National Aeronautics and
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How Safety Thinking Impacts Safety Learning: Creating Opportunities to Learn

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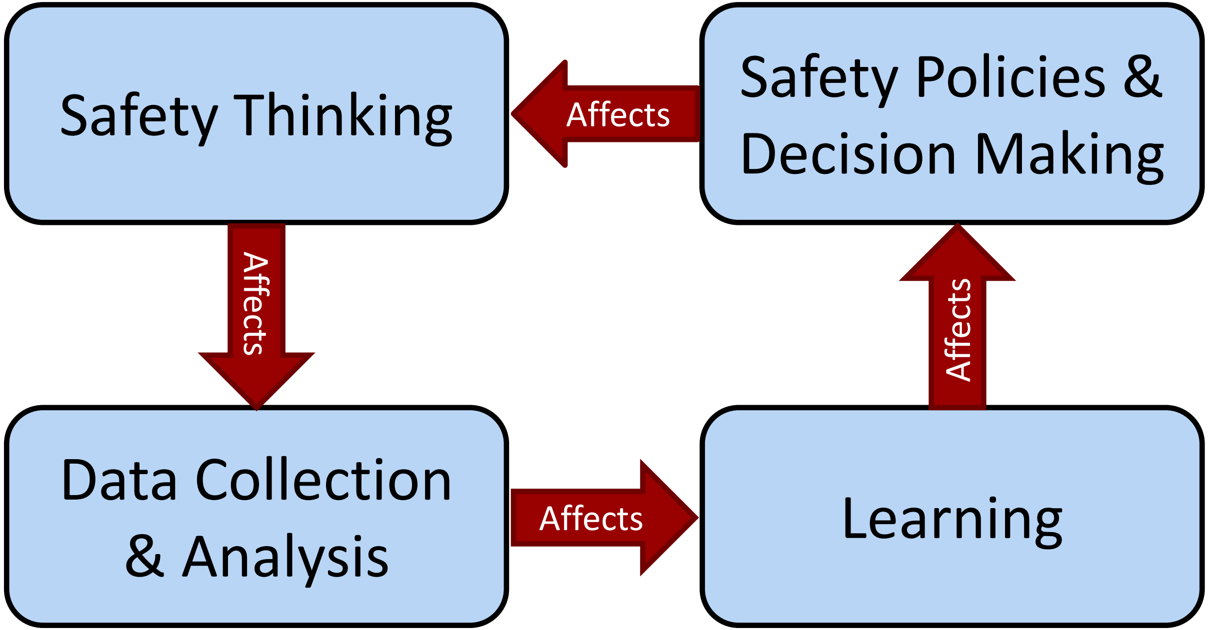
The importance of thinking about safety thinking

Decision makers in organizations want to make data-informed decisions about safety management and system design.



Impacts of systematically limiting data

- Human performance includes both desired and undesired actions – actions that promote safety, as well as actions that can reduce safety
- When our safety thinking systematically restricts the data we collect and analyze, this
  - Restricts our opportunities to learn
  - Affects our safety policies and decision making

Opportunities for Learning

- Learning is a consequence of interactions between people and their environment
- People are learning (almost) all the time
- Learning can be structured and deliberate, but also unstructured and implicit
- Organizations don’t learn, but they influence people’s learning

Creating Knowledge

Retaining Knowledge

Transferring Knowledge

Some Factors that Improve Learning and Memory

- Motivation (Weiner, 1966)
- Prior knowledge (Cohen, 1981)
- Rehearsal and practice (Craik & Lockhart, 1972))
- Elaboration (e.g., Yogo & Fujihara, 2008; McLeod et al., 2010)
- Organizing information (e.g., Bellezza, 1981)
- Spacing out your practice (e.g., Ebbinghaus, 1885)
- Sleep (e.g., Abel & Bauml, 2013)

Data-Informed Decision Making

- Goal: Study a sample from a population such that conclusions from a sample can be generalized to the population
- Risk: Non-random samples are often subject to bias
  - Sample systematically over-represents some segments of the population, and under-represents others
- Consequence: Results can be erroneously attributed to the phenomenon under study rather than to the method of sampling

Example: How safety thinking affects safety policies

Safety-producing behaviors vastly outnumber human errors in aviation

- Human error has been implicated in 70% to 80% of accidents in civil and military aviation (Weigmann & Shappell, 2001).
- Pilots intervene to manage aircraft malfunctions on 20% of normal flights (PARC/CAST, 2013).
- World-wide jet data from 2007-2016 (Boeing, 2017)
  - 244 million departures
  - 388 accidents

Outcome

Attributed to Human Intervention	Not Accident	Accident	
No	195,199,690	78	195,199,768
Yes	48,799,922	310	48,800,232
	243,999,612	388	244,000,000

Investigated (310)

Poorly Understood (48,799,922)

Identifying “Useful” Sources of Data

- What data about safety-producing behaviors can we collect and analyze?
  - Operator-, observer-, & system-generated data
  - What data do we already collect, but could analyze differently?
  - What data *could* we collect and analyze, but do not?
- How can we measure the “productive safety” capability of a system?
  - How do operators prevent, prepare for, and recover from failure?
  - How do operators create and leverage safety-building opportunities?
  - How do organizations support or hinder exercising these capabilities?

Example: Operator-generated data

Coding UNDESIRED Behaviors/States

- Loss of situation awareness
- Distraction
- High workload

ASRS Report #1433006

We had 9000 ft selected on the MCP as the bottom altitude for the arrival. At some point before BURRZ the airplane began descending below FL240. We were briefing a possible runway change and did not stop the descent until FL236. At the same time ATC called and asked about our altitude. I replied that we were trying to control altitude and would call him back. The airplane was not responsive through the MCP panel at all. The controller cleared us to descend to FL230. At that time he instructed us to call Washington Center and gave us a phone number. I replied that we were busy trying to control the altitude of the aircraft and would call him back. We then received the phone number and switched to Atlanta Center and had an uneventful approach and landing. We wrote up the MCP and altitude hold in the logbook and contacted maintenance. I do not know the outcome as we had to swap airplanes for our next leg. The CHSLY arrival is all but unusable in the A320 series. There needs to be a software change and the controllers need to stick with their procedures and stop issuing so many speed and altitude restrictions in conjunction with the arrival.

…What happened …is a daily occurrence now covered in Company communications about crew actions to mitigate the deviation. In this particular case, the aircraft's descent could not be controlled.

Coding DESIRED Behaviors/States

- Anticipate – Conduct pre-event briefing to discuss what to expect
- Monitor – Environment for cues signaling change from normal
- Monitor – Own internal state
- Respond – Reprioritize tasks to compensate for resource constraints
- Learn – Share information to facilitate others' learning
- Learn – Understand formal expectations

Example: Observer-generated data

What different insights about operators' safety-related behaviors are learned from the application of different knowledge frameworks to the collection and analysis of observer-based data?

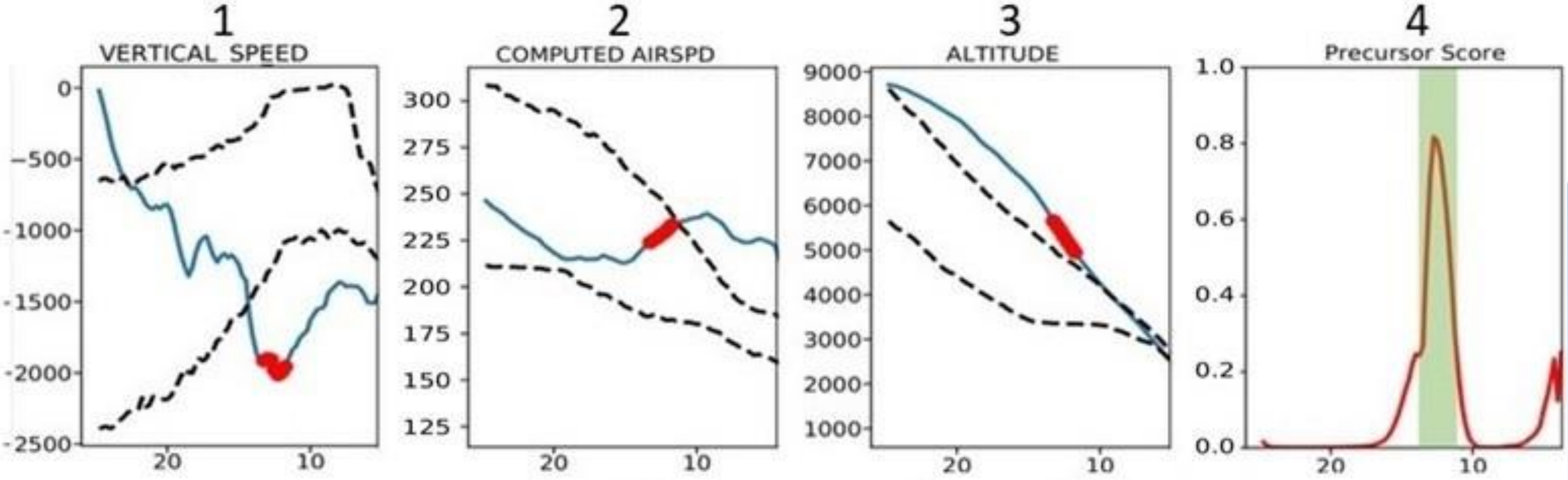
- Using videos of simulated air carrier arrivals involving "routine" contingencies
- Observers trained on different frameworks will collect and analyze observations
  - Line Operational Safety Audit (LOSA) / Threat & Error Management Framework
  - American Airlines Learning and Improvement Team / Safety-II-based Framework

Image credit: NASA

Example: System-generated data

<u>High-speed exceedance at 1000 ft</u>

- Used sample of 1000 flights, half with adverse event and half without
- Algorithm detects high-probability predictors of a pre-defined adverse event
- *<u>Non-event flights</u>* examined for high precursor probabilities
- Pilot transferred aircraft energy from altitude to speed, preserving capability to reduce energy further by introducing drag



A case study

- An astronaut aboard the International Space Station (ISS) suffered a close call during an Extra-Vehicular Activity (EVA)
- The subsequent mishap investigation board (MIB) identified causal factors that the ISS Program believed they were already addressing

“Why do we keep having these tragedies and not learning the lessons they are teaching us?” – Chris Hansen, MIB Chairman

EVA-23: What Happened?

- On July 16, 2013, two crewmembers performed maintenance tasks outside of the ISS during Extravehicular Activity (EVA) 23.
- Forty-three minutes into the EVA, one of the crewmembers reported water from an unidentified source inside of his helmet at the back of his head.
- The amount of water increased and moved to his face, creating a potential suffocation hazard, and the EVA was terminated.
- A mishap investigation board (MIB) later identified the source and cause of the water in the astronaut's helmet.
- In the course of the investigation, the MIB also noted that the presence of water in the helmet had been "normalized."
- Water entering the helmet had been observed in the past and over time, had become accepted as normal suit behavior.
- This normalization resulted in missed signals of the seriousness of the event, which led to delays in recognition and response.

Astronaut Luca Parmitano. Image credit: NASA

EVA-23 MIB: Selected Findings

- Crew member training did not include this failure mode.
- Flight Rule to address this failure mode did not exist.
- Suit Hazard Report did not identify the hazard.
- ISS Community perception was that drink bags leak.
- Minor amounts of water in the helmet were normalized.
- Flight Control Team accepted the explanation that the water during EVA 22 was from the drink bag.
- Ground Team allowed time pressures of impending EVA to influence actions.
- The ISS Program conducted EVA 23 without recognizing the suit failure that occurred on EVA 22.
- Flight Control Team's perception of the anomaly report process as being resource intensive made them reluctant to invoke it.

Astronaut Luca Parmitano. Image credit: NASA

NASA. (2013). Mishap Investigation Report: International Space Station (ISS) EVA Suit Water Intrusion High Visibility Close Call, IRIS Case Number: S–2013– 199–00005, Redacted copy available at: http://www.nasa.gov/sites/default/files/files/Suit_Water_ Intrusion_Mishap_Investigation_Report.pdf.

EVA-23 MIB: Selected Findings

Missed opportunities to…

- Crew member training did not include this failure mode.
- Flight Rule to address this failure mode did not exist.
- Suit Hazard Report did not identify the hazard.

→ **Anticipate**

- ISS Community perception was that drink bags leak.
- Minor amounts of water in the helmet were normalized.

→ **Monitor**

- Flight Control Team accepted the explanation that the water during EVA 22 was from the drink bag.
- Ground Team allowed time pressures of impending EVA to influence actions.

→ **Respond**

- The ISS Program conducted EVA 23 without recognizing the suit failure that occurred on EVA 22.
- Flight Control Team's perception of the anomaly report process as being resource intensive made them reluctant to invoke it.

→ **Learn**

EVA-23: What (Else) Can We Learn?

- Reliance on prediction and prevention left ISS vulnerable when responding to unexpected events
- No training focused on recognition and dealing with uncertainty
- “Weak signals” of impending problem were present during everyday work, but were insufficiently understood
- Unintended/unrecognized pressures can lead to reluctance to speak up
- Focus on “error chains” in mishap investigation limited learning
- Numerous desired behaviors occurred throughout the “mishap”

Astronaut Luca Parmitano. Image credit: NASA

Key Take-Aways

- Individuals are (almost) always learning
- Organizations can affect the creation, retention, and transfer of knowledge
- When we characterize safety only in terms of errors and failures, we ignore the vast majority of human impacts on the system
- When we *systematically* restrict opportunities to learn, not only do we learn less and less often, but we can draw misleading conclusions
- Many opportunities exist to collect and analyze largely unexploited operator-, observer-, and system-generated data on desired behaviors
- Identifying, collecting, and interpreting data on operators’ everyday safety-producing behaviors is critical for developing an integrated safety picture

Thank you!

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