



Cognitive Task Analysis for Flight Path Management

Building Expertise to Manage Risk in Unexpected Situations

Captain Mike Tarsa

United Airlines Flight 232

July 19th, 1989

- McDonnell Douglas DC-10, DEN to ORD
- Complete loss of hydraulic systems, no flight controls
- 296 passengers
 - 184 survived
 - 13 were uninjured
- An extraordinary FPM challenge



Why were Captain Haines and his crew able to perform so well?

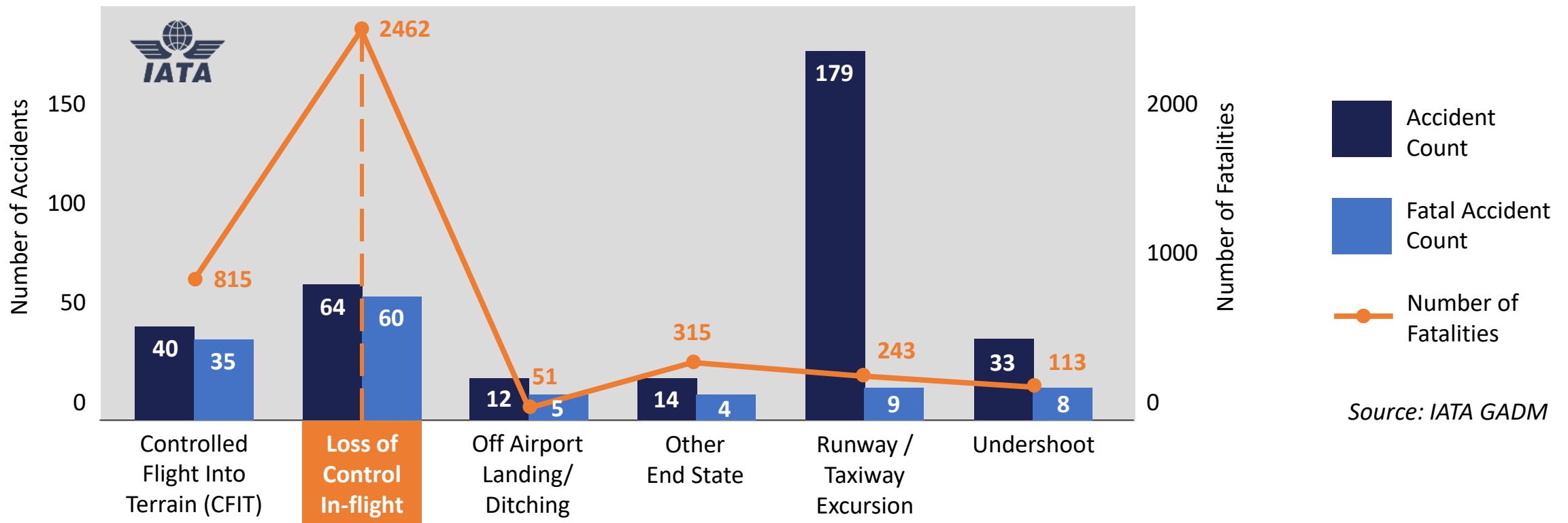
Flight Path Management

- Current issues and risks
- Existing training models and guidance
- Cognitive task analysis: general overview
- How cognitive task analysis can be utilized in training and evaluation

Loss of Control (LOC)

LOC-I is the number one fatal accident category

2009 – 2018 Loss of Control—Inflight Accident Analysis Report



Operational Use of Flight Path Management Systems

*Final Report of the Performance-based
operations Aviation Rulemaking Committee/
Commercial Aviation Safety Team
Flight Deck Automation Working Group*

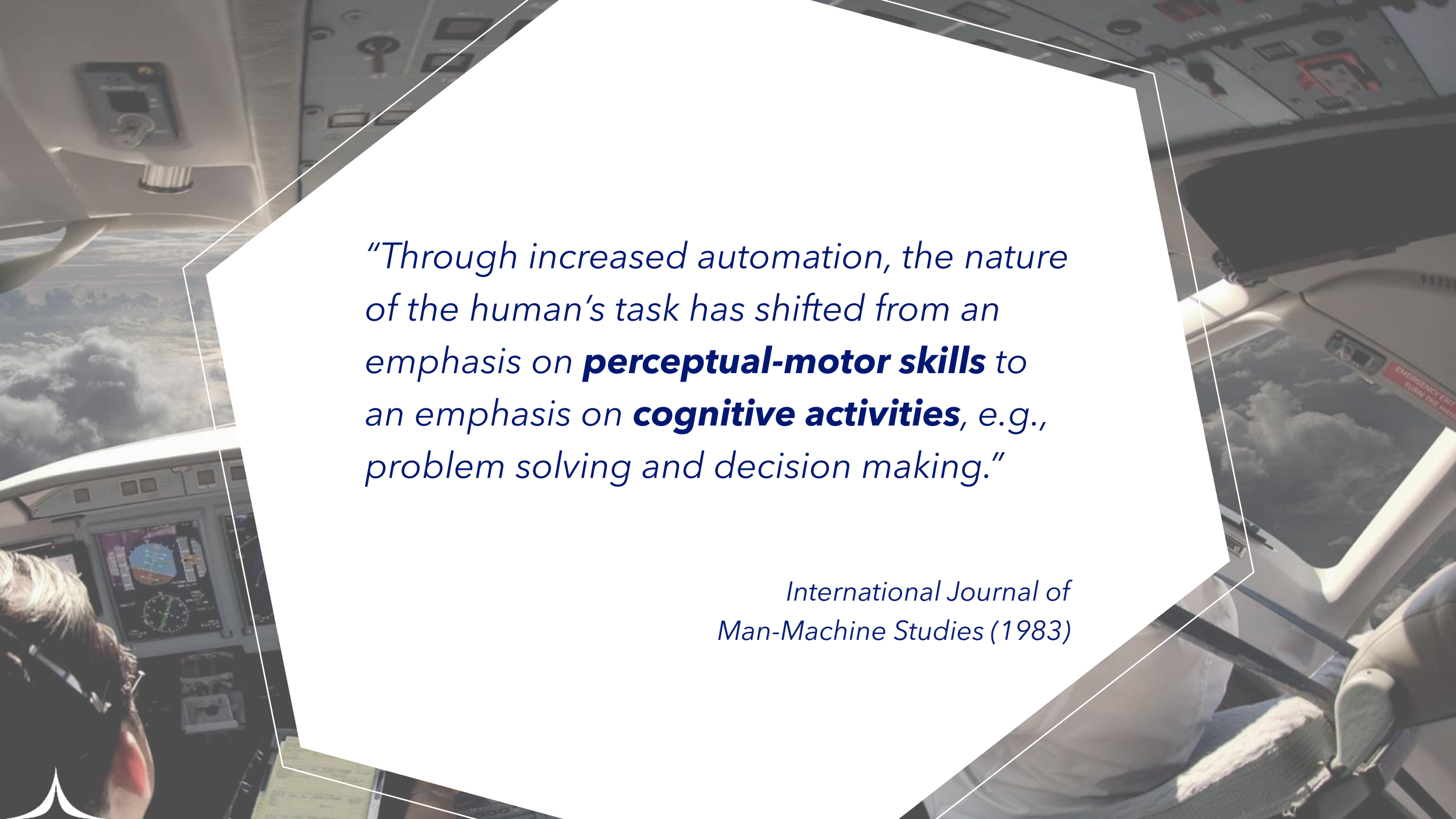
September 5, 2013



Industry & FAA Response - 2013 to 2022

FAA Advisory Circular 120-123 (2022)

- Automation management, automated and manual flight path control
- Focus on the big picture rather than on the procedural steps in each task
- Monitoring the aircraft's flight path and energy state while maintaining situation awareness
- Guidance for policies, procedures, and training content

The background of the slide is a photograph of an airplane cockpit. On the left, a pilot's head and shoulders are visible, looking out the window. The cockpit is filled with various instruments, including a large primary flight display (PFD) showing a horizon and altitude, and several smaller secondary displays. The right side of the image shows the yoke and part of the instrument panel. A large, white, irregularly shaped geometric overlay is positioned in the center-right of the image, containing the main text. The text is in a dark blue, serif font, with some words in bold. The overall lighting is bright, suggesting daylight.

*“Through increased automation, the nature of the human’s task has shifted from an emphasis on **perceptual-motor skills** to an emphasis on **cognitive activities**, e.g., problem solving and decision making.”*

*International Journal of
Man-Machine Studies (1983)*

ISD

- **FAA:** ISD is required by regulation and guidance (AQP and competency-based training systems)
- **ICAO:** ISD is required to customize competency-based training (adaptive competency model)



ISD

1. Instructional goals
2. Knowledge and skills needed to meet goals
3. Context, in which the new skills must be utilized
4. Capabilities and existing knowledge



Analysis

Analyze your training situation to understand the gaps you need to fill.

ISD

Task analysis is:

- Essential to good instructional design
- Probably the most important part of the instructional systems design (ISD) process



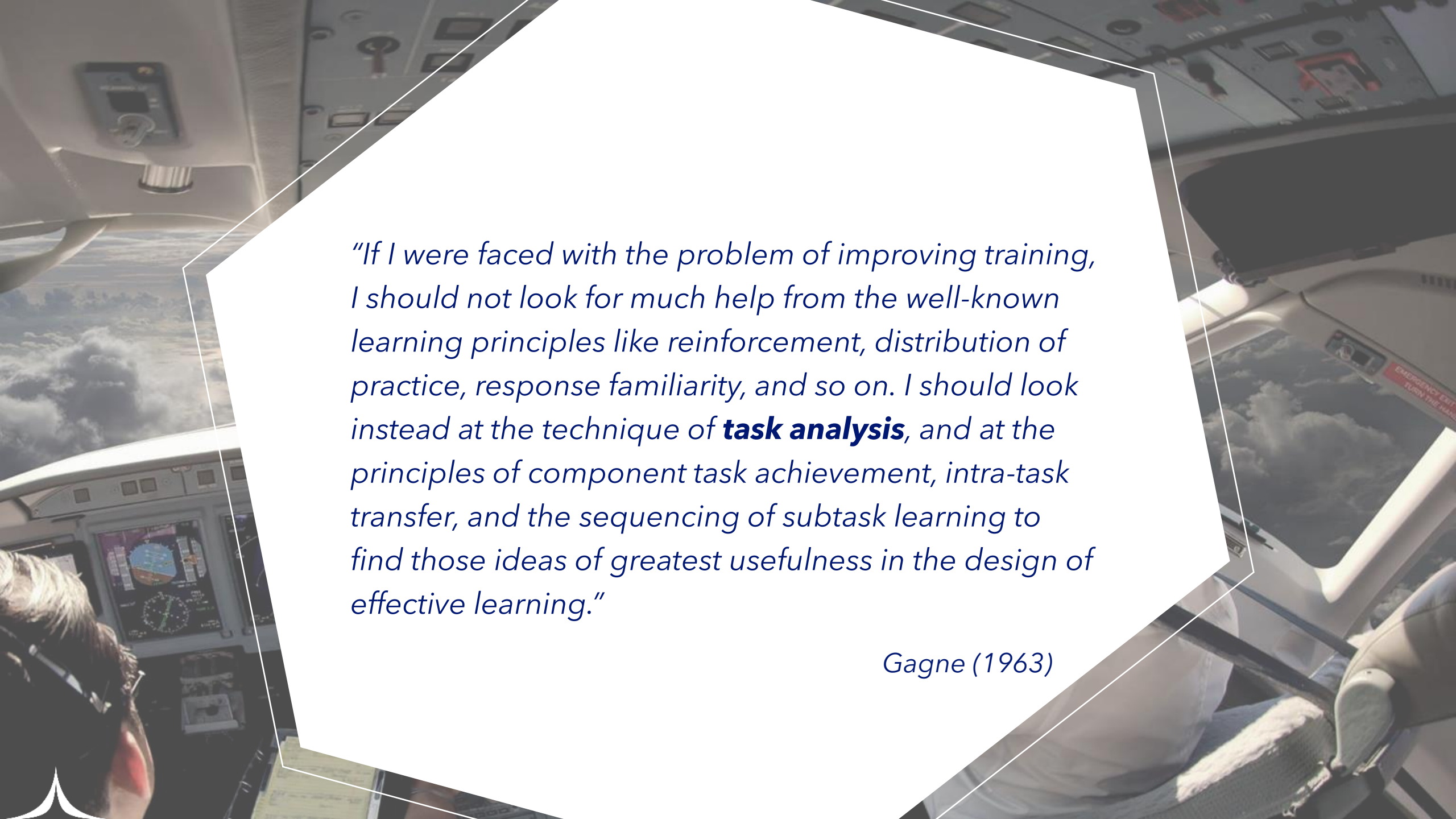
A Task Analysis

Essential Knowledge

Skills

Attitudes

How people react to the situation or demand on their skills

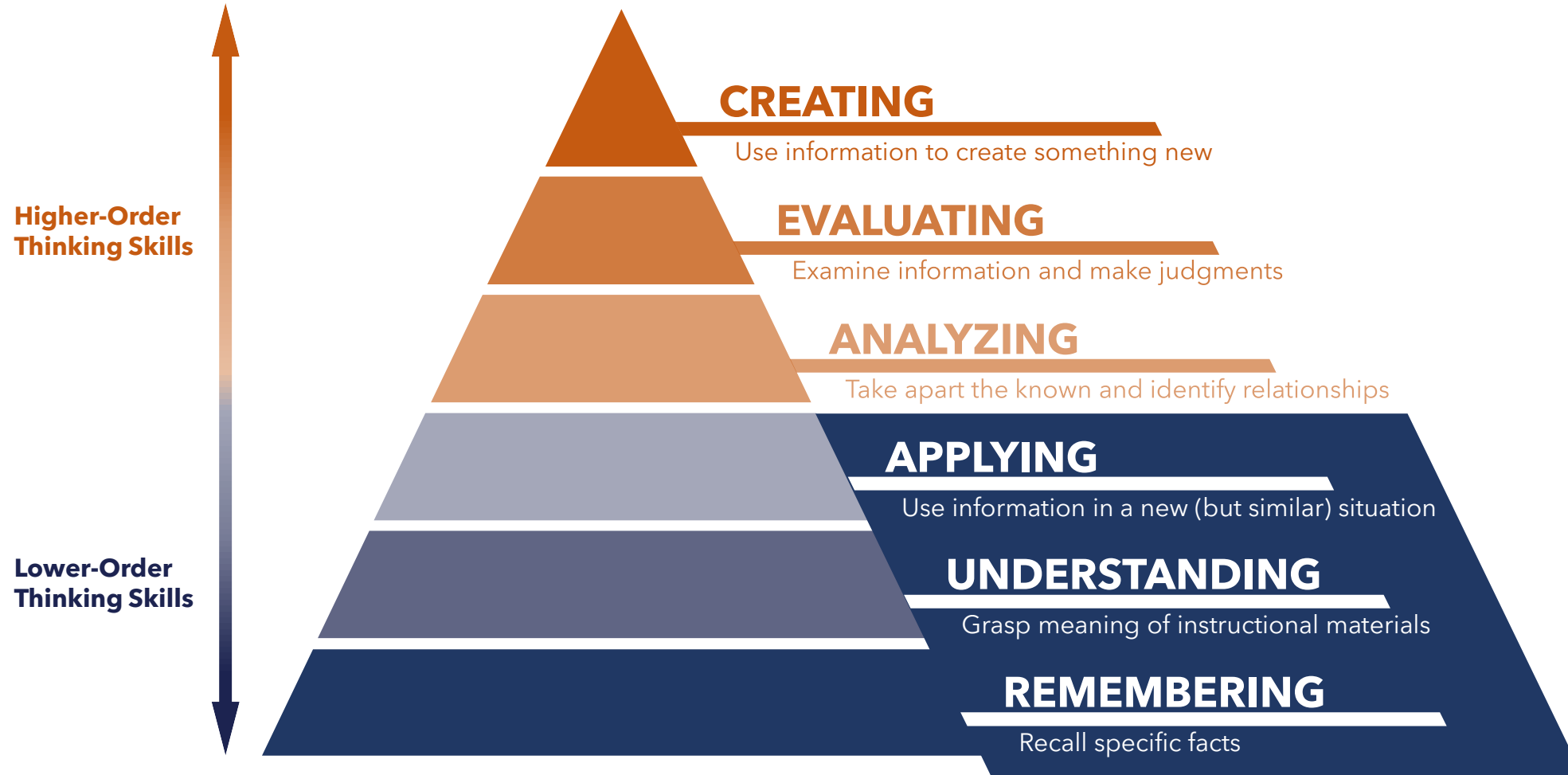


*"If I were faced with the problem of improving training, I should not look for much help from the well-known learning principles like reinforcement, distribution of practice, response familiarity, and so on. I should look instead at the technique of **task analysis**, and at the principles of component task achievement, intra-task transfer, and the sequencing of subtask learning to find those ideas of greatest usefulness in the design of effective learning."*

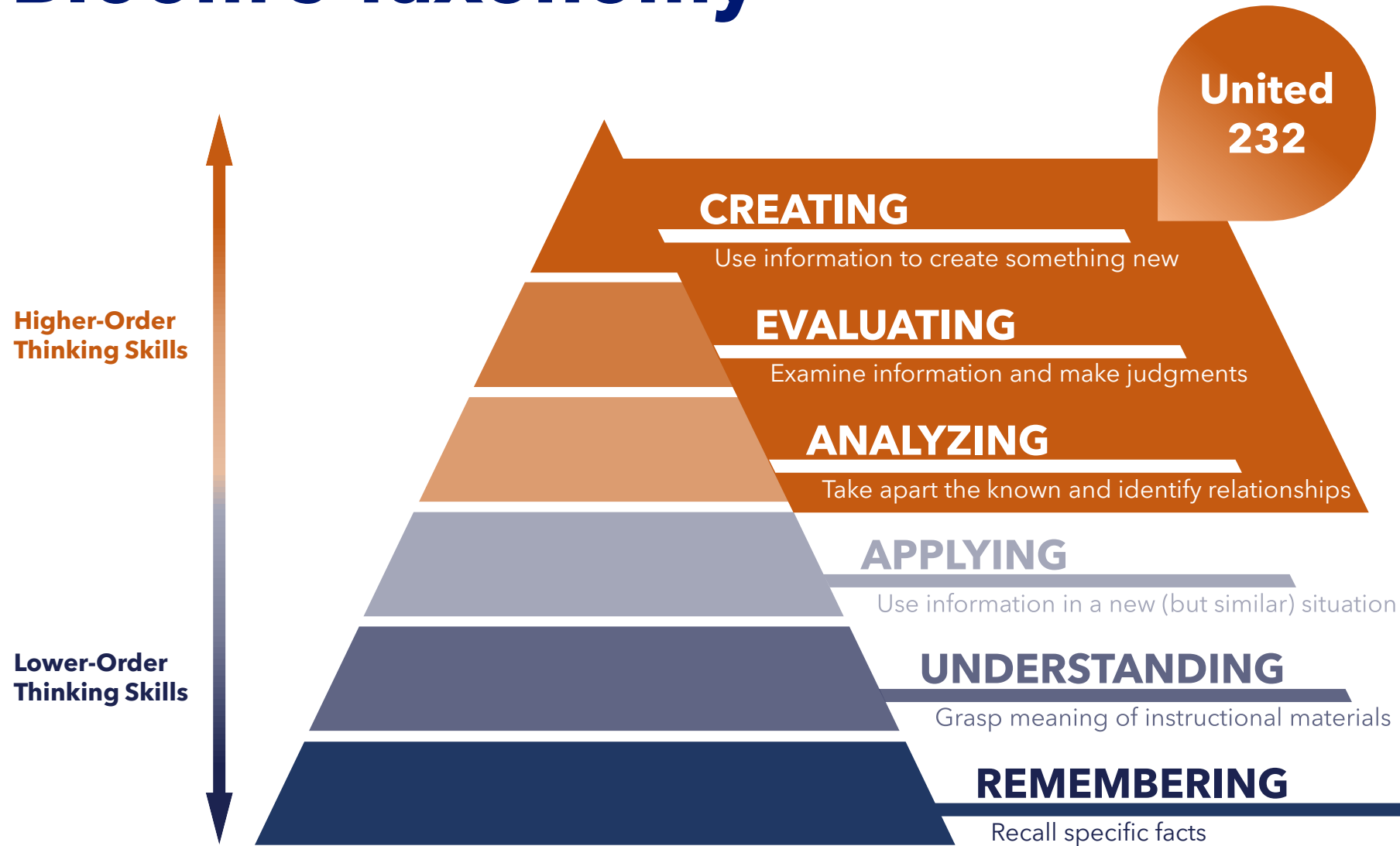
Gagne (1963)

Bloom's Taxonomy

Cognitive Domain (2002)



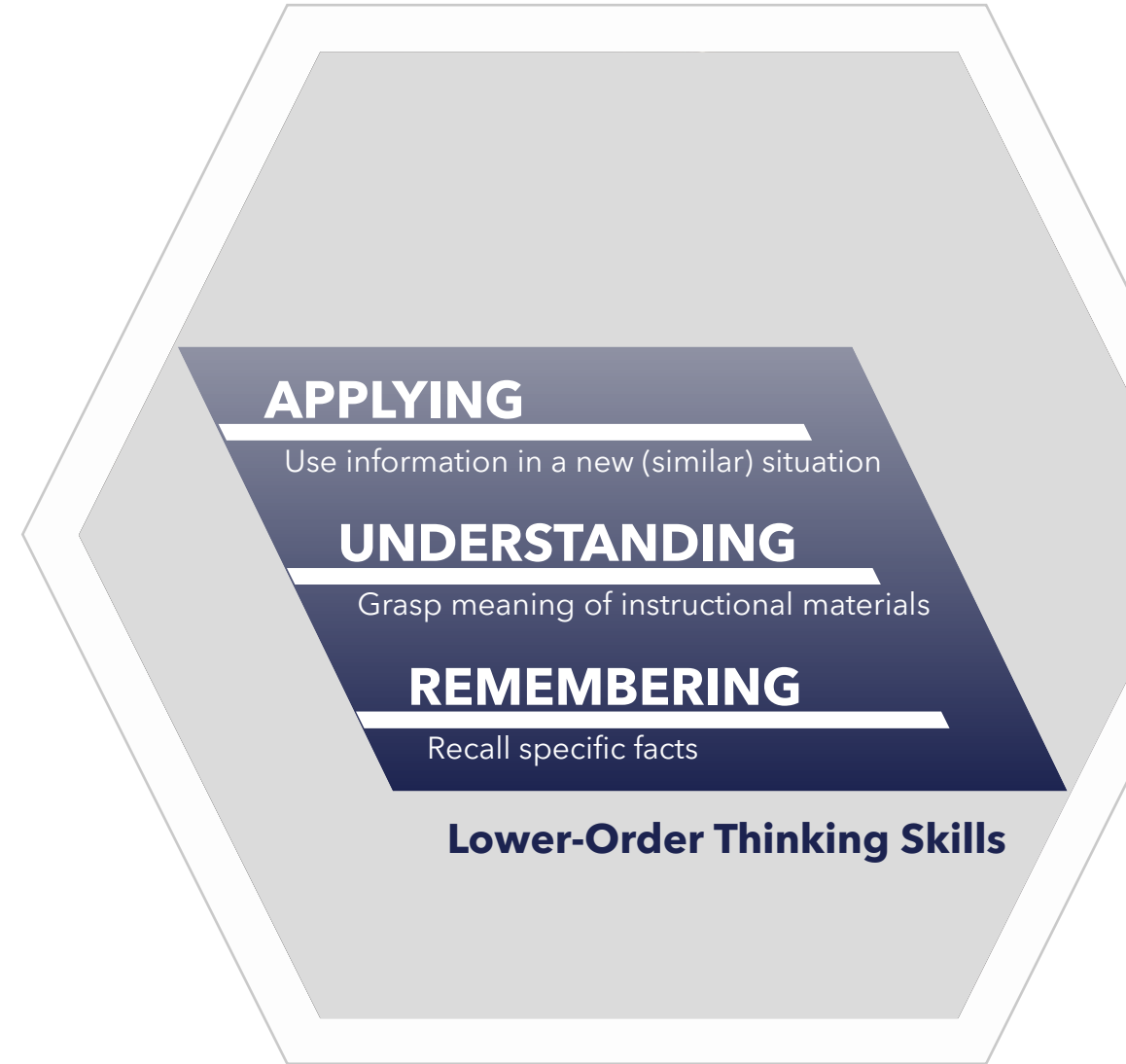
Bloom's Taxonomy



ILS Approach

Sample Task Analysis (FAA)

- **6.2.1 Perform CAT I Coupled ILS Approach**
 - (K) Know description of CAT I Precision Approach, when to perform it and procedures to be followed
 - (CS/MS) Perform actions required for a CAT I Coupled ILS Precision Approach
- **6.2.2 Perform CAT I Un-Coupled ILS Approach**
 - (K) Know description of CAT I Precision Approach, when to perform it and procedures to be followed.
 - (CS/MS) Perform actions required for a CAT I Un-Coupled ILS Precision Approach
- **6.2.3 Perform Coupled ILS CAT II Approach (Two Engine)**



Qual Standards: ILS

Example from the FAA AQP Library

Observable Behaviors

1. Crew completes checklist correctly
2. Crewmembers select, tune, identify, and monitor the operational status of ground and airplane navigation equipment associated with the ILS approach
3. Crew reviews displaced thresholds, meteorological conditions, NOTAMs, or ATC instructions associated with the ILS
4. Crew applies gust/wind factors and evaluates meteorological phenomena such as wind shear, microburst, and other related safety of flight factors
5. PF maintains proper course/attitude, as commanded by the flight director
6. PF avoids descent below the DH before initiating a missed approach procedure or transitioning to a landing
7. PF transitions to a normal landing approach only when the airplane is in a position from which a descent to a landing on the runway can be made at a normal rate of descent using normal maneuvering

Observable Behaviors

From ICAO Aircraft Control Competency - Hinting at Cognitive Tasks

- Demonstrates manual aircraft control skills.
- Detects deviations through aircraft scanning.
- **Maintains spare mental capacity during manual control.**
- Maintains the aircraft in the normal flight envelope.
- Knows how and when to use flight management systems.
- Demonstrates correct methods for engagement/disengagement of autoflight systems.
- Demonstrates appropriate use of flight guidance.
- Maintains mode awareness of autoflight systems, engagement, and transitions.
- Reverts to different modes when appropriate.
- Detects deviations from the desired aircraft state (flight path).
- **Anticipates/recognizes mishandled autoflight system.**
- Takes appropriate action to restore autoflight state.

Behavioral objectives alone do not address the internal mental processes that control the learner's actions!

Cognitive Task Analysis

A New Approach Using Old Tricks for Training Flight Path Management

GOAL

To uncover the mental models, decision-making processes, problem-solving approaches, and knowledge structures that individuals use

BENEFITS

Particularly useful when tasks involve complex cognitive demands, such as problem-solving, decision-making, and expertise-driven activities

FOCUS

Targets the underlying psychological processes and knowledge structures that are required to produce the correct overt behaviors at the appropriate time





Cognitive Skills

The ability to **retain** and **combine** knowledge, and then **apply** it to perform complex mental tasks, which include:

- Problem-solving
- Decision-making
- Situation assessment
- System monitoring
- Heuristic calculations (mental shortcuts)
- Visualizing special flight-path planning
- Temporal awareness (passage of time)

Behavioral vs. Cognitive Skills Examples

Instrument Scan

Scanning and understanding what the instruments read

Integrating the information into a 3D mental model

VNAV Approach

Programming and monitoring the FMS

Creating a contingency scenario in advance

Diversion

Knowing how to create divert plan

Managing stress associated with time pressure



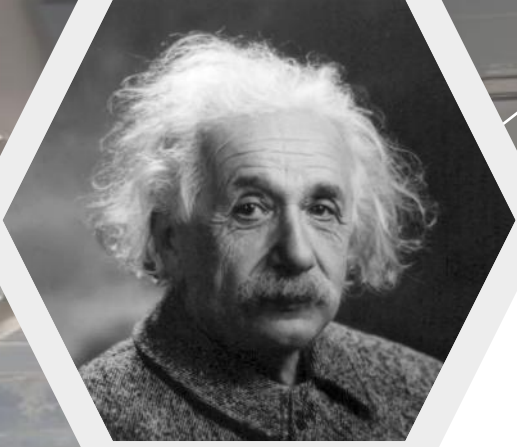
Current Flight Training

Focuses on **reproductive thinking**:

- Procedure and repetition
- Restricts cognitive ability by a phenomenon called "functional fixedness"

Do we train for **creative thinking**?





*"I do not carry such information in my mind, since it is readily available in books. The value of a college education is not learning of many facts, but the **training of the mind to think.**"*

Albert Einstein



Mitigating LOC

- Often no pre-existing procedure or checklist
- Startle and surprise situations (UPRT)
- Competencies needed:
 - Monitoring
 - Situation awareness
 - Situation Control

FAA Advisory Circular 120-123 (2022)

Monitoring

- Driven by understanding the situation (*sense making*) and creating and validating expectations
- Task/attention management (strategic and tactical)
- Can be trained effectively (identify relevant information, integrate operational understanding)
- Goal of effective monitoring: **situation awareness**



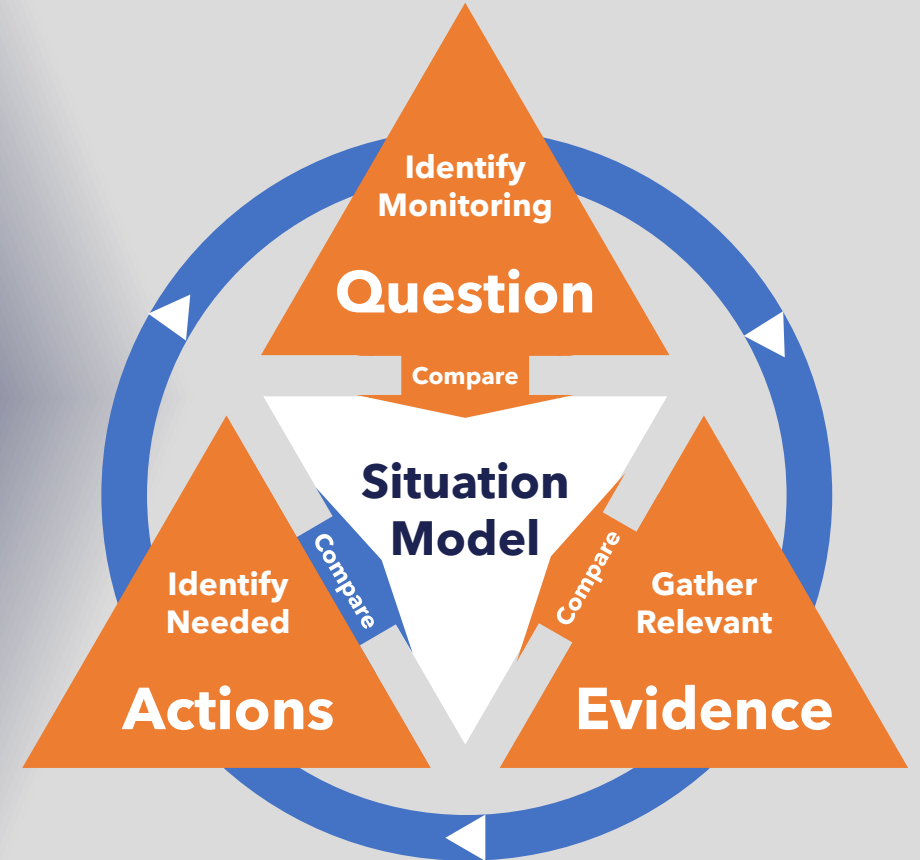
Situation Awareness

Perception - Comprehension - Projection

Tasks:

- Identify and question the situation
- Compare with exiting mental model
- Recognize what evidence needs to be gathered to understand change
- Compare the new understanding with the existing situation
- Decide what action to take to control the situation

All of these are **cognitive skills**.



Murray & Martin (2012)

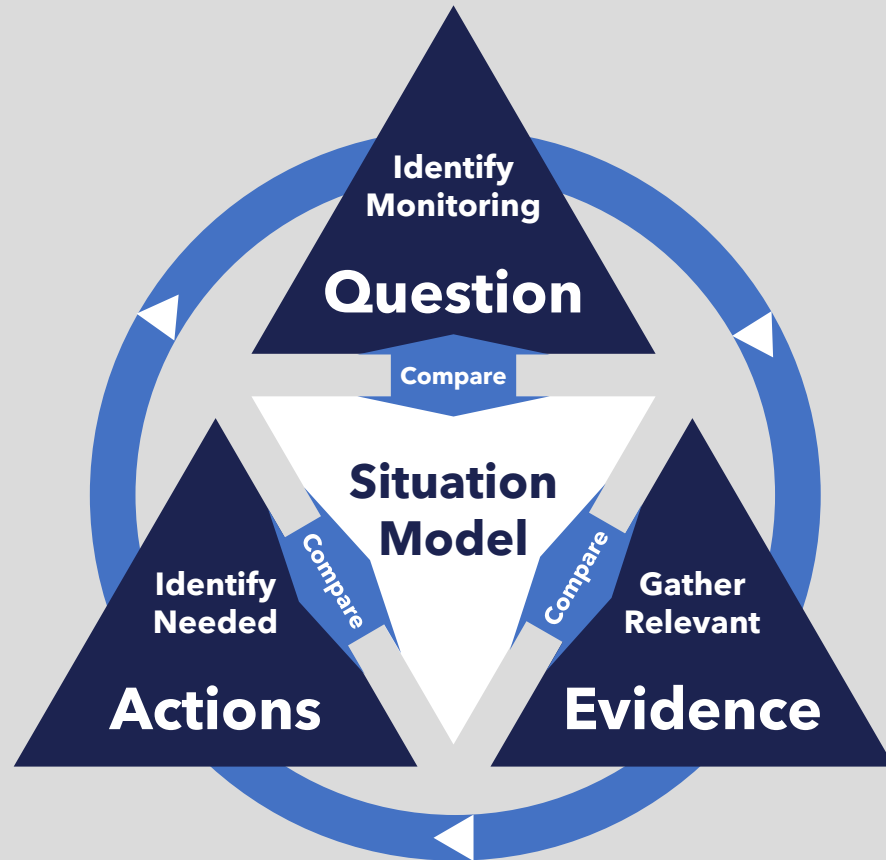
Situation Control

Tasks:

- Plan FPM well ahead of the aircraft (altitudes, speeds, configurations)
- Monitor changes effectively
- Perceive – Comprehend – Project

Cognitive skills:

- Storage of information (learning)
- Recalling information at the right time (coding and chunking)
- Temporal awareness (passage of time)
- Inquiry



Murray & Martin (2012)

Example: Takeoff

- **Situation Model:** IAS will increase at level off
- **Perceive:** What is seen, heard, felt?
- **Monitor:** Rate of acceleration
- **Question:** Why is rate not as expected?
- **Update situation:** Airspeed stagnation
- **Gather Evidence:** AC configuration/ Power setting
- **Update situation:** Auto Throttles not in CLIMB
- **Identify Action:** Manual throttle control to CLIMB
- **Compare:** Power now in CLIMB range
- **Update situation:** Airspeed accelerating



Building an Improved JTL with CTA

ANALYZE

- Learning task, AND ...
- **Cognitive process** that affects the learning task
- **Personality variables** of the learners that interact with the task

DISCOVER

- Elicit from **experts** what knowledge and processes they use when performing a complex task.
- Discover and document in training how they perform the target task at a **high level of proficiency**.

CONDUCT

- **Interview** the experts (SMEs) in their domain
- SMEs to **identify** the thought processes and types of skills they apply when executing these complex tasks exceptionally well.
- **Design** your training based on your findings.

Cognitive Skill Action Verb Examples to Articulate Performance Objectives

Acknowledge

Allow

Carry Out

Check

Compare

Confirm

Demonstrate

Ensure

Establish

Evaluate

Examine

Exhibit

Identify

Infer

Interpret

Inventory

Judge

Maintain

Manage

Measure

Monitor

Predict

Question

Recognize

Reduce

Survey

Synthesize

Use

Verify



CTA in Current Training

Most airlines already touch on cognitive skills:

- Most experienced instructors and evaluators recognize high performers
- Your existing SMEs can often articulate how a high performer manages the behavioral tasks
- Documenting these higher-order skills makes them accessible to all IEs and learners
- Aligns your training with individuals' cognitive processes and mental models



CTA Applied

Example of Improved Task Analysis with Cognitive Elements

6.1.1 Perform ILS Approach

- **Manage** automated approach control
- **Assess** performance of automated approach system
- **Identify/Inventory** inconsistencies of expected systems performance
- **Recall** specific knowledge of system operation
- **Compare** performance with aircraft configuration
- **Synthesize** differences into situation model
- **Predict** change in flight path/airspeed based on aircraft configuration
- **Identify** changes needed to correct difference between desired and expected
- **Manage** actions to effect changes





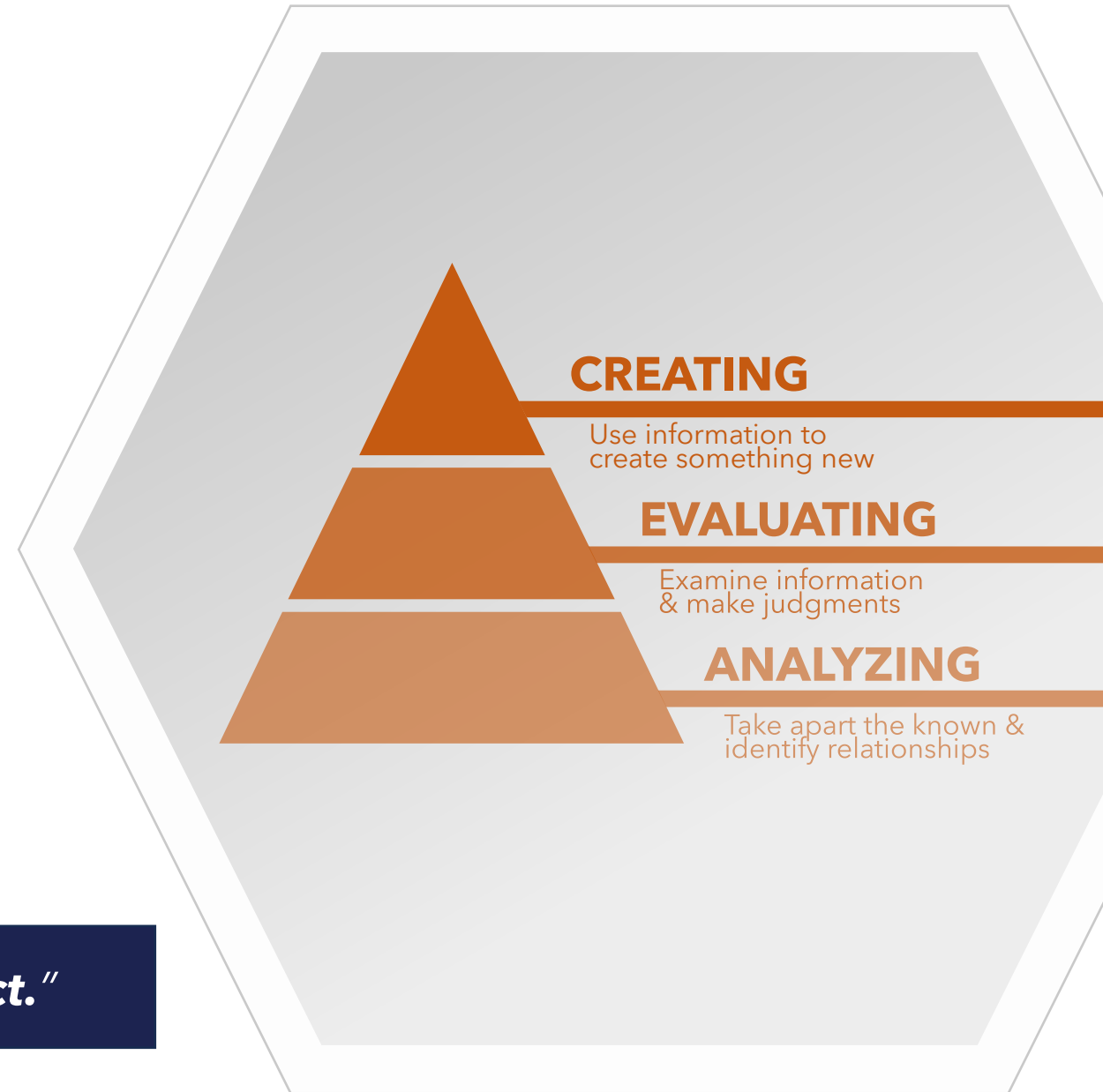
Challenges of CTA

- It is difficult to know what's going on in someone's mind.
- Traditional observable behaviors do not correlate with cognitive processes.
- Training and evaluating cognitive skills leans heavily on briefings and facilitation.
- Cognitive skills must be inferred or reflected by other observable behaviors.
- Instructors and evaluator training is critical.

Facilitating Using CTA

- Use elements of task analysis and performance objectives
- Enable self-awareness and self-discovery
- Use CTA language to guide the performance analysis
- Document cognitive elements of FPM tasks

*"You get what you **inspect**, not what you **expect**."*





Summary

The main objectives of CTA for effective FPM training are:

1. Uncover the knowledge and expertise needed for expert performance in **YOUR** operation
2. Incorporate these higher-order thinking elements into the task analysis
3. Inform training development and instruction (cognitive processes and mental models used when performing a task)



Cognitive Task Analysis for Training Flight Path Management

Captain Mike Tarsa