

Monitoring for Flight Path Management: Inputs to Pilot Monitoring Training

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NASA Ames Research Center

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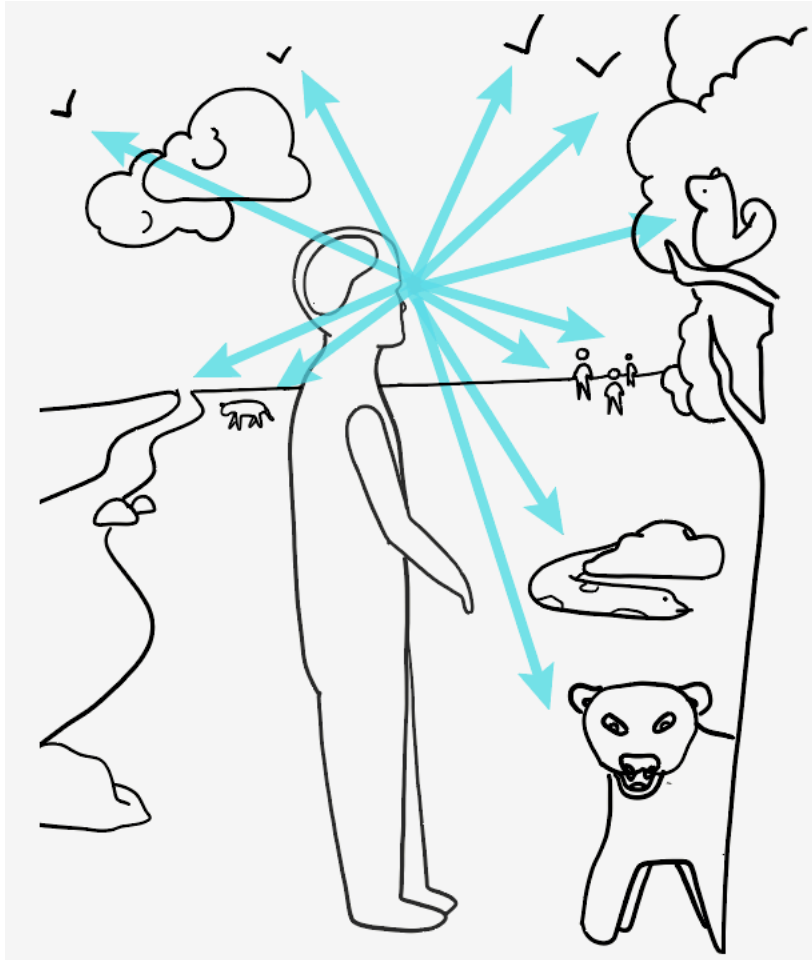


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Monitoring is Not . . . Vigilance

Sustained attention on a single source is not a typical activity



We seek information around us to make sense of the world

Monitoring is Not . . . Effort

There are many barriers to sustaining attention on FPM

Monitoring for FPM is incredibly demanding, and there are many paths to failure.

- ❖ High workload from operational tasks
- ❖ Interruptions and distractions (operational and non-operational)
- ❖ Mind-wandering
- ❖ Stress and fatigue
- ❖ Channelized attention
- ❖ Inattention blindness
- ❖ System automation

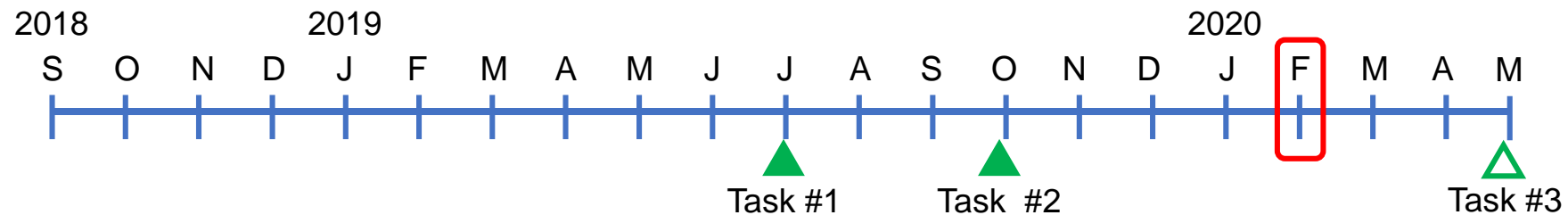
**Sustained attention on FPM or complete awareness
is not possible throughout a pilot's duty time**

Primary Points to Take Away

- ❖ Monitoring is much broader than gathering data from the world. It is driven by sense-making/understanding and expectation (a strength!). And, it needs to lead to managing deviations.
- ❖ A major driver of monitoring is the Situation Model and the identification of information relevance
- ❖ A second major driver of monitoring is Task (attention) Management; There is both a strategic and a tactical element of Task Management.
- ❖ There is no support for a description of monitoring expertise in terms of sequences of fixations.
- ❖ Factors contributing to effective training include
 - Identification of relevant information (for the situation)
 - Integrating operational understanding with information about the current situation
 - Use of briefing/debriefing both as a training outcome and a training method.
- ❖ We should treat PM as a role equal to (and different from) that of the PF

The Project Scope

- ❖ Task 1. Lit Review: Effectiveness of Training on Monitoring
- ❖ Task 2. Review: The Current State of Training
- ❖ Task 3. Recommendations: What training approaches are best suited to training monitoring
- ❖ Potential Applications of the Work:
 - Inputs to a revision of Advisory Circular 120-71B “Standard operating procedures and pilot monitoring duties for flight deck crewmembers”
 - Future pilot tasks with increasingly automated system



How is Monitoring Trained Traditionally?



We have not found anyone who was trained on a technique to monitor the full FD interface



Flight Path Management (FPM)

What is it?

- ❖ According to the Flight Path Management Working Group (FPMWG) to the ACT ARC, FPM is defined as **“the planning, execution, and assurance of the guidance and control of aircraft trajectory and energy, in flight or on the ground.”**
- ❖ Specifically, we focus on pilot activities used to achieve flight path targets and to keep the airplane operating within the flight envelope and away from external obstacles and threats [also includes taxiing on the ground].
- ❖ Our focus does NOT include “mission planning”

Monitoring for FPM

What are the specific data gathering activities?

- ❖ Confirm that the airplane is within the flight envelope
- ❖ Confirm the aircraft state meets the targets represented on the interface (e.g., am I flying at the assigned airspeed?)
- ❖ Confirm the airplane systems are configured for the current or upcoming segment of the flight path (e.g., VNAV is engaged, AP is armed for approach)
- ❖ Confirm airplane energy state meets to FPM targets (e.g., will I be able to make the next altitude and airspeed restrictions?)
- ❖ Obtain feedback on pilot control actions (including systems and automation inputs).
- ❖ Monitor the operational environment (e.g., scanning for weather, traffic and terrain hazards; monitoring radio traffic)
- ❖ Monitor activities and workload of the other flight crew member(s).
- ❖ Identify and assess any airplane flight path-related alerts

How Can Monitoring for FPM Fail?

Focus is on failures that have operational consequences

- ❖ Imminent upset – Many LOC accidents: airspeed falling away (Turkish Airways 1951) or rolls away from wings level (Kenya Airways 507). Also, terrain awareness.
- ❖ Incorrect airplane state or configuration – Fails to see that APP isn't armed . . . LNAV isn't armed . . . airplane not configured for take-off (Spanair 5022)
- ❖ Fails to meet flight path targets – Fails to see that the airplane is not closing in on the airspeed or heading target; or longer term, fails to see that the airplane will not meet the altitude and airspeed restrictions at a waypoint on descent.
- ❖ Fails to identify important changes in the flight environment – Misses cues about the need to prepare for likely changes to the flight plan; e.g., altitude or airspeed change
- ❖ Fails to maintain awareness of crew resources – Fails to maintain awareness that the FO is heads-down on a task a non-FPM task.
- ❖ Fails to call out a deviation/problem – PM knows about a significant deviation but fails to call PF's attention to it (Asiana 214).
- ❖ Fails to intervene when a deviation is not being managed – Fails to act in a timely way to manage a deviation. From 'speaking up' all the way to intervening on controls.

Monitoring is not . . . a “signature” scanning pattern?

Do skilled pilots scan the instruments in a standard sequence?

- ❖ We reviewed the literature on eye-tracking, focusing on studies of commercial transport pilots performing flight tasks in a realistic simulator setting.
- ❖ A few of these studies focus on the use of core flight instruments during a manual approach and compare scanning patterns (fixation sequences).
- ❖ Two patterns are mentioned:
 - radial or attitude-oriented
 - circular
- ❖ In one study (51 pilots), 60% of the pilots used the radial pattern; 30% used the circular pattern
- ❖ In another study, the majority of pilots used a radial pattern

There were NOT strong skill differences between groups

Primary Measures used in ET Studies

And, do they reveal skill differences?

❖ ET measures

- % Dwell time
- Event-triggered fixations
- Fixation dwell time
- Fixation sequences
- Aol neglect latency
- Aol relevance

There is a pretty good understanding of how fixations are distributed over Aols for routine flight maneuvers or flight phases.

This method allows you to connect flight performance with fixations at a more fine-grained level. Good data here on FMA fixations.

May be a good indicator of skill early in pilot training. For more experienced pilots, we don't know.

Potentially interesting measure; seldom-used. Single study does not show skill differences.

Some promising results in terms of showing skill differences. Unfortunately, these studies have not focused on transport pilots.

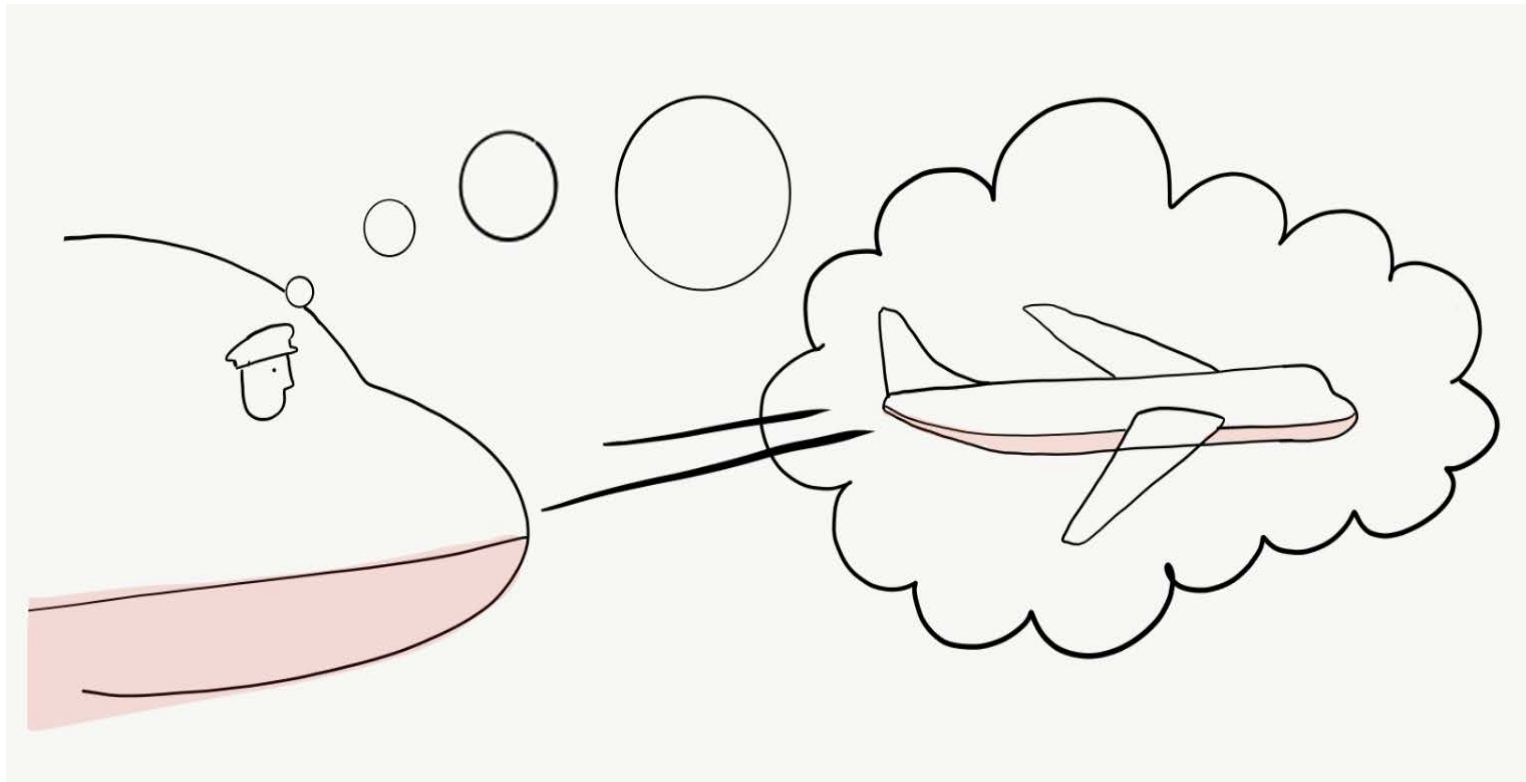
ET measures for PF and PM; 2 studies:

- Flying approaches, manual and autoflight
- PF and PM had similar patterns of fixations on core instruments; they were not complementary

What is Monitoring?

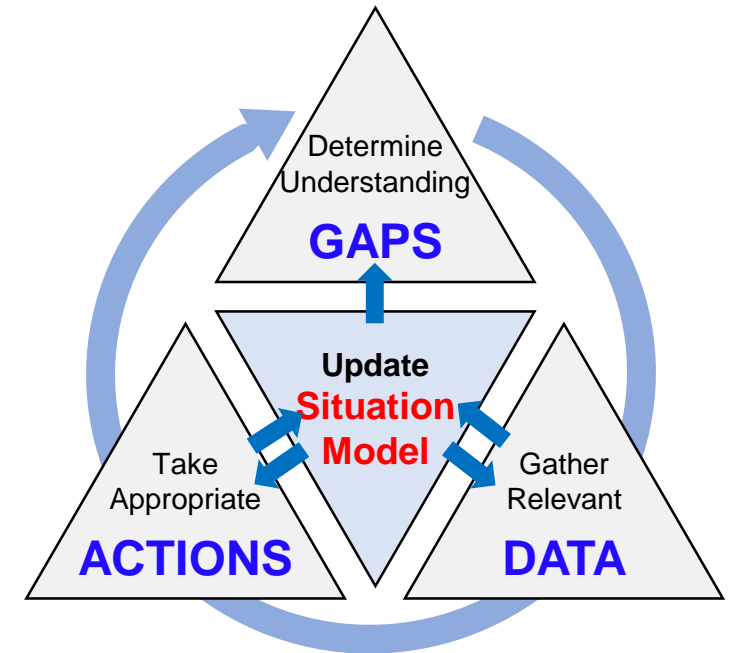
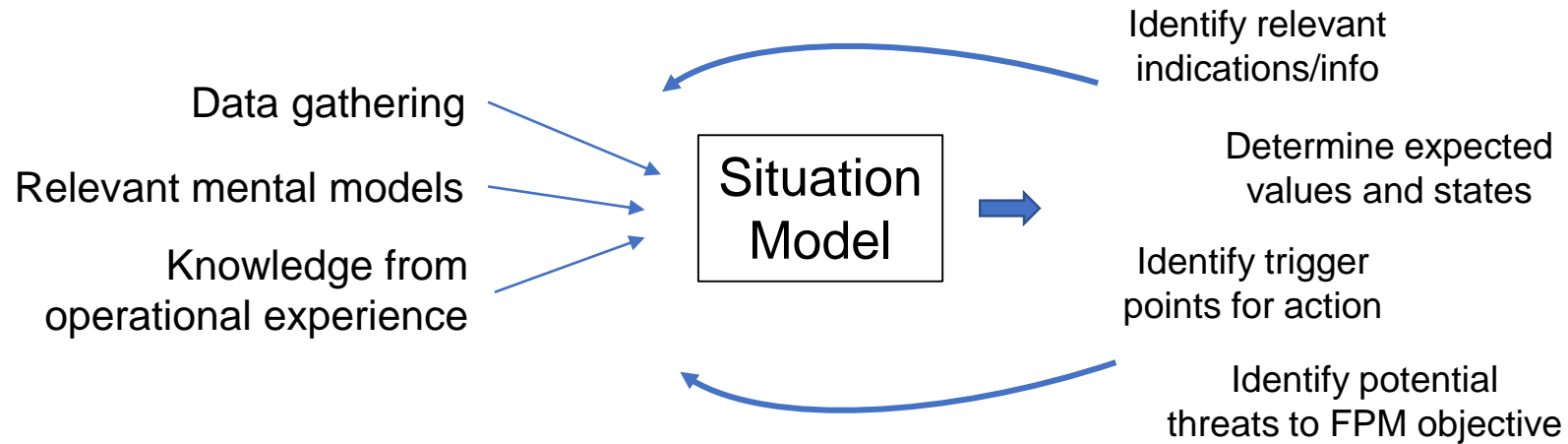
Not only to see but to understand!

Monitoring in the broad sense means “Flying ahead of the plane.”



Monitoring Expanded - The Situation Model / Understanding

Monitoring is more than pointing your eyes



Efficient Information Extraction

Operational Knowledge (and mental models)

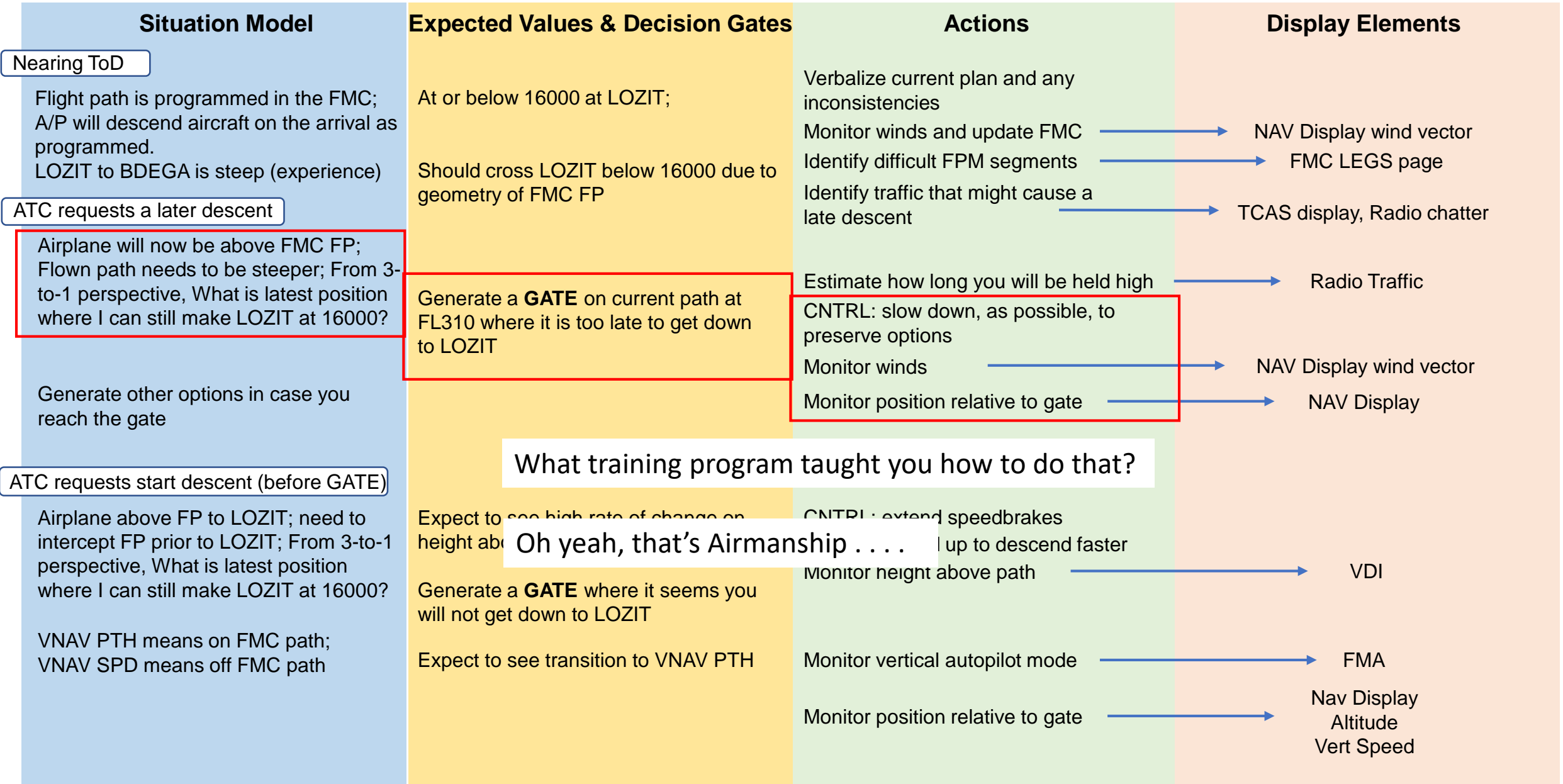
Situation Model

Interface Configuration

Threat Identification

Situation: The airplane is held at cruise altitude past the ToD point, and there is a waypoint altitude that may be hard to make.

Example: In CRZ at FL310; flying the BDEGA3 arrival (LEGGs transition) into SFO. The waypoint LOZIT has an 'at or below' restriction at 16000.

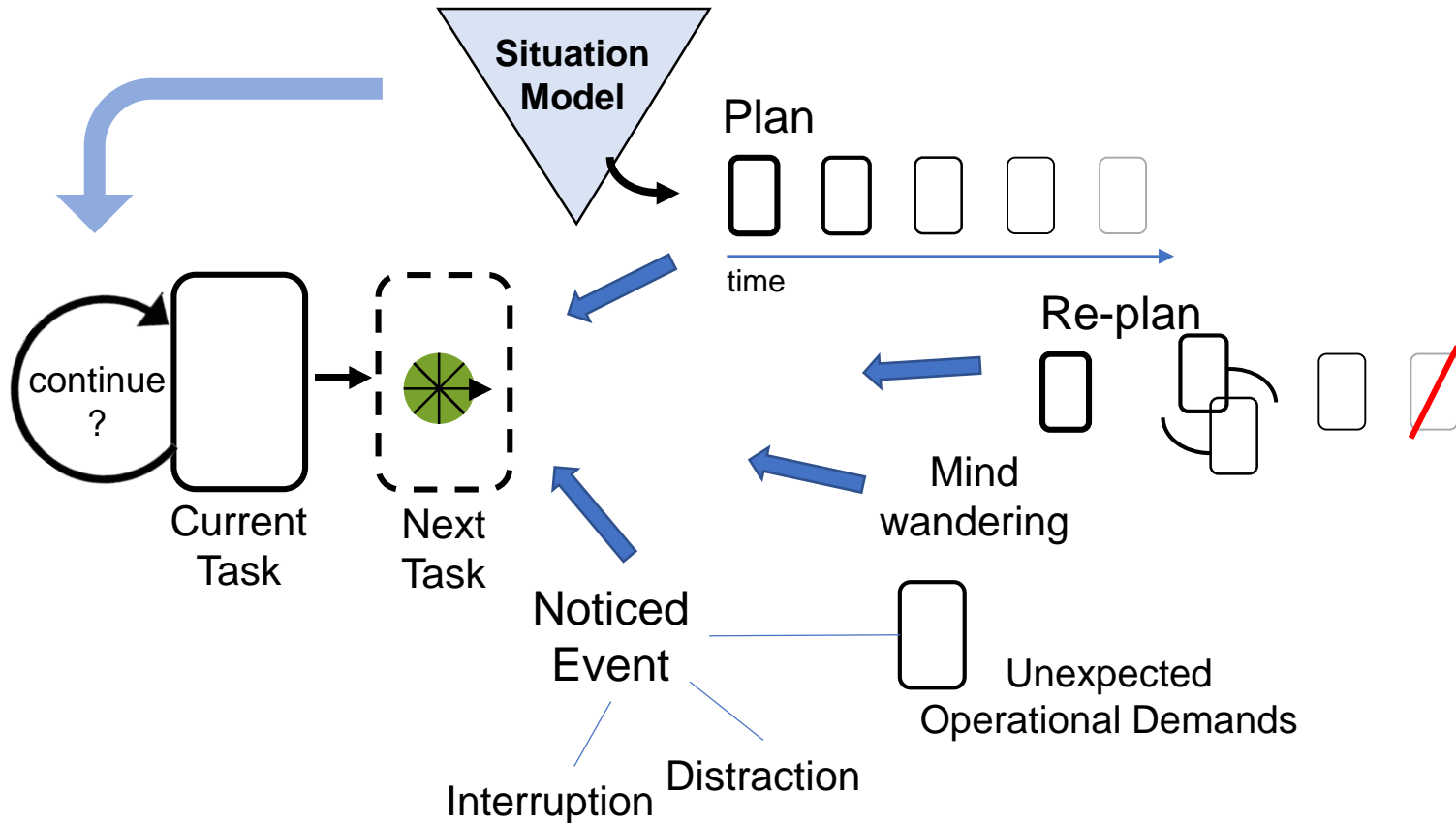


What training program taught you how to do that?

Oh yeah, that's Airmanship

Monitoring Expanded - Task Management / Attention

Monitoring is more than pointing your eyes



Strategic Task Management
Attention Switching

Monitoring Expanded – Problem Management (as a crew)

Monitoring is more than pointing your eyes

Problem Identification

Intervention

Communication



Using Communication to Support Effective Monitoring

Need to balance communication structuring with workload

- ❖ Crew performance can benefit by providing a structure for flight crew communication that covers
 - Current FPM objective(s)
 - “Our next objective is to cross (waypoint) at or below 17,000 and 260 kts.”
 - Current potential hazards or threats to FPM
 - “We started down a bit past the FMS top of descent point, and we have a tailwind we didn’t expect.”
 - Relevant indications to monitor
 - “Please keep an eye on our position above path on the vertical deviation indicator and monitor how quickly we are losing airspeed.”
 - Expected behavior—e.g., for autoflight or airplane performance—and signs that things are not going as planned
 - “I think we need to get down before we can bleed off airspeed but I hope we are close to our target airspeed by 10 nm before the waypoint. Also, we are in VNAV SPD now but I expect to revert back to VNAV PTH soon.”
 - Trigger points, or the point at which the PM should ensure that the PF is aware of a deviation.
 - “If we are not back to VNAV PTH within 15 nm before the waypoint, let me know.”

The Full Range of Knowledge & Skills

And where there is potential value in training

XX *Efficient Information Extraction*

 *Operational Knowledge*

 *Situation Model*

 *Interface Configuration*

 *Threat Identification*

 *Strategic Task Management*

XX *Attention Switching*

 *Problem Identification*

 *Intervention*

 *Communication*

What Can We Learn about Training of Monitoring/Awareness

A literature review across domains

- ❖ Five Performance Domains
 - Piloting
 - Surgical
 - Air Traffic Control
 - Driving
 - Sports

- ❖ We looked for studies that trained practitioners and measured training effectiveness on monitoring / awareness / understanding
- ❖ It is unusual (almost non-existent) for a training program to focus on monitoring / data-gathering only

Aviation / Pilot Performance

- ❖ Two comprehensive studies are worth looking at (both from the early 2000s)
 - ESSAI study out of the EU
 - Advanced CRM (Brief / Discuss / Advocate / Resolve)
- ❖ Focus on information relevance and projecting into the future
- ❖ Link more general CRM concepts to specific scenarios and procedures, which is hard for pilots to do on their own
- ❖ In some studies, lower-fidelity simulations were effective; observation of others were effective.

Surgical Performance

- ❖ Very large literature here; we focused on studies with a training intervention and performance-based measures. Many lessons taken from aviation and applied to medicine.
- ❖ Identifying and training on important/relevant information (risk factors) in the operational setting (or in a simulator).
- ❖ Again, role of briefing was important
 - Brief; work a scenario (in a simulator); debrief for evaluation
 - In many studies, more time is dedicated to debriefing than to the scenario
- ❖ As with aviation, integration of materials into the operational setting is important.

Air Traffic Control Performance

- ❖ There were few training studies here
- ❖ An important study takes advantage of the strategy of concept / brief / simulate / debrief

Driving Performance

- ❖ Major focus here on "hazard anticipation" (information relevance), which is tied to learning where to look for potential hazards
- ❖ Again, debriefing was a valuable tool for learning.

Sports Performance

- ❖ The one domain in which gaze training can be an effective training technique.
 - awareness of other players
 - to regulate action
- ❖ Changing perspectives is used to train team coordination
- ❖ The fixation techniques are used to drive actions and are quite different from the dynamic flow of information you would find in aviation.

Lessons Across Domains

- ❖ Focus is on sense-making / understanding the situation; NOT on gaze patterns
- ❖ Training methods
 - Conceptual introduction + Briefing + Simulator Practice + Debriefing
 - Design of key behavioral scenarios
 - Graded difficulty
- ❖ Training targets
 - Relevant mental models
 - What information is important when
 - Best place to get information, including display set up (as well as why wanted)
 - Practice integrating information about the current situation with operational knowledge of how things work; this is hard.
 - Working with crew to set up plan and track monitoring activity.

Review of Current Airline Training

A series of discussions with airlines about monitoring and training

❖ US Domestic Operators

- Alaska Airlines
- American Airlines
- Compass Airlines
- Delta
- FedEx
- SkyWest Airlines
- United Airlines

❖ Foreign Operators

- Air France
- Air New Zealand
- British Airways
- Emirates Airlines
- KLM
- Lufthansa
- Qantas
- Swiss Airlines

❖ Pilot Unions / Pilots

- ALPA, HF
- ALPA, Training
- CAPA, Safety
- IFALPA, HuPer
- Harry Nelson
- FAA FPM WG

❖ Researchers

- ICAO, HF
- LOSA Collaborative
- HeliOffshore
- Boeing Australia
- NLR
- CAE
- US Air Force

Primary Discussion Questions

- ❖ What are the current problems in monitoring at your airline? Or, where do you see the flight crew performance problems involving monitoring?
- ❖ In either initial or recurrent training, do you evaluate the PM?
- ❖ Can the PM fail the evaluation due to performance as a PM?
- ❖ What, if any, training do you provide that focuses on monitoring skills, or on the role of PM?
- ❖ What are the roles of the pilot monitoring, as it regards FPM? How does it differ from the role of the PF, again, regarding FPM?
- ❖ Turning finally to a more-specific aspect of monitoring: FMAs and autoflight awareness. What is your airline's policy on callouts for FMAs?

Simple Answer Counts

Not every operator answered every question

	US Operators		Foreign Operators	
	Positive	Negative	Positive	Negative
Evaluate PM as an individual?	2	5	5	2
Fail PM as an individual?	2	5	6	--
Have developed PM beh markers?	2	5	--	6
Have monitoring training?	4	3	4	1
PM should mon diff from PF?	1	1	5	--
Call out all FMAs?	--	5	7	--

FPM Monitoring-Related Events

What are operators reporting as their biggest concerns?

- ❖ Significant safety events and near misses
- ❖ Trying to limit workload (SOP overload, time pressure, distractions) to preserve flight crew resources for monitoring
- ❖ Failing to call out flight path deviations . . . no awareness or not speaking up?
- ❖ Inappropriate autopilot state
- ❖ Worst flight phases: taxi, descent/arrival, go around

What is the Appropriate PM Role?

Here are some statements we heard

- ❖ PM is the last line of defense . . . the most important role in the flight crew?
- ❖ Why are pilots qualified as a PF but not as a PM?
- ❖ PM is a manager . . . of flight deck technology . . . for go around
- ❖ PM keeps the big picture
- ❖ We don't know what the role of the PM should be

Training and Evaluating Monitoring

Many operators have added some training related to monitoring

- ❖ Training topics related to monitoring for FPM; some examples
 - managing/negotiating workload between PF and PM
 - PM callouts of deviations
 - practicing PM duties into a risky environment
 - Areas of Vulnerability / awareness of workload
 - awareness of how both PF and PM can have unique awareness
 - barriers to effective monitoring
 - for instructors on how to evaluate monitoring

- ❖ Half the operators evaluate the PM separate from the flight crew, but this evaluation focuses on the PM's "technical" skills

- ❖ Two operators have started evaluating PM for non-technical skills . . . but there is a concern with the instructors' ability to perform this evaluation

Would Eye-Tracking Technology Help?

And how would you use it?

- ❖ Several foreign operators are having an eye-tracking system integrated into a FFS
 - Emirates
 - Qantas
 - Singapore
- When or how frequently should the instructor consult the support tool?
- Will the support tool prompt the instructor?
- How much time does this take away from the instructor's ability to observe the flightcrew more directly?
- Can the support tool be used to mark events to be reviewed during the debriefing?
- Can the support tool indicate what areas should be fixated and then show that they were or were not fixated during some critical time period?
- Can the support tool be tied in to scoring monitoring behavior automatically?
- Can the support tool be used to annotate monitoring failures; e.g., to indicate whether deviations were caught another way and there were no undesired operational consequences?
- Does the support tool provide information about the validity of the fixation data (since these systems can be less reliable depending on factors such as eye shape)?

Broader Issues and Concerns

- ❖ Treat the PM like a PF: Develop the appropriate knowledge and skills for the PM.
... PM license?
- ❖ Develop observable behaviors for monitoring (PM)
... more generally, how does one evaluate the PM appropriately? [Task 3 report]
- ❖ Is there value in integrating eye tracking into the FFS? How would you use it?
- ❖ How does monitoring fit within the larger set of non-technical skills?
- ❖ SOPs to better support monitoring (but concerns about workload)
- ❖ How can you make FMA callouts more meaningful?
- ❖ A desire to do training for monitoring that is NOT evaluation-oriented

How do We Bring Industry Together and Improve Performance?

Many operators struggling with the same issues

- ❖ Many operators have similar concerns and have developed training, technology, procedures
- ❖ Foreign operators have taken the lead in some areas
- ❖ Is it time for a multi-day, international workshop / symposium that would cover topics such as
 - integrating eye-tracking into the FFS
 - evaluation measures
 - training ideas
 - training scenario development
 - PM qualifying / licensing
 - use of SOPs to support monitoring, maybe to replace FMA callouts
 - review of safety events
 - links to startle and surprise

Going Forward; What Further Activities should be Pursued

Some ideas for turning research into practice

- ❖ List of "monitoring challenges" that should drive simulator scenarios (and cognitive task analysis)
- ❖ Comparison of communication techniques, including scope, structure, workload, how sensitive to context
- ❖ A model for developing training along the lines we have specified:
 - scenario with interesting challenges
 - CTA to get at ID of threats and expectations, one or several methods for using displays/indications to monitor it, including display config, including relevant MMs, with structured communication
 - knowledge, brief, perform scenario, debrief
 - Link specific skills to general CRM skills
- ❖ Build a separate scenario to touch on task management and attention switching
- ❖ Observable behaviors for sim training (how to score) (e.g., anticipating values)
- ❖ Better specify role of PM; specific skills and knowledge → inputs to licensing?
- ❖ Value/Role of ET technology during training (how to use it without getting overwhelmed)

Primary Points to Take Away

- ❖ Monitoring is much broader than gathering data from the world.
It is driven by sense-making/understanding and expectation (a strength!).
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Thanks for your time!

