investigation and analysis.

In 2004, FRA sponsored the development of a preliminary concept of operations for a software tool that would enable railroad accident investigators (FRA, railroad, or others) to systematically examine human factors issues. That work was completed in 2004. That effort consisted of the following tasks:

- Identify an appropriate human factors framework
- Document the state of the practice in accident investigations
- Develop a set of user requirements
- Produce an initial concept of operations

The initial concept of operations involved three components: a portable WinCE-based application that could be used in the field to support data collection; a desktop/laptop PC Windows application that could be used in a hotel room, office, or other location to support data analysis, reporting, and identification of corrective actions; and a centrally located server that would support and maintain the master accident database (see Figure 1). See Reinach, Viale, Wiegmann, and DeGraw, 2004, for more information on this initial effort.

This report describes follow-on development and demonstration of a prototype software tool based on this earlier work. HEIST is a software program that helps accident investigators systematically consider a range of possible human factors contributing factors. Investigators do not need to be formally trained in human factors to use HEIST. HEIST is based on a well-accepted systems theory of accident causation and human error (Reason's Swiss Cheese model) and is structured around a validated human factors classification system—the Human Factors Analysis and Classification System (HFACS) (HFACS; Wiegmann & Shappell, 2003). HFACS was originally developed to address aviation accidents and mishaps. Through earlier work (see Reinach, Viale, Wiegmann, & DeGraw, 2004; Reinach & Viale, 2006; Viale & Reinach, 2006), this classification system was modified to more specifically apply to the railroad industry. Whereas a number of commercially available root cause analysis (RCA) software programs exist, as well as human error taxonomies that can be used to classify accident contributing factors, none use a classification system to drive data collection in the first place. One of the major benefits of HEIST is that it uses an HFACS-based taxonomy of human factors contributing factors to drive data collection, as well as classification.

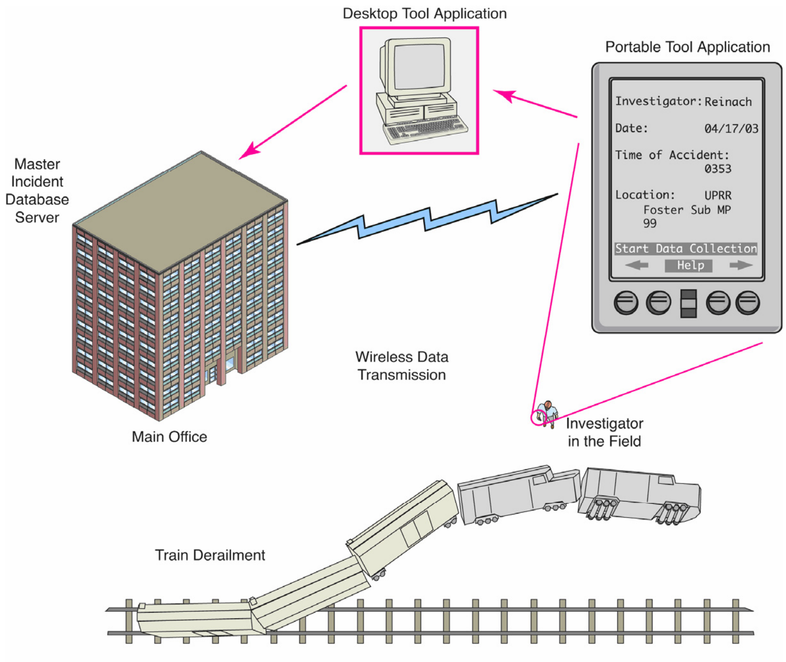

Figure 1. Human factors accident investigation software initial concept of operations

HEIST is guided by a number of principles, including the following:

- HEIST investigations are designed to shed light on what happened and why.
- HEIST is nonpunitive.
- Accidents/incidents are not solely caused by one event; rather, multiple factors play a role in each accident/incident.
- The immediate act that precedes an accident/incident is simply the last step in a series of events that led to the occurrence.
- HEIST focuses on unwinding the tape to explore all of the factors that led to the incident. To do this, individual, organizational, technological, and environmental factors are examined. Each of these factors can be, and often is, at least partly responsible for providing a situation conducive to the accident/incident's occurrence. HEIST supports examination of all these factors.
- HEIST can help to methodically and objectively shed light on these multiple contributing factors—many of which are otherwise difficult to find.

1.2 Objective

The objective of this program was to develop a working prototype of HEIST and demonstrate the tool with FRA Office of Safety stakeholders.

1.3 Overall Approach

The overall approach used to develop HEIST involved the following sequential steps:

1. Refine the concept of operations based on feedback from FRA Office of Safety stakeholders.
2. Develop a functional specification for the software.
3. Implement the functional specification (i.e., develop the software).
4. Debug and improve HEIST using an iterative process.
5. Demonstrate HEIST to Office of Safety stakeholders and provide a brief user trial period to obtain Office of Safety feedback.
6. Update HEIST based on Office of Safety feedback.

1.4 Scope

HEIST looks for active and latent contributing factors. Specifically, it probes for human factors contributing factors at the operator, supervisory, technological, and organizational levels, as well as contextual factors outside the organization, such as the regulatory and political environment. HEIST focuses on human factors contributions. It does not address mechanical-, signal-, equipment-, and track-related contributing factors, except if a human factors component applies to them. HEIST is designed to support accident and incident investigations, as well as close call and operational test failure investigations. HEIST does not currently address highway-rail grade crossing accidents, however, since the dynamics involved in grade crossing accidents are more complex, involving motorist behaviors and actions.

1.5 Organization of the Report

This report is organized into several sections. Section 2 discusses development of HEIST. Section 3 describes HEIST and the tools that make up HEIST. Section 4 discusses possible future directions to take with further development of HEIST. Lastly, Section 5 presents a list of references used in this report. The report also contains two appendices. Appendix A contains details on how the classification system used to support HEIST was modified from its original form. Appendix B contains a copy of the questions used to structure FRA Office of Safety feedback during the HEIST demonstration and user trial period. The report also includes a list of abbreviations and acronyms used throughout.

2. HEIST Development

Section 2 briefly discusses the development process used to produce HEIST. To begin, a kickoff meeting was held with FRA Office of Safety stakeholders. Based on feedback at this meeting and subsequent conversations with Office of Safety stakeholders, the initial concept of operations was modified. Modifications included a reduction in scope to focus on the core human factors data collection and analysis tools, as well as a change in hardware platform. HEIST was originally planned for a combination of WinCE-based handheld devices and laptop/desktop PCs. It was felt, however, that a better solution would be to combine the two capabilities into one ruggedized Tablet PC device that could be used in the field, as well as in a hotel room, office, or conference room.

The next step was to develop a functional requirements specification that outlined HEIST's functions and capabilities, as well as user options. This was an iterative process. Once the functional requirements specification was complete, the software tools were developed. Many of HEIST's data collection and classification tools started as paper-based tools used in several previous FRA-sponsored RCA projects (Reinach & Viale, 2006; Viale & Reinach, 2006). Thus, HEIST development relied heavily on updating the tools to reflect lessons learned from the other projects and modifying the paper-based tools to become more interactive. To this end, significant time was spent exploring and mapping out user interactions with each tool. Section 3 discusses each individual HEIST tool.

Many of the tools are based on a modified version of the HFACS taxonomy, referred to as the HFACS-Railroad (or HFACS-RR) taxonomy. HFACS was originally modified for use in the railroad industry in the earlier FRA-sponsored RCA projects. See Reinach and Viale (2006) for details on how the original HFACS taxonomy was modified to apply to the railroad industry. HFACS-RR was further modified as part of the HEIST development process to ensure that the taxonomy, and its category definitions, could be used to support accident investigations, such as HEIST, and close call investigations, such as FRA's Confidential Close Call Reporting System (C3RS). Since FRA sponsored both research programs, it was important that both use a single, underlying taxonomy or framework of human error as the basis for development. Appendix A discusses the modifications in detail. The new HFACS-RR taxonomy expanded the number of low-level HFACS-RR classification categories from 23 (original HFACS-RR) to 33. Figure 2 presents the updated HFACS-RR taxonomy used to support HEIST data collection and classification.

HEIST software was developed through an iterative process over the course of approximately 7 months. A user manual was also developed to accompany and support HEIST. Toward the end of the development process, HEIST was demonstrated at FRA. FRA Office of Safety stakeholders were asked to experiment with HEIST for 2 weeks after the demonstration and to provide feedback on the tool's capabilities and functions, as well as its usability. Appendix B presents a list of the user evaluation questions provided to Office of Safety stakeholders to guide user feedback. Subsequent to the user trial period, additional enhancements were made to HEIST based, in part, on FRA Office of Safety feedback during the demonstration and subsequent user testing period.

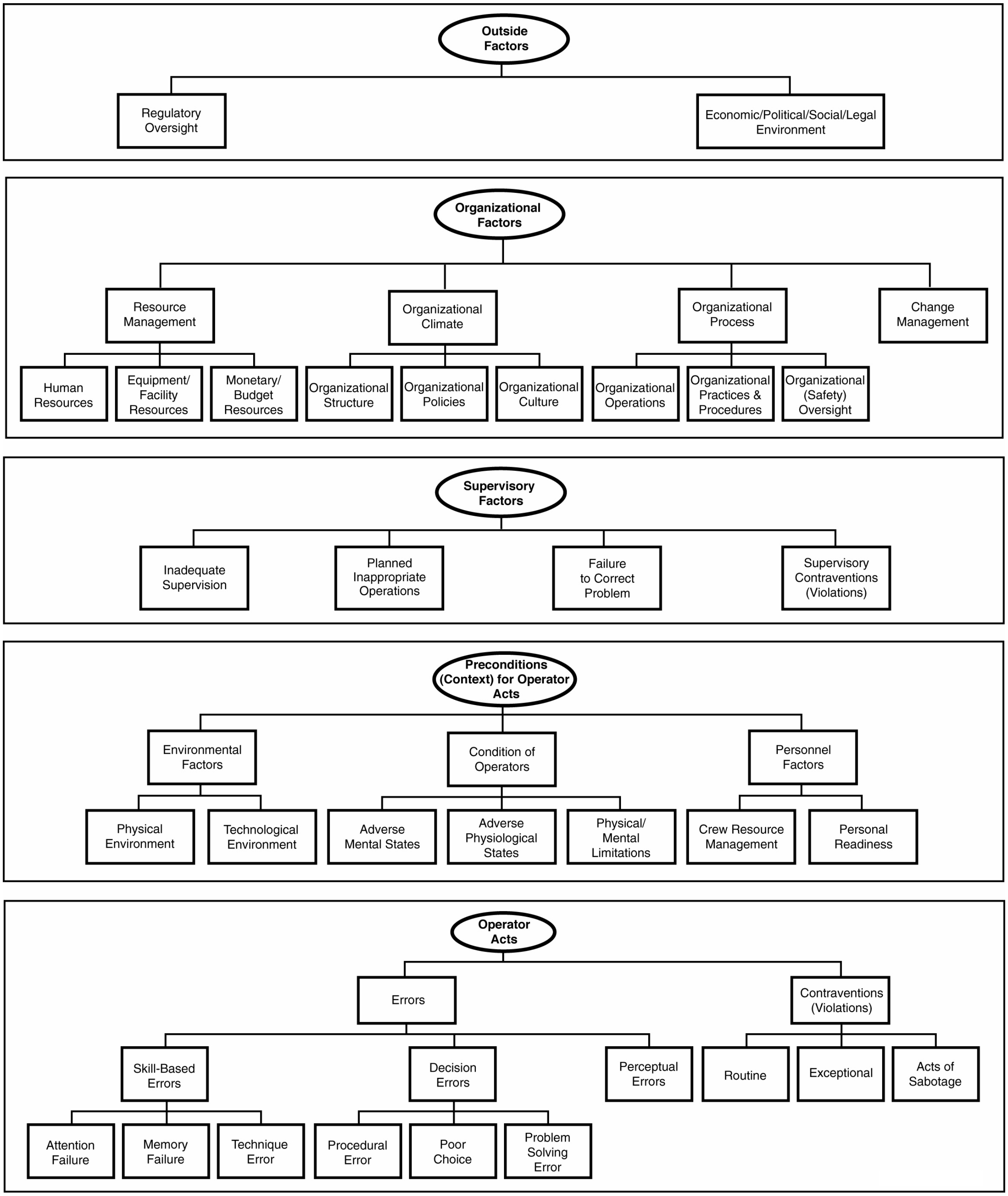

Figure 2. HFACS-RR revised for HEIST and C3RS

3. HEIST Overview and Tools

3.1 HEIST System Overview

HEIST was built using the .Net software development framework. It is designed to be used on a ruggedized Tablet PC that can be used in the field, but it can operate on any other computer running Microsoft Windows XP (i.e., another laptop or desktop PC). HEIST can be used in the field and/or an office environment to collect, analyze, classify, and report on accidents, incidents, and close calls. Although not implemented in its current form, HEIST's concept of operations includes transmission of accident/incident/close call data to a centralized accident database. Figure 3 shows a schematic of the HEIST concept of operations.

HEIST is comprised of a number of individual tools—some are interactive while others are printable documents. Individual tools, based on the HFACS-RR taxonomy, support data collection, data classification, and reporting. Currently, HEIST does not support the identification of contributing factors (i.e., analysis). Since identification of contributing factors is still a combination of art and science, the design philosophy behind HEIST is to support an investigator in collecting information and classifying contributing factors, but the actual determination of what contributed to an accident is still up to the investigator. Furthermore, HEIST currently does not support corrective action identification. HEIST is intended to complement existing methods used by the FRA inspector in conducting accident/incident investigations.

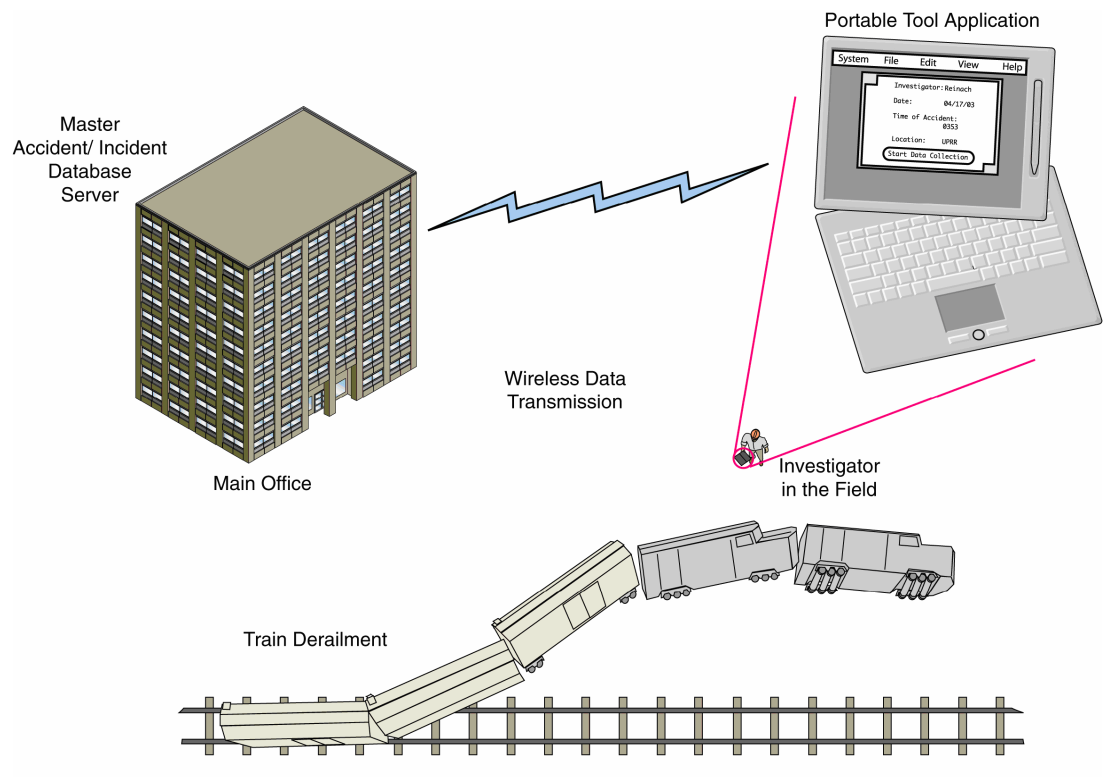

Figure 3. HEIST concept

When launched, HEIST offers the user a number of options. A user may start a new investigation or resume an ongoing investigation. He/she may review various online data collection aids to support the collection of information relevant to the investigation, classify contributing factors for an accident, generate a report, or practice using the human factors taxonomy to classify contributing factors. The following sections, organized by HEIST function, discuss each of these options.

3.2 Data Collection Tools

HEIST allows investigators to enter basic descriptive information related to an accident/incident and further provides a number of tools designed to aid the investigator in considering and collecting relevant human factors information at each level of HFACS-RR.

Accident/incident summary form. To begin, HEIST allows investigators to create a new accident/incident file and enter basic top-level descriptive information about the event, such as date and location of the accident/incident; personnel, equipment, and railroads involved; nature of the occurrence; method of operation; and track type; as well as information related to environmental conditions. Figure 4 provides a screen shot of the HEIST accident/incident summary form.

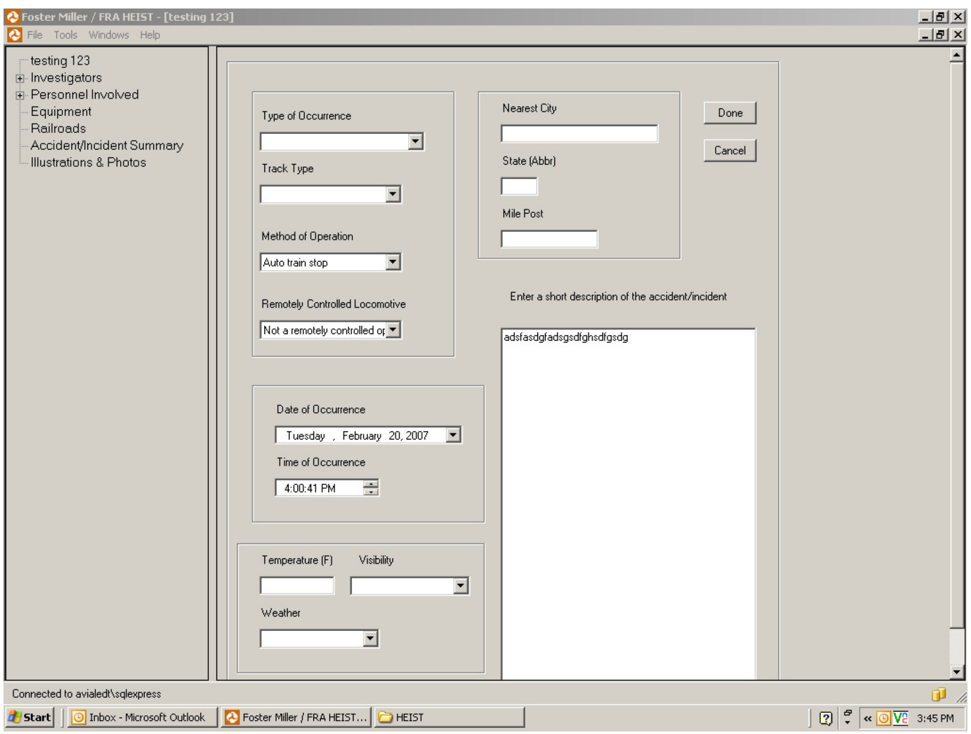

Figure 4. HEIST accident/incident summary form page

In addition to allowing descriptive input, HEIST offers a number of data collection tools that serve as a reference for investigators, providing a range of human factors issues to consider when collecting information about the accident/incident. These tools are designed to aid investigators in considering human factors at the operator, supervisory, technological, and organizational levels, as well as contextual factors outside the organization, such as the regulatory and political environment. As each accident/incident is different, these tools are not intended to be exhaustive, but rather they are designed to support the investigator in considering and collecting basic relevant human factors information at each level. It is ultimately left to the discretion of the investigator to determine which questions and data are most relevant to the accident/incident. A description of each of these tools follows.

Interview guides. HEIST contains three separate interview guides (i.e., sets of interview questions): an operator interview guide, a supervisory personnel interview guide, and an upper level manager interview guide. Interview questions are organized around the five levels of the HFACS-RR human factors taxonomy. A HEIST user chooses only those questions that are relevant to the particular investigation.

Checklist of things to consider. The checklist includes a number of questions and suggestions that may aid investigators during the data collection process. The list of items includes questions for the investigator to think about, as well as physical items that he/she may want to review as part of the data collection part of the investigation (e.g., training records and railroad operating rules and procedures). Checklist items are organized around five main topics: task-related information, operator information, equipment/environment/operations information, supervision/management information, and other information. Although the checklist is not organized around the HFACS-RR human factors taxonomy like the interview guides, it does address sources of information relevant to all five levels of the HFACS-RR taxonomy. The checklist is a broad-based list addressing a variety of possible accidents and scenarios, but it is not exhaustive. An inspector can use this checklist to help identify, prioritize, and examine relevant information as part of the investigation. This list can be viewed as a PDF or in an editable format.

Data collection aid. This data collection aid is an interactive diagram of the human factors taxonomy used in HEIST. An investigator may mouse over any category to obtain a popup definition of that category (see Figure 5). In addition, clicking on any lower level category (those enclosed in a dashed line) opens a window with recommended data and information to consider and collect during the investigation. The data collection aid is designed with the HFACS-RR taxonomy as its backbone. Investigators can use the aid to review HFACS-RR categories, look at HFACS-RR definitions, and review a list of accident/incident information sources specific to each HFACS-RR category.

Human factors taxonomy diagram. The human factors taxonomy diagram is a printable diagram of the HFACS-RR taxonomy. The diagram can be viewed as a PDF or in an editable format.

Human factors taxonomy definitions. Definitions for each HFACS-RR category are provided along with examples. Definitions draw heavily from Wiegmann and Shappell's *A Human Error Approach to Aviation Accident Analysis* (2003) and Eurocontrol's *Systemic Occurrence Analysis Methodology* (SOAM, 2005). Definitions can be viewed as a PDF or in an editable format.

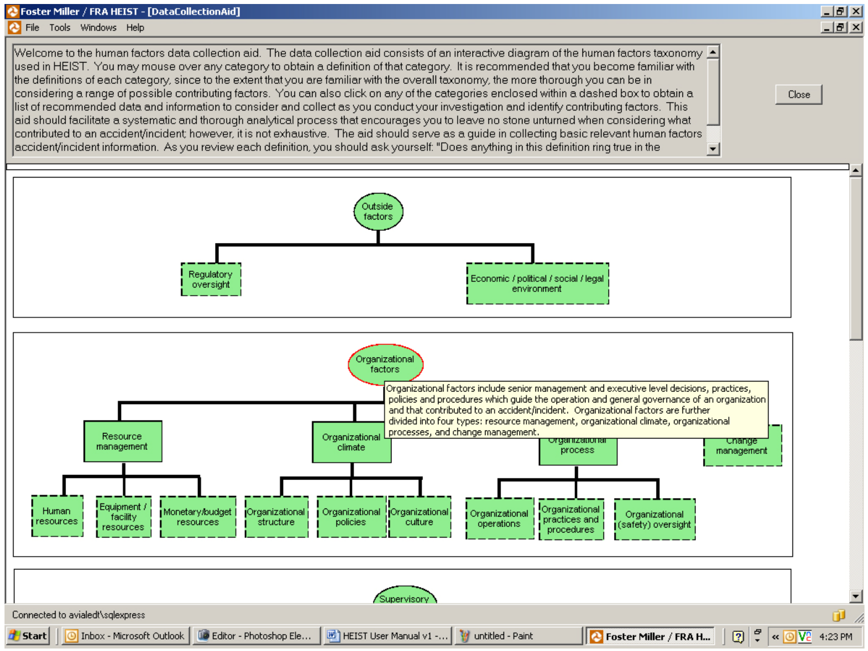

Figure 5. HEIST data collection aid (with mouse-over definition shown)

3.3 Data Classification Tools

HEIST contains several tools to aid investigators in using the HFACS-RR taxonomy to classify contributing factors once they have been identified.

HEIST Practice. This tool serves as a training aid to enable users to become familiar with the HFACS-RR taxonomy and categories by providing them with an opportunity to practice classifying contributing factors from National Transportation Safety Board (NTSB) accident investigations. The practice module contains synopses and selected contributing factors from three NTSB railroad accident investigations. For each accident investigation, the practice tool presents the user with the synopsis followed by a list of the contributing factors. The user must map each NTSB contributing factor to an HFACS-RR category. To use the tool, a user first selects a contributing factor from the list of available contributing factors, and then he/she selects, from an interactive diagram, the HFACS-RR category that he/she feels best classifies the contributing factor. An investigator can then check the accuracy of his/her classification decision against answers that are provided. If an investigator makes an incorrect classification, constructive feedback is provided to shepherd the user to the correct classification. Figure 6 provides a screen shot of the HEIST practice tool.

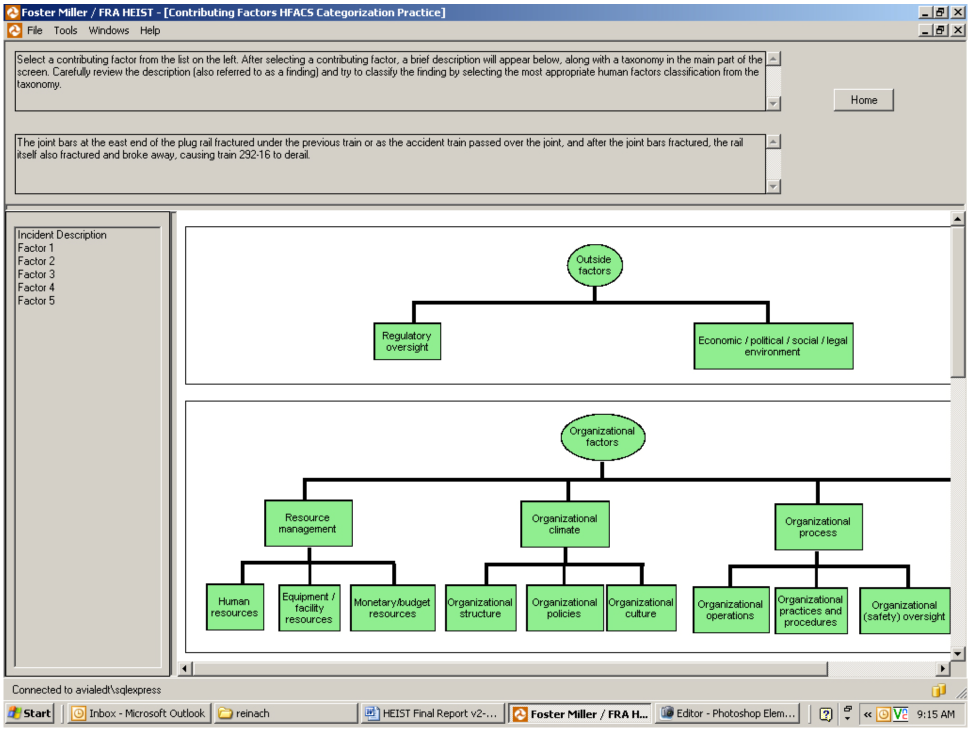

Figure 6. Screen shot of HEIST practice tool

HEIST Analysis Tool (HAT). HAT, despite its name, is a classification tool designed to enable investigators to enter and classify contributing factors they have identified based on the HFACS-RR human factors taxonomy. HAT functions similarly to the HEIST practice tool: users select a contributing factor from those they have identified and then use the interactive taxonomy to select the most appropriate HFACS-RR category. A help function is included within HAT to provide interactive assistance in classifying contributing factors. Within the help function, a user is guided to the most appropriate classification based on his/her answers to a series of questions (see Figure 7). Once a user has classified the contributing factor, HAT records the classification and prompts the investigator to classify another contributing factor. Users repeat this process until all contributing factors have been classified.

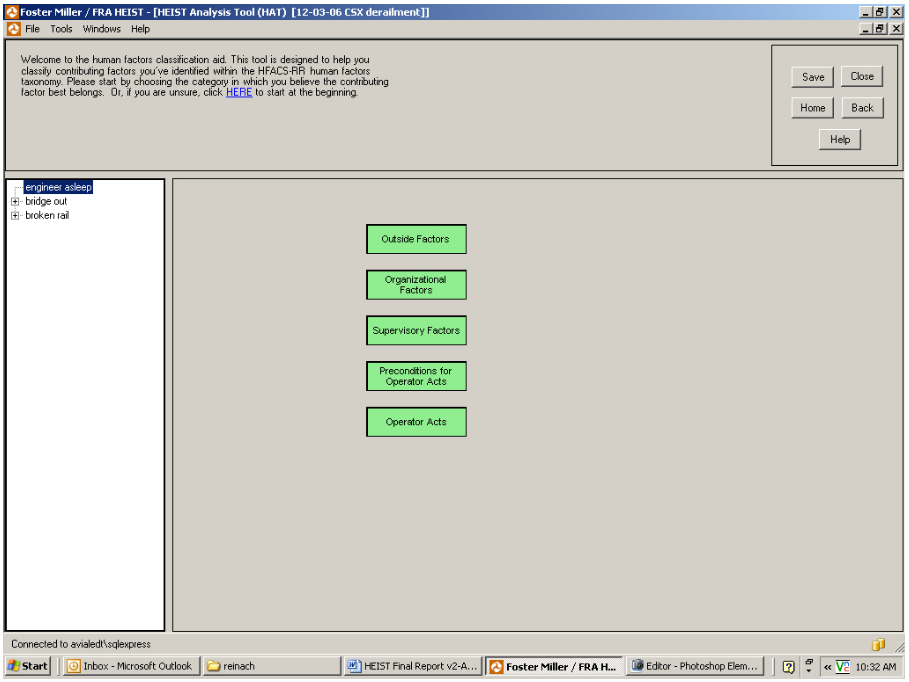

Figure 7. HAT help function

3.4 Reporting Tools

HEIST can generate basic investigation reports. Reports include any or all of the following three sections: descriptive information (e.g., time of day, type of occurrence, method of operation); illustrations, photos, and diagrams; and results of the HFACS-RR analysis. Reports can be viewed online and printed, and their contents can be copied and pasted into a word processor or other editable format.

3.5 Software Requirements

HEIST runs on computers with Windows XP (Pro or Tablet) Service Pack 2 installed. The host computer should have at least a 500 MHz Pentium III class processor or better, 512 MB of RAM, and at least 700 MB of hard disk space. Further information on HEIST's software components and the installation procedure are included with the HEIST installation CD and discussed in the user manual.

4. Future Directions

HEIST is currently in what can be considered its alpha (as opposed to a beta or complete) version. Although it is robust enough and has enough features to be used in its current form, additional enhancements and a field test with FRA Office of Safety inspectors would significantly add value to HEIST. Section 4.1 discusses some possible enhancements to improve HEIST, while Section 4.2 discusses possible next steps to implement enhancements to HEIST and conduct a field test with intended users of HEIST.

4.1 Future Enhancements

Proposed enhancements to HEIST address increased functionality, as well as improved usability, and are briefly discussed in the following sections. This list is not an exhaustive list. Rather, this list is the starting point for all possible improvements. Further discussion with FRA and other users is suggested to ensure that the right enhancements are implemented, including enhancements not identified below but that may be critical to FRA and other users.

4.1.1 RCA Tool

Currently, by design, HEIST includes data collection and data classification tools but not an analysis tool. The reason for this omission is that each inspector may have his/her own method of analyzing accident data to identify contributing factors. Because this process is part art and part science, the design of HEIST defers to the user. It may be valuable, however, to provide an RCA tool to aid inspectors who do not necessarily have their own analysis approach or who want to explore another approach for identifying accident contributing factors. The tool could be optional—available for those who wish to use it to support their investigation, but not required, in case some inspectors prefer to use their own approach to identify contributing factors. One type of tool may be a simple five-why approach, where the tool may guide a user to repeatedly ask (five times) why a certain action or event occurred. This and other RCA approaches should be examined to identify the most suitable method to incorporate into HEIST to support railroad accident investigations.

4.1.2 Timeline Tool

A timeline tool, such as a multilinear events sequencing (MES) diagram, can aid investigators in building a unified timeline of events for multiple parties involved in an accident/incident. The MES diagram is a single, chronologically arranged depiction of all events relating to the accident/incident and divided by each operator involved. A timeline tool aids the investigator in sorting out the events that occurred over both large and very small periods of time, and this tool can aid the investigator in ensuring that he/she has collected enough information about an accident (i.e., if the timeline reveals a gap for one or more individuals for a period of time, the investigator may determine that he/she needs to collect more information).

4.1.3 Digital Audio Capture

HEIST can be equipped with a digital audio recorder embedded in the Tablet PC or other host computer to enable inspectors to use HEIST to conveniently record and play back interviews with operators, supervisors, and/or officers.

4.1.4 Freehand Sketch Capture

Currently, HEIST allows a user to import or add electronic images already stored on the host computer. If desirable, HEIST can be designed to include an application that would allow an inspector to freehand draw a diagram or other figure/picture. A voice-over capability or properties capability could also be explored for this capability, so that an inspector could include annotated, descriptive information about the diagram that can be used for later analysis or for conveying information to another party, such as a supervisor.

4.1.5 Regulatory, Railroad, and Other Reference Materials

It may be valuable for FRA inspectors to use HEIST as a repository for, or have access to, electronic, searchable versions of various regulatory, State, and railroad-specific regulations, rules, and operating practices to aid the inspector in conducting an investigation. Candidate reference materials include: FRA regulations, equipment specifications (e.g., Universal Machine Language Equipment Register), and railroad materials, such as track diagrams, time tables, rule books, and current bulletins/orders/special instructions.

4.1.6 Automated Railroad Data Download

This capability would involve downloading railroad data related to the accident to HEIST. Data may include locomotive or remote control locomotive event recorder data, computer-aided dispatch data, track diagram information, and automatic equipment identification data. It is necessary to determine first whether or not data are available from railroads in an electronic format and second whether or not these data can be downloaded.

4.1.7 Work Schedule Calculator

A work schedule calculator can help investigators predict operator alertness as a possible contributing factor based on work schedule data and sleep habit information. Dr. Steven Hursh has created a stand-alone operator alertness calculator based on his Sleep, Activity, Fatigue, and Task Effectiveness model (Hursh et al., 2004). FRA has been exploring the use of this tool to aid their accident investigations. Dr. Hursh's work schedule tool could be embedded within, or linked to, HEIST. Dr. Hursh's work schedule and sleep habits data collection instrument also would need to be incorporated into HEIST for use with the work schedule tool.

4.1.8 Central Database

The current version of HEIST sets up and uses a database that is located on the computer on which HEIST is installed. To optimize the value of HEIST, it should have a centrally located database that HEIST users can access remotely to upload and download data. This is because the real utility of HEIST will be realized only after a significant amount of data have been collected over time and input into one master database. Then reliable human factors data analyses can be performed on the HEIST-enhanced accident data.

4.2 Possible Next Steps

Briefly, a logical set of next steps to advance HEIST to a beta version may include the following tasks:

1. Revise HEIST to include a selection of enhancements based on input from FRA Office of Safety stakeholders.
2. Update the user manual.
3. Conduct a field test with regional Office of Safety inspectors. Office of Safety stakeholder input will be critical in assuring participation by FRA regions, as well as identifying one or more locations to conduct the field test.
4. Revise HEIST and the user manual based on field-test participant (i.e., HEIST user) feedback.

5. References

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Appendix A.
HFACS and HFACS-RR

Appendix A illustrates the transformation that HFACS has undergone to make it more suitable for application to the railroad industry. This appendix is organized into three sections. The first section discusses Wiegmann and Shappell's (2003) original HFACS taxonomy. The second section discusses the first of two rounds of modifications that were made to HFACS, the result of which was called HFACS-RR. The third and final section discusses the most recent modifications that were made to HFACS-RR to integrate the needs of the HEIST program and the C3RS program, both sponsored by FRA.

A.1 HFACS

HFACS (Wiegmann & Shappell, 2003) has its basis in Reason's generic error modeling system and Swiss Cheese model of accident causation (Reason, 1990). The Swiss Cheese model depicts accidents as arising from holes in an organization's defenses at various levels of the organization, beginning with the operator and working all the way up to organizational decisions and conditions. Active failures by the operator combine with latent conditions or factors upstream in the organization to lead to an accident (or incident or close call). Accidents (and incidents and close calls) occur, therefore, when all of the active and latent factors (i.e., holes) line up to allow accident energy (depicted as a straight line) to penetrate these various organizational levels. An organization's defenses and barriers can, however, prohibit the alignment of active and latent factors and conditions, thereby preventing accidents (and incidents and close calls).

Wiegmann and Shappell (2003) originally developed HFACS as a classification system to help analyze U.S. naval aviation mishaps. HFACS was subsequently broadened to also include commercial and general aviation domains. HFACS models error at four different levels, beginning with the operator and moving upward in the organization. The four levels mirror Reason's Swiss Cheese model of error. The four levels of HFACS are unsafe acts (Reason's active failures—the operator activity that occurs closest in time and space to an accident, incident, or close call), preconditions for unsafe acts, unsafe supervision, and organizational influences. These latter three levels relate to Reason's latent factors or conditions, and they often exist for years before they contribute to an accident, incident, or close call. For each level, Wiegmann and Shappell (2003) identified a number of second-level categories. Some second-level categories divide further into third-level categories. A total of 19 unique categories of contributing factors exist. Figure A-1 illustrates the structure of the HFACS taxonomy, including the nesting style of different category levels. HFACS applies Reason's Swiss Cheese model of human error to an accident, incident, or close call classification system and provides a theory-driven structure to accident, incident, and close call investigation findings. For a discussion of each unique category's definitions, see Wiegmann and Shappell (2003).

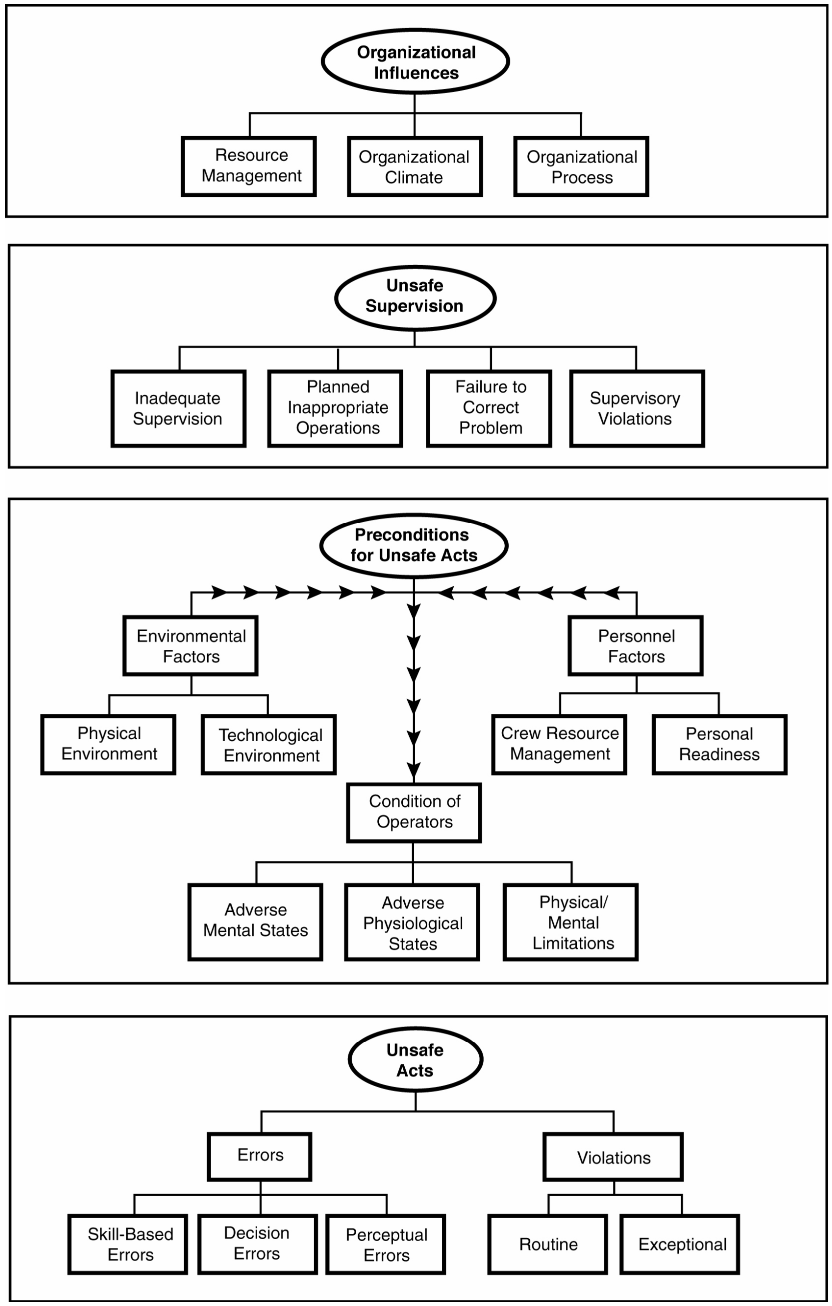

Figure A-1. Original HFACS taxonomy (Wiegmann & Shappell, 2003)

The use of a theoretically-driven RCA approach ensures that the accident, incident, or close call contributing factors identified during an investigation go beyond what happened to why an error occurred. Furthermore, such an approach allows for identifying the relationship between contributing factors more readily (for example, some types of errors may be linked to other types of contributing factors). Classifying errors based on their underlying theoretical nature enables identifying global trends across error forms, which on the surface may appear totally different. Consequently, and perhaps most importantly, one can identify corrective actions more readily to prevent errors and accidents, incidents, and close calls from recurring, since the data collected during the investigation highlight the underlying systemic problems that contributed to the events in the first place.

HFACS primarily provides the means to analyze data available from existing accident, incident, and close call investigations. HFACS is also a methodology, however, that can guide accident, incident, and close call investigations and support collection of human factors-related information. In fact, some Federal agencies, such as the U.S. Coast Guard and the U.S. Department of Defense, are now experimenting with the use of HFACS to support accident, incident, and close call investigations, as well as analysis (Wiegmann & Shappell, 2003; A. Carvalhais, personal communication, October 11, 2005).

The initial development and application of HFACS, however, was for the aviation domain. As a result, it was necessary to make minor changes to HFACS to optimize its relevancy to the railroad industry. The following section discusses these changes.

A.2 HFACS-RR

To ensure the best fit between HFACS and the railroad industry and to increase its acceptance within the railroad industry, several changes were made to HFACS. The overall tree structure of HFACS remained. The modified HFACS taxonomy was simply called HFACS-RR or HFACS-Railroad. An advantage of the original HFACS is that it uses generic terms and descriptors that are applicable to a range of industries and activities. Although others have made minor alterations to HFACS to suit their particular application, for example, to address air traffic control (HFACS-ATC; Scarborough & Pounds, 2001) and military activities (Canadian Armed Forces or CF-HFACS; see Wiegmann & Shappell, 2003), most of the original HFACS taxonomy remains in HFACS-RR to preserve the original structure. This facilitates future comparisons between data collected using HFACS-RR and HFACS-based accident, incident, and close call analyses in other industries.

To begin, the names of the top HFACS level were changed to have a more neutral tone. For example, unsafe acts of operators became operator acts. Table A-1 presents the original and modified terms.

Table A-1. Original HFACS and new HFACS-RR top-level categories

Original HFACS Top-Level Category	Modified HFACS-RR Top-Level Category
Unsafe acts of operators	Operator acts
Preconditions for unsafe acts	Preconditions for operator acts
Unsafe supervision	Supervisory factors
Organizational influences	Organizational factors

A new fifth level named outside factors was also added to the HFACS-RR taxonomy. Outside factors include the regulatory environment and the economic/political/social/legal[1] environment

[1] The legal environment includes other-than-regulatory laws that affect railroad operations.

in which railroads operate. Outside factors cover those influences outside the railroad or organization that affect how the organization operates and its decisions.

Other changes to the original HFACS taxonomy (and contained in the new HFACS-RR taxonomy) include the following:

- Replaced the term violations with the term contraventions throughout the HFACS-RR taxonomy to avoid stigma and biases associated with violations. Violations in the railroad industry are often associated strictly with (operating, safety) rules. Contraventions are generally more shortcutting and rule bending, and they may not necessarily be tied to violating a specific rule.
- Added a new subcategory under operator acts/contraventions called acts of sabotage. Acts of sabotage are related to the investigation only when the act is in response to a problematic organizational factor that is identified.
- Changed the organizational practices category to organizational practices and procedures.[2]
- Added fourth subcategory under the organizational factors category called organizational contraventions. This subcategory addresses upper level management and executive contraventions and short-cutting of existing organizational (i.e., internal) procedures or processes. This subcategory also addresses externally imposed municipal, State, and Federal regulations. This category parallels supervisory contraventions and contraventions of the operators themselves.

Figure A-2 presents the new HFACS-RR taxonomy with these modifications incorporated. The new HFACS-RR taxonomy contains a total of 23 unique categories of accident, incident, and close call contributing factors.

[2] Wiegmann and Shappell (2003) originally discuss procedures under the organizational influences/organizational process subcategory. The authors changed procedures to practices and procedures in the HFACS-RR taxonomy since many of the activities undertaken in a railroad switching yard environment involve practices (more broad methods of operation), rather than procedures, which are more specifically prescribed methods.

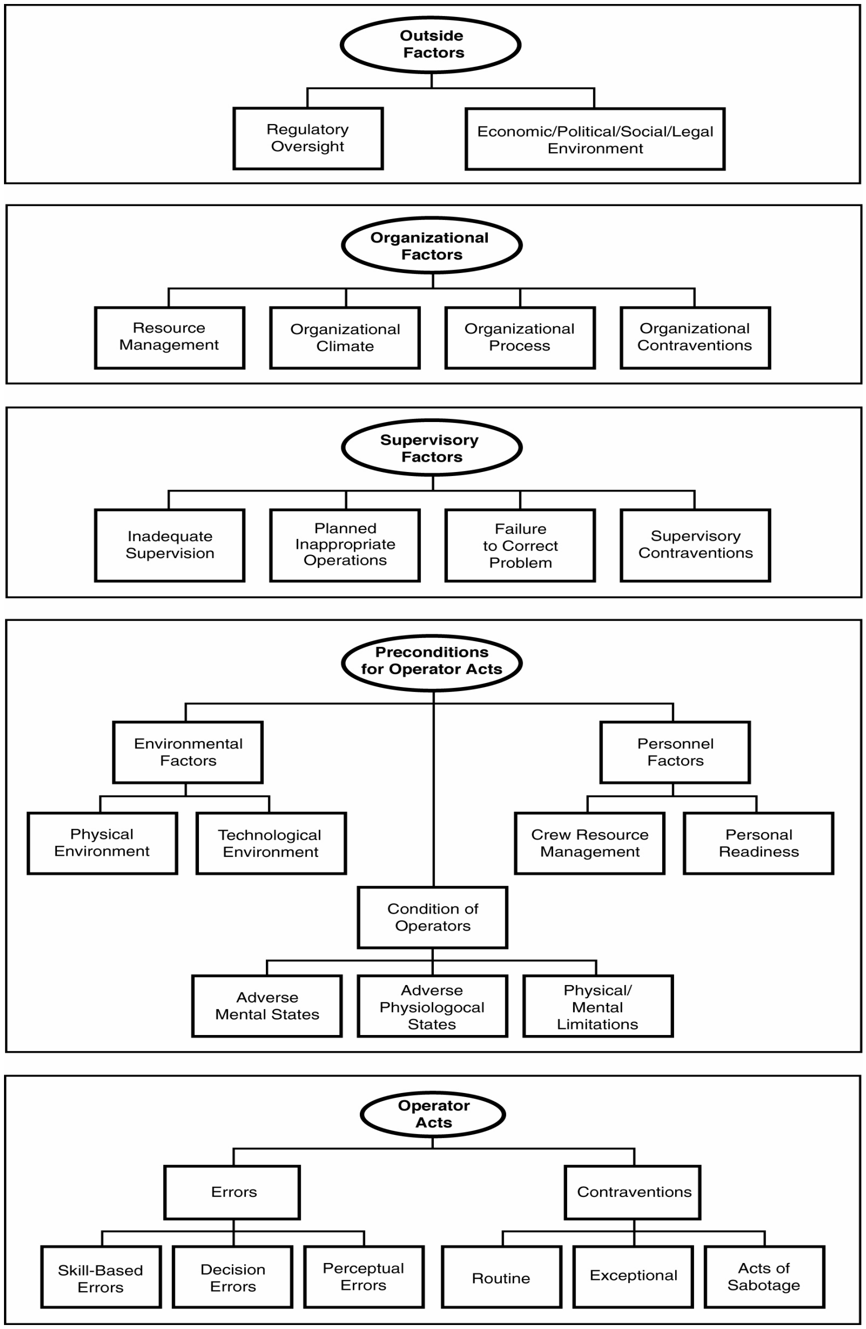

Figure A-2. HFACS-RR

A.3 HFACS-RR Update

Most recently, HFACS-RR underwent another round of modifications, this time to accommodate the needs of the C3RS program. The goal was for both HEIST and C3RS to be based upon, and use, the same underlying human factors taxonomy. Since it was desirable to maintain the HFACS-RR structure, HEIST researchers worked with the C3RS project manager to update the HFACS-RR taxonomy specifically to accommodate elements of a second human factors taxonomy, Eurocontrol's Systemic Occurrence Analysis Methodology (SOAM; 2005). The update also involved improved definitions for each HFACS-RR category.

The process involved the following steps:

- Researchers reviewed SOAM and mapped each SOAM category to an existing HFACS-RR category. Where researchers felt that the SOAM category was not explicitly covered by the HFACS-RR definition, the SOAM category was added to the appropriate HFACS-RR category definition, often as an example. Occasionally, the wording of the SOAM category was changed when it was felt that the railroad industry would better understand the new wording (like HFACS, SOAM was originally developed for the aviation industry).
- Researchers were unable to incorporate six SOAM categories into HFACS-RR due to a lack of full understanding of their meaning, or, in one case (error proneness), researchers felt that it was not a meaningful or useful category to include. The six unused SOAM categories were: poor signal/noise ratio, poor access to job, high-risk target, skill overcomes danger, error proneness, and strong motor programs (frequency bias, similarity bias).
- Researchers added one new HFACS-RR category based on SOAM, which was change management. It was added as a second-level category under organizational factors because researchers felt that change management included a unique set of issues not otherwise captured in the existing HFACS-RR taxonomy.
- An additional level of categories was added to the following five HFACS-RR categories based on Wiegmann and Shappell's (2003) original HFACS taxonomy and definitions:
    - Skill-based errors were subcategorized into attention failures, memory failures, and technique errors.
    - Decision errors were subcategorized into procedural errors, poor choices, and problem-solving errors.
    - Resource management was subcategorized into human resources, equipment/facility resources, and monetary/budget resources.
    - Organizational climate was subcategorized into organizational structure, organizational policies, and organizational culture.
    - Organizational process was subcategorized into organizational operations, organizational practices and procedures, and organizational oversight.
- The following changes were made to HFACS-RR category names:
    - Added "context" in parentheses in the preconditions for operator acts category.
    - Added "safety" in parentheses in the organizational oversight category.
- The following HFACS-RR category definitions were modified:
    - Moved accident investigations from organizational policies to organizational (safety) oversight.
    - Changed crew scheduling to rostering and moved from planned inappropriate operations to human resources. Although seniority is locally based, establishment of work schedules and crew pairing is often carried out by a centrally located or

headquarters-based department, not the local supervisors who plan train movements and operations.

  - Moved signage from physical environment to technological environment.
  - Removed the organizational contraventions category. Now organizational contraventions are presented as examples of, and part of the definition of, organizational culture. Contraventions/violations, which imply individual behavior, make sense to identify at lower levels where people operate within the context of an organization. At the organizational level, however, it is more meaningful to focus on the organizational environment and its culture, practices and procedures, and structure, rather than on contraventions/violations, which strongly suggest the actions of individuals.

- Lastly, whereas HEIST refers to deviations from rules and operating procedures as contraventions, the C3RS program will use the term violations. This change is nominal only.

Figure A-3 illustrates the new HFACS-RR taxonomy. The updated HFACS-RR taxonomy has 33 unique categories.

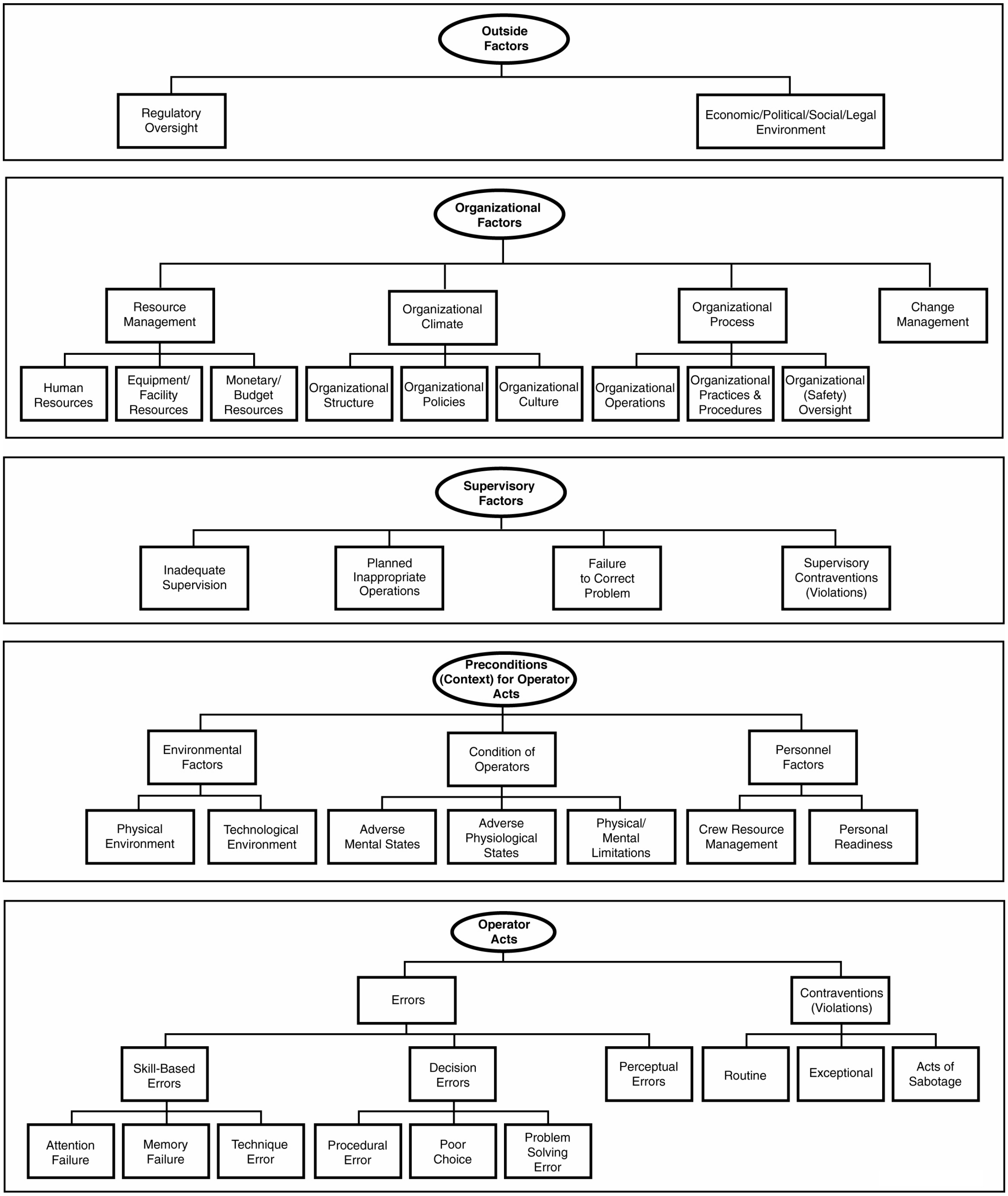

Figure A-3. Updated HFACS-RR taxonomy

Appendix B.
User Evaluation Form

Appendix B contains a copy of the user evaluation questions distributed to FRA stakeholders to help structure and obtain their feedback after using HEIST.

1. Please identify any *problems* (i.e., bugs, glitches, unforeseen software faults or errors) you found while using HEIST. Please provide, as best you can, (1) the circumstances under which you encountered the problem, as well as (2) a full description of the problem. Feel free to use a separate document to list problems you encountered.

2. What changes to HEIST would you suggest? Consider the interface and how you used the software when answering this question. Also consider the quantity of instructions provided throughout HEIST and the clarity of the instructions. Please be as detailed as possible. Feel free to use a separate document to list suggested changes.

3. What enhancements, such as future functions and features, would you like to see in future versions of HEIST? Please be as detailed as possible. Feel free to use a separate document to list these enhancements.

4. How easy was it to use HEIST? (Check the most appropriate description in the table below.)

	Very easy to use
	Mostly easy to use
	Moderately easy to use
	Moderately hard to use
	Mostly hard to use
	Very hard to use

5. What suggestions do you have to make HEIST easier to use?

6. How helpful was the user manual? (Check the most appropriate description in the table below.)

	Very easy to use
	Mostly easy to use
	Moderately easy to use
	Moderately hard to use
	Mostly hard to use
	Very hard to use

7. What suggestions do you have to make the user manual easier to use? Please be specific.

8. How useful do you feel HEIST would be to the Office of Safety and the railroad industry as a whole? (Check the most appropriate description in the table below.)

	Very useful
	Moderately useful
	Not useful

9. Please share any additional feedback you have about the current design of HEIST.

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Abbreviations and Acronyms

C3RS	Confidential Close Call Reporting Systems
FRA	Federal Railroad Administration
HAT	HEIST Analysis Tool
HEIST	Human Error Investigation Software Tool
HFACS	Human Factors Analysis and Classification System
HFACS-RR	Human Factors Analysis and Classification System-Railroad
MES	multilinear events sequencing
NTSB	National Transportation Safety Board
RCA	root cause analysis
SOAM	Systemic Occurrence Analysis Methodology