National Aeronautics and Space Administration

System-Wide Safety Assurance: Human Systems Solutions

Michael Feary
HSS Technical Lead

2011 Annual Technical Meeting
May 10–12, 2011
St. Louis, MO

Impact of Research

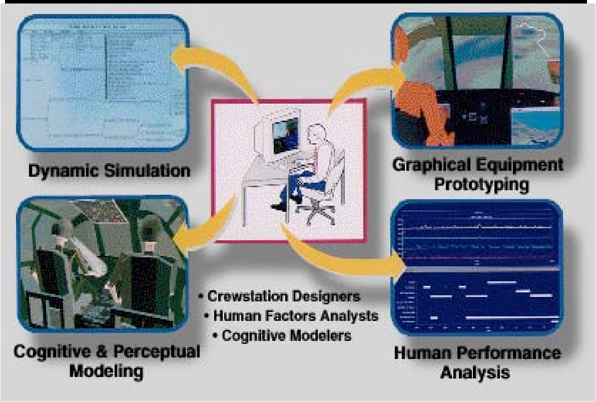
What are we trying to do?

- Improve safety and reduce cost by creating tools that incorporate human performance considerations early in the design of human-automation systems.
- Develop theoretical and applied understanding of human cognitive function and its impact on human-automation interaction.
- Understand the impact of human performance on safety during air and ground operations.

Objective Physiological

Assessment of Human Performance

Modeling and Predictive Methods



Why?

- 64% of all major US air carrier accidents were attributed to crew performance.
- Understanding human performance limitations can help improve the design of new human-automation systems to make them both resilient and cost effective.

Human Engineering for an Effective Air-Navigation and Traffic-Control System

Research Objective I. *Determination of the Relative Abilities of Humans and Machines to Perform Critical Functions in Air-Navigation and Traffic-Control Systems.*

Research Objective II*. Determination of the Capacities of Human Operators for Handling Information in a Communication System.*

Research Objective III. *Determination of the Essential Information Required at every -Stage in the Operation of an Air-Navigation and Traffic-Control System.*

Research Objective IV. *Establishment of Criteria and "Indices-of-Merit" for Human-Operator and Human-Machine Performance.*

Research *Objective V.* *Determination of Principles Governing the Efficient Visual Display of Information.*

Research *Objective VI.* *Determination of Optimum Conditions for the Use of Direct Vision.*

Research *Objective VII.* *Determination of the Psychological Requirements for Communication* Systems.

Research *Objective VIII.* *Optimum Human-Machine Systems Engineering.*

Research Objective IX. *Maximum Application of Existing Human-Engineering Information.*

Fitts, 1951b

HSS Technical Challenge

<u>Increasing Safety of Human – Automation Interaction by Incorporating Human Performance</u>

Develop analysis tools that incorporate known limitations of human performance and enable design of robust human-automation systems (FY 20).

Goal:

Develop revolutionary and first-of-a-kind methods and tools that incorporate the limitations of human performance throughout the design lifecycle of human-automation systems to increase safety and reduce validation costs in NextGen.

Benefits:

- Methods and tools to help designers, trainers and operators predict human performance, and identify, evaluate and resolve Human – Automation interaction issues.
- Tools for identification of novel system failures.
- Computational Human Model-Based safety design tools.

SSAT Research Framework: Approach

Level 2 – *Project Level*

Goal – Develop validated multidisciplinary tools and techniques to ensure system safety in NextGen to enable proactive management of safety risk through predictive methods.

SSAT 2.1 Technical Challenges	SSAT 2.2 Systems Analysis	SSAT 2.3 *Partnerships and Outreach*	SSAT 2.4 Research Test and Integration

Level 3 – *Subproject*

SSAT 3.1 Verification & Validation of Flight Critical Systems	SSAT 3.2 Data Mining and Knowledge Discovery	SSAT 3.3 Human Systems Solutions	SSAT 3.4 Prognostics and Decision Making

Level 4 – *Subproject Elements*

- SSAT 4.1.1: Argument-Based Safety Assurance
- SSAT 4.1.2: Authority and Autonomy
- SSAT 4.1.3: Distributed Systems
- SSAT 4.1.4: Software Intensive Systems

- SSAT 4.2.1: System-Level Reasoning
- SSAT 4.2.2: Anomaly Detection from Massive Data Streams
- SSAT 4.2.3: Discovery of Causal Factors
- SSAT 4.2.4: Prediction of Adverse Events

- SSAT 4.3.1: Human Automation Tools, and Models
- SSAT 4.3.2: Operational Complexity Metrics and Methods
- SSAT 4.3.3: Human Performance Mechanisms

- SSAT 4.4.1: Decision Making under Uncertainty
- SSAT 4.4.2: Diagnostics
- SSAT 4.4.3: Prognostics
- SSAT 4.4.4: Software Health Management

"Validated, proactive solutions for ensuring safety in flight and operations"

SSAT Research Framework: Approach

Level 2 – *Project Level*

Goal – Develop validated multidisciplinary tools and techniques to ensure system safety in NextGen to enable proactive management of safety risk through predictive methods.			
SSAT 2.1 Technical Challenges	SSAT 2.2 Systems Analysis	SSAT 2.3 *Partnerships and Outreach*	SSAT 2.4 Research Test and Integration

Level 3 – *Subproject*

SSAT 3.3 Human Systems Solutions

- SSAT 4.3.1: Human Automation Tools, and Models
- SSAT 4.3.2: Operational Complexity Metrics and Methods
- SSAT 4.3.3: Human Performance Mechanisms

"Validated, proactive solutions for ensuring safety in flight and operations"

SSAT Research Framework: Approach

- SSAT 4.3.1: Human Automation Tools, and Models
- SSAT 4.3.2: Operational Complexity Metrics and Methods
- SSAT 4.3.3: Human Performance Mechanisms

Human – Automation Tools and Models

Example of Research Problem

CS § 25.1302 Installed Systems and Equipment for Use by the Flight Crew

"…installed equipment must be shown, individually and in combination with other such equipment, to be designed such that qualified flight crewmembers trained in its use can safely perform their tasks associated with the intended function by meeting the following requirements:

"… (b) The flight deck controls and information intended for the flight crew use must:

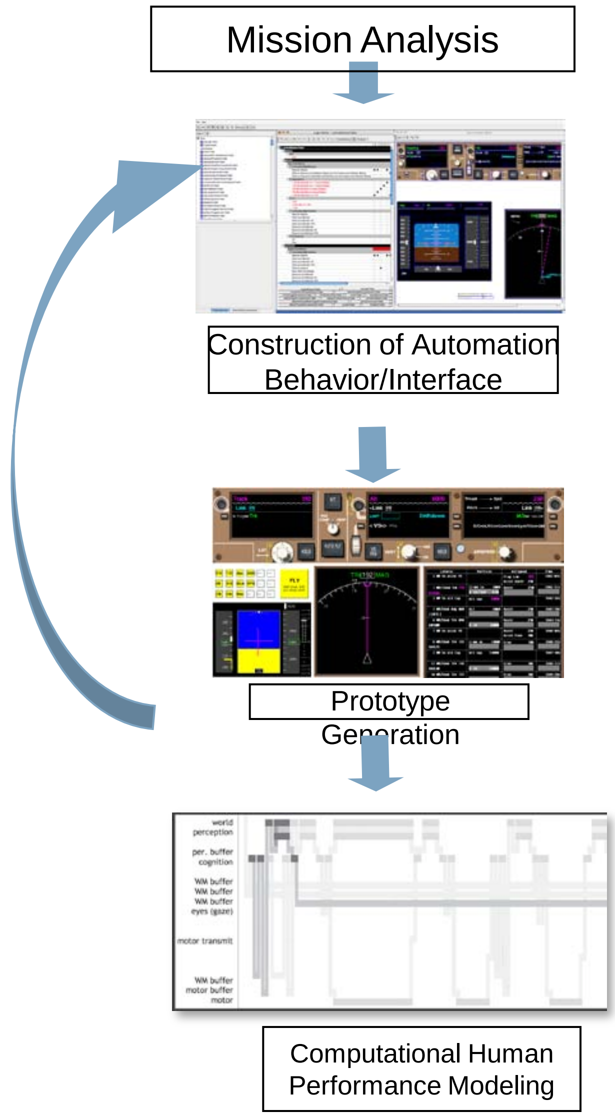
i. Be presented in a clear and unambiguous form, at *resolution* and *precision* appropriate to the task, and

ii. Be accessible and usable by the flight crew in a manner consistent with the *urgency*, *frequency*, and *duration* of their tasks, and…"

Human – Automation Analysis

How well can we evaluate the predict Human – Automation Interaction performance and problems in design?

- Challenges:
  - Can provide metrics and parameters that are directly applicable to design issues?
  - Can we develop HAI methods and tools that are usable within design process constraints?
  - Can we computationally optimize strategies/action sequences?



Major HAI Tool Challenges

Need to provide Human – Automation Interaction analysis tools which are:

Robust

- The tools need to overcome the “illusion of precision”. The precision of the results needs to match the confidence in the results

Useful

- The tools that need to be useful in the limited design and evaluation timecycle, by design personnel without extensive expertise (i.e. not cognitive scientists)

Scalable

- Defining a “minimum” set of information to allow computational tools to provide help
- Presenting large amounts of data and information that are interpretable

Supportive

- The tools need to be generalizable to help with the new and changing roles in NextGen

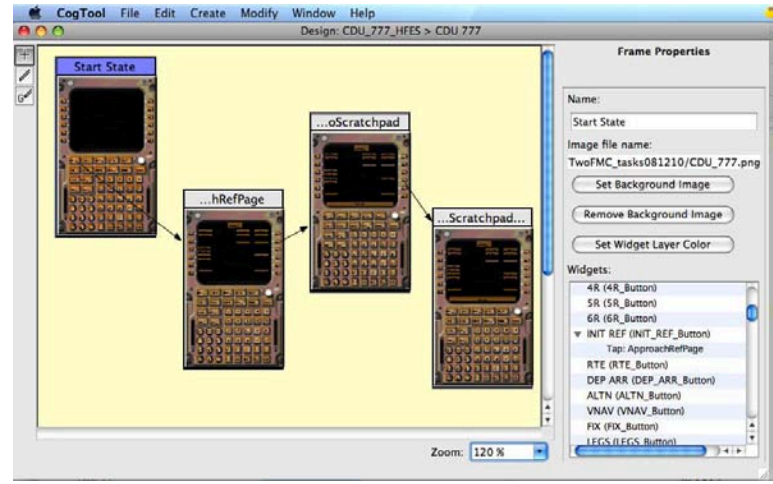
Making Human Automation Interaction Analysis Affordable

Aviation Cogtool Explorer with Semantic Analysis (Carnegie-Mellon Univ.)

• Combined a tool that allows a designer to quickly build a representation of a procedure, then analyze it with multiple techniques including:

–Information foraging analysis for pilot attention

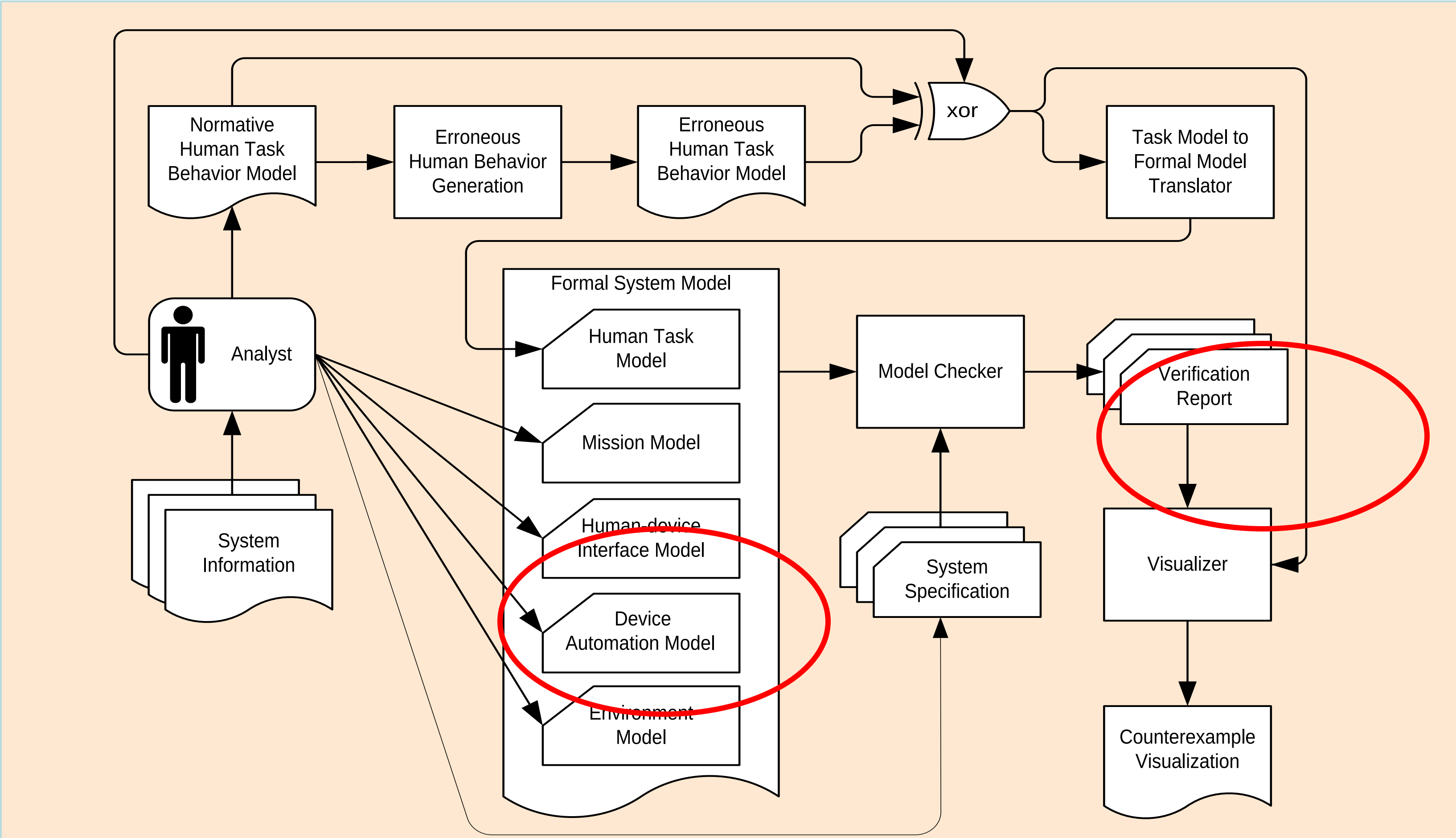
–Latent semantic analysis for pilot cognition, based on an aviation “corpus” database that simulates the knowledge of typical airline pilots



Original Label	Text	Cosine	Heading Or Link	Specific Heading
LCD screen display	step lcd screer	0.46	Heading	LCD screen display
Mode Keys	mode keys init	0.18	Heading	mode keys init
Keyboard alphanun	keyboard alph	0.14	Heading	keyboard alpha
Function Keys	function keys (	0.11	Heading	function keys
2R Flaps 30 degree	2R Flaps 30 de	0.49	Link	LCD screen display
1R Flaps 25 degree	1R Flaps 25 de	0.47	Link	LCD screen display
4R Flap Speed Ente	4R Flap Speed	0.39	Link	LCD screen display
INIT REF Initializat	INIT REF Initia	0.32	Link	Mode Keys
3L Landing Ref refe	3L Landing Re	0.27	Link	LCD screen display
6L Index IDENT ide	6L Index IDEN	0.21	Link	LCD screen display
4L EGLL27R 12108	4L EGLL27R 1	0.18	Link	LCD screen display
A B C D E F G H I J	A B C D E F G	0.14	Link	Keyboard alpha
FMC COMM Flight N	FMC COMM Fli	0.12	Link	Mode Keys
MENU aircraft subs	MENU aircraft	0.09	Link	Mode Keys
CLR clear from scra	CLR clear from	0.09	Link	Function Keys

John (Carnegie Mellon (now IBM)) , Blackmon, and Polson, (Univ. of Colorado) and Sherry (George Mason U

Connecting to Validation and Verification



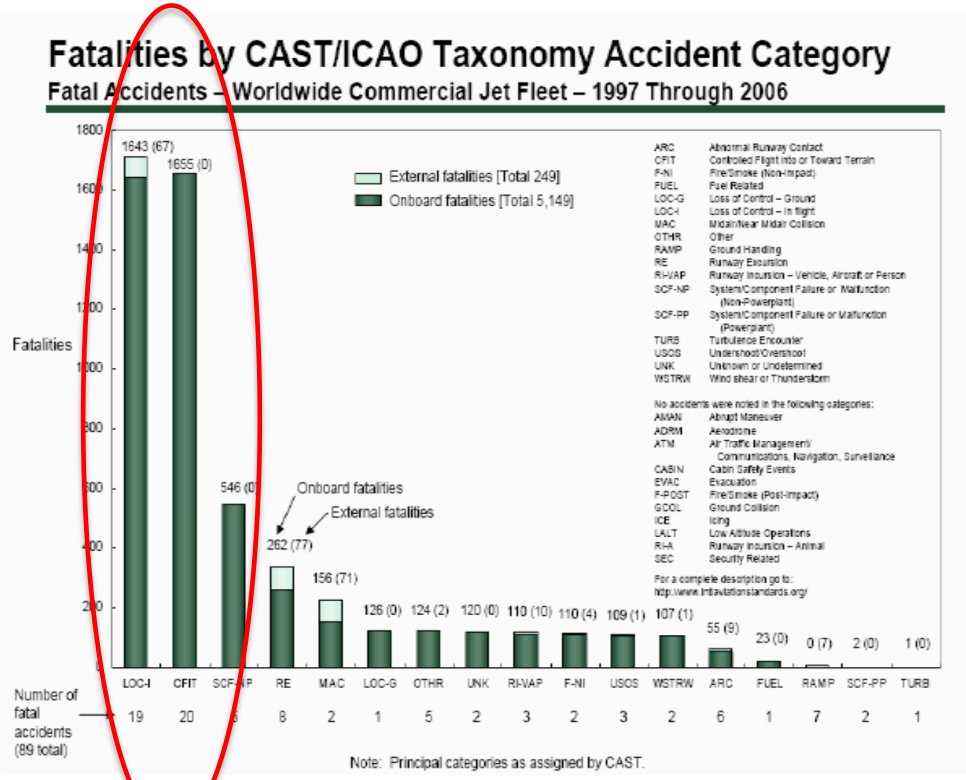
Operational Complexity Metrics and Methods

Human Error Countermeasures, Operational Training, and Procedures

- Improved Safety in Commercial Transport Operations:
  - Developed Crew Resource Management (CRM) concepts and methods
    - Used by all major airlines and in military operations
    - Adapted to other fields, such as medicine
  - Redesign of all procedures with a major US air carrier
    - Pilot errors reduced 80%, Pilot satisfaction 95%
  - Similar redesigns adopted by multiple airlines
    - Improved monitoring, debriefing, concurrent task management
  - FAA revised official guidance based on our research
    - e.g., Advisory Circulars 120-51 (CRM) and 120-71 (SOP)
  - Authorship of FAA handbook materials
- Improved Safety in General Aviation Operations:
  - Determination of event occurrences in GA (implementation with NTSB)
  - Pilot education through web-based training

Barshi (NASA Ames)

Human Performance Mechanisms



NASA Human Rating Requirements

- 2.5.3.2 All human-rated space flight systems shall be designed so that neither two human errors during operation or in-flight maintenance nor a combination of one human error and one failure shall result in permanent disability or loss of life.

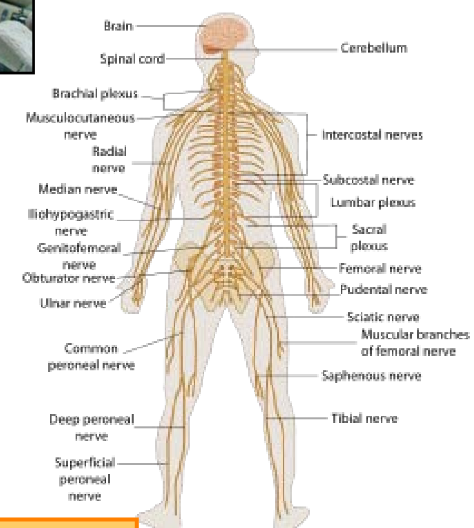
- 2.5.3.3 The program shall consider tailoring requirement 2.5.3.1 if:
  - a. It can demonstrate that two -failure tolerance is either impractical or negatively impacts overall system reliability, and
  - b. Test data, hazard analyses, and comprehensive risk analyses together provide certainty that the system will have a very high reliability without two-failure tolerance.
  - Impractical refers to cost prohibitive. Certainty that a system will have a high reliability refers to demonstration of high confidence. Very high reliability is reliability consistent with the accepted crewed aerospace industry standard at the time of each program's initiation.

NASA's Role in easyJet Airline's Human Factors Monitoring Program (HFMP) Study

easyJet.com

Physiological Measurements*

1. Can fatigue levels be correlated with rosters AND is scheduling strategy a primary causal factor of performance-degrading levels of fatigue.
2. What measures can be implemented during normal operations to monitor fatigue levels that could affect aircraft performance.
3. What data provide reliable information on causal and contributing factors of fatigue.
4. Fatigue profiles of flight and cabin crews over the course of flights and whether they converge.



Analysis of data from two perspectives:

Crew performance

Aircraft performance

Results of the analyses will be combined to relate decrements in aircraft performance to decrements in crew performance.

Not all degradation in aircraft performance is due to decrements in human performance.

Statler, Arsintescu, NASA Ames

Design of Audio-Haptic Studies for Control of Multiple Synthetic Speech Messages within a NextGen Datalink Communication Display (ARC)

INSPIRATION:
Simple, effective design for managing multiple audio communications (line select-hold-priority)

Problem The NextGen data link system will likely use synthetic speech messages to replace visual text displays for ATC and company communications. To ensure safety, intelligibility and reliability, critical questions must be answered on how to best enable interaction with the propagation of audio communications required for autonomous operation within the NextGen environment

Solution Research will be conducted involving development of reconfigurable interactive Displays, using auditory-haptic cueing to aid message comprehension performance (speed, accuracy), ensure perceived quality, and minimize workload

NEXTGEN UPDATE 1:
Reconfigurable virtual display with auditory cues for haptic substitution (iPad touch screen)

NEXTGEN UPDATE 2:
Reconfigurable display using real switches (force sensor) to provide haptic and variable audio feedback

DATA LINK STREAM

6 BUTTON SDLI INTERFACE PANEL (VIRTUAL OR REAL)

"AUDIO BRAIN":
-RECEIVES DATA LINK TEXT MSGS ALONG WITH PRIORITY & TYPE TAGS
-TEXT TO SPEECH FUCNTION
-SPATIALIZE AUDIO, OTHER DSP
-ASSIGN TO LINE BUFFERS = BUTTONS 2-6)
-CHECK IF LINE SELECT-RELEASE- HOLD
-PROVIDE AUDIO FEEDBACK RE BUTTON POSITION (TOUCHDOWN; ENGAGE)
-PROVIDE AUDIO ALERT FOR INCOMING MSG (TONE OR SPEECH w/ LINE #)

COM SYSTEM (RADIO PANEL, HEADSET)

EXPERIMENT (SIM) SOFTWARE
-START DISTRACTOR SIMULATION
-SIMULATE DATA LINK STREAM: 50 MESSAGES PER STIMULUS "SCORE" DELIVERED TO AUDIO BRAIN (OR SIMULATED VERSION OF AUDIO BRAIN)
-COLLECT TIMING, ACCURACY DATA
-WRITE DATA FILE FOR EXCEL ANALYSIS

FLIGHT SIM DISTRACTOR TASK (PFD AND JOYSTICK)

SDLI (Speech Data Link Interface)

Hardware-software architecture within flight simulator for research studies emulates flight deck implementation design

Dependent variables include:
-Time to respond to the aural DLM alert (*t1*)
-Time to complete audition of a single DLM (*t2*)
-Time to respond to priority messages (*t3*)
-Missed DLM alerts (*m1*); non-completed DLM (*m2*)
-Priority status not recognized (*p1*)
-Button selection accuracy (*B1*)

Cognitively Bounded Rational Analysis

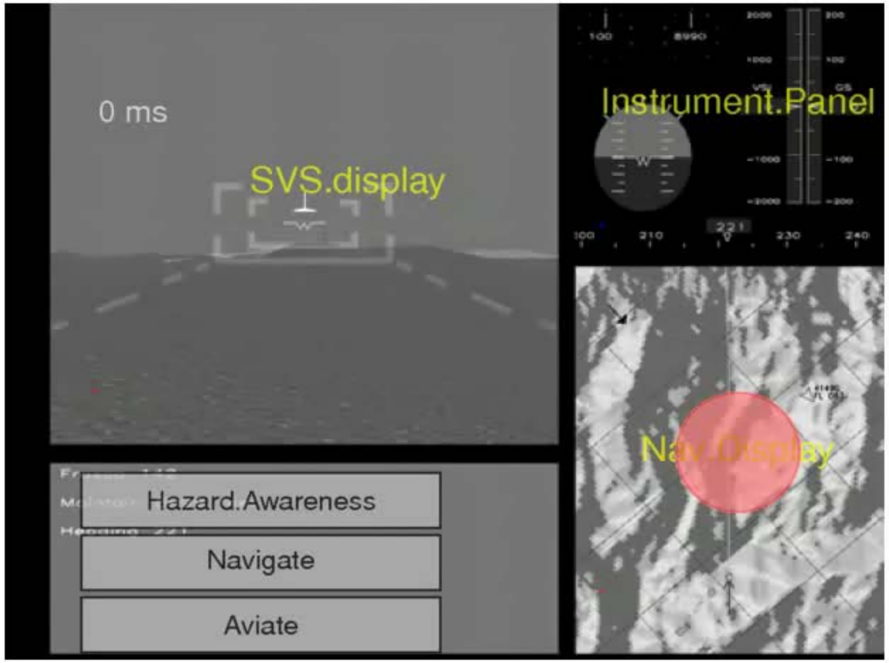
1. **<u>Grounding in optimal control theory</u>**, statistical decision theory, machine learning theory. Mathematical foundations - speaking the same language as the rest of engineering/science.

2. Addresses **<u>individual differences</u>** in architecture and knowledge.

3. Foundation for **<u>evaluation of devices in context</u>**.

4. Tighter link to **<u>state-of-the-art in cognitive science</u>**.

5. **Utility is part of the modeling**.
   - Robustness metrics within subspaces of strategy, architecture, and task environment.
   - Upper and lower bounds on performance (worst/best case) (within selected subspaces of strategy, architecture, task environment.)
   - Upper and lower bounds conditioned on ecologically valid task environment distributions.
   - Upper and lower bounds conditioned on ecologically valid architecture distributions.
   - Condence intervals that take into account uncertainty in human performance parameter estimates



Products

Publications

Papers: Too many papers to mention here…

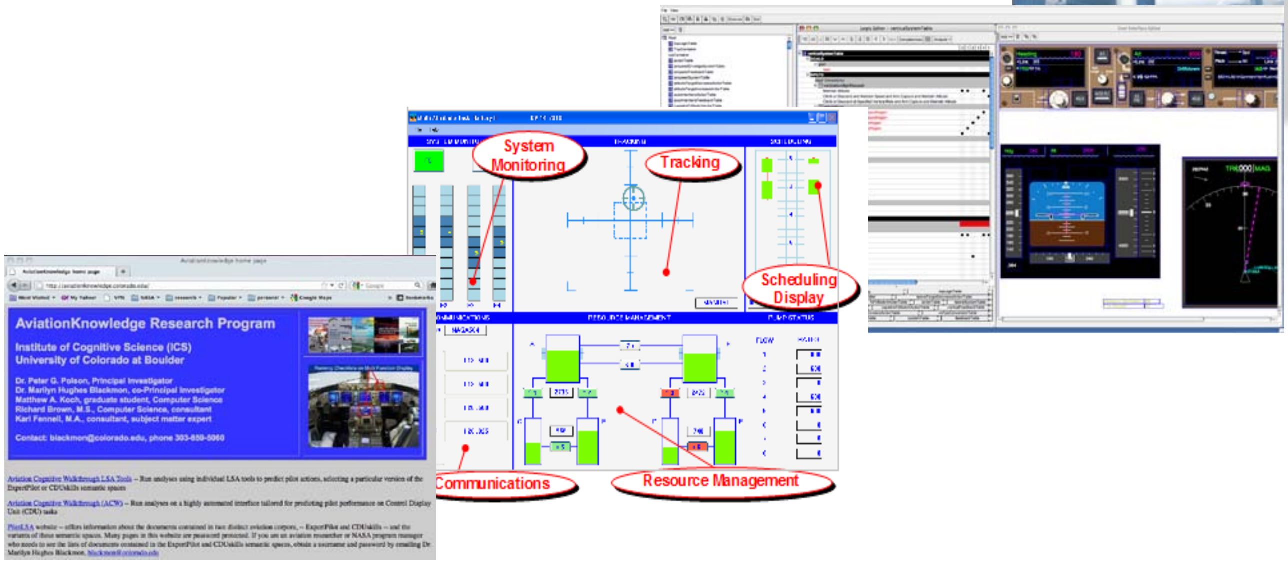
Books: Dismukes et al., Foyle et al.,

Tools

ADEPT available for release (contact michael.s.feary@nasa.gov)

MATB available for release (contact larc-matb-info@nasa.gov)

Aviation Knowledge space (Aviationknowledge.colorado.edu/)



Summary of Collaborative Activities

Partnerships via Space Act Agreement (SAA)	
The Boeing Company	Generating requirements definition, design analysis and evaluation of flight deck concepts
Gulfstream Corp.	Human – Automation design and evaluation (in development)
EasyJet	Study in Human Performance and Data Mining
ONERA	Study in Human Performance and Data Mining;

Partnerships via Interagency Agreement	
FAA	ASRS
FAA	NextGen Human Factors Research
FAA	Human Factors Research
USAF	Human Automation Research, psychophysiological Research (in development)

Longstanding Relationships	
Airlines	All major carriers, as well as most unions and trade groups

Thank You

Michael.S.Feary@nasa.gov

SIMOC:
Simulation/Oculometer Integration for Two-Crew Operations – Determining Indices of Workload, & Crew Performance

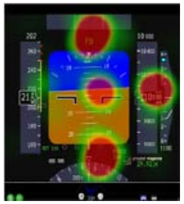
Objective

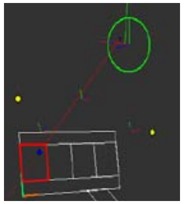
Unobtrusively obtain pilots' point-of-gaze (POG) data during realistic simulation tests.

Determine indices of pilot and crew workload, and crew performance based on this POG data.

Standard Oculometer Metrics

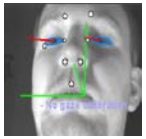
- Head position and orientation
- Point of Gaze
- Eyelid closure & Pupil size
- Intersection of gaze with defined areas
- Gaze quality & diagnostic information
- Fixation counts & durations
- Burn maps (histograms)
- Saccades & transition probabilities
- Blinks, blink rate





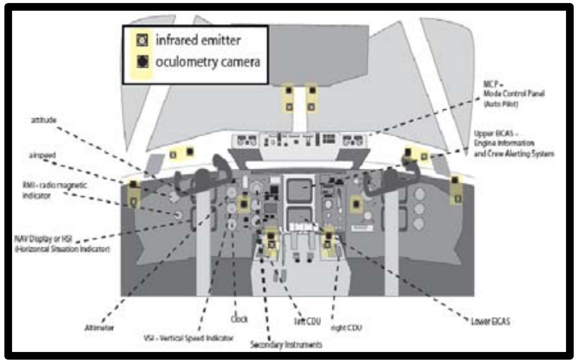
Metrics Under Development

- Pilot Workload
- Crew Coordination
- Crew Monitoring Coverage
- Crew Cross-Checking



Technical Challenges

- Unobtrusively embed oculometer equipment in simulation interface
- Develop data collection integration
- Data quality assessment
- Determine metrics for workload and crew-coordination
- Assess data collection in motion conditions



Latorella, Ellis, Lynn (NASA Langley)

Current SIMOC Capability

NASA Langley's Integrated Flight Deck (IFD) Simulator. Advanced current day commercial transport, similar to B737.

Smarteye oculometer components: 10 camera & 4 flashes installed and tested.

** This configuration supported FAA-sponsored investigation of Datacom acceptability on arrivals and departures.*

** A reduced version of SIMOC was installed in NASA Langley's Research Flight Deck (RFD) to support NEXTGEN*

Future Installation Work

- Cover side-mounted Electronic Flightbags
- Test when simulator is on motion-base
- Improved Area of Interests for external view
- Automated data quality assessment
- Fused POG on rectified, single scene image

Impact

More sensitive, unobtrusive, objective, and continuous measurements of workload and crew performance during evaluations of NEXTGEN display & operational concepts.

Sponsoring Projects

System-Wide Safety & Assurance Technologies
&
Vehicle Systems Safety Technologies

NASA MATB-II: The New and Improved Multi-Attribute Task Battery

Objective

Create a testing platform that:

- allows us to investigate human performance in multi-tasking contexts that require use of automated tasks;

- is representative of piloting tasks, but does not require pilot domain knowledge.

The Original NASA MATB

- Developed in 1990 for PCs in Quick Basic.

-Documented in Comstock & Arnegard (1992) NASA-TM-104174

- Widely used:
  - Cited in over 136 papers.
  - Used for testing in over 50 studies
  - Used in over 10 countries outside U.S.

Broad Application

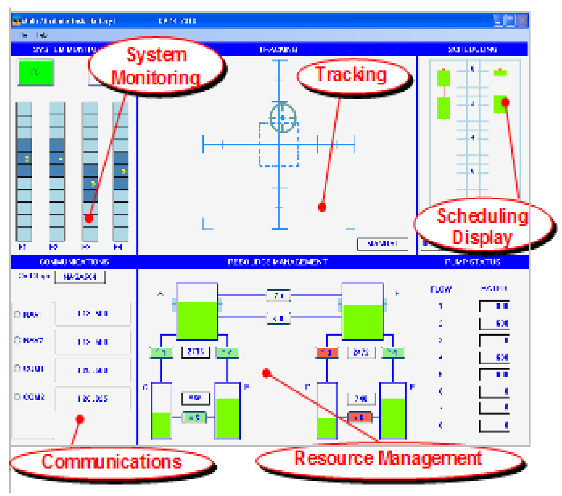
Aviation, Nuclear Power, Drug Efficacy & Effects, Fatigue, Automation Complacency, Adaptive Automation …

First in-house customer, Chad Stephens & Alan Pope Operator Engagement Index & Adaptive Automation (sponsored by Aviation Safety's Vehicle Systems Safety Technologies program).

Several other labs have requested new version.

Current NASA-MATB-II Tasks

- System monitoring
- Tracking (Manual/Automated)
- Schedule of tracking transitions
- Communications
- Resource management



NASA MATB-II, v.1.0 Now Available!

For more information, please email: larc-matb-info@nasa.gov

Technical Challenge

Revised NASA Langley Multi-Attribute Task Battery

- Visual Studio Basic.net for Windows (XP, Vista, 7)
- Improved, GUI-supported task scripting capabilities
- Improved tracking target generation algorithm
- GUI has point & click and keyboard entry
- Training mode explains testing elements
- 80 pre-recorded audio messages for communications task
- Enriched data collection features
- Source-code distribution to encourage development
- Website to encourage user collaboration

The Future of NASA MATB

- Interfacing to external devices
- More sophisticated levels of task automation
- More precise and flexible data reporting
- Within-task performance feedback windows
- Experimenter toolkit for adding custom tasks
- Experimenter toolkit to change task size/position

Sponsoring Program

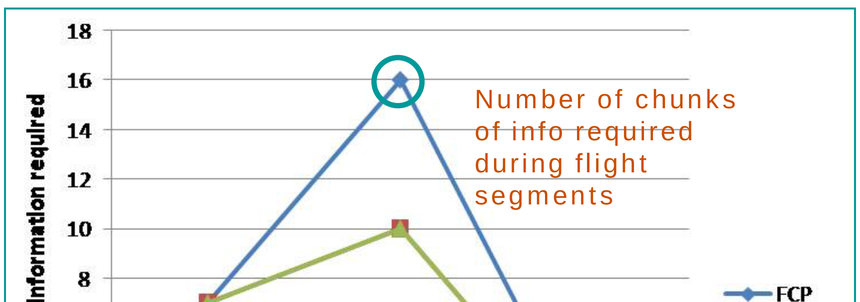
System-Wide Safety & Assurance Technologies

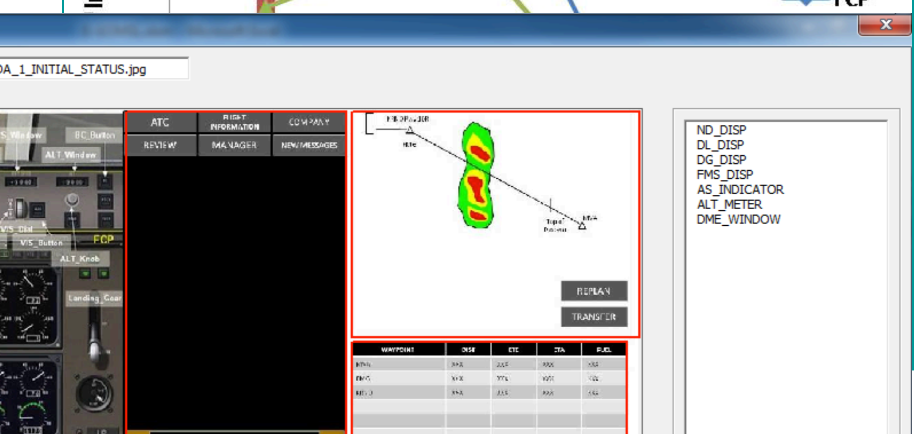
Comstock, Santiago-Espada, Latorella (NASA Langley) & Myer (SGT)

ACM-DAS: ADVANCED COMPUTATIONAL MODELING FOR THE DESIGN OF AUTOMATED SYSTEMS

– In making settings for reroute in Segment 1…
  - FCP required 16 chunks
  - CDU/CDU+ required 10 chunks
  - FCP produced greatest lateral path deviations in test trials.
  - Model suggested cause was WM stack exceeding 5 chunks (Kieras, 1997).

- Model indices of auto complexity were significantly correlated with:
  – Pilot HR across segments ($r>0.8$).
  – Vertical path deviations (greater complexity translated to increased deviations) ($r>0.8$) .



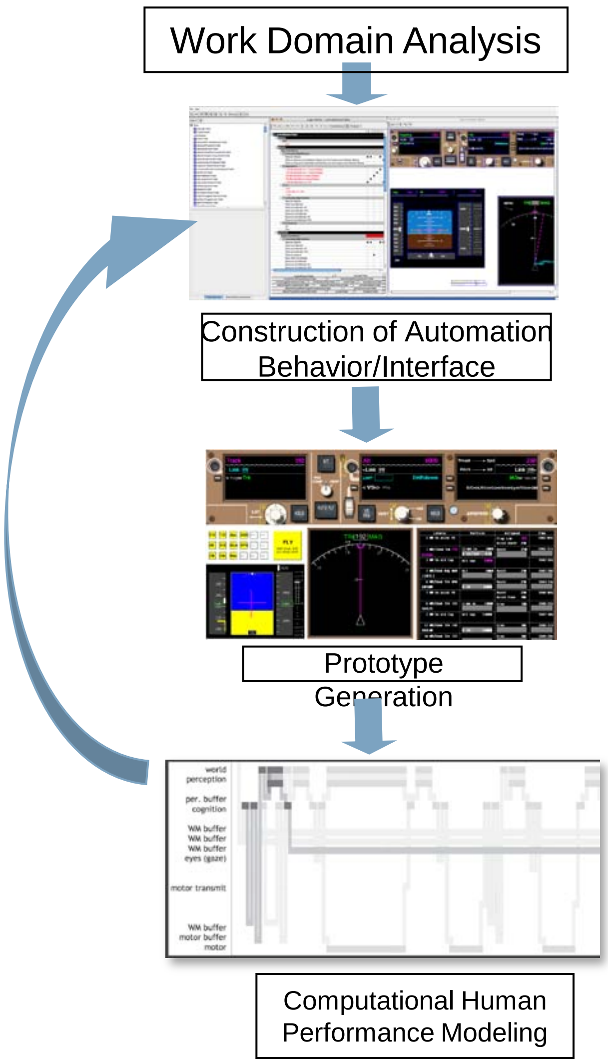


Correlation analysis (Spearman's ρ) on HR measure with model predicted WM chunk count (among task steps; n=132):
– Significant positive relation ($\rho=0.2055$, $p=0.0181$)
• T-test for significant differences in heart-rate (HR) response under min. and max. WM load.
– Monitoring (MIN: WM=1) vs. Replanning

Automation Interaction Challenge Areas

1) Evaluation: How well can we assess overall Human – Automation Interaction performance, and predict problems?

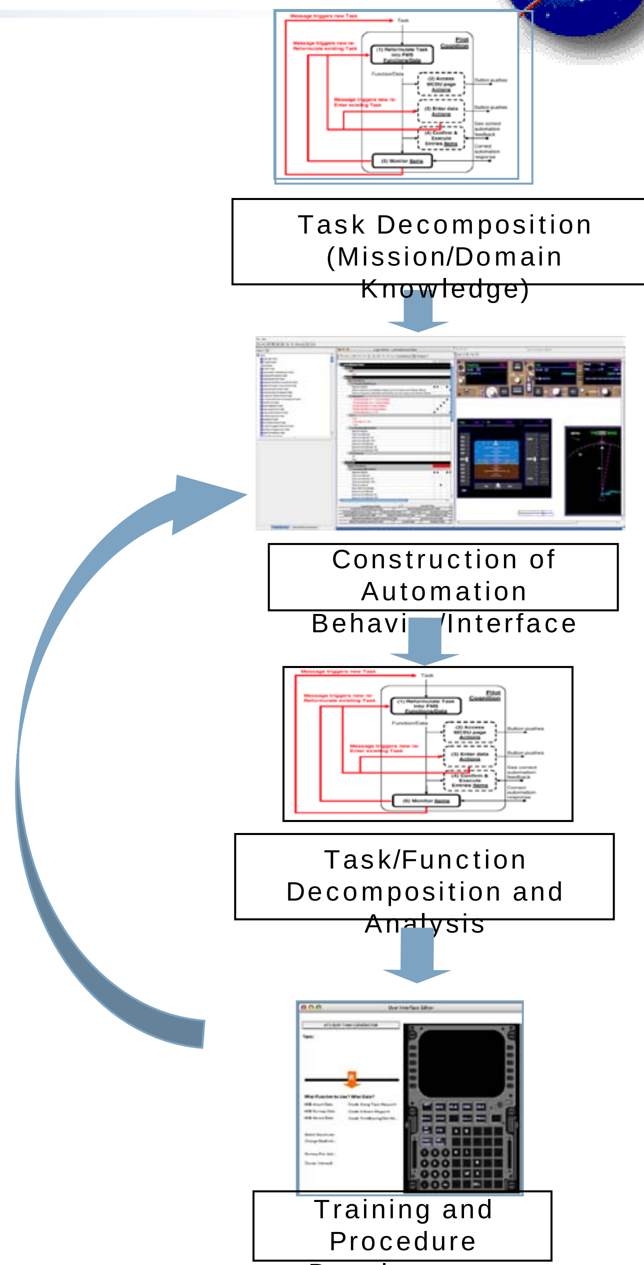
- Challenges:
  - Can we provide methods and tools usable within design process constraints?
  - How do predict what people will do in the real world?
    - Can we computationally determine strategies/action sequences?
      - Rewards/penalties for deviating from procedures
      - Need the utility functions
  - What development work needs to be done to enable human performance modeling optimize a design in the design process timeframe?



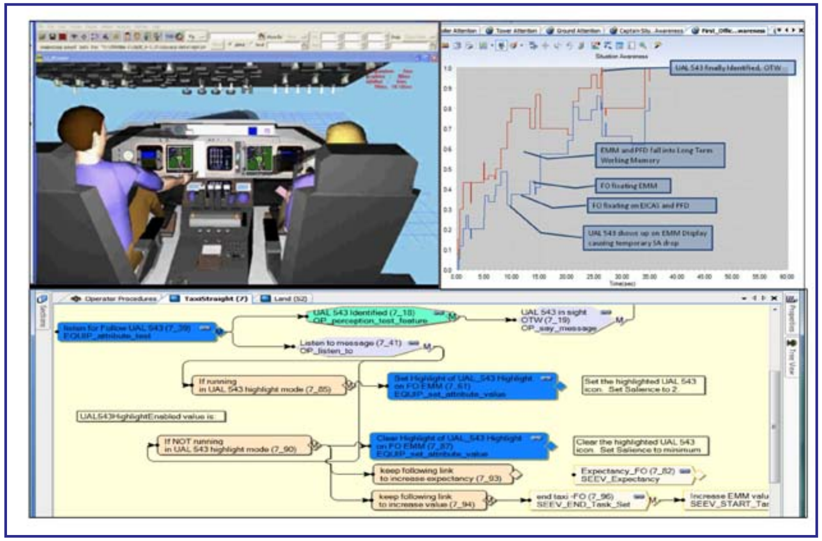
Automation Interaction Challenge Areas

2) Understanding our environment: How well can we match the automation to the task constraints?

- **Focus Issues:**
  - How can we involve domain experts in the complex design decisions which occur during development?
    - How we can support initial development by matching identified work structures with interface components?
  - What can we use that already know about interaction from other domains?
    - Engagement
    - Libraries and schemas of successful interaction



Computational Situation Awareness (CSA) Design Tool

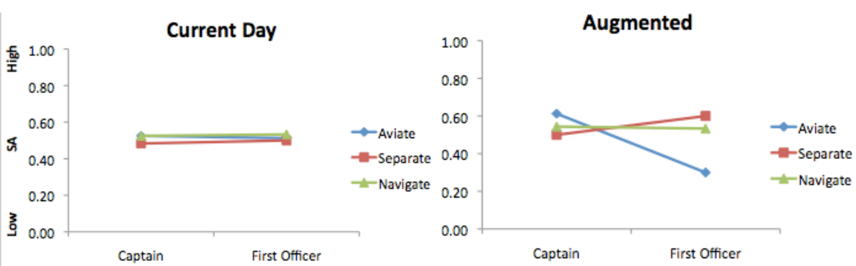


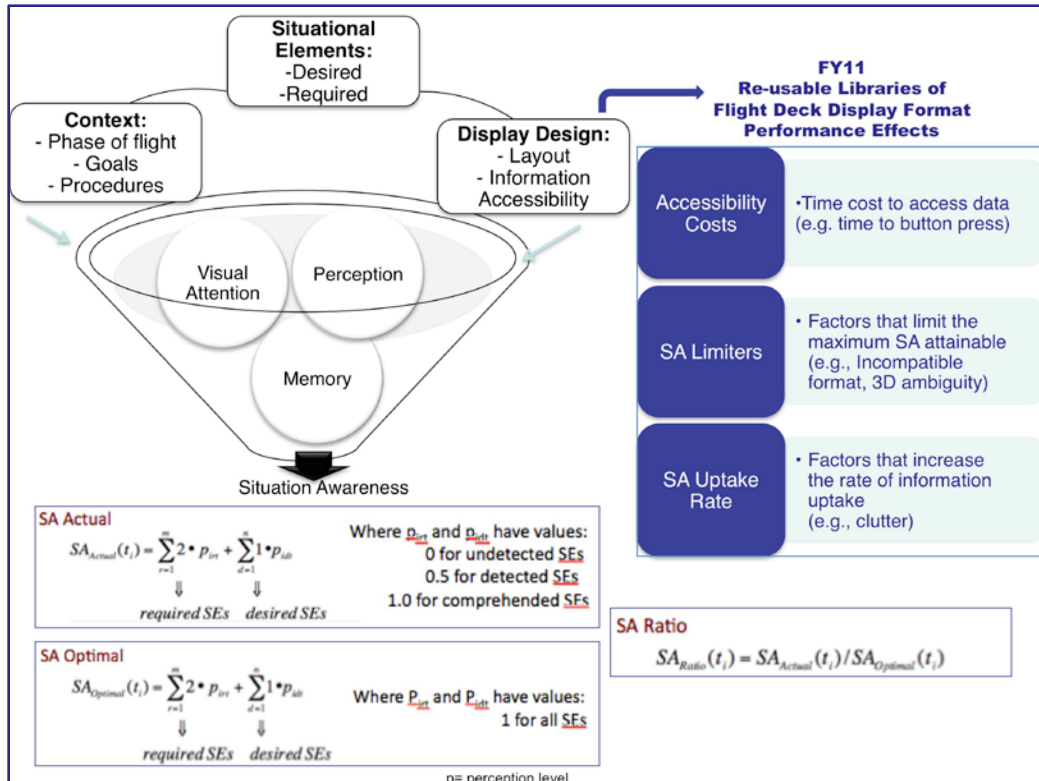
Objective: Develop a human performance model - based design tool to enable the design and evaluation of flight deck displays that optimize pilot situation awareness.

FY 11: Conduct meta-analysis of empirical data to generate re-usable libraries that capture the effect of display formats on human performance and SA.

Previous Work: Model Verification

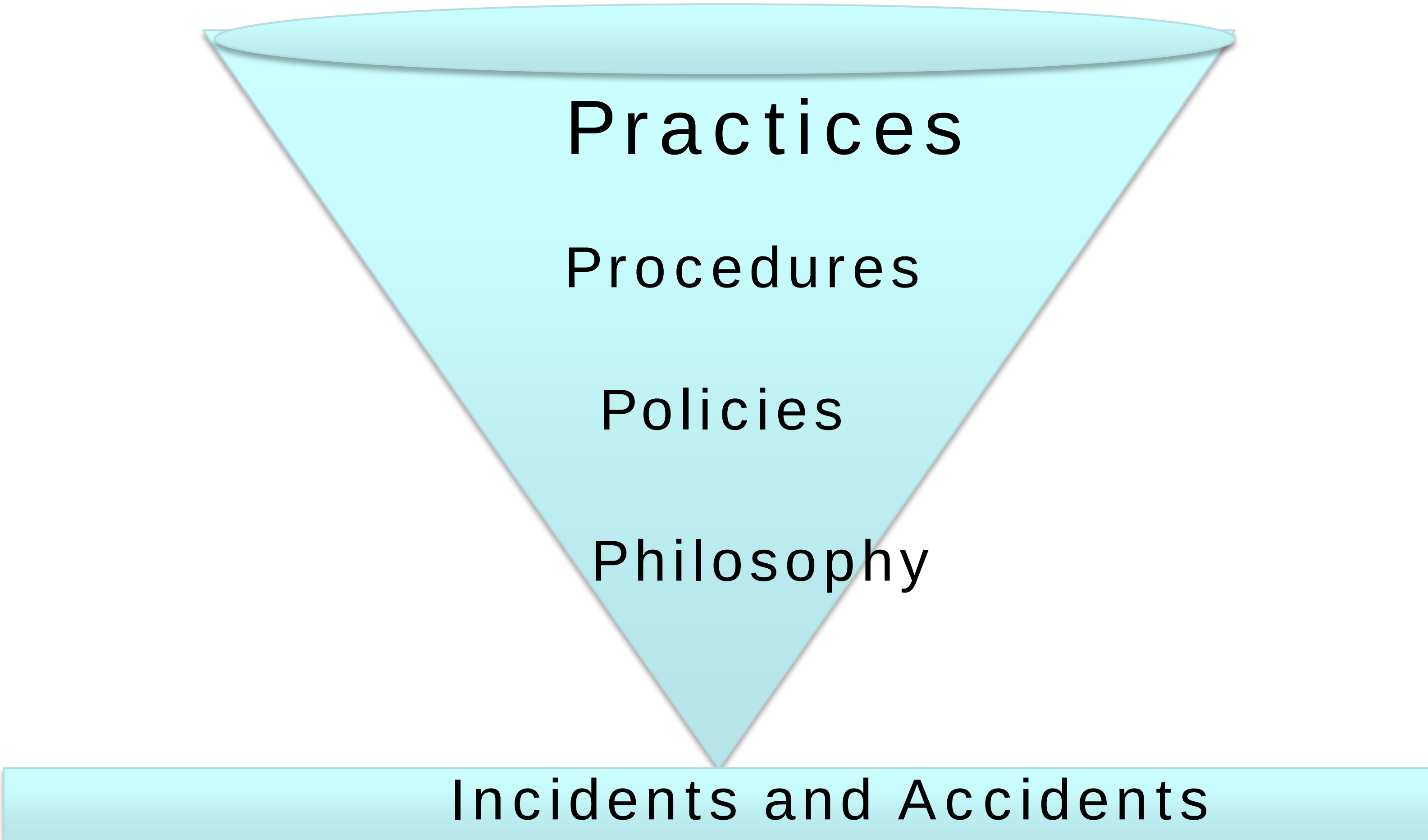
The model's SA predictions for three high-level tasks (aviate, separate, navigate) were sensitive to scenario characteristics: display layout (HUD vs. HDD), information availability (traffic, weather, terrain), display format (2D vs. 3D CDTI), and pilot procedures (shared vs. distributed responsibilities).





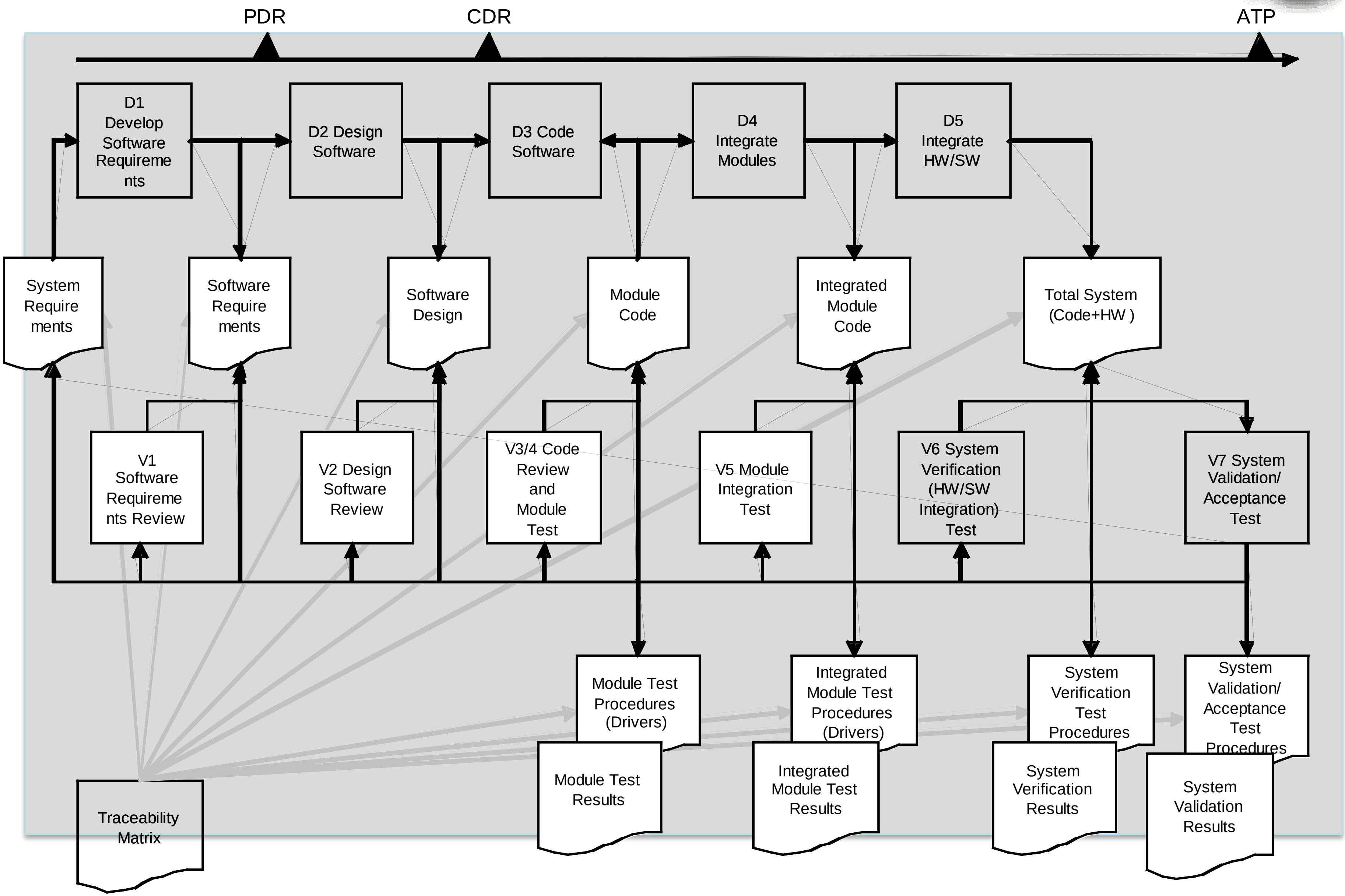
Hooey, B. L., Gore, B. F., Wickens, C. D., Scott-Nash, S., Socash, C., Salud, E., & Foyle, D. C. (2010, in press). Modeling Pilot Situation Awareness. In C. Cacciabue et al., (Eds.) Human Modelling in Assisted Transportation. Heidelberg: Springer.

Hooey, Gore, Salud, and Foyle (NASA Ames)

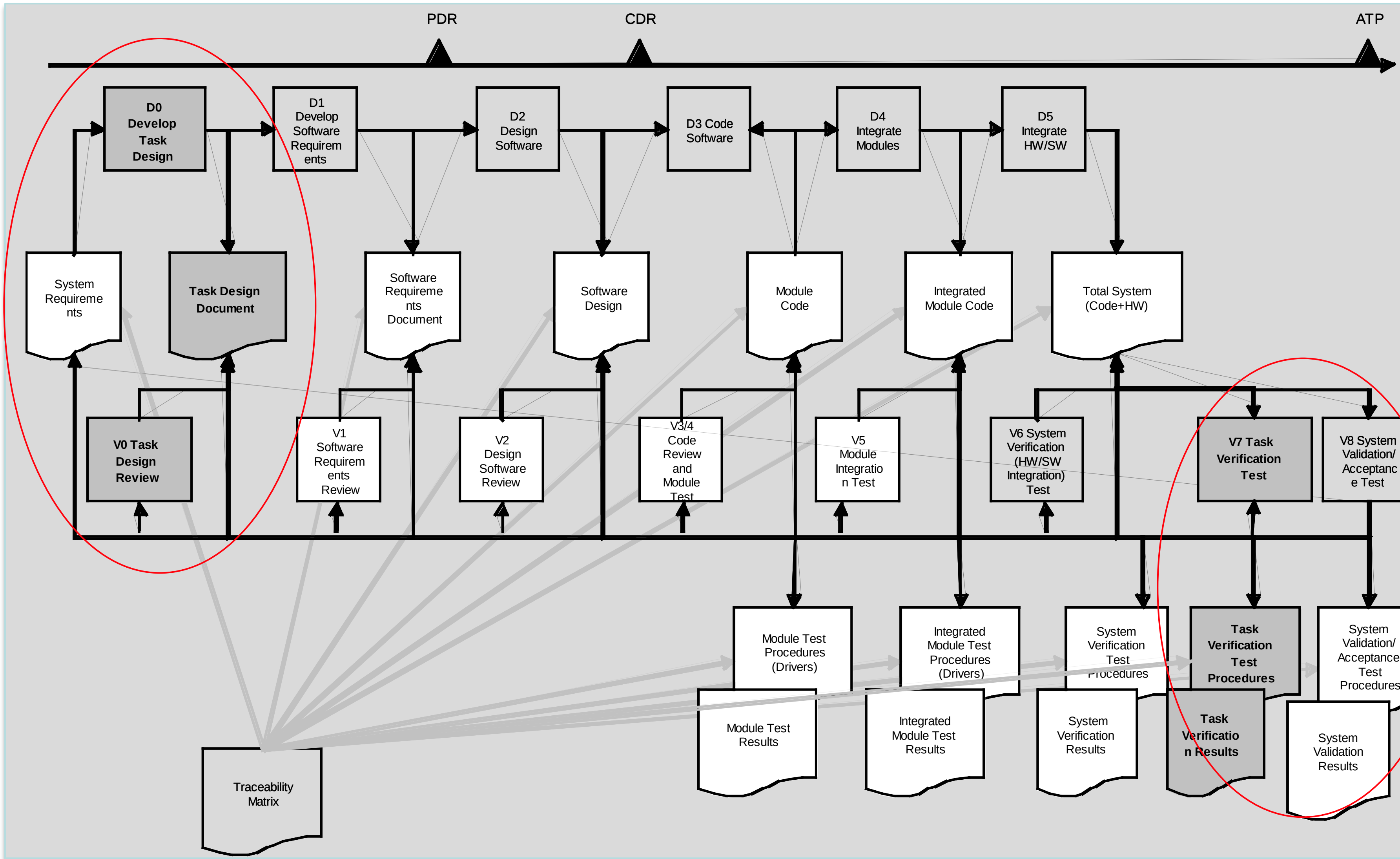


Degani and Wiener, 19

RTCA DO-178B Software Design Process



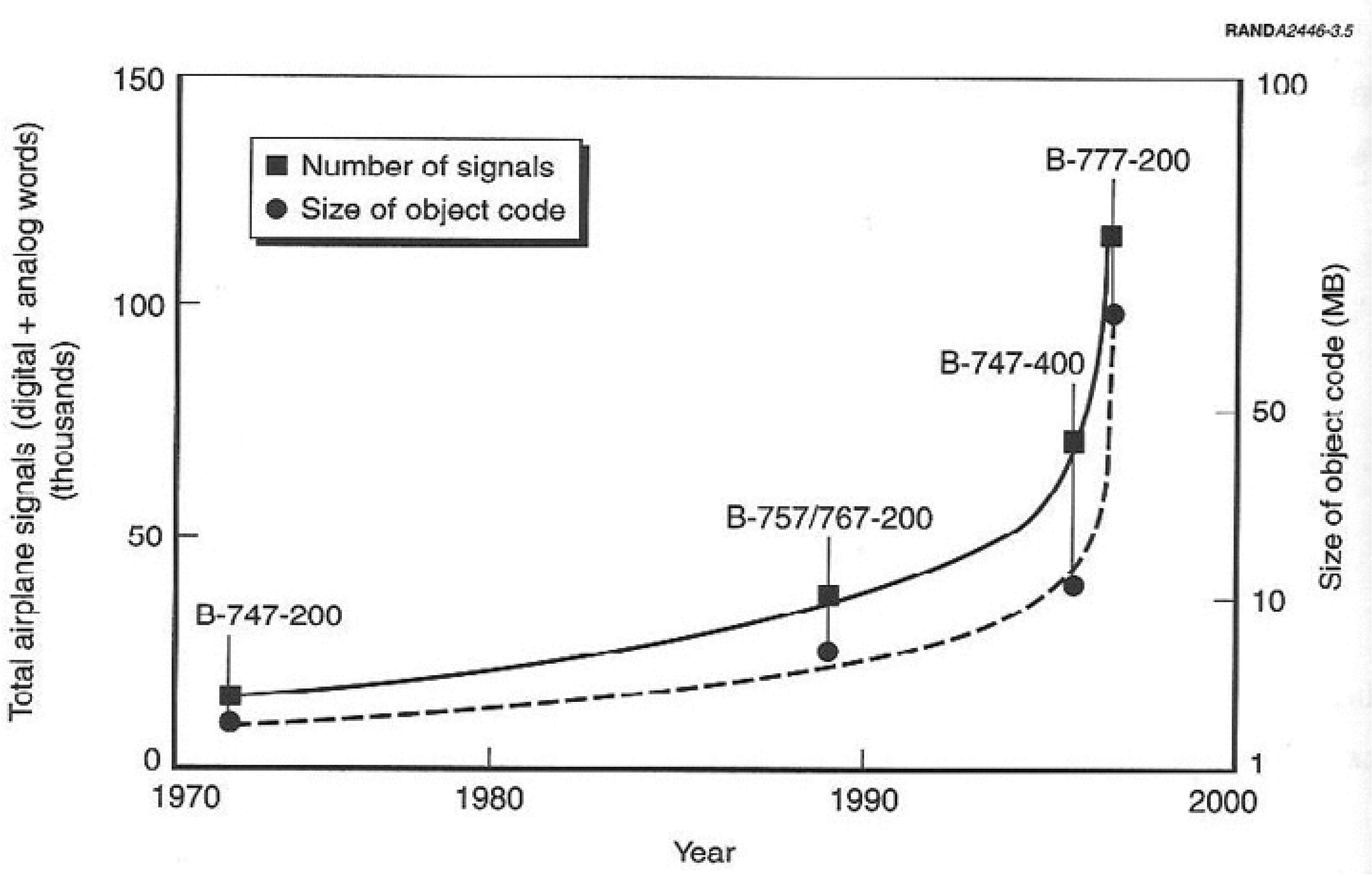
Automation Task Design and Verification



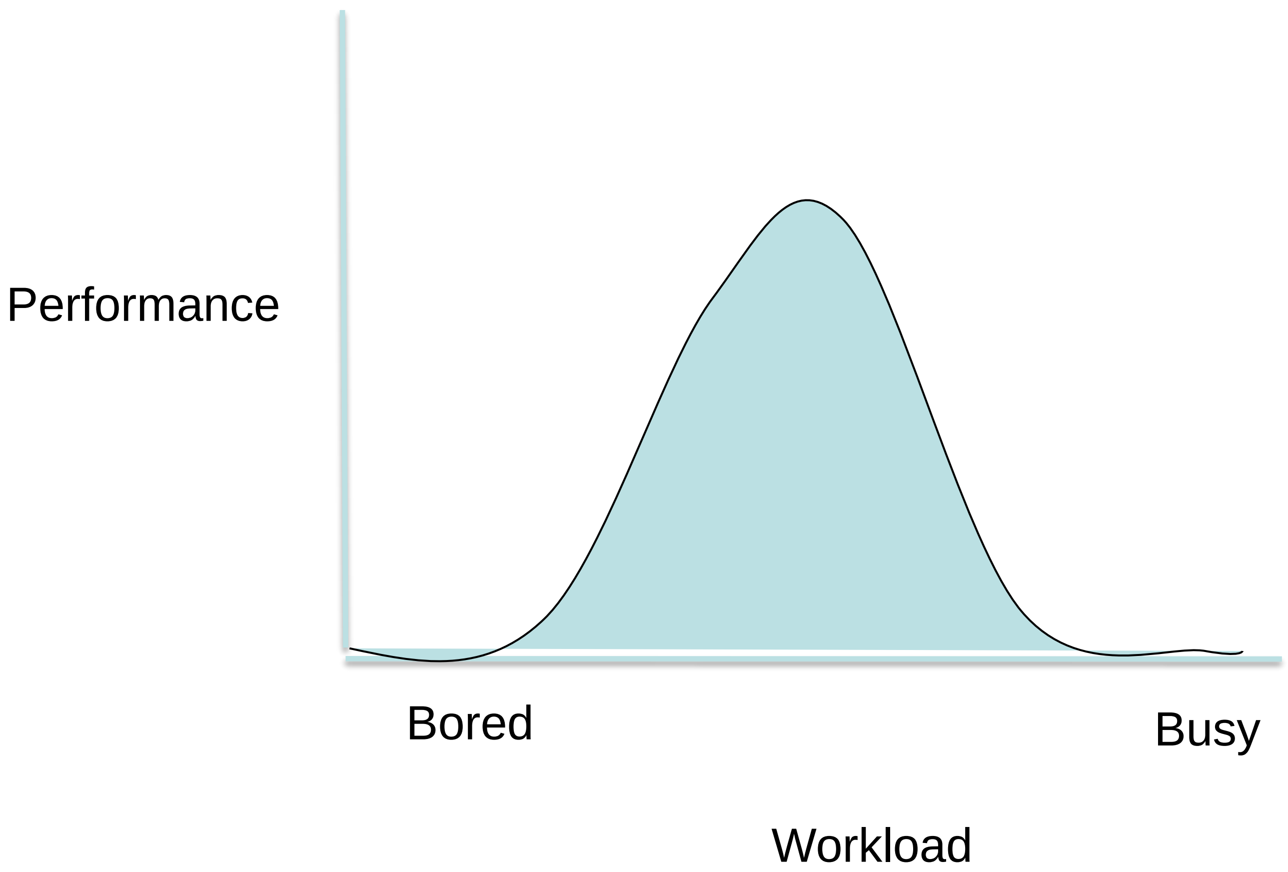
(Sherry, Feary)

Validation and Verification

Automation Development



Operational Impacts of Automation



Fitts, 1951b

Technical Approach and Deliverables

Increasing Safety of Human – Automation Interaction by Incorporating Human Performance (2020)
Goal: Develop analysis tools that incorporate known limitations of human performance and enable design of robust human-automation systems.
.

Technical Challenge Validated
- JPDO R2130, R2138
- NRC 2006 Decadal Survey
- Nat'l Aero R&D Plan Feb 2010

Benefits of Successful Completion
Methods and tools to help designers trainers and operators predict human performance, and identify, evaluate and resolve Human-Automation Interaction issues, and novel system failures.

Challenge

Human-Automation Tools and Models
Methods for Development of Interface Requirements (2013)
Develop Human – Automation Interaction analysis methods and tools (2013)
Tools for Identification of novel system failures (2014)
Develop Computational Human Model-Based Safety Design Tools (2014)

Human Performance Mechanisms
Methods to determine human functional state (2012)
Human system modality mapping (2013)
Improved models of operator information processing and functional status limitations(2014)

Theme

Operational Complexity Metrics and Methods
Develop executable data extraction and abstraction model (2013)

Discipline capability

Collaboration w/ FAA	Collaboration w/ASP	Collaboration w/VSST

Fundamental research
Human performance modeling, perceptual and cognitive performance measurement, physiological measurement, cognitive task analysis, formal methods,

ndamental Research

NTSB Most Wanted

- = Unacceptable response
- = Acceptable response, progressing slowly
- = Acceptable response, progressing in a timely manner
- = Being assessed, classification code to be assigned soon

Federal Issues

Unacceptable response	**Improve Oversight of Pilot Proficiency** **Action Needed by** The Federal Aviation Administration	• Evaluate prior flight check failures for pilot applicants before hiring. • Provide training and additional oversight that considers full performance histories for flight crewmembers demonstrating performance deficiencies.
Unacceptable response	**Require Image Recorders** **Action Needed by** The Federal Aviation Administration	• Install crash-protected image recorders in cockpits to give investigators more information to solve complex accidents.
Unacceptable response	**Improve the Safety of Emergency Medical Services (EMS) Flights** **Action Needed by** The Federal Aviation Administration	• Conduct all flights with medical personnel on board in accordance with stricter commuter aircraft regulations. • Develop and implement flight risk evaluation programs for EMS operators. • Require formalized dispatch and flight-following procedures including up-to-date weather information. • Install terrain awareness and warning systems (TAWS) on aircraft used for EMS operations.
Acceptable response, progressing slowly	**Improve Runway Safety** **Action Needed by** The Federal Aviation Administration	• Give immediate warnings of probable collisions/incursions directly to flight crews in the cockpit. • Require specific air traffic control (ATC) clearance for each runway crossing. • Require operators to install cockpit moving map displays or an automatic system that alerts pilots when a takeoff is attempted on a taxiway or a runway other than the one intended. • Require a landing distance assessment with an adequate safety margin for every landing.
Unacceptable response	**Reduce Dangers to Aircraft Flying in Icing Conditions** **Action Needed by** The Federal Aviation Administration	• Use current research on freezing rain and large water droplets to revise the way aircraft are designed and approved for flight in icing conditions. • Apply revised icing requirements to currently certificated aircraft. • Require that airplanes with pneumatic deice boots activate the boots as soon as the airplane enters icing conditions.
Acceptable response, progressing slowly	**Improve Crew Resource Management** **Action Needed by** The Federal Aviation Administration	• Require commuter and on-demand air taxi flight crews to receive crew resource management training.
	Reduce Accidents and Incidents Caused by	• Set working hour limits for flight crews, aviation mechanics, and air traffic controllers based on fatigue research, circadian rhythms, and sleep and rest requirements. • Develop a fatigue awareness and countermeasures training program for controllers and those who


PRIVATE
SIGN
DO NOT
READ


Unattended Children
will be given an espresso
and a free puppy.

Potential Payoffs of Research

How is it done today, and what are the limits of current practice?

- Human – Automation Interaction guidance and evaluation is heavily dependent on individual human expertise and is reactive to current problems.
- The development of design tools is still in a nascent stage with few formal methods or tools to help designers, trainers and operators predict human performance, and identify, evaluate and resolve Human – Automation interaction issues.

What is new in our approach?

- We will enable the deployment of new and enhanced tools and methods for improving the safety profile of human-automation tools by relying less on individual expertise.
- We will develop innovative procedures to incorporate human performance limitations in the design cycle to reduce cost and improve the safety profile of elements in NextGen.

What are the payoffs if successful?

- NextGen will be enabled through the reduction in cost and improvement in safety profile of human-automation systems.
- Cost of verification and validation of human-automation systems can be reduced with better incorporation of human performance during design.
- Improved system resilience due to understanding of human attention and cognition.

SSAT Research Framework: Approach

Level 2 – *Project Level*

Goal – Develop validated multidisciplinary tools and techniques to ensure system safety in NextGen to enable proactive management of safety risk through predictive methods.

SSAT 2.1 Technical Challenges	SSAT 2.2 Systems Analysis	SSAT 2.3 *Partnerships and Outreach*	SSAT 2.4 Research Test and Integration

Level 3 – *Subproject*

SSAT 3.1 Verification & Validation of Flight Critical Systems	SSAT 3.2 Data Mining and Knowledge Discovery	SSAT 3.3 Human Systems Solutions	SSAT 3.4 Prognostics and Decision Making

Level 4 – *Subproject Elements*

- SSAT 4.1.1: Argument-Based Safety Assurance
- SSAT 4.1.2: Authority and Autonomy
- SSAT 4.1.3: Distributed Systems
- SSAT 4.1.4: Software Intensive Systems

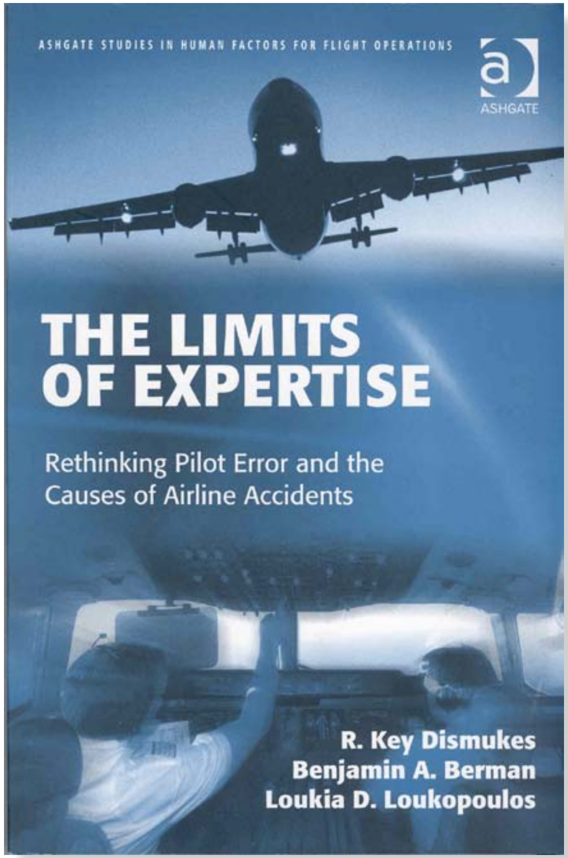
- SSAT 4.2.1: System-Level Reasoning
- SSAT 4.2.2: Anomaly Detection from Massive Data Streams
- SSAT 4.2.3: Discovery of Causal Factors
- SSAT 4.2.4: Prediction of Adverse Events

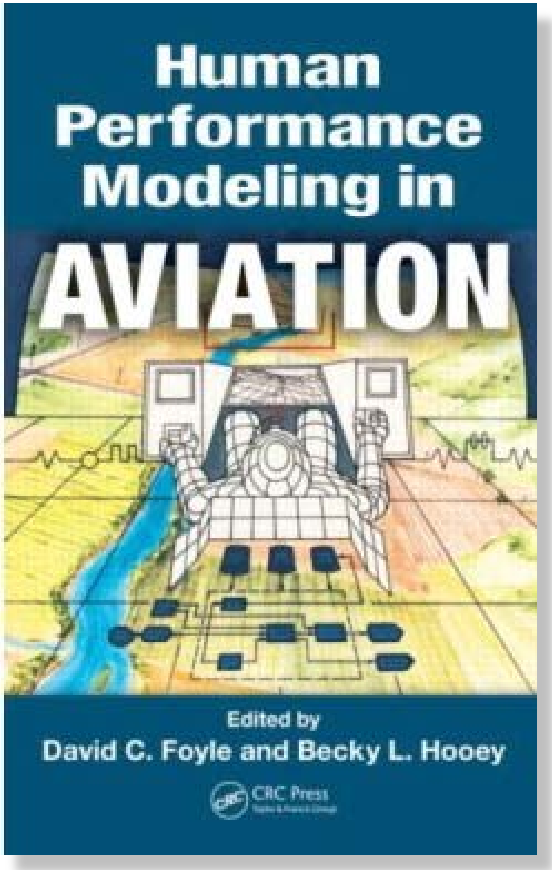
- SSAT 4.3.1: Human Automation Tools, and Models
- SSAT 4.3.2: Operational Complexity Metrics and Methods
- SSAT 4.3.3: Human Performance Mechanisms

- SSAT 4.4.1: Decision Making under Uncertainty
- SSAT 4.4.2: Diagnostics
- SSAT 4.4.3: Prognostics
- SSAT 4.4.4: Software Health Management

"Validated, proactive solutions for ensuring safety in flight and operations"

Human Performance





>2000 copies sold

>500 copies sold

Accident Causes