Aligned with your needs.

The Automation Design Advisor Tool

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Motivation for the Project

Automation Interaction Design and Evaluation Methods

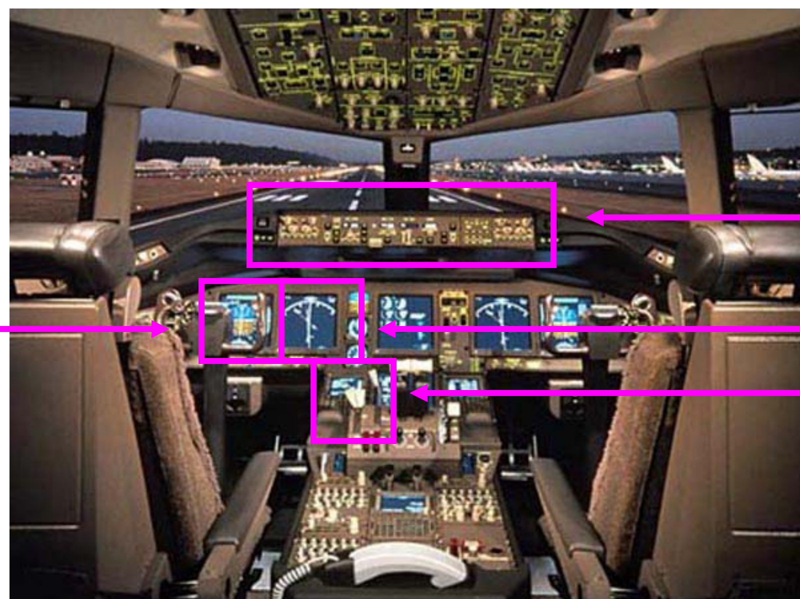
- Motivation: Expected increased role of automation in NextGen
- Goals:
  - Develop methods and tools to test designs
  - Implement HAI error-prediction methods and/or models
  - Uncover cognitive inefficiencies and remove design errors early in the design process
  - Provide useful feedback about the efficacy of conceptual HAI designs

Approach

- Focus on the Flight Management System
- Identify problems with the current system
- Develop a tool to address these issues, based on cognitive models of human-system and human-automation interaction
- Review empirical literature and operational lessons learned
- Work with Subject Matter Experts
- Conduct small evaluations throughout
  - Individual module validations
- Conduct large scale evaluations
  - Overall usability
  - ADAT-based evaluations and comparisons

Project Focus Area: Flight Management System

- A key piece of flight-deck technology
  - Select and manage trajectories
  - Provides feedback regarding automation control of flight status
  - Implements flight control actions
- Presents numerous human-automation interaction challenges



Primary Flight Display (PFD) with Flight Mode Annunciators (FMAs)

Mode Control Panel (MCP)

Navigation display (Nav)

Control Display Unit (CDU)

From www.boeing.com

What are some problems with current FMS design?

- Interaction complexity
- Need to memorize / access inert knowledge
- Information presentation issues
- Use of abbreviations and acronyms
- Lack of a vertical situation display
- Mode confusion
- Overrides – complex and not labeled

ADAT Overview

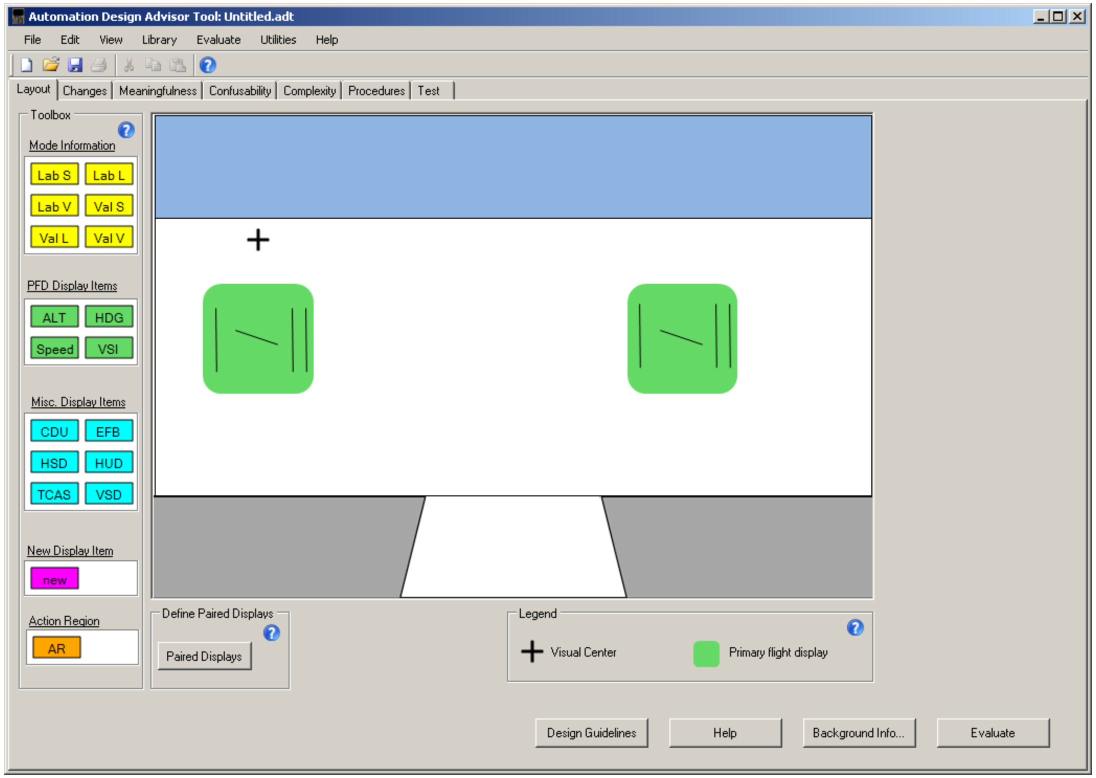
- Goals
  - Empower the FMS designer to create more usable systems
  - Improve pilot-automation interaction
  - Be relevant for current day and NextGen operations
- What ADAT includes
  - Modules that review specific aspects of FMS design
    - Based on human factors design principles
    - Empirical studies of FMS / flight deck performance and operational experience
    - Models of human-system and human-automation interaction
  - Pilot attention models
    - Salience, expectancy, effort and value (SEEV)
    - Noticing-SEEV (N-SEEV)
  - Specific guidance and relevant literature summaries
  - FMS Design Comparison capabilities

ADAT Inputs and Outputs

- The designer inputs:
  - Information on the proposed FMS
  - Where interaction will occur – displays and controls
  - How interaction occurs
  - Factors related to the design
- The tool provides:
  - Scores related to different human factors design issues (0-10)
  - Potential design deficiencies
  - Predicted pilot scanning and noticing behavior
  - Comparisons of multiple FMS designs
  - Specific design guidance based on FMS and flight-deck automation research
  - Access to a library of FMS-related guidelines

The Six Modules

- Layout
- Changes
- Meaningfulness
- Confusability
  - Alphanumeric
  - Graphical
- Complexity
- Procedures

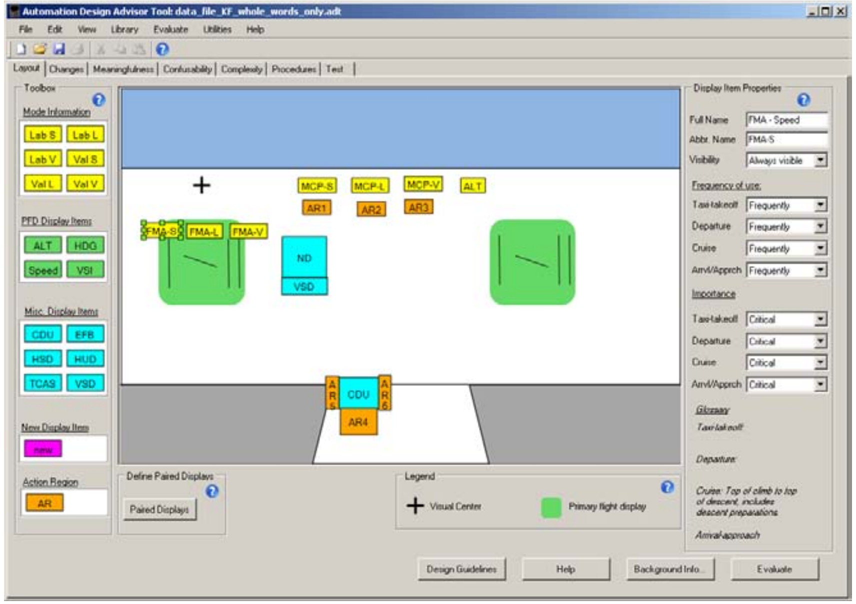


Each module includes a computational model of pilot-cognitive behavior and performance mechanisms involved

Modules compute the degree of adherence or violation of good HF design principles

Layout Module

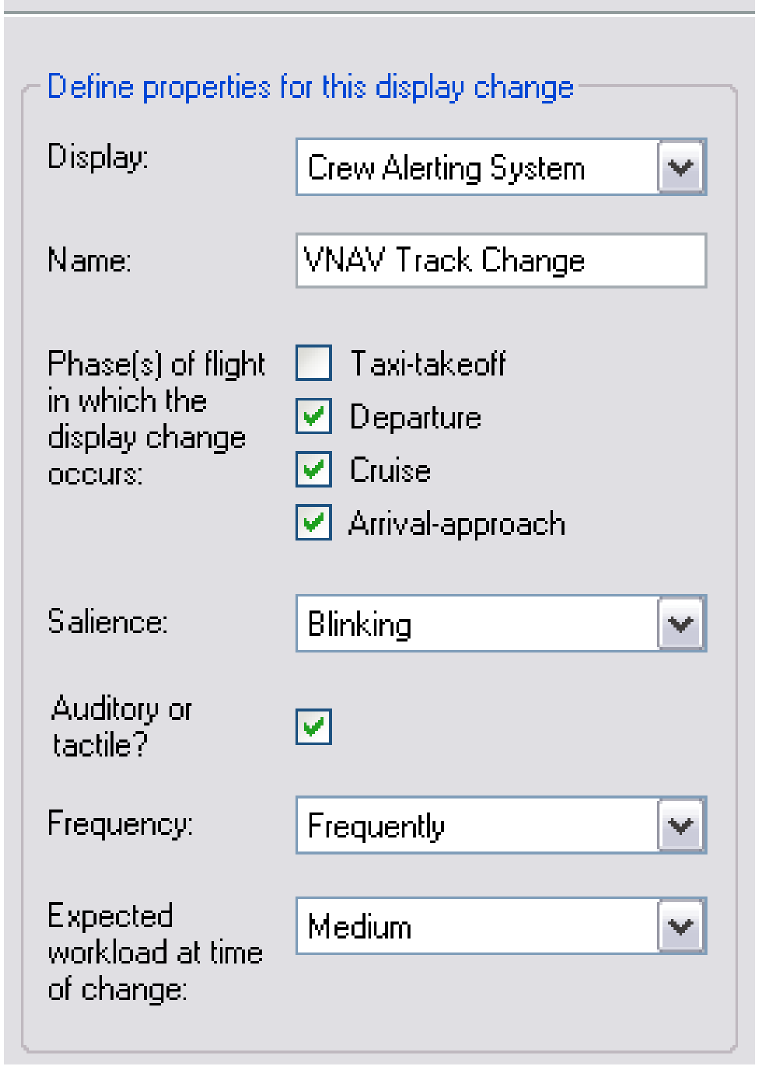
- Addresses the positioning of information on the flight deck
  - Location of displays
  - Accessibility of information
  - Frequency of use
  - Sequence of use
  - Importance



- Contribute to an overall score for the quality of the layout

Changes Module

- Identify display in which change occurs
- Select phases of flight
- Specify salience of display
- Indicate if auditory or tactile feedback is included
- Identify frequency with which it occurs
- Identify expected pilot workload when the change occurs



Meaningfulness and Confusability

- Meaningfulness assesses the understandability of terms used in the FMS
  - Human Factors principles of abbreviations and acronyms
  - Assessments using a latent semantic analysis engine with an aviation corpus (University of Colorado)
- Confusability of terms and symbols addresses how likely it is that pilots will mistake one item for another
  - Feature matching
  - For terms: percent of identical characters in a pair of terms
  - For symbols: similar colors or similar physical features lead to penalties

Complexity Module

Model penalizes designs that impose mode complexity based on:

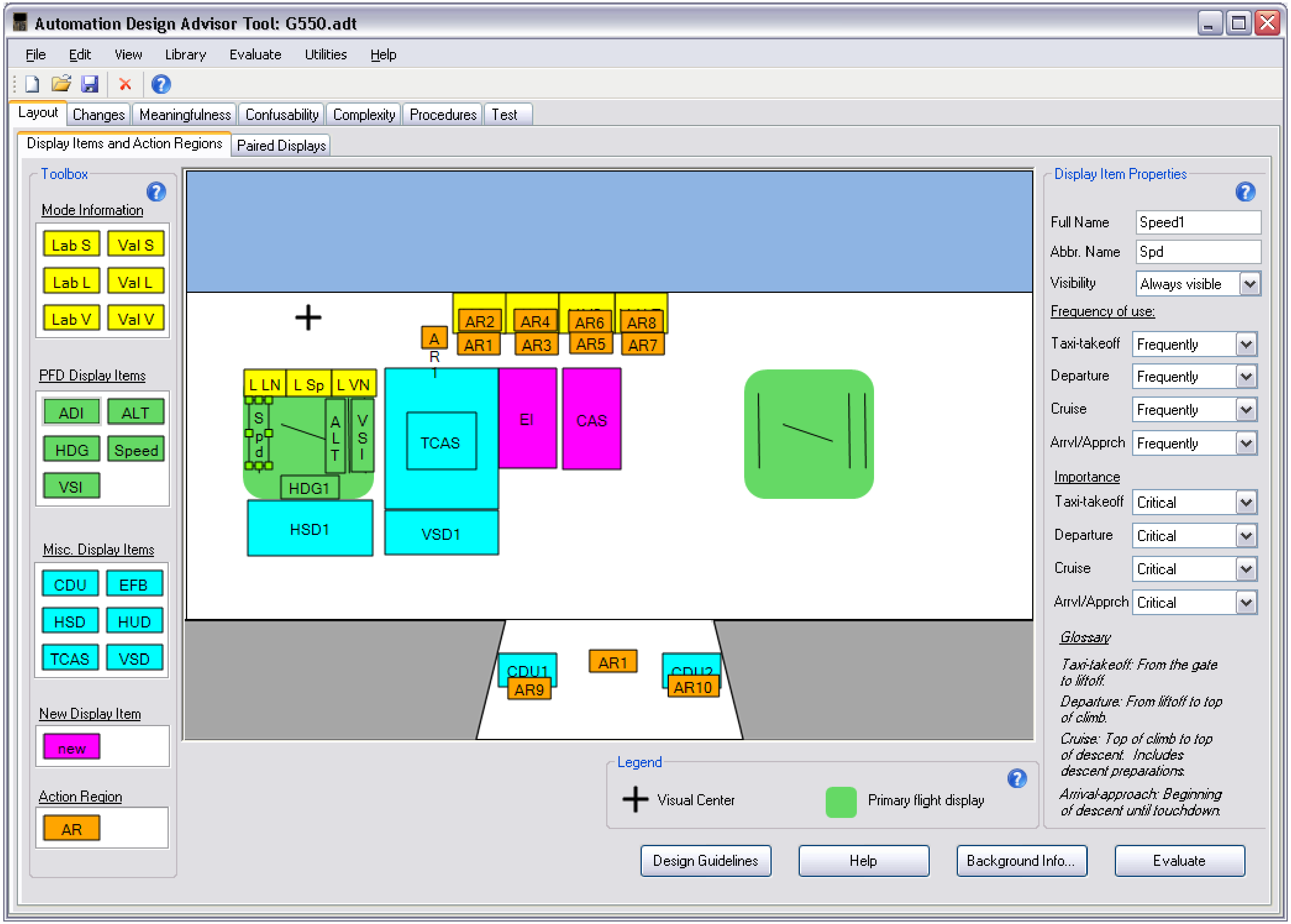
- An extensive number of modes
- Modes controlling interacting axes (particularly speed and altitude)
- Mode changes that delete a flight path parameter or constraint
- Mode changes that are triggered (initiated) by an agent other than the pilot
- Modes that cannot be accessed in certain situations
- Modes that have insufficient feedback regarding their implications for the future trajectory.

These inputs are combined in a linear additive model that assigns weighting to these penalties.

Procedures Module

- Addresses the interactions the pilot takes with the system
  - Number of steps involved for each procedure
  - Where the actions are taken
  - If prompting is provided for the actions
  - If feedback is provided for actions
  - Location of the feedback relative to the action region
  - If the sequence of actions corresponds to air traffic control instructions
- These factors are combined in a linear equation that penalizes poor design

Sample ADAT Inputs and Results



Sample ADAT Inputs and Results

Automation Design Advisor Tool: Results

Overview | Layout | Changes | Meaningfulness | Confusability | Complexity | Procedures

Overall Layout Scores

Taxi / Takeoff:	6.61
Departure:	5.68
Cruise:	5.45
Arrival / Approach:	4.61

Layout scores

Display Frequency

	Avg. Frequency Score
Taxi-Takeoff	4.65
Departure	5.13
Cruise	4.83
Arrival-Approach	4.25

Paired Display

	Avg. Sequence of Use Score
Taxi-Takeoff	7.85
Departure	4.95
Cruise	4.95
Arrival-Approach	4.39

Display Importance

	Avg. Importance Score
Taxi-Takeoff	5.58
Departure	7.10
Cruise	6.54
Arrival-Approach	4.92

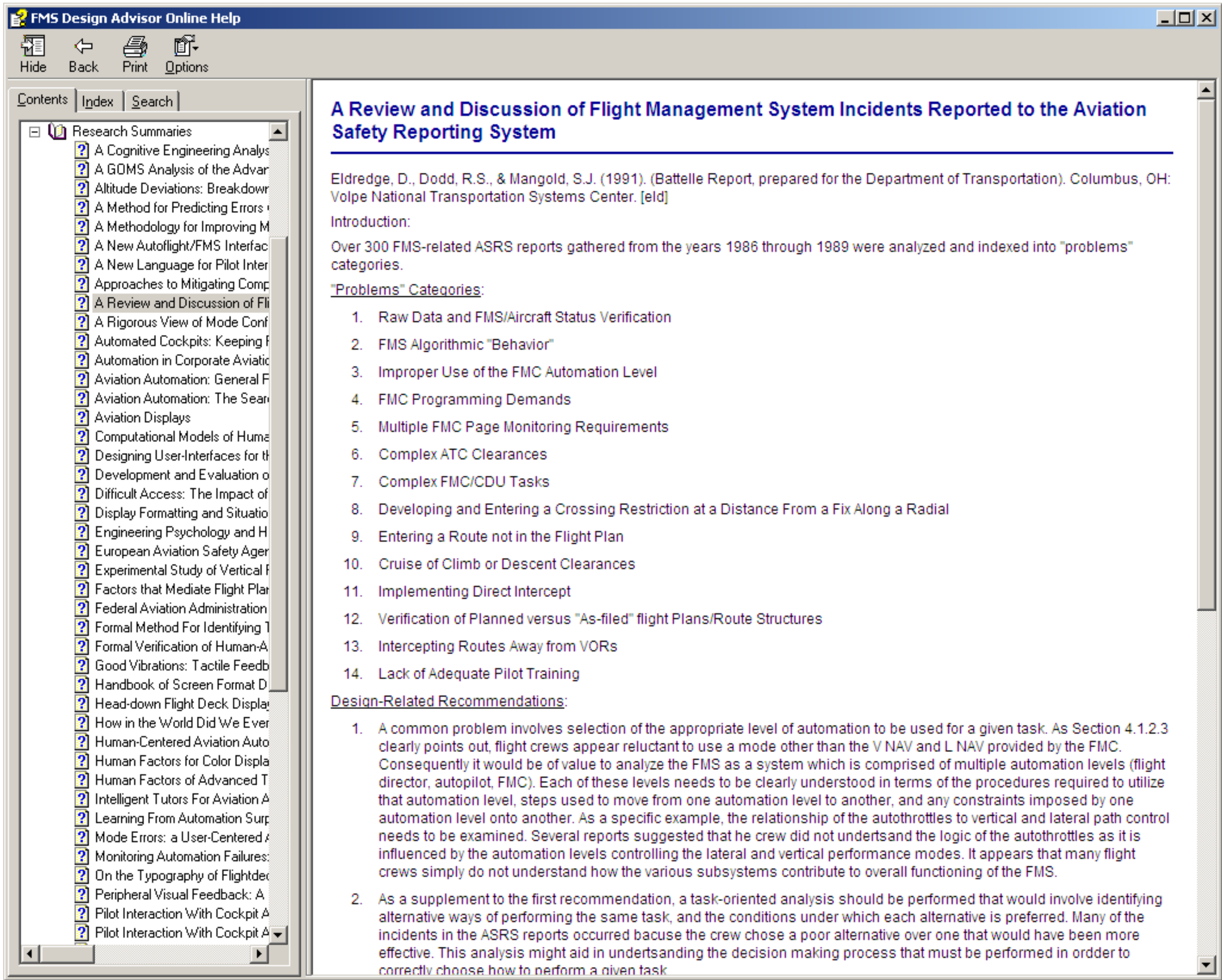
Design problem **Guidelines** **Relevant research**

Problems and Guidelines

	Design Problem	Guideline	Relevant Research
1.	Critical information is too far from the visual center.	Locate critical information near the visual center	Eldredge, 1991
			Wickens, Vincow, Schopper, & Lincoln, 1997
2.	Critical information is hidden from view.	Critical information should be visible at all times	FAA HFDS
			Wickens, 2003
		Less-critical information can be placed in a less-central location.	EASA CS-25
			Eldredge, 1991
		Low-priority (supporting) information can be hidden from view if it is easy to obtain (1 key press).	EASA CS-25
3.	Frequently-used information is too far from the visual center	Locate frequently-used information near the visual center.	FAA HFDS
			Wickens, Vincow, Schopper, & Lincoln, 1997
4.	Frequently-used information is hidden from view	Frequently-used information should be visible at all times	FAA HFDS

Close

Specific Guidance, Based on Problems



FMS Design Advisor Online Help

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A Review and Discussion of Flight Management System Incidents Reported to the Aviation Safety Reporting System

Eldredge, D., Dodd, R.S., & Mangold, S.J. (1991). (Battelle Report, prepared for the Department of Transportation). Columbus, OH: Volpe National Transportation Systems Center. [eld]

Introduction:

Over 300 FMS-related ASRS reports gathered from the years 1986 through 1989 were analyzed and indexed into "problems" categories.

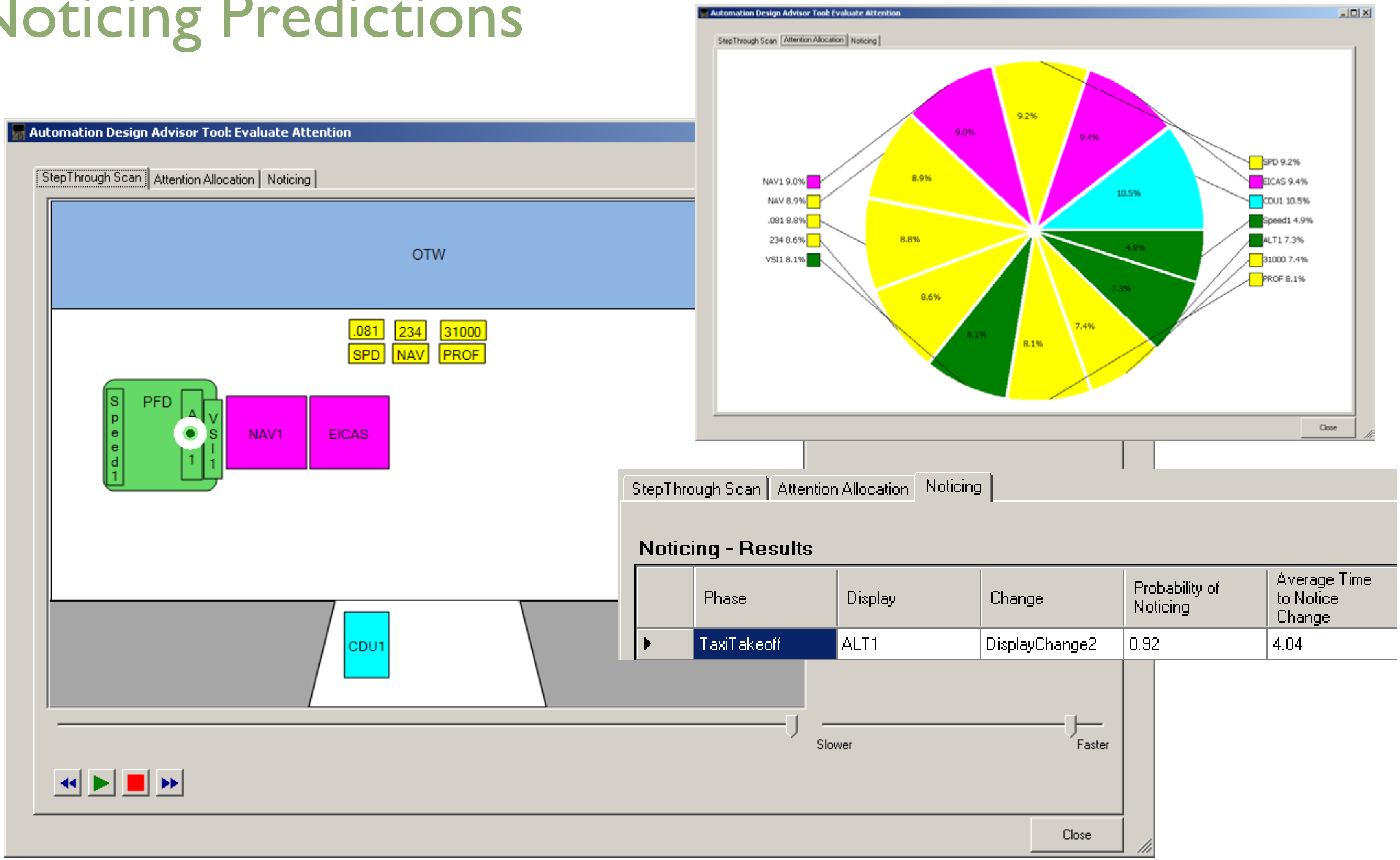
"Problems" Categories:

1. Raw Data and FMS/Aircraft Status Verification
2. FMS Algorithmic "Behavior"
3. Improper Use of the FMC Automation Level
4. FMC Programming Demands
5. Multiple FMC Page Monitoring Requirements
6. Complex ATC Clearances
7. Complex FMC/CDU Tasks
8. Developing and Entering a Crossing Restriction at a Distance From a Fix Along a Radial
9. Entering a Route not in the Flight Plan
10. Cruise of Climb or Descent Clearances
11. Implementing Direct Intercept
12. Verification of Planned versus "As-filed" flight Plans/Route Structures
13. Intercepting Routes Away from VORs
14. Lack of Adequate Pilot Training

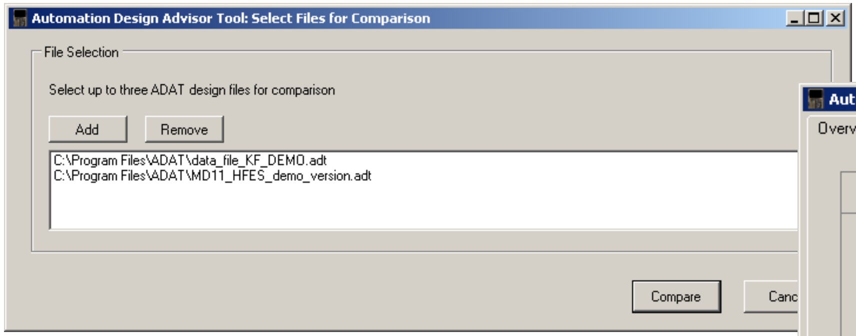
Design-Related Recommendations:

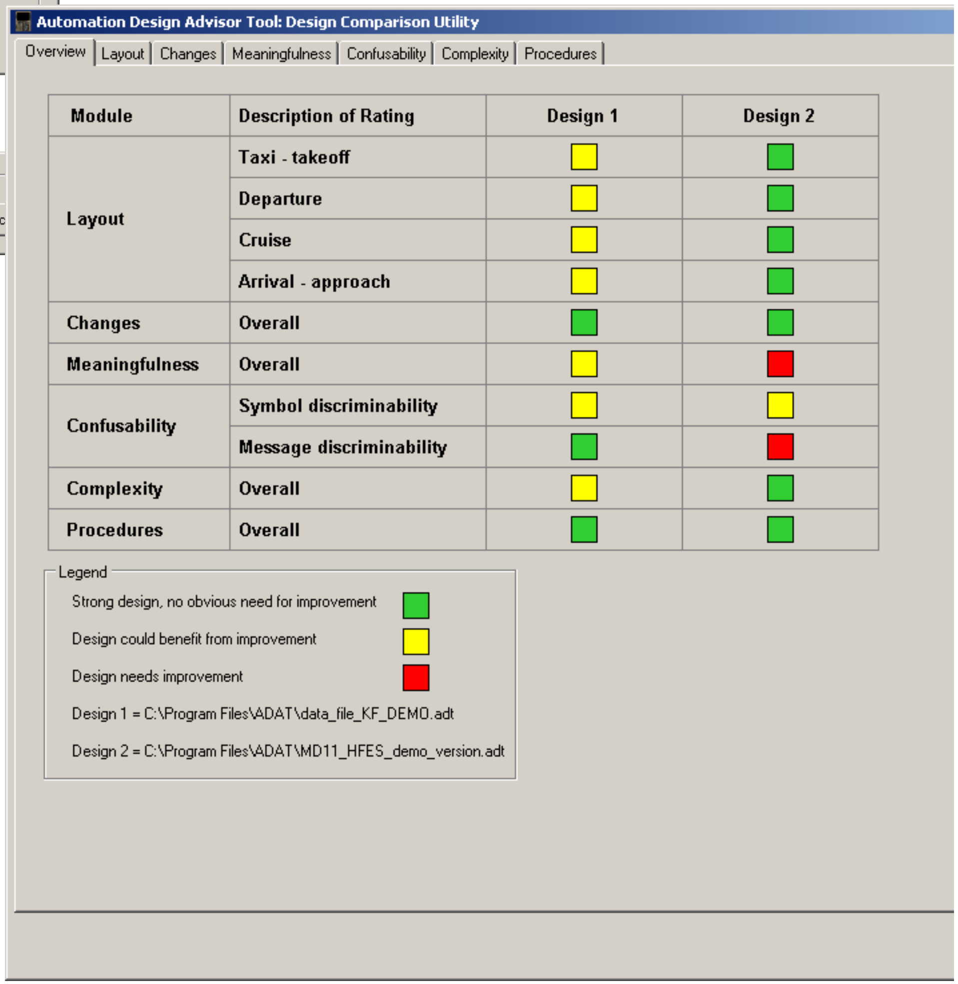
1. A common problem involves selection of the appropriate level of automation to be used for a given task. As Section 4.1.2.3 clearly points out, flight crews appear reluctant to use a mode other than the V NAV and L NAV provided by the FMC. Consequently it would be of value to analyze the FMS as a system which is comprised of multiple automation levels (flight director, autopilot, FMC). Each of these levels needs to be clearly understood in terms of the procedures required to utilize that automation level, steps used to move from one automation level to another, and any constraints imposed by one automation level onto another. As a specific example, the relationship of the autothrottles to vertical and lateral path control needs to be examined. Several reports suggested that he crew did not undertsand the logic of the autothrottles as it is influenced by the automation levels controlling the lateral and vertical performance modes. It appears that many flight crews simply do not understand how the various subsystems contribute to overall functioning of the FMS.
2. As a supplement to the first recommendation, a task-oriented analysis should be performed that would involve identifying alternative ways of performing the same task, and the conditions under which each alternative is preferred. Many of the incidents in the ASRS reports occurred bacuse the crew chose a poor alternative over one that would have been more effective. This analysis might aid in undertsanding the decision making process that must be performed in ordder to correctly choose how to perform a given task

SEEV and N-SEEV Attention Modeling and Noticing Predictions



Comparison Utility





Validation Efforts and Results

- Performed 4 ADAT evaluations with 3 different FMS designs, 4 different evaluators
- Compared current-day commercial and corporate technologies and a future, innovative design concept
- Compared ADAT scores with empirical research

Current MCP Design

Potential Future (integrated) MCP Design

From Prada, L.R., Mumaw, R.J., Boehm-Davis, D.A., and Boorman, D.J. (2006). Testing Boeing's Flight Deck of the Future: A Comparison Between Current and Prototype Autoflight Panels. *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting*, pp. 55-58.

Validation Efforts and Results

- Results of the ADAT evaluations:

	FDF UM	*FDF Alion*	*Boeing 777*	*GS 550*
Layout	8.4	9.0	6.1	7.5
Changes				9.7
Meaningfulness	7.1	5.4	5.9	3.6
Confusability	9.7	9.8	7.6	7.6
Complexity			7.5	6.4
Procedures	6.3	8.1	5.4	5.7
	Future concept		Current Day/ Commercial	Current Day/ Corporate

- Current day systems with FDF: FDF Better
- Current day commercial with corporate: mixed
- Two FDF evaluations: Inter-rater differences
- Reveals differences, but sensitive to assumptions and depth of analysis

Validation Efforts and Results

ADAT Evaluation Scores

	FDF UM	*FDF Alion*	*Boeing 777*	*GS 550*
Layout	8.4	9.0	6.1	7.5
Changes				**9.7**
Meaningfulness	7.1	5.4	5.9	3.6
Confusability	9.7	**9.8**	7.6	7.6
Complexity			7.5	6.4
Procedures	6.3	8.1	5.4	5.7

Empirical Results of Procedural Performance*

	Training Accuracy	*Transfer Session 1*	*Transfer Session 2*
FDF	69%	86%	68%
Generic FMS	57%	65%	53%
Significance	P=.20	P<.05	ns

Both indicate ~ 30% performance benefit in FDF

* Mumaw, R., Boorman, D. J., & Prada, R. L. (2006). Experimental Evaluation of a New Autoflight Interface. Proceedings HCI-Aero 2006, International Conference on Human Computer Interaction, Seattle, WA.

Summary

- The Design Advisor tool can help FMS designers by:
  - Providing feedback on potential human factors design issues early in the design process
  - Identifying particular design weaknesses and suggesting targeted improvements
  - Offering access to specific, research-based guidelines
  - Modeling pilot attention on the flight deck
- The Design Advisor is flexible, to address:
  - Current-day FMS design
  - NextGen FMS design