Source-Mechanism-Outcome: A Simple, Yet Effective Hazard Description Model

Don Swallom

Madison, Alabama

Hazard Description Models

- ***Important***
  - ***Help identify hazards***
  - ***Describe in terms that facilitate identifying effective mitigation measures***

Hazard Models

- **Historically two shortfalls:**
  - **Too complex either in the way the components of a particular model are described or in the terminology used**
  - **Or they are structured so that they cannot be applied to all classes of hazard**

Source-Mechanism-Outcome Model

- **The first component - the "source"**
- **An activity, condition, or circumstance that has the potential to do harm to an asset**
  - **An asset is simply defined as something of value that must be protected**
    - Personnel, facilities, equipment, operations, data, the public, and the environment, as well as the system itself
- **That which has the potential to cause harm**

Sources - Things That Cause Harm

- Sharp edges
- Hydraulic pressure
- Height above ground
- Temperature extremes
- Fire
- Radiation
- Explosives
- Hazardous material leaks or spills
- Operator error
- Fatigue
- Utility outage
- Potholes
- Ad infinitum…

Source-Mechanism-Outcome Model

- **Mechanism**
  - **That process or sequence of events that allows or enables the source to cause the harm**
  - **Might be described in very simple terms or it may require a complex multi-linear diagram to understand it**

Source-Mechanism-Outcome Model

- **Outcome**
  - **The harm which the source brings about through the mechanism**

A Simple Example - “Being Burned”

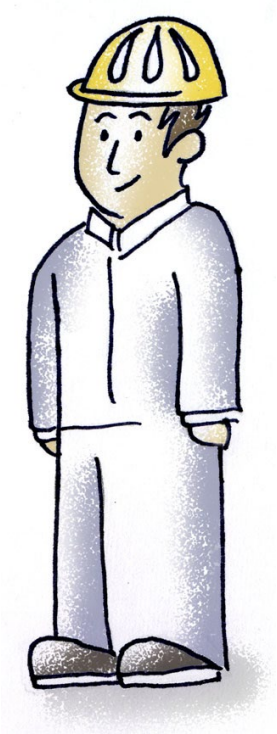
Using the model

- Source - Heat
- Mechanism - Contact with the heat source
- Outcome - Burned skin

Dave West's example:

"Source-Mechanism-Outcome"

Source



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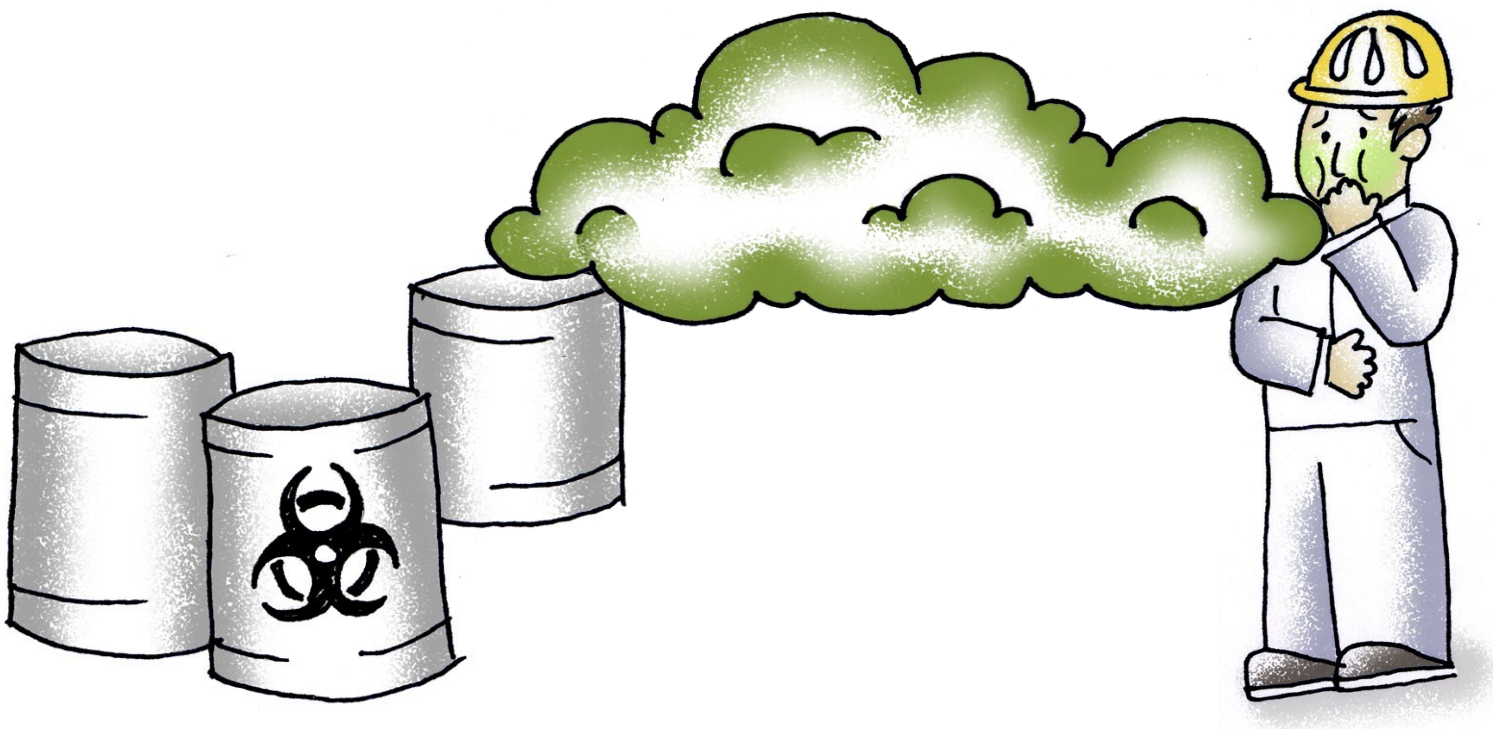

Source **Mechanism**

Dave West's example:

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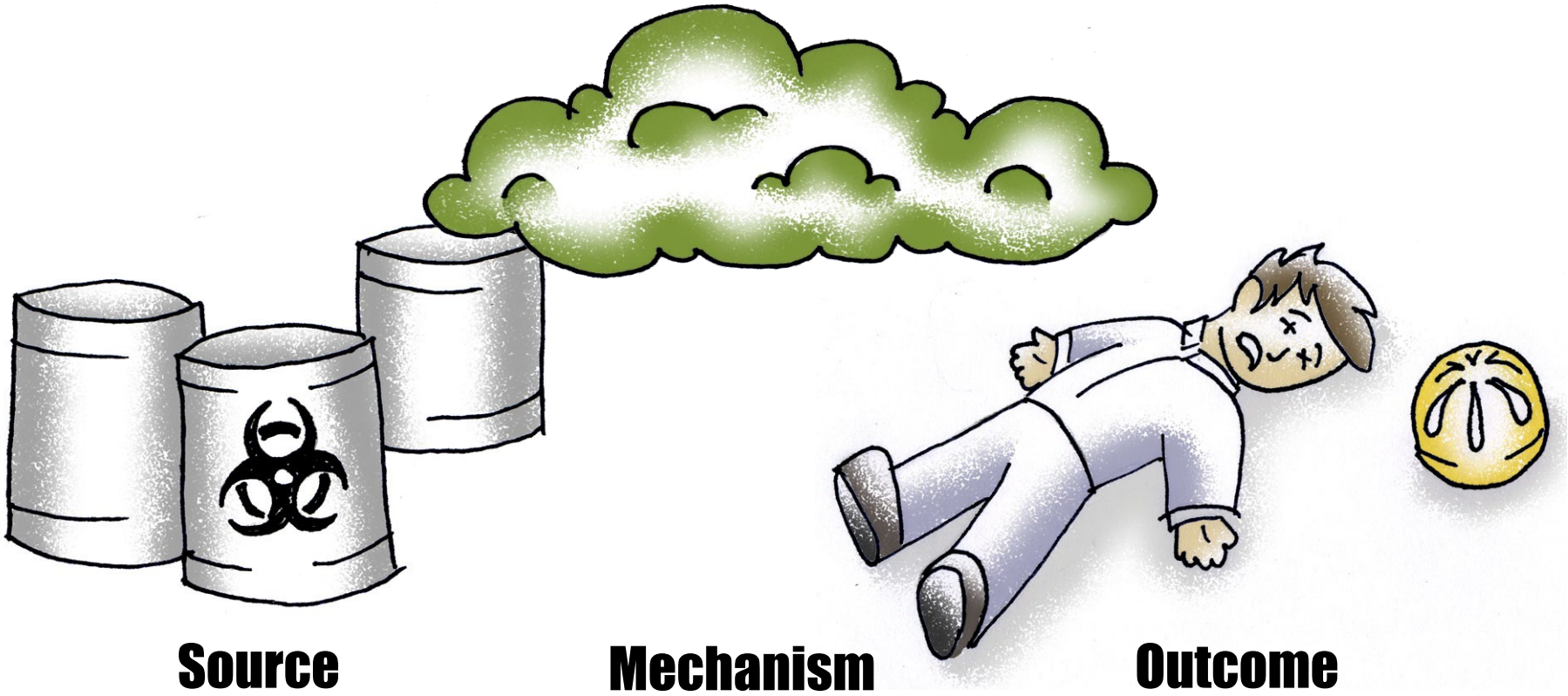
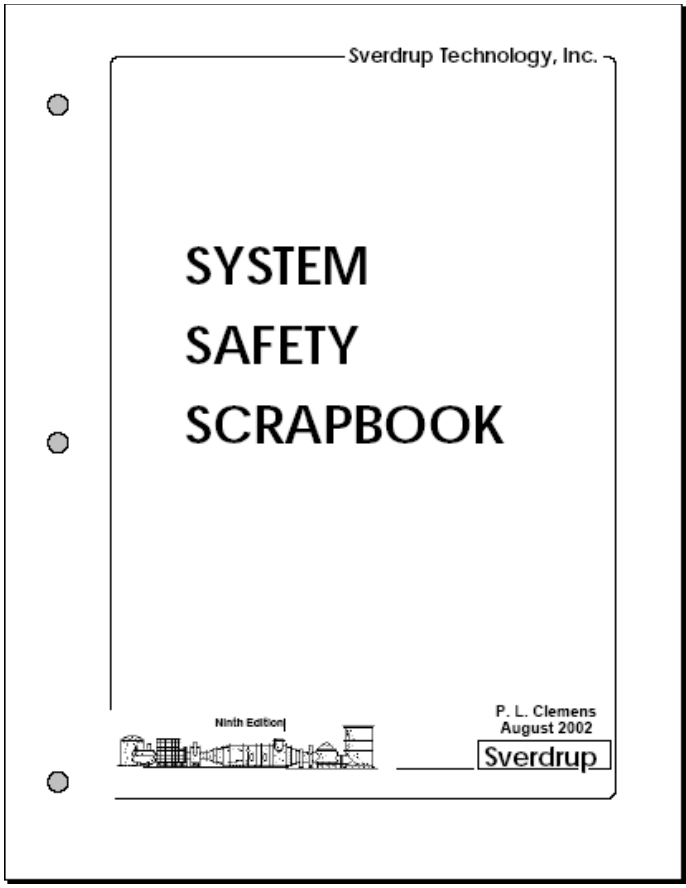


History of Source-Mechanism-Outcome

1984 - System Safety Scrapbook

- A compilation of one page tutorials, “sheets”
- Authored by Pat Clemens since 1983
- Sheets published “as needed”
- Each dealt with single aspect of system safety practice
- Purpose:
  - Reinforce concepts presented in formal training
  - Improved communication in matters of system safety
  - Sharpen system savvy, analytical skills
- Published by A-P-T Research, Inc.



1984 - System Safety Scrapbook

- **Sheet 84-3**
  - **First recorded mention of the source-mechanism-outcome model**
  - **Often name a hazard according the severity component of its risk**
    - Describe the consequence of the hazard rather then the hazard itself
    - Source-mechanism-outcome model created to counteract this tendency

1984 - System Safety Scrapbook

- **Sheet 84-3 example**
  - **“Fatal Highway Crash”**
    - Consequence of many real hazards: excessive speed, worn tires, etc.
  - **To avoid:**
    - Make the description tell a story -“little scenario”
    - Addresses the Source, the Mechanism, and the Outcome (i.e., Consequences)
    - “Worn tires leading to blowout at high speed resulting in loss-of-control crash and driver fatality”

1994 - NASA Reference Pub 1358

- ***System Engineering "Toolbox" for Design-Oriented Engineers***
  - **Authored by B.E. Goldberg, Pat Clemens, and others**
  - **Produced by Marshall Space Flight Center, Huntsville, AL**
  - **Source-mechanism-outcome was included in the section on preliminary hazard analysis authored by Clemens**

1994 - NASA Reference Pub 1358

(4) Detect and confirm hazards to the system. Identify the targets threatened by each hazard. A hazard is defined as an activity or circumstance posing “a potential of loss or harm” to a target and is a condition required for an “undesired loss event.” **Hazards should be distinguished from consequences and considered in terms of a source (hazard), mechanism (process), and outcome (consequence).** A team approach to identifying hazards, such as brainstorming (sec. 7.7), is recommended over a single analyst. If schedule and resource restraints are considerations, then a proficient engineer with knowledge of the system should identify the hazards, but that assessment should be reviewed by a peer….

1998 – NIOSH Publication

- “System Safety and Risk Management: A Guide for Engineering Educators”
- Co-authored by Pat Clemens & Dr. Rod Simmons
- Instructional module in Project SHAPE (Safety and Health Awareness for Preventive Engineering)
  - Collaborative project between NIOSH, engineering professional societies, and engineering schools to enhance the education of engineering students in occupational safety and health
- Page III-3 described the S-M-O model in similar fashion as the Systems Engineering Toolbox

1998 – Scrapbook Sheet 98-1

- ***"Describing Hazards? Think Source / Mechanism / Outcome"***

  –More detailed definition of the three elements of a hazard description

  A hazard description contains three elements that express a threat: a source — an activity and/or a condition that serves as the root. a mechanism — a means by which the source can bring about the harm. an outcome — the harm itself that might be suffered.

1998 – Scrapbook Sheet 98-1

“An open-topped container of naphtha may be a source, but without a mechanism and an outcome, is it a hazard? Suppose it’s in the middle of a desert — no ignition sources and no personnel within several miles? Not much of a hazard. Relocate it to the basement of an occupied pre-school facility near a gas-fired furnace. Source, mechanism and outcome now become clear — and it’s a hazard.”

1998-2006

- **Prestigious Textbooks**
- **Drafts of U.S. Army and Department of Defense directives and plans**

A Detailed Example

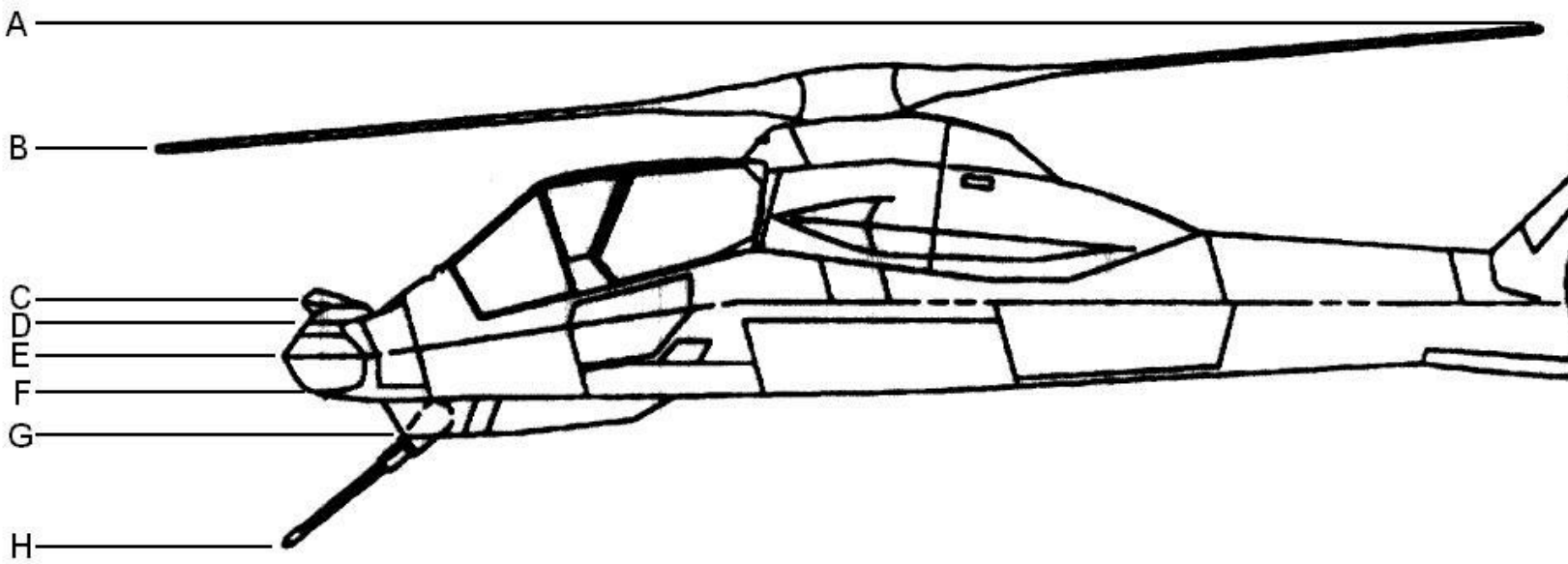
- ***U.S. Army's RAH-66 Comanche helicopter***
- **Wire strike**
  - **Tempted to use the term "wire strike"as the hazard description**
    - Just the mechanism
  - **Hazard description was:**

"The demonstration and validation aircraft will not have wire-strike protection. For the engineering and manufacturing development aircraft, the lower wire-strike protection has not been defined."

Comanche Wire Strike Hazard

Strike Zones

Span	%
A-B	24
B-C	29
C-D	4
D-E	6
E-F	7
F-G	8
G-H	21
Total	100



A Detailed Example

- **Describes the hazard in terms of the lack of hazard mitigation**
  - **Not in terms of source-mechanism-outcome**
- **Changed to "Flight into wires may result in catastrophic loss of aircraft and loss of life"**
  - **Mechanism and outcome "touched on"**

Source

The mission of Comanche requires it to fly close to the Earth's surface using nap-of-the-earth, contour and low-level flying. Flight in this environment means the crew must detect and avoid horizontally strung mechanical, electrical transmission, and communication cables (wires).

Mechanism

The mission of Comanche requires it to fly close to the Earth's surface using nap-of-the-earth, contour and low-level flying. Flight in this environment means the crew must detect and avoid horizontally strung mechanical, electrical transmission, and communication cables (wires). Crews may fail to detect wires due to degraded visibility, poor navigation, or loss of situational awareness. Crews may fail to avoid wires due to not detecting them or failure to follow established procedures for crossing wires. Failure to detect and avoid the wires results in the aircraft flying into the wires. Wires of sufficient diameter will not break and may become trapped or entangled in the main rotor, the TASS, the external stores, antennas, or the landing gear. This results in serious damage to whichever of these components the wire strikes. Further, the aircraft may become caught on the wire resulting in losing aircraft control and impact with the ground.

Outcome

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Source – Mechanism – Outcome

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A Detailed Example

- ***Now, one can see the source, the mechanism, and all outcomes of the hazard***
  - **Clearly and thoroughly described**
  - **Much easier to identify and implement mitigators to reduce the risk**

Mitigation

- Improved night vision devices to help the crews see the wires
- Detection devices to spot wires using infrared or electromagnetic signatures
- Improved mapping of wires combined with extremely accurate navigation systems
- Improved heads-up displays and controls to keep pilots eyes focused outside

Improved Wire Detection

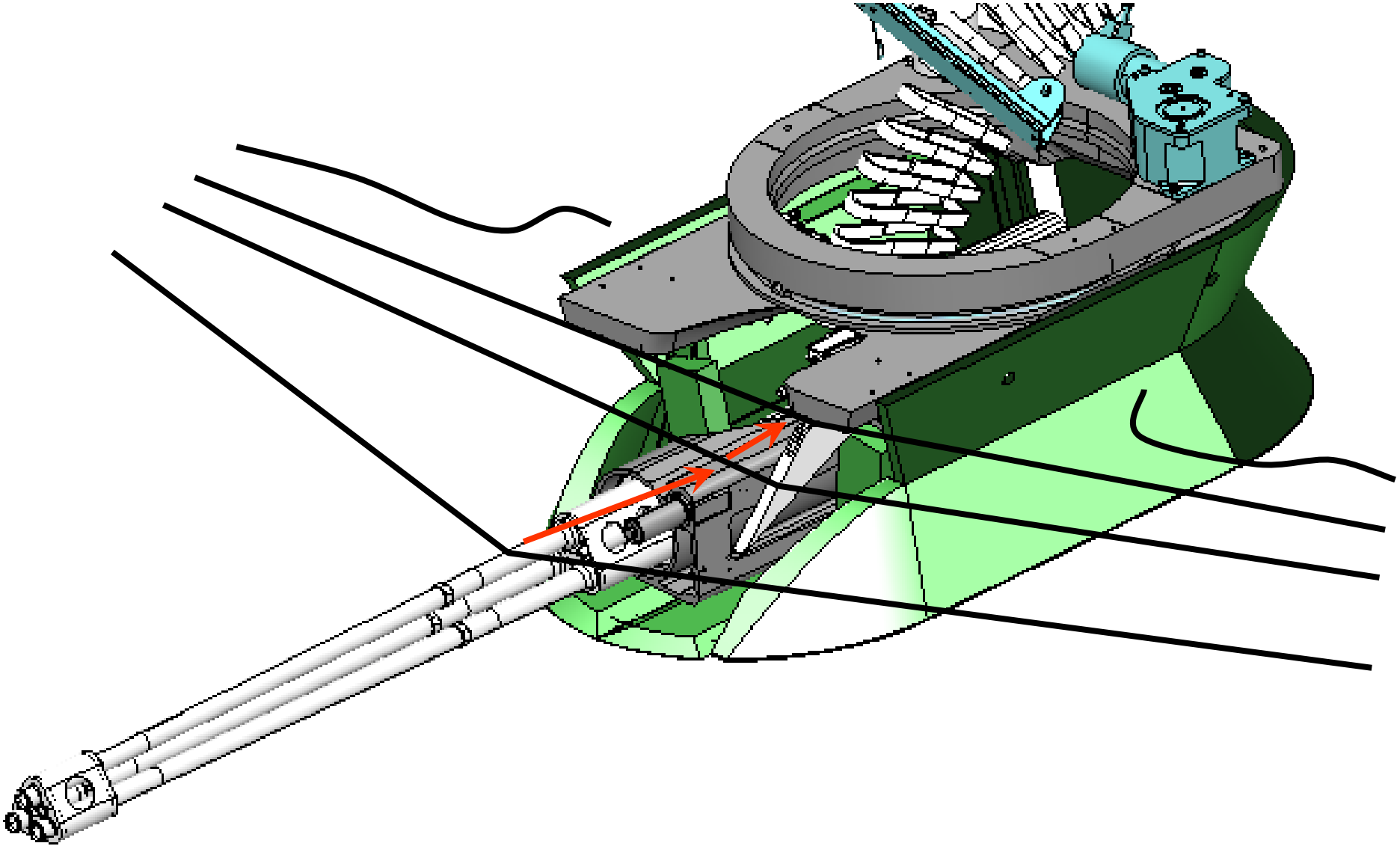
FLIR With No Processing

FLIR With Electronic Processing

Mitigation

- **Improve the design of aircraft structure to allow wires to be shed on contact instead of caught in the structure**
- **Antennae, landing gear, and other external structures retracted when not in use**
- **Structures designed to break free when they contact wires to allow the aircraft to continue flight**
- **Well-placed wire cutting devices cut the wire if it cannot be avoided**

Turreted Gun System Cutter

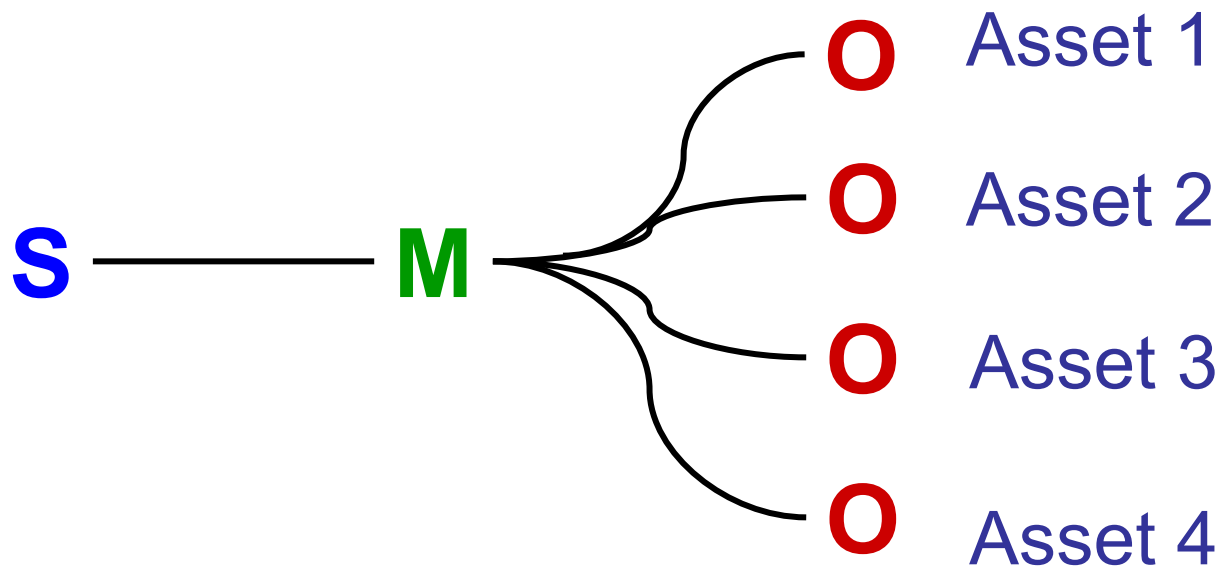


Strength

- S-M-O can be adapted to describe hazards and make them easier to understand and manage
- One combination of source and mechanism may have the potential to cause harm to more than one asset
- An effective way to deal with these multiple outcomes from one source and mechanism is to treat each outcome, each harmful impact on an asset, as a separate hazard

Single source and mechanism with multiple outcomes

Source – Mechanism – Outcome



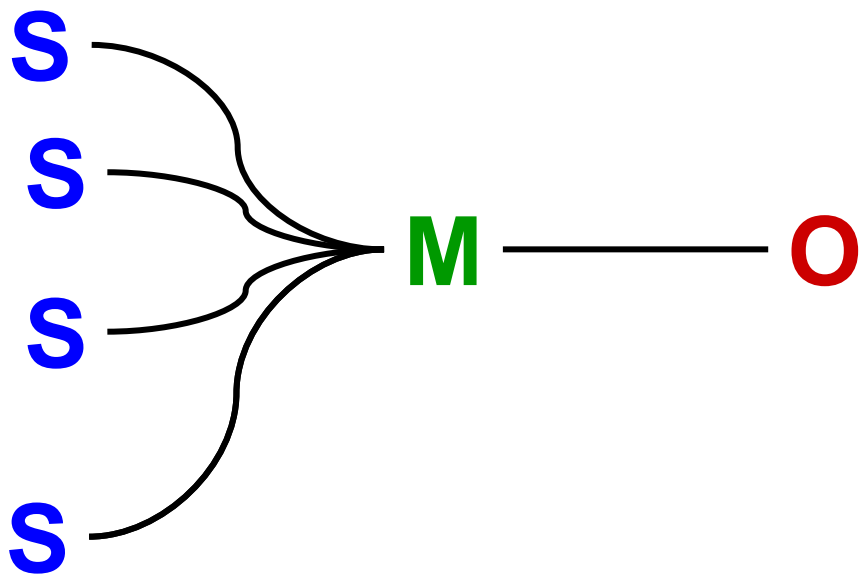
Identify each potential mitigator and its effectiveness in reducing the risk to each asset weighed against the cost and feasibility of the mitigator

Single source and mechanism with multiple outcomes

- Some cases outcomes may be tightly linked
- Example: hazard mechanism includes aircraft impact with the ground
- “Death or serious injury to personnel” is linked to “serious damage to or loss of aircraft”
- Two outcomes might best be treated as components of a single hazard

Multiple Sources with a Single Mechanism and Outcome

Source – Mechanism – Outcome



Multiple Sources with a Single Mechanism and Outcome

A combination of environmental stressors (fatigue, operations tempo, high winds, lack of training, family situation, heat, noise, vibration, degraded visual environment, night vision goggles, seat discomfort, etc.) reduce a helicopter pilot's capacity to deal with the task loading (hovering and maneuvering in close proximity to obstacles, simultaneous mission operations, weapons management, selecting target coordinates, airborne target handover, firing weapons, changing radio frequencies, etc.) as the mission proceeds.

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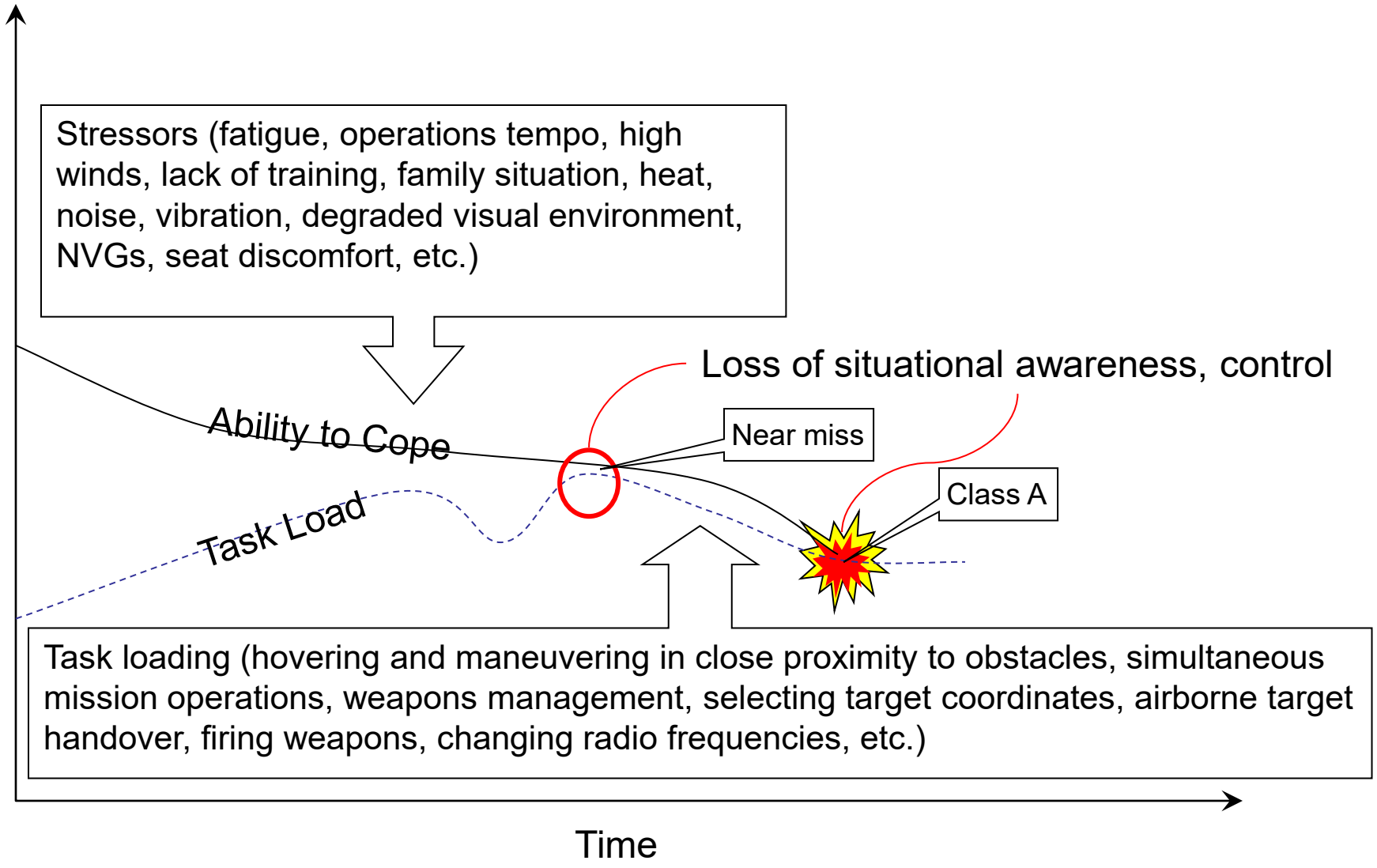
Multiple Sources with a Single Mechanism and Outcome



Stressors

- **Many are things that the pilot or his leadership must manage using principles of risk management**
  - **Training**
  - **Operations tempo**
  - **Extended deployment**
  - **Family and financial issues**
  - **Illness or death of a family member**
  - **Passover for promotion**

Stressors

- **Other stressors can be addressed in the aircraft design:**
  - **Excessive heat or cold in the cockpit**
  - **Helmet weight distribution and discomfort**
  - **Seat discomfort**
  - **Noise**
  - **Excessive vibration in the cockpit**
  - **Excessive dust**
  - **Irritating odors**
  - **Bulky, heavy aircrew life support equipment**
  - **Flight control geometry**
  - **Restricted arm and leg movement**
  - **Display screen size**
  - **Display word font size and color**
  - **Display icon and graphic size, brightness, color, definition**
  - **Needed information not displayed**
  - **Information overload**
  - **Glare of displays on windscreen at night**
  - **Accessing controls and displays with gloved hands**

Mitigation

- **Reduce environmental stressors as much as possible**
  - **Sustain an adequate level of alertness and effectiveness**
- **Keep pilot workload as low as practicable**
  - **Cockpit automation**
  - **Well-designed controls and displays**
  - **Allow the pilot to focus on flight-safety-critical tasks**
  - **Spend minimum time on less critical tasks**

Mitigation

- Hazard description follows the source-mechanism-outcome model
- But too much to include in one hazard
  - Many sources contributing to the outcome through one mechanism
- Solution
  - Break out the sources of the hazard
  - One source - One hazard

Example break out hazard - Stressor

Excessive heat in the cockpit combined with other environmental stressors and task loading

Example break out hazard - Stressor

Excessive heat in the cockpit combined with other environmental stressors and task loading **bring the crew to the point where they cannot cope with the task load and lose situational awareness (LOSA). This results in failure to see and avoid obstacles or loss of control of the aircraft resulting in impact with the terrain or obstacles and**

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Example break out hazard - Task

The alphanumeric keyboard configuration of the Control Display Units

Example break out hazard - Task

The alphanumeric keyboard configuration of the Control Display Units **results in extended attention on data entry. This combined with other task loading and environmental stressors brings the crew to the point where they cannot cope with the task load and lose situational awareness (LOSA). This results in failure to see and avoid obstacles or loss of control of the aircraft resulting in impact with the terrain or obstacles**

Example break out hazard - Task

"The alphanumeric keyboard configuration of the Control Display Units results in extended attention on data entry. This combined with other task loading and environmental stressors brings the crew to the point where they cannot cope with the task load and lose situational awareness (LOSA). This results in failure to see and avoid obstacles or loss of control of the aircraft resulting in impact with the terrain or obstacles **and serious damage to or loss of aircraft and serious or fatal injury to the crew.**

How to avoid breaking the camels back

- Eliminate or reduce the weight of each straw
- Each source addressed by the various design teams
- Reduce the risk from the overarching mechanism and outcome

Source-Mechanism-Outcome Model with other Hazard Identification Tools

- **Example: Functional Hazard Analysis**
  - **Identifies the functions of a system and its subsystems**
  - **Evaluates the safety impacts if functions fail or are degraded**
  - **Result: Extensive list of hazards closely tied to requirements of the system**
- **Does produce good information about the hazards of the system**
  - **Does not always identify what causes functions to fail**

Functional Hazard Analysis

- **Enter source-mechanism-outcome:**
  - **For a function to fail or degrade there must be a source**
  - **Multiple sources = multiple hazards**
  - **A mechanism or mechanisms produce the function failure or degradation**
  - **Failure of a function also produces an outcome or outcomes**
  - **NO source or NO mechanism or NO outcome = NO HAZARD**
- **Source-Mechanism-Outcome useful no matter the hazard ID tool**

Conclusion

- Source-Mechanism-Outcome a useful tool
- Simple yet effective in understanding the nature of a hazard
- Works well with any hazard identification method
- Hazards clearly and thoroughly described
- Easier to identify and implement mitigators
- Successfully applied to the hazards of a wide assortment of systems
- Model included in GEIA-STD-0010