Use of Human Factors Analysis for Wildland Fire Accident Investigations

M. Ryerson-Grett[1], C. Whitlock[2]
[1]USDI Bureau of Land Management, Office of Fire and Aviation, ID, USA
[2]USDA United State Forest Service, Missoula Technology and Development Center (MTDC), MT, USA

Abstract

Accident investigators at any level are challenged with identifying causal factors and making preventative recommendations. This task can be particularly complicated considering that 70 percent to 80 percent of accidents are associated with human error. Due to complexities of the wildland fire environment, this is especially challenging when investigating a wildland fire-related accident. Upon reviewing past accident investigations within the United States federal wildland fire program, many investigations stop short of identifying root causes of human factors that contributed to the accidents. This element of investigation is critical in accident prevention and can have a direct impact on wildland fire policies and standards.

We would like to present to the international wildland fire community a means of human factors analysis used in the United States—Human Factors Analysis and Classification System (HFACS). This model has been used primarily in aviation related accidents, and we are currently working towards implementing it for ground wildland fire accidents (and incidents) within the United States federal wildland fire program. This model provides a tangible means of analyzing human factors, which often have many dimensions. After all, it is typically the actions or inactions of people that are directly linked to an accident, but we have failed to adequately account for this in past investigations.

The goals of our presentation will be to provoke thought and discussion, and share an extremely useful investigation tool with the international fire community to improve wildland firefighter safety. We believe that when applied to wildland fire investigations, this model can significantly contribute to firefighter safety through preventative measures that may lead to improved firefighter training, wildland fire policy and/or standard changes.

Full Paper Submission

It is well known in the world of accident investigations that about 80 percent of accident causes are directly linked to human factors. After reviewing past accidents within the United States federal wildland fire program, it is surmised that most of these investigations have stopped short in identifying accident causal factors related to the human element. Past investigations have primarily focused on policy, training, environmental factors, and equipment failures. Although these focal areas are critical to identifying fire-related accident causal factors, they provide us with minimal to no information on human interaction in the causal factors of the accident. Several reasons for this investigation oversight can be attributed to:

- Human factors are often not directly observable or measurable.
- Fear of impression of blaming victims or organizations.
- Firefighting culture is operationally focused; therefore so are its accident investigations.
- Investigators lack tools or training in identifying human factors.

The goals of this paper are to provide the reader with the knowledge and tools to help wildland fire managers and accident investigators better identify human factor accident (or incident) causal factors to ensure that appropriate accident prevention actions take place. After all, the goal of accident investigation is accident prevention.

The realm of human factors is complex and incorporates many disciplines such as psychology, physiology, sociology, biomechanics, systems science, and management science. To help simplify human factors for accident investigation purposes, the model of Human Factors Analysis and Classification System (HFACS) has been adopted as the basis for human factors analysis for on-the-ground wildland fire investigations by the United States Forest Service (USFS) and Bureau of Land Management (BLM), which make up the largest federal firefighting forces in the United States. HFACS has been utilized by the aviation industry in the United States for some time and has been adopted by aviation investigators in the Departments of the Interior and Agriculture. The HFACS model may appear complicated at first glance, but it is important to understand its genesis to know how to use the analysis. The HFACS model is based on James Reason's "Swiss Cheese" model of human error. This genesis of human error is described by Reason as four levels of human failure, each influencing the next (Exhibit 1).

In this model, the taxonomy of errors begins with the first level, *Unsafe Acts*. This level depicts the actions or inactions by an individual that is directly linked to the accident. This is the level where most accident investigations focus and consequently where most causal factors are identified. This level, Reason describes as "active" failures that are easily detectable.

The last three levels are considered "latent" failures, which may lie dormant or undetected for any given amount of time (e.g., hours, days, week, months, years) until the day when they indiscriminately appear and are often overlooked by investigators. The first of the latent failures is the *Preconditions for Unsafe Acts*. These failures are best described by examples such as firefighter fatigue, poor interpersonal communications and coordination. We have often seen in accident investigations where fatigue has contributed to failure of communication and coordination resulting in poor decisions where errors result.

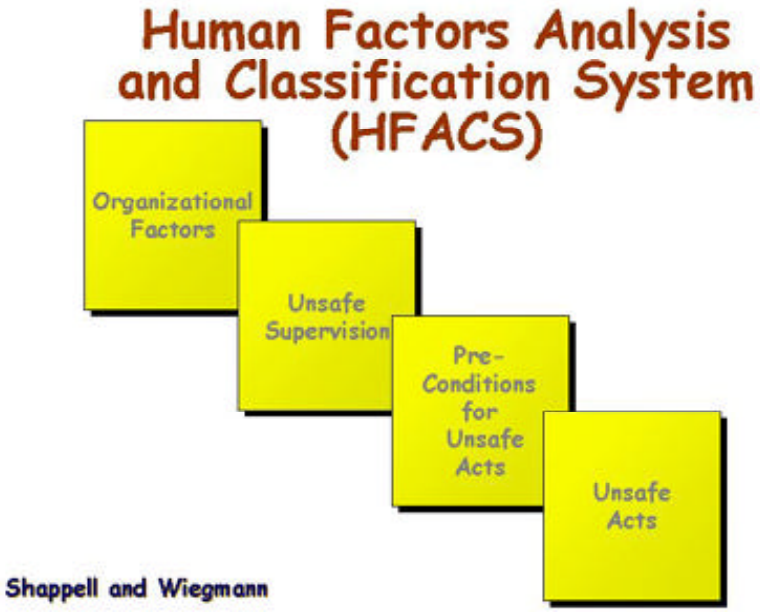

Exhibit 1

The third level of human failure, *Unsafe Supervision*, is more appropriately defined as inadequate supervision. As a latent error, poor or minimal supervisor performance or attention can have a direct impact on employee's actions or inactions, but go unnoticed until an accident occurs.
Reason goes onto to identify organizations as having an impact at all levels, thus the last level of *Organizational Factors*. Many of our past investigations have failed to identify systemic organizational factors as influencing accident causation. This model identifies the need to identify accident causal factors at all levels within the organization before appropriate prevention measure can be addressed.

The holes in the "Swiss cheese" appear when defenses at each level are not established or not adequate enough to prevent an accident from occurring. The holes/defenses are not stagnant and will appear and disappear depending upon when they are applied (Exhibit 2).

Exhibit 2

When active and latent failures line-up while the holes in defenses are aligned, an accident results. Reason terms this the accident trajectory (Exhibit 3). In wildland fire terms, mitigation measures are not identified or practiced, which results in a negative outcome (injury, fatality, escaped fire).

The HFACS authors have taken Reason's model and further defined and expanded upon the four levels to provide better descriptors of how to apply it during accident investigations. They have essentially filled in the holes of the cheese. Thereby, allowing for better identification of human factor causal factors that will lead to appropriate corrective actions and ultimately prevent the same or similar accident from occurring (Exhibits 4-5).

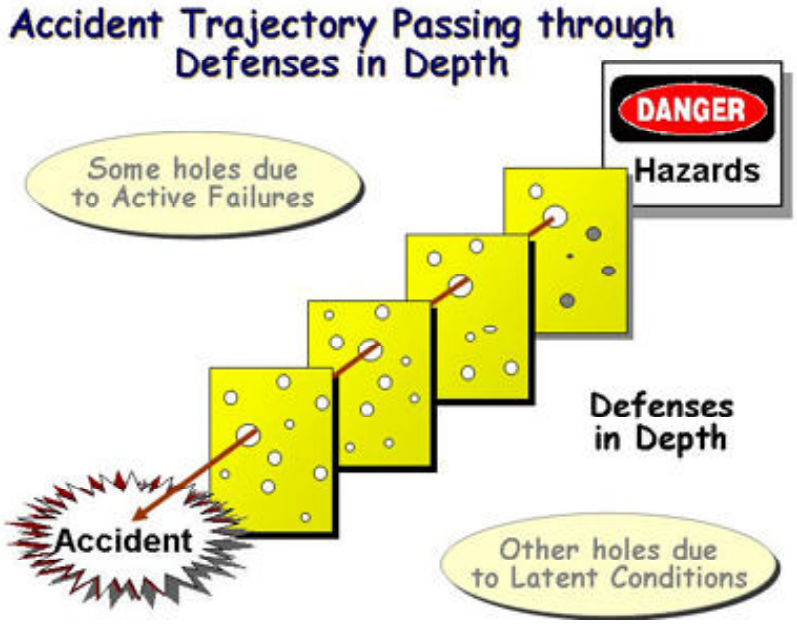

Exhibit 3

The HFACS is based on numerous naval and commercial aviation accidents within the United Stated. The USFS and BLM have taken the HFACS analysis and "de-aviationized" it to create a Human Factors Accident and Incident Analysis (Attachment 1) for on-the-ground wildland fire accident investigations. Many other human factor models are available, but HFACS was

chosen due to the logical and corresponding analysis elements that were easily adaptable to wildland fire.

With the integration of human factors into our accident investigations, we are at the beginning of a new era in accident prevention for the wildland fire program. Thorough human factors analysis can result in effective intervention and prevention strategies and provide for appropriate recommendations that will ultimately lead to improved firefighter safety.

The entire HFACS document, plus the USFS Accident Investigation Guide, as well as the BLM's Chief Investigator Guide can be found on the National Interagency Fire Center website at www.nifc.gov, select the safety category. Recommended additional reading includes:
"Managing the Risks of Organizational Accidents", James Reason (1997)
"Managing the Unexpected", Karl Weick and Kathleen Sutcliffe (2001)

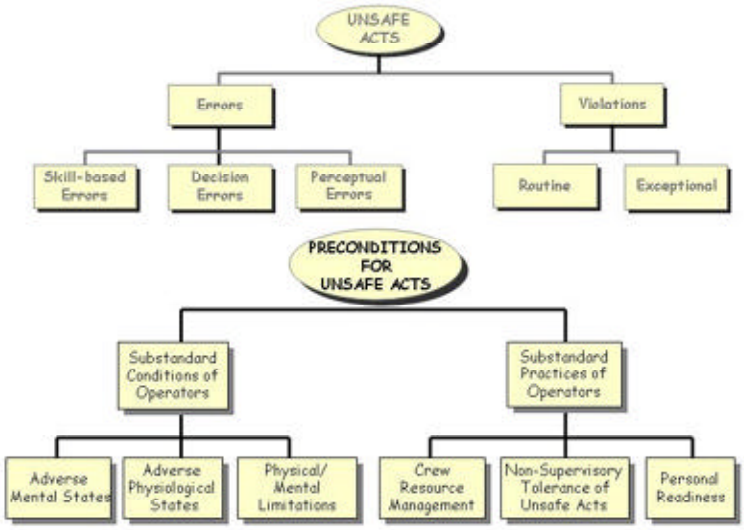

Exhibit 4

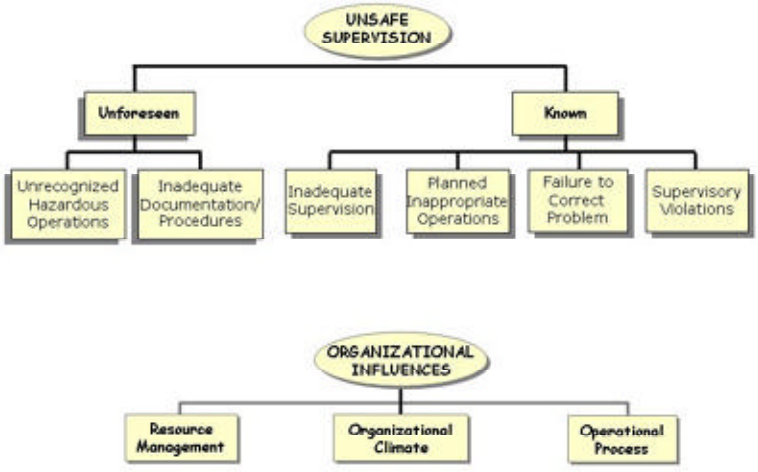

Exhibit 5

Human Factors Accident and Incident Analysis

1. Sensory and Perceptual Factors

Misjudgment of distance, clearance, speed, etc.
False perception caused by visual illusion
- Conditions that impair visual performance:
  - Featureless terrain (such as a desert, dry lake, water, snow)
  - Darkness and poor visibility
  - Smoke and changing smoke patterns
  - Mountainous terrain or sloping runway
  - Anomalous light effects that cause flicker vertigo
  - Low contrast of objects to background or poor illumination
  - View into bright sunlight or moonlight
  - Shadows
  - Whiteout snow conditions

Spatial disorientation and vertigo
Conditions that affect sense of body position:
- Loss of visual cues
- Adverse medical condition or physiological condition (alcohol and drug effects, hangover, dehydration, fatigue and so forth)
- Moving head up and down, looking in and out to change radios, answering or using cell phones

Loss of situational awareness
- Types:
  - Geographic disorientation (such as deviation from route, loss of position awareness)
  - General loss of situational awareness (such as failure to perceive hazardous condition)
  - Erroneous situational assessment (misinterpretation of situation or condition)
  - Failure to predict or anticipate changing conditions
  - False hypothesis confirmation bias (persistent false perception or misconception of situation)

Attention failure (such as failure to monitor or respond when correct information is available)
- Types:
  - Failure to visually scan outside the vehicle or equipment for hazards
  - Omission of checklist items
  - Failure to respond to communication or warning
  - Control-action error:
    - Failure to set, move, or reset control switch (lapse)
    - Unintentional activation of control switch (slip)
    - Control-substitution error (slip)
    - Control-reversal error (slip)
    - Control-adjustment or precision error (slip)

Conditions that affect attention and situational awareness:
- Inattention (focus on information unrelated to tasks)
- Channelization, fixation (psychological narrowing of perception)
- Distraction (preoccupation with internal [mental] event or with external event)
- Task overload due to systems (such as communications)
- Task overload due to equipment systems assignment factors
- Cognitive workload (problem-solving concentration or information overload)
- Habit influence or interference
- Excessive crew stress or fatigue
- Excessive workload or tasking
- Inadequate briefing or preparation
- Inadequate training or experience for assignment
- Negative learning transfer (such as during transition to new assignment)
- Adverse meteorological conditions
- Tactical-situation overload or display-information overload
- Inadequate crew motivation or inadequate vigilance
- Inadequate equipment design

2. Medical and Physiological

Carbon Monoxide poisoning
Self-medication (without medical advice or against medical advice)
Motion sickness
Incompatible physical capabilities
Overexertion while off duty
Influence of drugs or alcohol
Cold or flu (or other known illness)
Excessive personal stress or fatigue
Inadequate nutrition (such as omitted meals)
Hypoxia
Heat
Cold
Stress induced by heightened state of alertness
Affects of smoke
Dehydration
Other medical or physiological condition
- Conditions that may cause adverse medical or physiological state:
  - Assignment tasking or job fatigue (such as on duty more than 14 hours, late-night or early morning operations)
  - Cumulative fatigue (such as excessive physical or mental workload, circadian disruption, or sleep loss)
  - Cumulative effects of personal or occupational stress (beyond stress-coping limit)

(Continued)

Emergency condition or workload transition (from normal operation to emergency operation)
Medical or physiological preconditions (health and fitness, hangover, dehydration, and so forth)

3. Knowledge and Skill

Inadequate knowledge of systems, procedures, etc. (knowledge-based errors)
Types:
Knowledge-based
Inadequate knowledge of systems, procedures
Used improper procedure
Illstructured decisions
Failure in problem solving
Inadequate equipment control, or inadequate accuracy and precision of equipment maneuvering (skill-based error)
Types:
Breakdown in visual scan
Failure to see and avoid
Over or under reacting
Over or under controlling
Inadequate experience for complexity of assignment
Misuse of procedures or incorrect performance tasks (rule-based error), such as:
Failure to perform required procedure
Use of wrong procedure or rule(s)
Failure to conduct step(s) in prescribed sequence
Conditions that lead to inadequate operational performance:
Lack or variation of standards
Loss of situational awareness in varying environment
Demonstration of performance below required proficiency standards or currency standards
Demonstration of inadequate performance or documented deficiencies
Inadequate essential training for specific task(s)
Inadequate recent experience or inadequate experience
Lack of sensory input
Limited reaction time

4. Assignment Factors

Failure of dispatch to provide correct critical information (such as frequencies, location, other equipment or resources)
Poor communication with other assets (such as ground or aircraft)
Inadequate or faulty supervision from ground or tactical aircraft
Lack or variation of standards
Nonparticipant or non-communicative equipment or resources at the scene
Loss of situational awareness in varying environment
Changing plans tactics (change of teams on incidents)
Unanticipated change of radio frequencies
Intentional deviation from procedures
Unintentional deviation from procedures
Demonstration of performance below required proficiency standards or currency standards
Demonstration of inadequate performance or documented deficiencies
Inadequate essential training for specific task(s)
Inadequate recent experience or inadequate experience for assignment
Transition (learning new equipment or operational systems)
Inadequate knowledge of tactical situation
Lack of sensory input
Limited reaction time
Conditions that lead to inadequate special use assignment performance
Smoke
Wind shifts
Changes in fire behavior
Low visibility
Unexpected or non-participant equipment, resources, or aircraft
Assignment intensity
Assignment creep
Assignment urgency
Failure to recognize deteriorating conditions
Time compression
Diverts to new incidents
Excessive communication demands
Past assignment success based on high risk behavior

5. Personality and Safety Attitude

Demonstration of overconfidence
Demonstration of excessive motivation to achieve assignment
Reckless operation
Demonstration of anger or frustration on the job
Demonstration of stress-coping failure (such as anger)
Overly assertive or nonassertive
Inadequate confidence to perform tasks or activities
Acquiescence to social pressure (from organization or peers) to operate in hazardous situation or condition
Failure to report or act upon incidents of misconduct
Toleration of unsafe acts and behaviors
Poor equipment or assignment preparation

(Continued)

6. Judgment and Risk Decision

Acceptance of a high-risk situation or assignment
Misjudgment of assignment risks (complacency)
Failure to monitor assignment progress or conditions (complacency)
Use of incorrect task priorities
Intentional deviation from safe procedure (imprudence)
Intentional violation of standard operating procedure or regulation
- Types:
  - Violation of orders, regulations, SOP
  - Crew rest requirements
  - Inadequate training
  - Violated agency policy or contract
  - Failed to comply with agency manuals
  - Supervisor knowingly accepted unqualified crew
  - Failed to obtain valid weather brief
  - Accepted unnecessary hazard
  - Not current or qualified for assignment

Intentional disregard of warnings
Noncompliance with personal limits
Noncompliance with published equipment limits
Noncompliance with prescribed assignment parameters
Acquiescence to social pressure (from organization or peers)
- Conditions leading to poor safety attitude and risky judgment
  - History of taking high risks (personality-driven)
  - Pattern of overconfidence
  - Personal denial of wrongdoing
  - Documented history of marginal performance or failure
  - Excessive motivation (did not know limits)
  - Reputation as a reckless individual
  - Failure to cope with life stress (anger or frustration)
  - Overly assertive or nonassertive (interpersonal style)
  - Influenced by inadequate organizational climate or safety culture (such as lack of adequate supervision)

7. Communication and Crew Coordination

Inadequate assignment plan or brief
Inadequate or wrong assignment information conveyed to crew (dispatch errors or supervisor errors)
Failure to communicate plan or intentions
Failure to use standard or accepted terminology
Failure to work as a team
Inability or failure to contact and coordinate with ground or aviation personnel
Inadequate understanding of communication or failure to acknowledge communication
Interpersonal conflict or crew argument during assignment
- Conditions leading to inadequate communication or coordination:
  - Inadequate training in communication or crew coordination
  - Inadequate standard operating procedures for use of crew resources
  - Inadequate support from organization for crew-coordination doctrine
  - Failure of organizational safety culture to support crew resource management

8. System Design and Operation

Use of wrong switch or lever or control
Misinterpretation of instrument indication
Inability to reach or see control
Inability to see or interpret instrument or indicator
Failure to respond to warning
Selection or use of incorrect system operating mode (mode confusion)
Overreliance on automated system (automation complacency)
- Conditions that contribute to design-induced crew errors:
  - Inadequate primary equipment control or display arrangement
  - Inadequate primary display data or data format
  - Inadequate hazard advisory or warning display
  - Inadequate system instructions or documentation
  - Inadequate system support or facilities
  - Inappropriate type or level of automation, or excessive mode complexity

9. Supervisory and Organizational

Not adhering to rules and regulations
Inappropriate scheduling or crew assignment
Failure to monitor crew rest or duty requirements
Failure to establish adequate standards
Failure to provide adequate briefing for assignment
Failure to provide proper training
Lack of professional guidance
Failure to support or negative support of crews
Failure to monitor compliance with standards
Failure to monitor crew training or qualifications
Failure to identify or remove a known high-risk employee
Failure to correct inappropriate behavior
Failure to correct a safety hazard
Failure to establish or monitor quality standards

(Continued)

Failure of standards, either poorly written, highly interpretable, or conflicting
Risk outweighs benefit
Poor crew pairing
Excessive assignment tasking or workload
Inadequate assignment briefing or supervision
Intentional violation of a standard or regulation
Failure to perceive or to assess correctly assignment risks, with respect to:
- Hazards go unseen or unrecognized
- Environmental hazards or operating conditions assignment tasking and crew skill level
- Equipment limitations

Conditions leading to supervisory failures:
- Excessive operations or organizational workload (imposed by the organization or imposed by organizational chain)
- Inadequate organizational safety culture
- Supervisor is over-tasked
- Supervisor is untrained
- Inattention to safety management (inadequate safety supervision)
- Inadequate work standards or low performance expectations
- Inadequate or bad example set by supervisors
- Inadequate safety commitment or emphasis by supervisors
- Organization lacked an adequate system for monitoring and correcting hazardous conditions
- Supervisors did not promote and reward safe behavior or quickly correct unsafe behaviors
- Organization did not have adequate policies and procedures to ensure high quality work performance
- Organization had inadequate job-qualification standards or training program
- Organization had inadequate internal communication
- Organization had no system or an inadequate system for management of high-risk employees
- Organization had inadequate process or procedures for operational risk management
- Organization did not provide adequate human factors training

Organization did not ensure sufficient involvement of medical and occupational health specialists
Organization did not establish or enforce acceptable medical or health standards

10. Maintenance

Procedures
- Unwritten
- Unclear or not defined or vague
- Not followed

Records
- Discrepancies entered but not deferred or cleared
- Entries not recorded or not recorded in correct book(s)
- Improper entries or unauthorized signature or number
- Falsification of entries

Publications, manuals, guides
- Not current
- Were not used for the procedure
- Incorrect manual or guide used for procedure
- Not available

Training
- Not trained on procedure
- Training not documented
- Falsified
- Not current

Personnel
- Not properly licensed
- Insufficient (staffing)
- Improper or insufficient oversight
- Not properly rested

Management
- Nonexistent
- Ineffective
- Understaffed
- Ineffective organization chart
- Insufficiently trained

Quality Assurance
- Nonexistent
- Insufficiently trained
- Ineffective
- Not used when available

Inspection Guides
- Not available
- Procedures not followed
- Insufficient
- Not current
- Not approved
- Not signed off
- Falsified
- Unapproved signature or number

Tools or Equipment
- Improper use or procedure
- Not calibrated
- Not used properly
- Not trained for the special equipment or tool
- Not used
- No tool control program

REFERENCES

Kern, T.; Rauch, S.; Whitlock, C. (2000). 30 Mile Fatality Case Study, Powerpoint presentation.

Mancuso, V. (1995) Moving from Theory to Practice: Integrating Human Factors into an Organization. Professional paper, Delta Airlines.

Reason, J. (1997). *Managing the Risks of Organizational Accidents*. Burlington, VT:Ashgate Publishing Company.

Shappell, S.A., and Wiegmann, D.A. (2000). The Human Factors Analysis and Classification System—HFACS. U.S. Department of Transportation Report, DOT/FAA/AM00/7. Office of Aviation Medicine, Washington, DC.

U.S. Forest Service, Accident Investigation Guide, 2003 Edition, 00367-2808-MTDC.