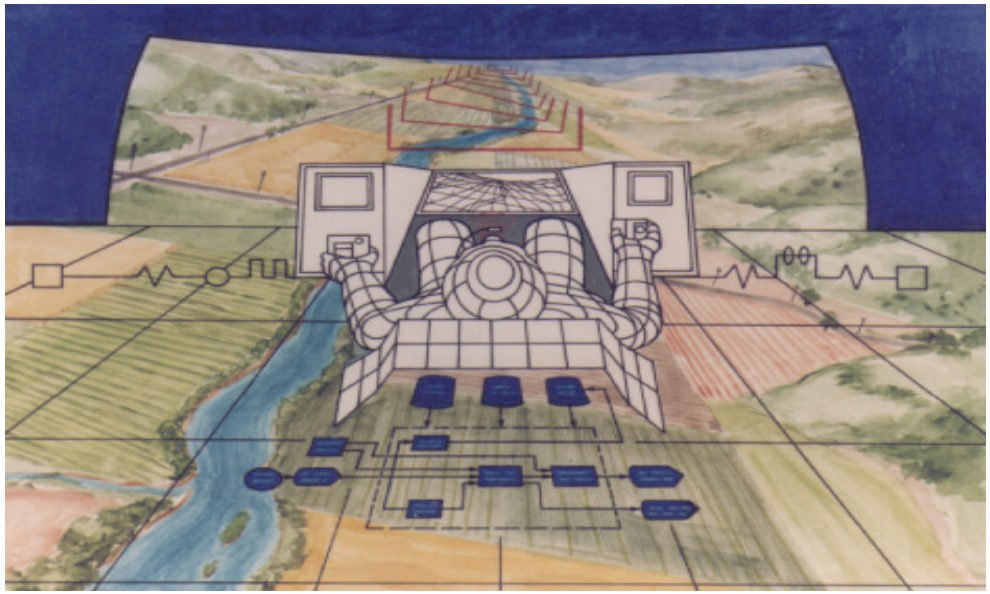
System-Wide Accident Prevention: Human Performance Modeling

Working Meeting
April 25, 2002



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Work Breakdown Structure

2.2 System-Wide Accident Prevention

Reduce accidents by mitigating system-wide accident precursors
Human Error Emphasis

- **2.2.1 Human Performance Modeling**
- 2.2.2 Maintenance Human Factors
- 2.2.3 Training
- 2.2.4 Program Human Factors

- **Error Context Definition**
- **Modeling Definition**
- **Verification & Validation**

Products:

- **Human Error / Performance Models**
  - **Techniques**
  - **Modeling Tools**
- **Mitigation Strategy Evaluations**

Problem, Approach, and Goal

Problem

- Accident precursors are complex interaction of latent error in a system design or procedure (and dynamic interaction of design, human operation and environment)
- Difficult to observe rare error and error precursors in aviation environment ($1x10^{-n}$)
- Design cycle (design, build, evaluate, field, revise) is difficult, expensive, and time-consuming

Approach

- Identify scenarios with high probability of human error
- Identify/model precursors to errors
- Assess technological and procedural solutions via development of computational models of scenarios and candidate solutions

Boeing Accident Prevention Strategies Report (1993)

- 232 commercial jet accidents (5713 fatalities) 1982-1991

Top Prevention Strategies

- Flying pilot adherence to procedures - 43%
- Other operational procedures - 37%
- Embedded pilot skills - 25%
- Nonflying pilot adherence to procedures - 23%
- Design Improvement - 21%
- Maintenance or inspection - 20%

Goal

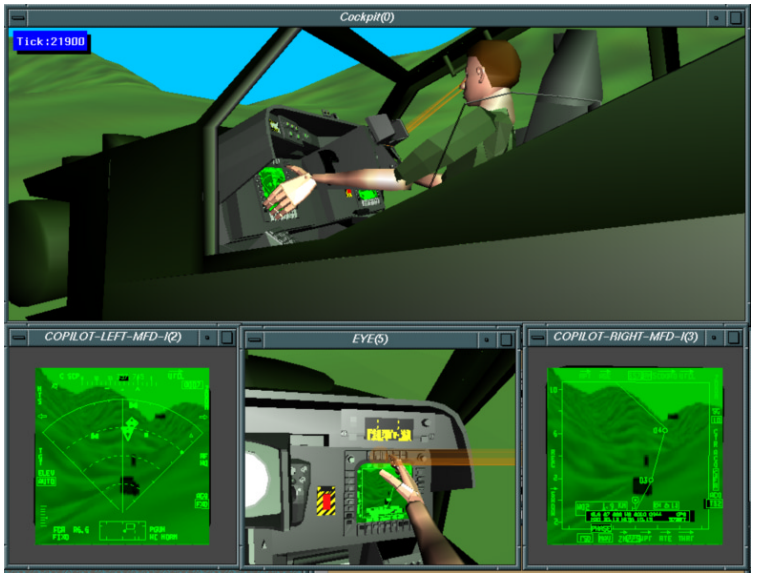
Develop modeling capability to:

- Test potential mitigation strategies
- Forecast likely pilot performance based on current knowledge of human cognition and perception

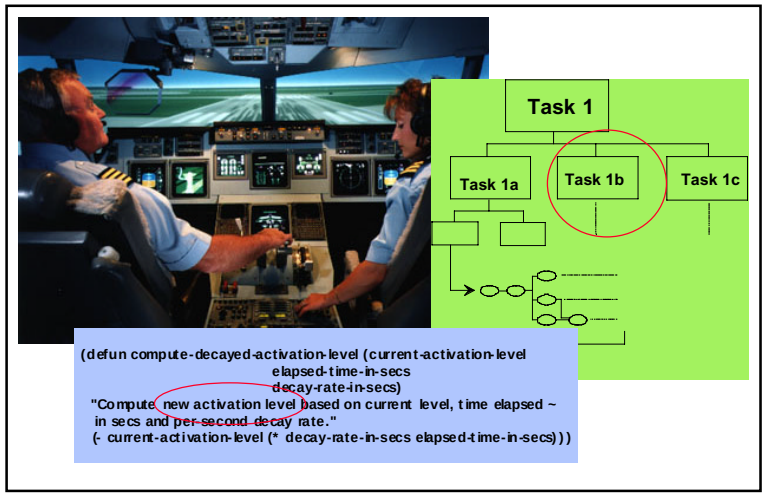
Human Performance Modeling

No! No! That s Self-Destruct!
Set Distance is the one on the left!

Error Context Definition



Modeling Definition



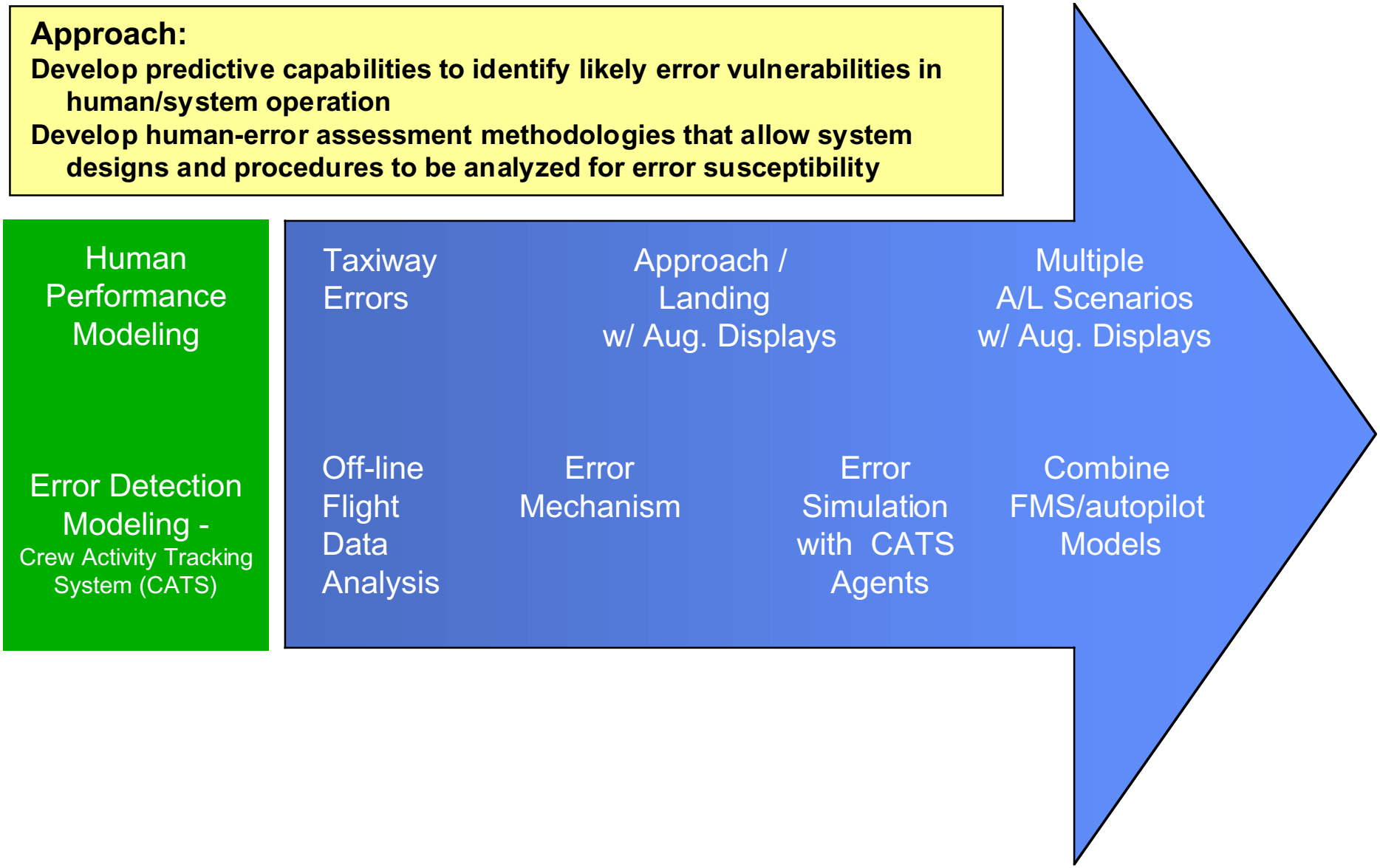
Verification & Validation

Approach FY01-FY04

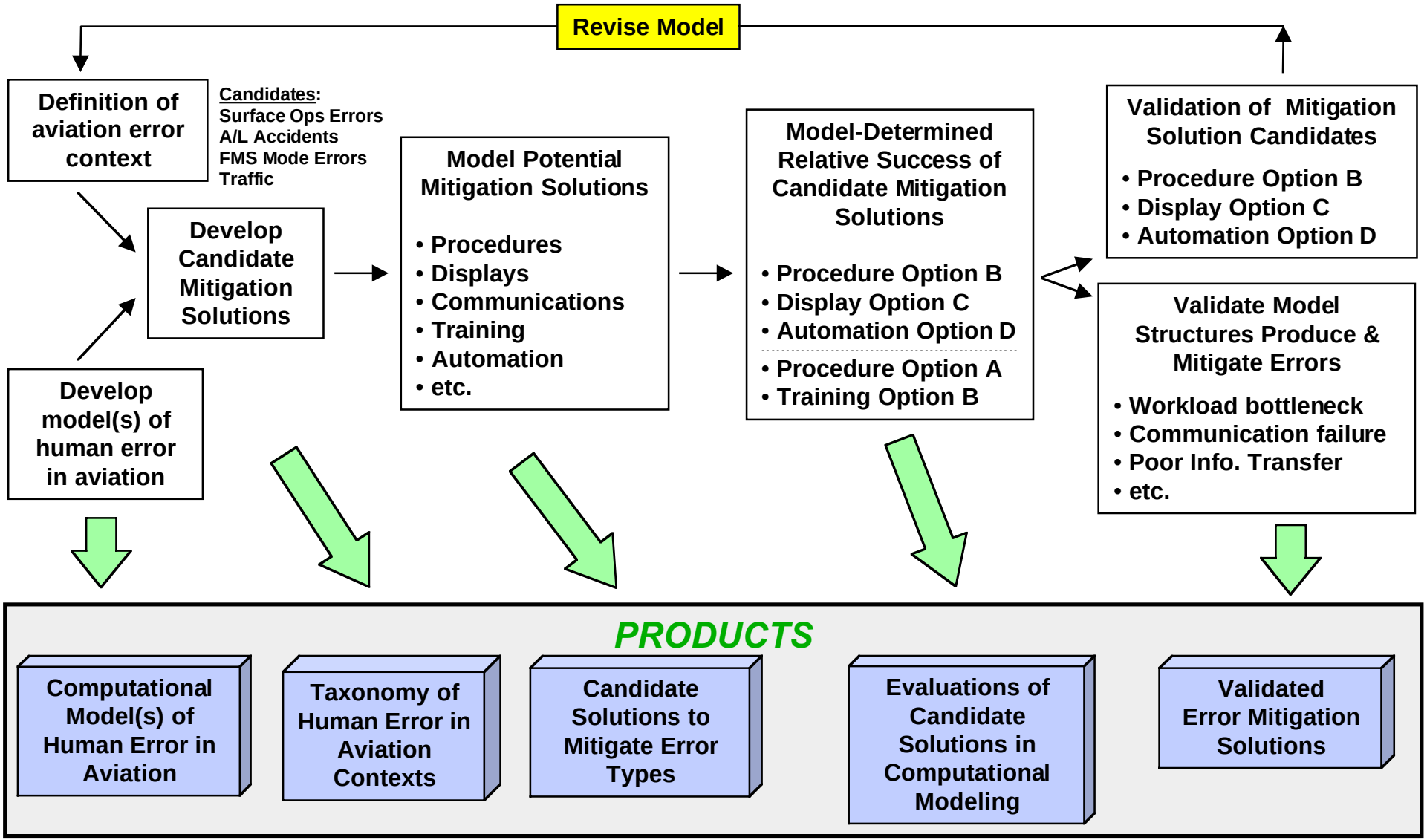
Approach:

Develop predictive capabilities to identify likely error vulnerabilities in human/system operation

Develop human-error assessment methodologies that allow system designs and procedures to be analyzed for error susceptibility



Modeling Process



Accomplishments

Identify Context of Aviation Error (L3 Milestone 2.2.1/1)

Context of Human Error in Commercial Aviation

Leiden, Keller & French, Micro Analysis & Design, Inc.

- **Characterized context in which human error in commercial aviation occurs (accidents and incidents)**
- **Approach and landing phases of flight concentration**
- **Accidents or incidents that could be potentially mitigated with a synthetic vision system (SVS)**

Significance: Guide creation of realistic scenarios for approach/landing augmented display human performance modeling effort

Identify Modeling Tools (L2 Milestone 2.2.1/2)

A Review of Human Performance Models for the Prediction of Human Error ,

Leiden, Laughery, Keller, French, Warwick & Wood (Micro Analysis & Design, Inc. / Soar Technology, Inc.)

- **Determined suitability of existing human performance modeling architectures for human error prediction (Network; Cognitive; Vision Models)**
- **Defined scope of errors that human performance models need to predict by compiling human error taxonomies**

  Situation Awareness (SA) —Endsley, 1998; Model of Internal Human Malfunction —Rasmussen, 1982; Model of Unsafe Acts — Reason, 1990; Information Processing Model — Wickens & Flach, 1988

Significance: Develop understanding of relative strengths and scope of models

Accomplishments (cont.)

Computational Models of Pilot Performance (L2 Milestone 2.2.1/3)

Functional Allocation Issues and Tradeoffs (FAIT) Analysis of Synthetic Vision Systems (SVS) Uhlarik & Prey, Kansas State U.

- FAIT identified human factors issues / tradeoffs between system functions, and potential sources of error within the system
- Identified training issues (with recommendations) for SVS
- Identified possible human factors bottlenecks in SVS-Pilot system

Significance: Guide creation of realistic issues for approach/landing augmented display human performance modeling effort

Taxi navigation error modeling

- Modeled full-mission simulation data of pilot taxi navigation error (ORD, low-vis)
- Pilot taxi model tools and results were presented at 2-day workshop 10/18-19/01
- Attendees included the 8 modeling teams, and approximately 65 members from industry, NASA, FAA, DOE/NRC and academia

Significance: Determine models capabilities, strengths, and scope

Human Error Detection Using Flight Data (Milestone 2.2.1/5)

- CATS (Crew Activity Tracking System) compared B757 ARIES Colorado flight data of crew actions to a model of correct operations
- CATS implementation for offline error analysis (Java ~30,000 lines) detected procedural errors by analysis of constraints
- Fast-time operation (up to ~20x real time)

Significance: Validation of engineering model with actual flight data

Current Efforts (FY02-03)

Computational Models of Approach & Landing With/without Augmented Displays (Generic SVS display)

Cognitive Task Analysis

- Baseline approach/landing
- Augmented display approach/landing

Part-task Pilot-in-loop Simulation

- Eye-tracking data
- Display monitoring / usage data
- Multiple scenarios (e.g., late runway reassignment, system failures)

Models of Approach/Landing

- Determine choke points (e.g., workload, SA at transition points)
- Error susceptibility
- Determine and evaluate error mitigation strategies

Error production using engineering models

- Expand CATS agent models
- Addition of error-producing mechanisms
- Engineering behavior model of cockpit error

Products to AvSP ASMM (Operator Models) & SVS (CTA, issues , procedures)

Aviation Safety Program (AvSP) 2.2 System-Wide Accident Prevention - Level II Milestones

LII MS#	Title/Description	Exit Criteria	TRL/ IRL	MTH/ CY	Level I Roll-up	Product
2.2 / 3	**Model High Error Probability Contexts and Solutions;** Computational modeling of pilot performance with and without augmented displays.	Evaluation report on computational simulations of commercial pilot performance in defined contexts. Report will include mode's coverage of diverse pilot activities, depth of causal explanation (underlying mental processes), and potential generalizability to new scenerios.	5/2	**3/03**	#4 (3/03)	Human performance models
2.2 / 5	**Revise Computational Models:** Revise models based on approach and landing flight simulation data	Updated evaluation report on computational simulations of commercial pilot performance. Report will include speed and ease of use, ability to predict errors not yet observed, and usefullness in suggesting improved design for new technology.	5/3	**6/04**	#5 (6/05)	Human performance models; intent inferencing models
					#5 (6/05)	
					#5 (6/05)	
2.2 - 11	**Integrated CATS Model of FMS-Autopilot Usage:** Integrate autoflight and Flight Management System models and evaluate with line pilots.	Computational model of combined FMS/autopilot operations.	4/1	6/04	#5 (6/05)	Intent inferencing Model

Aviation Safety Program (AvSP) 2.2.1 Human Performance Modeling - Level III Milestones

LIII MS #	Title/Description	Exit Criteria	TRL/ IRL	MTH/ CY	Level II Roll-up	Product
2.2.1 / 1	**Identify High Error Probability Contexts:** Identify key issues and precursors diring flight where human error commonly occurs.	Working paper/list of key cues and errors for aviation contexts.	3/1	**9/01** (com Dec 01)	2.2 / #3 (3/03)	Human performance models; intent inferencing models
2.2.1 / 2	**Identify Appropriate Modeling Tools:** Identify human error and performance models that represent aviation error chains.	A set of models/tools appropriate for use in defined contexts.	3/1	**9/01** (com-Sept 01)	2.2 / #3 (3/03)	Human performance models
2.2.1 / 4	**Identify Data for Simulation:** Explore sim and flight databases available to determine if required parameters are recorded.	Aquire required data from FDR and other cockpit sources for models.	3/1	**6/02**	2.2 / #12 (5/05)	Intent inferencing models
2.2.1 / 5	**Demonstrate CATS Human Error-Detection Using Flight Data:** Refine CATS model and develop data server; identify errors from B757 ARIES SVS EGE flight test data	CATS software package for offline B757 flight data analysis	5/1	**3/02**	2.2 / #12 (5/05)	Intent inferencing models
2.2.1 / 6	**Development of Intent Inference Models of Error Genesis:** Expand CATS agent models to include mechanisms that produce errors.	Software demonstrating error genesis	3/1	**9/02**	2.2 / #12 (5/05)	Intent inferencing models
2.2.1 / 7	**Cognitive Models of Approach/Landing:** Modify and expand cognitive models to encompass a specific approach/landing scenario for an augmented display.	Evaluation report on preliminary cognitive models of pilot behavior in an approach/landing scenario with and without an augmented display.	4/1	**12/02**	2.2 / #3 (3/03)	Human performance models
2.2.1 / 8	**Error Simulation with CATS Agents:** Develop CATS agents that make the errors detected by CATS from flight data.	Software demonstrating how errors detectable by CATS can be inexpensively simulated.	3/1	**3/03**	2.2 / #12 (5/05)	Intent inferencing models
2.2.1 / 9	**Advanced Cognitive Models of Multiple Diverse Scenarios:** Develop cognitive error models with consistent treatment of multiple scenarios for a singal augmented display.	Evaluation report on advanced computational simulations of diverse scenarios with and without an augmented display.	4/1	**3/04**	2.2 /#5 (9/04)	Human performance models
2.2.1 / 11	**Catalog/Classification of Errors Detectible by CATS:** Systematic description of all classes of errors detectible by CATS.	Report classifying all varieties of errors that CATS detects.	4/1	**6/04**	2.2 / #12 (5/05)	Intent inferencing models