

---

# Training for Expert Performance

## *Tools and Strategies*

*Thomas L. Seamster, Ph.D.  
Cognitive & Human Factors*



# Presentation

---

- ❑ Overview of Expert Performance
- ❑ Understanding Expert Performance - Structure
- ❑ Pilot Cognitive Skills
- ❑ Cognitive Skill Types - Hierarchical Content
- ❑ Interaction of Expert Performance and Skill Types
- ❑ Summary of Strategies and Tools



# Overview of Expert Performance - Structure

---

Why consider **Expert Performance** in the context of developing pilot training and assessment?

- ❑ It provides a disciplined way to **integrate** the current training footprints
- ❑ It suggests a training program that goes beyond **acceptable** to **expert** performance
- ❑ It provides the **structure** for **longitudinal** training and assessment programs



# Overview of Expert Performance

---

There are compelling operational reasons to better understand **expert performance** and its **skills**. In other words, this is not just an interesting research question:

*The less we know about the skills we are training, the greater the need for higher fidelity simulation (Proctor & Dutta, 1995). This seems a fair description of the current status in CRM training.*



# Overview of Expert Performance

---

- The theory of **Expert Performance** advanced by Ericsson and others suggests some valuable strategies for the **longitudinal** training of commercial pilots
- A key tenet of that theory is that superior performance is **NOT** primarily due to innate talent, rather it is due to focused, focused training (**effortful practice**) extended over the three phases of expert performance development



# Expert Performance and Experience

---

We distinguish between Expert Performance and Experience:

- ❑ **Expert Performance** is a higher level of performance attained through **Effortful Practice** to refine skills
- ❑ **Experience** alone, such as that gained through being a commercial pilot, is not sufficient to attain **Expert Performance**



# Overview of Expert Performance

---

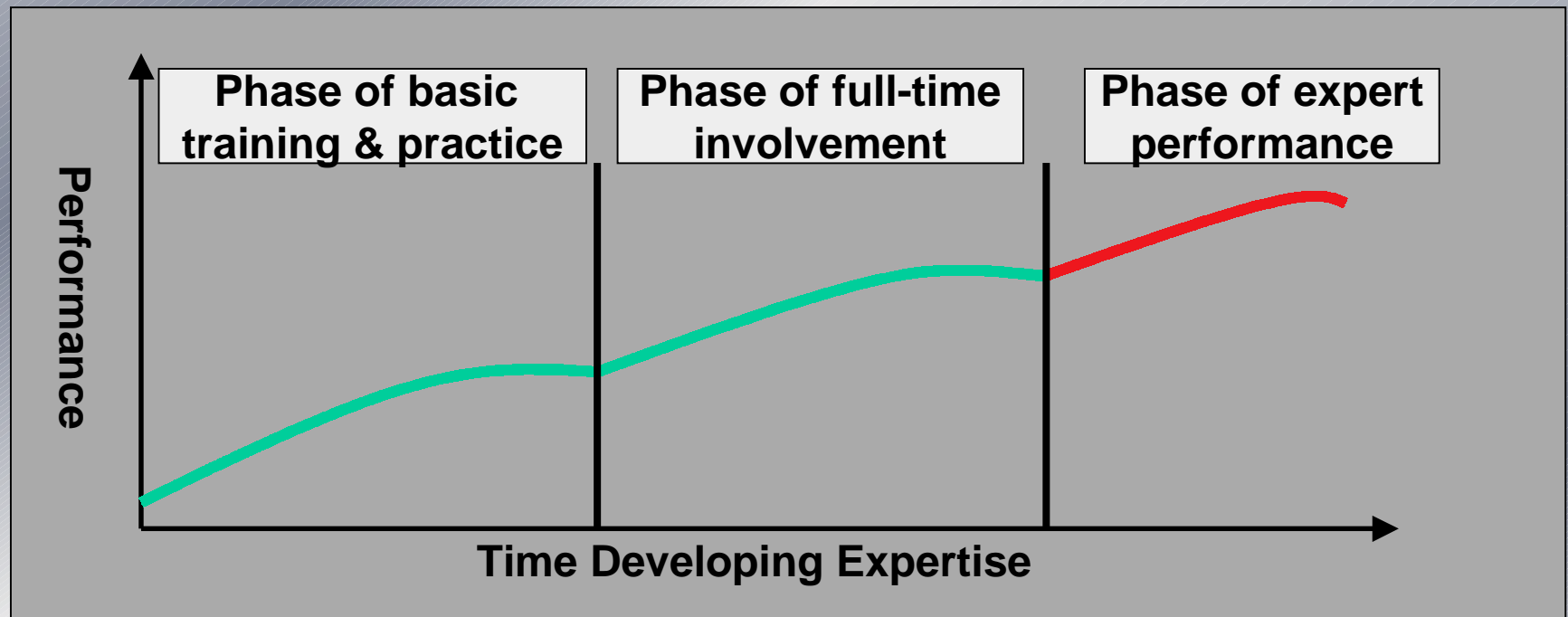
**Effortful Practice** has some of the following characteristics:

- It requires **full concentration**
- It is designed to **improve specific aspects** of performance through repetition
- It may involve **hundreds of practices** to improve a specific aspect
- It occurs at **frequent and predictable** times



# Overview of Expert Performance

Expert performance is usually developed over **10 years** of practice (Ericsson & Charness, 1994):





# Understanding Expert Performance

---

A theoretical basis for higher levels of performance is **Long-Term Working Memory (LT-WM)** (Ericsson et al., 1995):

- ❑ **LT-WM** is acquired in specific domains
- ❑ **LT-WM** provides an efficient linkage between Short-Term Working Memory and Long-Term Memory
- ❑ Key for aviation, **LT-WM** is significantly less affected by interruptions than is ST-WM



# Understanding Expert Performance

---

**Long-Term Working Memory** provides an explanation of Expert Performance:

- ❑ Suggests how performance improves through an increase in working memory capacity and improved memory structures
- ❑ Suggests methods, such as the use of interruptions, to assess performance
- ❑ Provides guidance for the further analysis of complex cognitive skills in aviation



# Understanding Expert Performance

---

**Long-Term Working Memory (LT-WM)**  
has been established in the following domains:

- Medical Diagnostic Expertise**
- Mental Abacus Calculation**
- Memorization of Restaurant Orders**
- Chess**



# Understanding Expert Performance - Medical

---

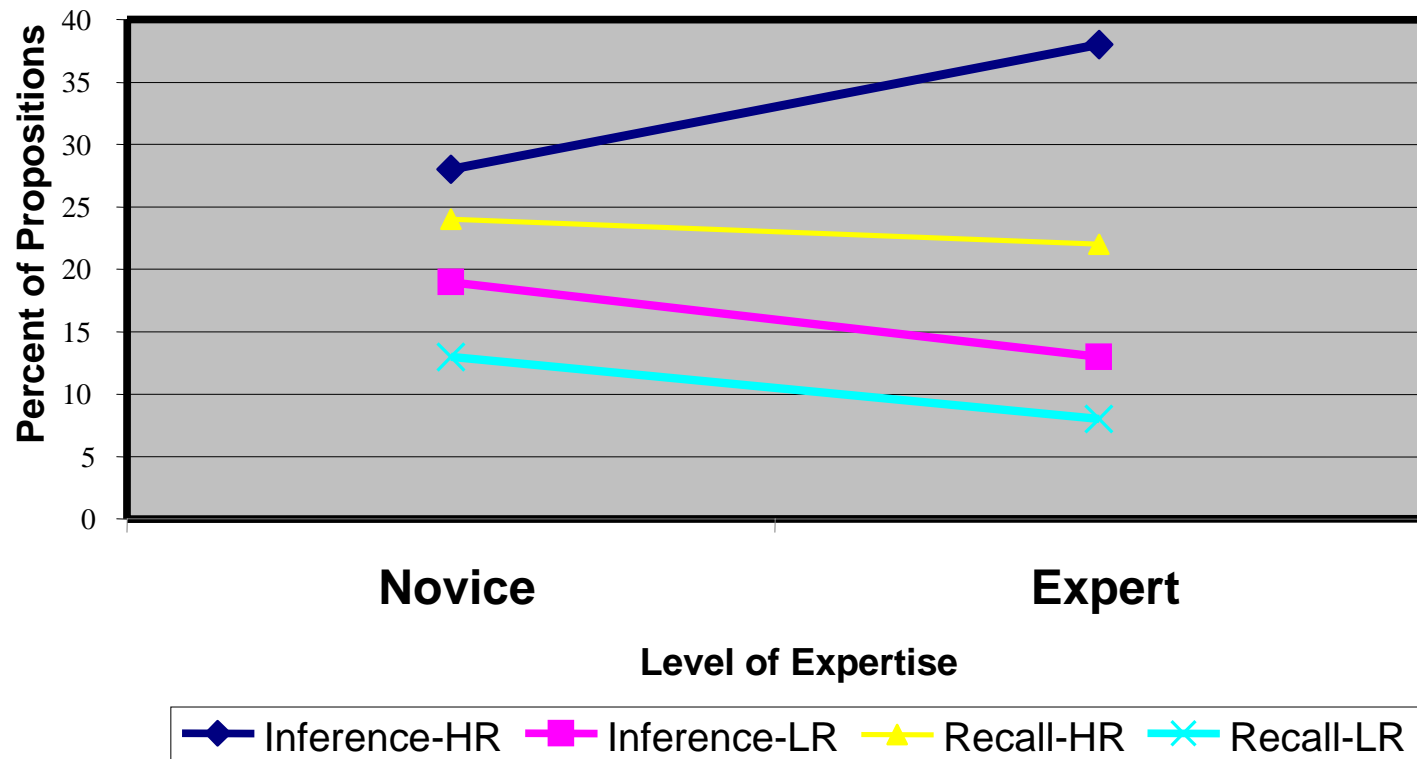
## Characteristics of Medical Expertise:

- ❑ Medical experts are able to recall more relevant information than novices
- ❑ That recall of relevant information is in an abstracted (more efficient) form
- ❑ Expert recall is less effected by the order in which the material is presented
- ❑ Medical experts may use LT-WM to improve diagnosis as well as to support reasoning



# Understanding Expert Performance - Medical

Inference and Recall on High & Low Relevance  
(Groen & Patel, 1988)



# Understanding Expert Performance - Aviation

---

What does this mean for aviation training?

- ❑ It takes both **time** (10 years) and **Effortful Practice** to develop **Expert Performance**
- ❑ **Effortful Practice** differs qualitatively from routine job performance or job experience
- ❑ **Effortful Practice** is tailored to the different phases in developing **Expert Performance**
- ❑ **Expert Performance** can be achieved by more than just a few “talented” people



# Expert Performance and Real Aviation Training

---

One airline, in their Advanced Maneuvers Program, has 3 levels of performance:

- ❑ **Basic/Survival Level:** Has basic knowledge and skills of the autoflight functions
- ❑ **Mastery Level:** Able to change efficiently to different levels of autoflight and quickly modify FMC plans
- ❑ **Tournament Level:** Able to use autoflight for optimum aircraft and flight performance



# Pilot Cognitive Skills

---

## What is a Cognitive Skill?

- ❑ A construct that includes the **content**, organization, and mental manipulation underlying good (or skilled) performance
- ❑ An element that is more efficiently trained in the context of task performance
- ❑ A mental process and structure that is developed through practice in the appropriate context





# Pilot Cognitive Skills Vs. Knowledge

---

Researchers, compared with those in aviation training, have greater tolerance for ambiguity:

- ❑ The distinction between **knowledge** and **skills** has not been consistent in the literature, with some researchers approaching issues from a knowledge perspective and others from a skills perspective
- ❑ From an aviation training and assessment perspective, a distinction (even a somewhat arbitrary distinction) is vital because **one set of methods** are used to train and assess **knowledge** and a **different** set for **skills**



# Pilot Cognitive Skills Vs. Knowledge

---

From the aviation training perspective, the distinction can be based on:

- ❑ Knowledge is the **surface information** of a particular domain that can be stored and retrieved in Long-Term Memory to perform a task. Knowledge is the type of information found in books and reference manuals. As such, knowledge is most effectively trained in the context of other domain concepts.
- ❑ Skill includes the **structured information** and **mental manipulation** required for efficient and effortless performance. Skill information is generally not found in books and must be elicited from skilled performers. Skill is most effectively trained in the context of actual task/subtask performance.



# Training Cognitive Skills Vs. Knowledge

---

In some cases, what we think of as being knowledge is actually best trained as a skill:

- ❑ If the knowledge is **loosely linked** to several types of skills or a broad range of tasks, then it may be trained and assessed as knowledge (via classroom/written instruction and paper & pencil tests)
- ❑ If the knowledge is **tightly linked** with a specific type of skill or set of subtasks, then it should be trained and assessed as a cognitive skill (via practice and task performance)



# Pilot Cognitive Skills and Behaviors

---

Behaviors, in the form of Observable Behaviors and Behavioral Markers are distinct from their associated skills:

- ❑ Behaviors are the viewable and assessable outcomes of performance, such as skilled performance
- ❑ **Behaviors** are used for **standard performance assessment** while **skills** are used to design and develop the curriculum, training, and **diagnostic assessment**



# Pilot Cognitive Skill Types - Content

---

In the area of CRM, many still categorize the relevant cognitive skills by Skill Topic rather than by Skill Type:

- ❑ **Skill Topics** include Decision Making, Situation Awareness, Workload Management, etc.
- ❑ **Skill Types** include Automated (NOT autoflight) Skills, Procedural Skills, Representational Skills (Mental Models), etc.



# Pilot Cognitive Skill Types

---

## Difference between Skill Topics and Skill Types:

- ❑ **Skill Topics** address the category of knowledge of the skill and have strong implications for the subject matter being understood or trained
- ❑ **Skill Types** address the underlying mental structure and manipulation, and they have strong implications for the timing, content and sequencing of the training



# Pilot Cognitive Skill Types

---

Both Skill Topics and Skill Types are important, but Skill Types require emphasis at this time because:

- ❑ They are central to the understanding of **complex skill development**
- ❑ They have many implications for curriculum **content sequencing** (LOFT design)
- ❑ They can provide a basis for refining **assessment** (e.g., LOE design)



# Pilot Cognitive Skill Types

---

Cognitive Skill Types address the following training challenges

- ❑ Cognitive skills have different **levels of detail** and **practice requirements**
- ❑ Certain cognitive skills are better trained before other skills (e.g., training sequence)
- ❑ Certain **skill types** are better trained and/or refined at more specific **phases** of expert performance development





# Pilot Cognitive Skill Types

---

Researchers can specify a substantial number of skill types, but for operational purposes in aviation (training development, implementation, and assessment), the following three suffice:

- ❑ Basic - Automated & Procedural Skills
- ❑ Intermediate - Decisional & Representational Skills
- ❑ Expert - Strategies (Metacognitive Skills)



# Pilot Basic Cognitive Skills

(Seamster et al., 1997)

---

- ❑ **Automated skills** - A basic cognitive skill type allowing rapid job performance with a minimum of cognitive processing, providing the foundation of skilled performance by contributing to efficient task execution
- ❑ **Procedural skills** - Building blocks of skilled performance leading to constrained sequences of physical and cognitive activities performed in predictable situations



# Pilot Intermediate Cognitive Skills (Seamster et al., 1997)

---

- ❑ **Representational skills** - A form of **mental model** that improves performance by providing an efficient simulation of key aspects of a system or process contributing to superior performance in part because they are relatively easy to process
- ❑ **Decisional skills** facilitate choosing among alternatives and are learned through experience that helps decision-makers decompose and better understand complex environments



# Pilot Expert Cognitive Skills

(Seamster et al., 1997)

---

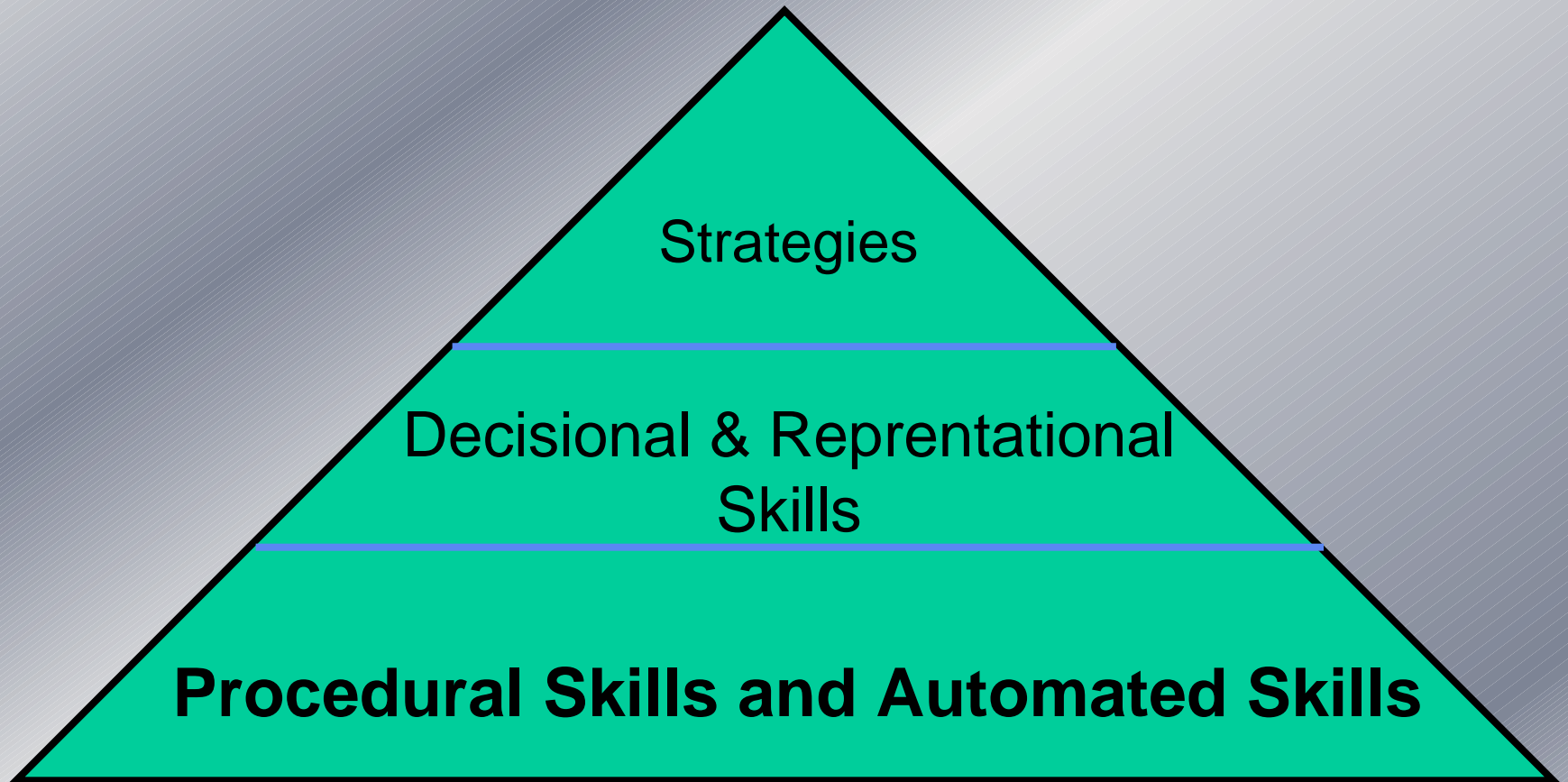
The most advanced skill type is the **strategy** which psychologists refer to as “metacognition.”

- ❑ **Strategies**, or metacognitive skills, enhance performance by providing self-monitoring and optimization of other skills. Strategies are the most complex and generally the last skill type to be fully developed in the skill hierarchy.



# Pilot Cognitive Skill Types

---



# Expert Performance by Skill Type Matrix

---

By combining the three phase of **Expert Performance** with **Skill Types**, we can outline training & assessment implications:

- ❑ Which **skill types** to emphasize across the three **phases of skill development**
- ❑ How to sequence skill training within a **phase of skill development**
- ❑ How to **diagnose** and pinpoint remediation during **assessment**



# Performance by Skill Type Matrix - Framework

	<b>Basic Skills</b>	<b>Intermediate Skills</b>	<b>Expert Skills</b>
<b>Basic Phase</b>	Most of the <b>basic skills</b> are trained here	<b>Intermediate skills</b> are introduced here	The concept of <b>expert skills</b> is introduced here
<b>Intermediate Phase</b>	Targeted <b>basic skills</b> are refined here	Most <b>intermediate skills</b> are trained here	Key <b>expert skills</b> are introduced here
<b>Expert Phase</b>	<b>Basic skills</b> are elicited here	<b>Intermediate skills</b> are elicited here	Most <b>expert skills</b> are developed and elicited here



# Basic Phase by Basic Skill Type Strategies

---

This cell suggests:

- Procedural** skills have been identified but **automated** skills still require analysis
- Developing some automated skills may require 100 or more repeats (CBT + LOS)
- Pilots and instructors should understand the need for **automaticity**
- Careful assessment at this phase will ensure a solid foundation





# Cognitive Skill Types and Real Pilot Training - An Example

---

Autoflight training & procedures (Sherry et al., 1999 and 2000) based on automated skill development:

- ❑ Identify autopilot and FMS behaviors that have the same Flight Mode Annunciation
- ❑ Define explicit and unique **mappings** between FMA and Autopilot/FMS behaviors
- ❑ Help develop **automaticity of mappings**



# Cognitive Skill Types and Real Pilot Training - An Example

---

For example the FMA display, THRUST - V/S, has at least the following three possible autopilot behaviors:

- Climb** Maintain MCP Alt - ROC (VS)
- Descend** Maintain MCP Alt- ROD (VS)
- Maintain Current Attitude/Speed



# Cognitive Skill Types and Real Pilot Training - An Example

NASA Research Autopilot Tutor [Version 0.70, 12/30/99] - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address: [ ]

**Autoflight Behavior:**

**CLIMB MAINTAIN MCP ALT - ROC**

Radio Altitude	is not valid is Valid
MCP Knob/Wheel Action	vs Wheel rotated All Knob pulled All Knob pushed
Prev Spd All FMA	None CLIMB   CLIMB CLIMB   GO AROUND CLIMB   CLB THROUGH THRUST   VS THRUST   ALT HOLD THRUST   ALT HOLD (Cap) THRUST   GS RETARD   FLARE WINDSHEAR   WINDSHEAR
MCP Altitude	is above capture region is within above capture region is within above overshoot region is within +/- 60ft is within below overshoot region is within below capture region is below capture region
Vertical Speed	is greater than +900 fpm is between +900 and +300 fpm is between +/- 300 fpm is between -300 and -900 fpm is less than -900 fpm
Airspeed	is above Vmax + 10 is above Vmax+10 in 10 secs is Vmax+5 to Vmax+10 is Vmax+5 to Vmax+10 in 10 secs is Vmax+5 to Vmin-5 is Vmin-5 to Vmin-10 in 10 secs is Vmin-5 to Vmin-10 is below Vmin-10 in 10 secs is less than Vmin-10
MCP VS	is more than 100 fpm is zero is less than -100 fpm
Autothrottle	not Available Available/not Engaged Engaged
Autopilot	not Available Available/not Engaged transition to Engaged Engaged Engaged transition to not Engaged
PROF	transitions to Engaged Engaged transitions to Disengaged

Rev 0.70 12/30/99

AUTOFLIGHT GOAL: MAINT CURRENT ALT FEET ( ) METER VS ( ) FPA

250 CLIMB MAINTAIN MCP ALT - ROC FT 8000 FPM 1000

AUTO FLIGHT

THRUST | HEADING 180 | V/S | 8000

MCP 8000 MCP

290 270 250 230 210

7500 7100 7000

AP Operations: Up and Away sNo: 16: 1 My Computer

# Performance by Skill Type Matrix - Framework

	<b>Basic Skills</b>	<b>Intermediate Skills</b>	<b>Expert Skills</b>
<b>Basic Phase</b>	Most of the <b>basic skills</b> are trained here	<b>Intermediate skills</b> are introduced here	The concept of <b>expert skills</b> is introduced here
<b>Intermediate Phase</b>	Targeted <b>basic skills</b> are refined here	Most <b>intermediate skills</b> are trained here	Key <b>expert skills</b> are introduced here
<b>Expert Phase</b>	<b>Basic skills</b> are elicited here	<b>Intermediate skills</b> are elicited here	Most <b>expert skills</b> are developed and elicited here



# Basic Phase by Intermediate Skill Type Strategies

---

This cell suggests:

- ❑ Compare basic with expert performance to identify additional **intermediate skills**
- ❑ Basic training curriculum **introduces** intermediate skills (decisional/representational)
- ❑ Instructors should use increased workload to demonstrate the future **need of intermediate skills**, but should not expect their full development during assessment



# Basic Phase by Expert Skill Type Strategies

---

This cell suggests:

- Include full range of organizational experts in identifying new strategies and skills
- The **concept** (knowledge) of **strategies** (expert skills) is part of the curriculum
- Pilots should understand the long-term requirements of expert performance
- During assessment, point toward, but do not expect, expert performance at this time



# Intermediate Phase by Skill Type Strategies

	<b>Basic Skills</b>	<b>Intermediate Skills</b>	<b>Expert Skills</b>
<b>Basic Phase</b>	Most of the <b>basic skills</b> are trained here	<b>Intermediate skills</b> are introduced here	The concept of <b>expert skills</b> is introduced here
<b>Intermediate Phase</b>	Targeted <b>basic skills</b> are refined here	Most <b>intermediate skills</b> are trained here	Key <b>expert skills</b> are introduced here
<b>Expert Phase</b>	<b>Basic skills</b> are elicited here	<b>Intermediate skills</b> are elicited here	Most <b>expert skills</b> are developed and elicited here



# Intermediate Phase by Basic Skill Type Strategies

---

This cell suggests:

- The identification of skill problem areas is ongoing and must be operationally vital
- Monitor pilot performance data to identify curriculum deficiencies
- Restructure training (e.g., LOFT) to include feedback and focused practice
- In assessment, be sure the **basic skills** are developed prior to **intermediate skills**





# Intermediate Phase by Skill Type Strategies

	<b>Basic Skills</b>	<b>Intermediate Skills</b>	<b>Expert Skills</b>
<b>Basic Phase</b>	Most of the <b>basic skills</b> are trained here	<b>Intermediate skills</b> are introduced here	The concept of <b>expert skills</b> is introduced here
<b>Intermediate Phase</b>	Targeted <b>basic skills</b> are refined here	Most <b>intermediate skills</b> are trained here	Key <b>expert skills</b> are introduced here
<b>Expert Phase</b>	<b>Basic skills</b> are elicited here	<b>Intermediate skills</b> are elicited here	Most <b>expert skills</b> are developed and elicited here



# Intermediate Phase by Intermediate Skill Type

---

This cell suggests:

- ❑ Intermediate skills have been identified but require better **operational placement**
- ❑ Design LOFT/LOS to include practice of decisional/representational skills
- ❑ Pilots and instructors need to know how intermediate skills **improve performance**
- ❑ Assessment of intermediate skills should emphasize **context (POF)** and **conditions**



# CRM Task Analysis (ISD)

## Progress Over Past 10 Years

### 1990 Listing

(Few repetitions)  
(about 10)

- ✓ Assess descent method
- ✓ Assess weather
- ✓ Evaluate runway conditions
- ✓ Maintain position/terrain awareness
- ✓ Make decision to go around
- ✓ Monitor weather
- ✓ Plan adjustments to departure procedures
- ✓ Review terrain/obstacles

### 1995 Listing

(Many repetitions)  
(about 230)

- ✓ Assess problems
- ✓ Apply decision making
- ✓ Counsel crew members
- ✓ Demonstrate advocacy
- ✓ Identify symptoms of work overload
- ✓ Inquire effectively
- ✓ Recognize and resolve conflicts
- ✓ Utilize resources

### 2000 Listing

(Many repetitions)  
(about 90)

- ✓ Analyze situation
- ✓ Assess environment and traffic situation
- ✓ Evaluate flight plan
- ✓ Maintain mode awareness
- ✓ Manage flight progress
- ✓ Monitor VNAV
- ✓ Prioritize tasks appropriate to situation
- ✓ Share key information
- ✓ State action plan



# Progress in Task Analysis Skill Identification?

---

Within the limits of the ISD-based Task Analysis, there has been progress in the last 10 years identifying underlying cognitive skills:

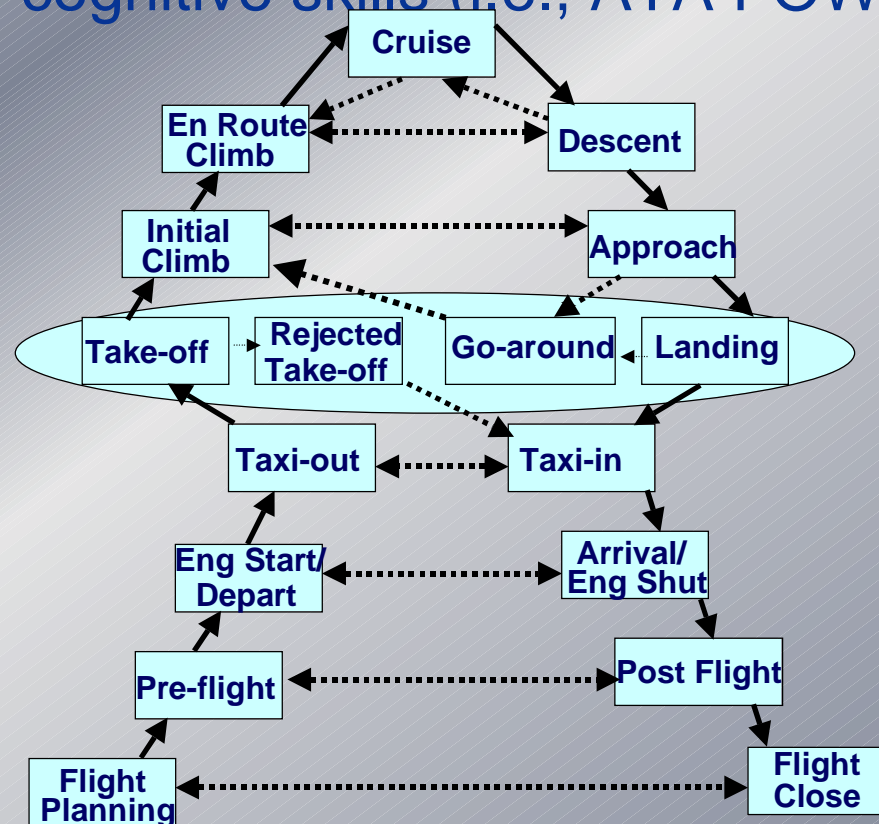
- ✓ There has been a shift from **attitude** to **cognitive skill**
- ✓ There has been an increase in “**repeated**” skills
- ✓ There is now a more **stable** base of skills from which to identify skills for further analysis (CTA)
- ✓ There is an increasing understanding of the **operational context** for these cognitive skills



# Progress in Task Analysis

## Skill Identification?

Task Analysis can provide a **Standard Operational** context for cognitive skills (i.e., ATA FOWG POF)



# Intermediate Phase by Skill Type Strategies

	<b>Basic Skills</b>	<b>Intermediate Skills</b>	<b>Expert Skills</b>
<b>Basic Phase</b>	Most of the <b>basic skills</b> are trained here	<b>Intermediate skills</b> are introduced here	The concept of <b>expert skills</b> is introduced here
<b>Intermediate Phase</b>	Targeted <b>basic skills</b> are refined here	Most <b>intermediate skills</b> are trained here	Key <b>expert skills</b> are introduced here
<b>Expert Phase</b>	<b>Basic skills</b> are elicited here	<b>Intermediate skills</b> are elicited here	Most <b>expert skills</b> are developed and elicited here



# Intermediate Phase by Expert Skill Type Strategies

---

This cell suggests:

- Compare basic with expert performance to identify strategies
- The concept (knowledge) of strategies (expert skills) is part of the curriculum
- Pilots experience the need to move from **acceptable** to **expert performance**
- During assessment, you are not looking for the expert skilled performance at this time



# Expert Phase by Skill Type Strategies

## Basic Skills

## Intermediate Skills

## Expert Skills

### Basic Phase

Most of the **basic skills** are trained here

**Intermediate skills** are introduced here

The concept of **expert skills** is introduced here

### Intermediate Phase

Targeted **basic skills** are refined here

Most **intermediate skills** are trained here

Key **expert skills** are introduced here

### Expert Phase

**Basic skills** are elicited here

**Intermediate skills** are elicited and refined here

Most **expert skills** are trained and elicited here





# Expert Phase by Basic Skill Type Strategies

---

This cell suggests:

- Work with a team of experts to achieve stable results identifying **basic skills**
- Use a formal set of measures (e.g., IRR) to calculate the level of expert agreement
- Implement instructor training on skill types and expert performance
- Use expert pilots and instructors to expand the ranks of expert performers



# Expert Phase by Intermediate Skill Type Strategies

---

This cell suggests:

- ❑ Top expert pilots and instructors are good sources of data for analyzing **strategies**
- ❑ Expert level curriculum allows for intermediate skill **refinement** and **extension**
- ❑ Training focuses on new skills with assessment covering essential skills
- ❑ Very focused intermediate skill feedback is essential to developing expert performance



# Expert Phase by Expert Skill Type Strategies

---

This cell suggests:

- ❑ Airline philosophy and policy must reflect **lifelong** learning and **expert performance**
- ❑ The concept of **effortful practice** is fully integrated in the pilot's environment
- ❑ Refine reward system to motivate pilots to move from the **acceptable** to the **expert**
- ❑ Top assessors are needed to refine expert performance



---

# Training for Expert Performance

*More Strategies Than Tools*

*Thank you*



