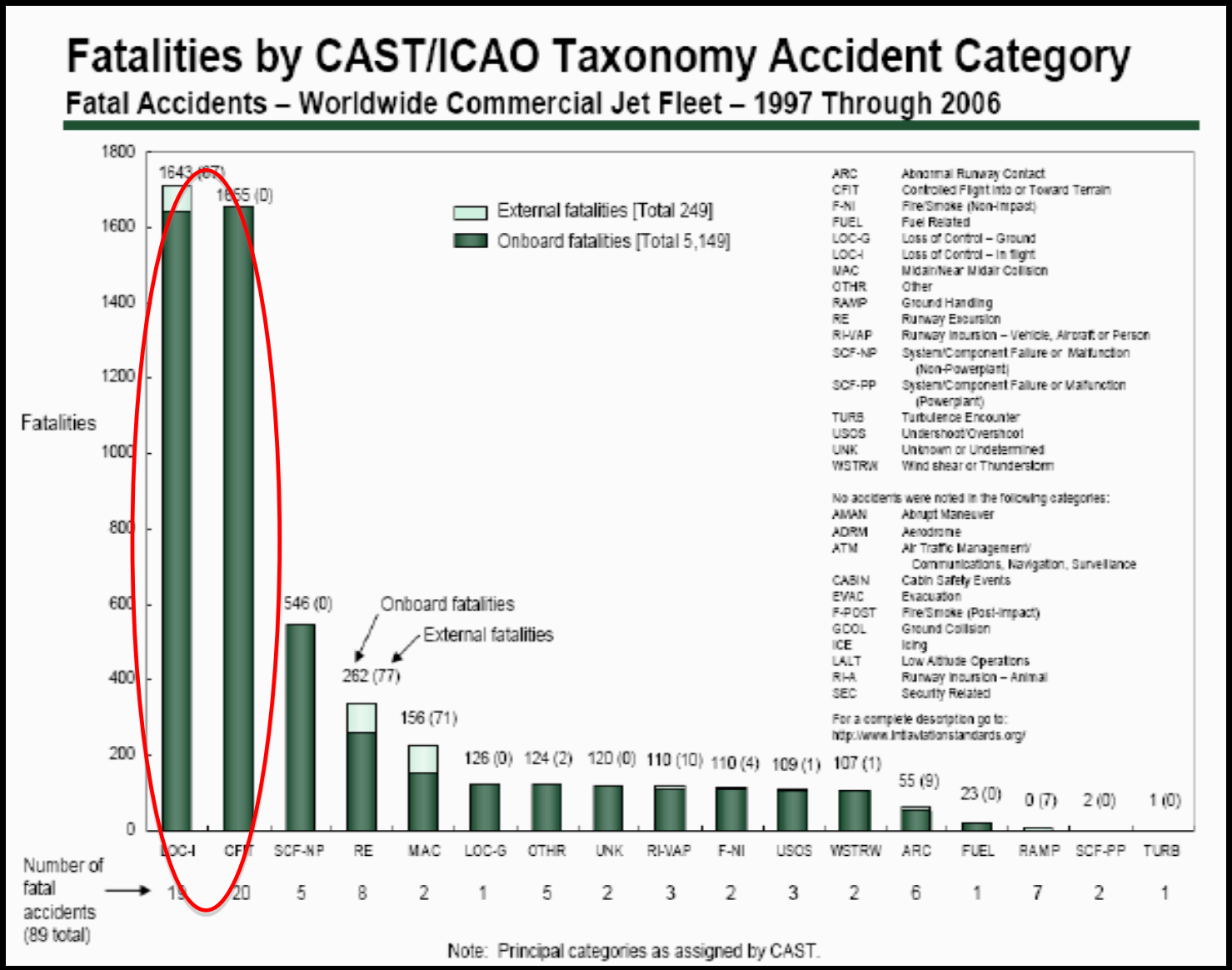
Human-Automation Interaction Design and Evaluation Tools

Outline

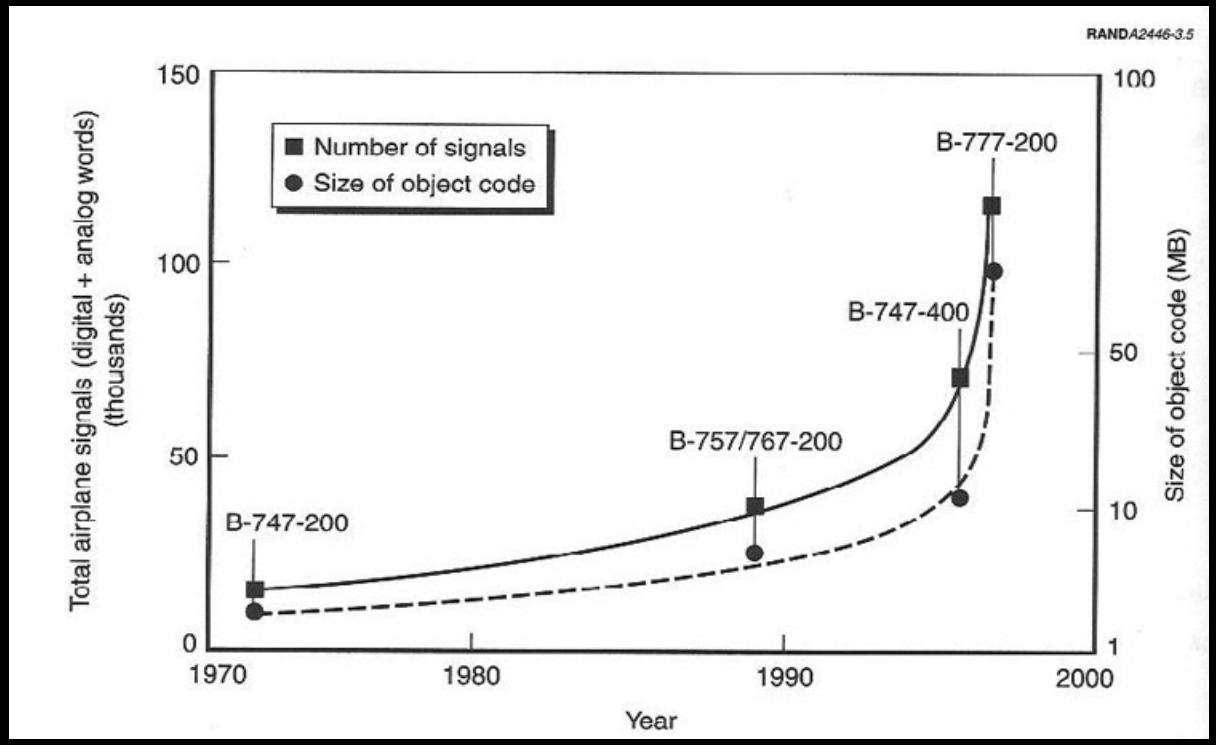
- **Human Automation interaction**
- **Research Challenges**
- **Research Approach**
  - Understanding
    - Work domain analysis
    - Visualization
  - Prediction
    - Human Performance
    - Formal Verification

Accident Causes

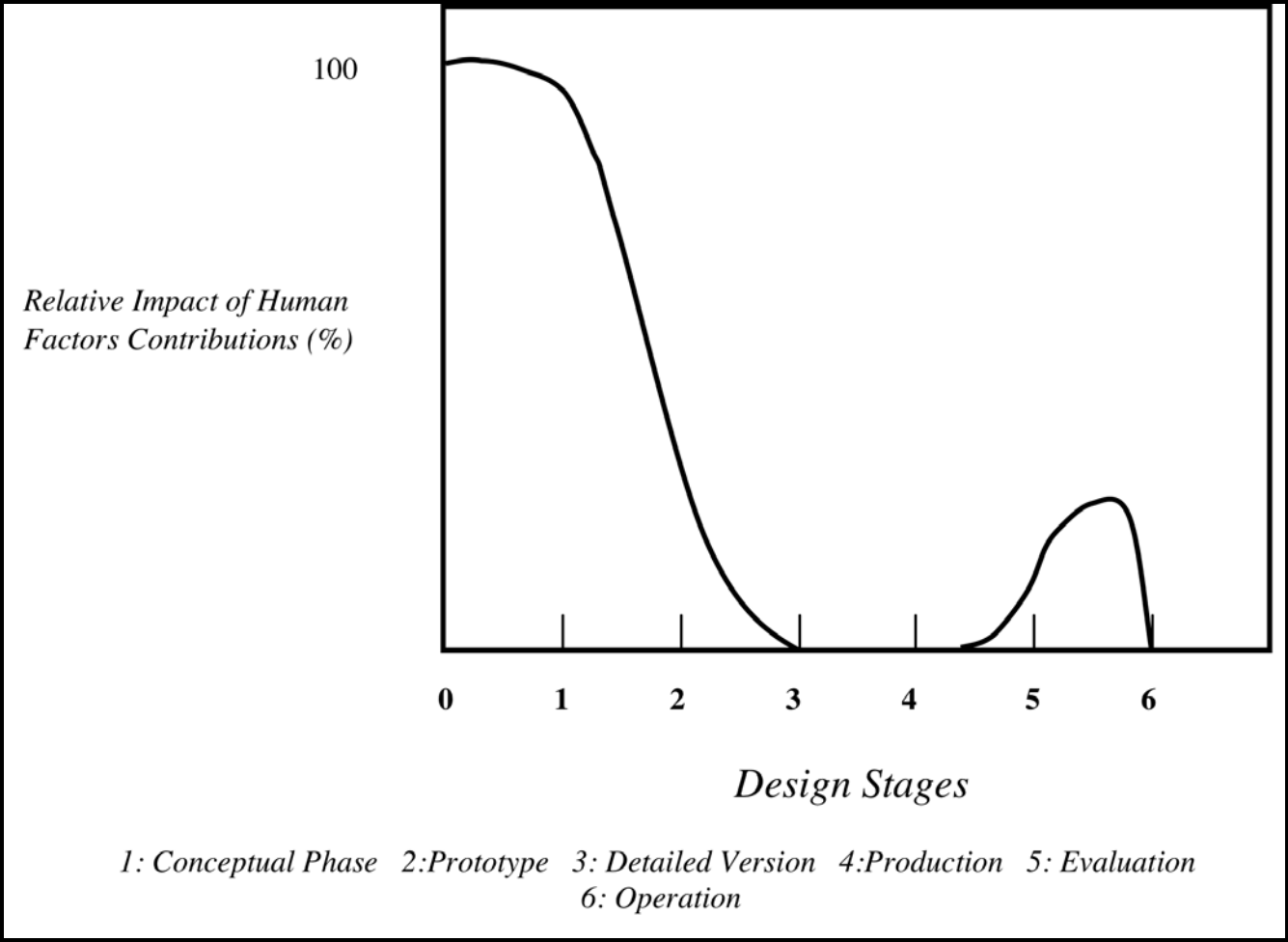


Automation Development

- Exponential increase in complexity, but reduction controls and dedicated displays
- Resultant Proliferation of modes, and multiple function controls and displays



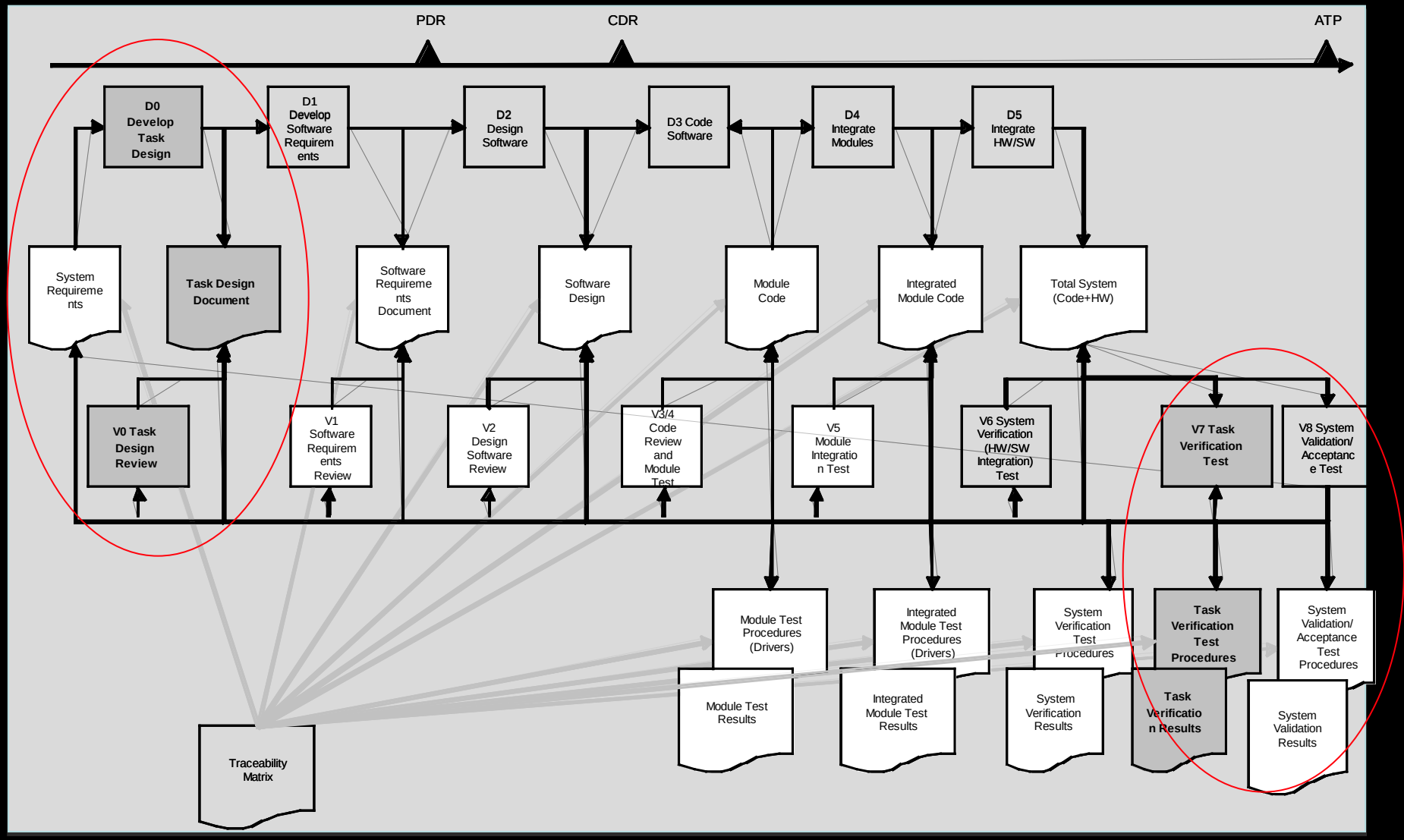
Methods and tools usable early in the design process



(Moraal and Kragt, 1990)

Validation and Verification

DO-178B Software Design Process



(Sherry, Feary)

HAI and Flight Deck Certification

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…"

NASA Human Rating Requirements

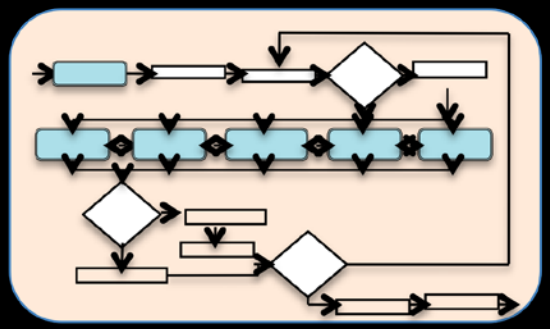
- **2.5.3.2 All human-rated space flight systems shall be designed so that neither two human errors during operation or in-flight maintenance nor a combination of one human error and one failure shall result in permanent disability or loss of life.**

- **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.

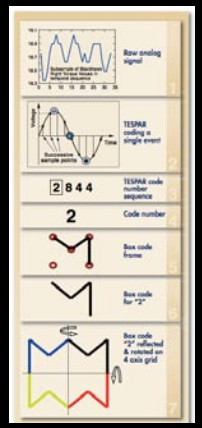
- **<u>FAA 25.1302: Demonstrating "intended function", task characteristics and integration</u>**

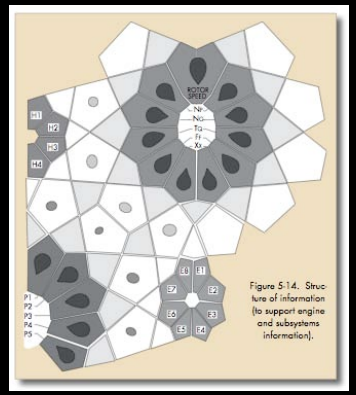
Methods and Tools for Validation and Verification

Work Domain Analysis

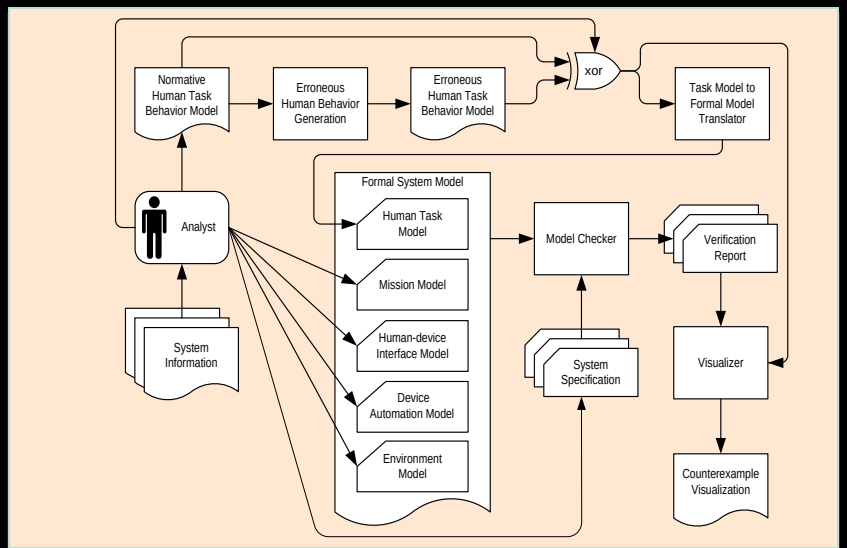


Visualization





Human – System Performance Analysis



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

Defining the Mission

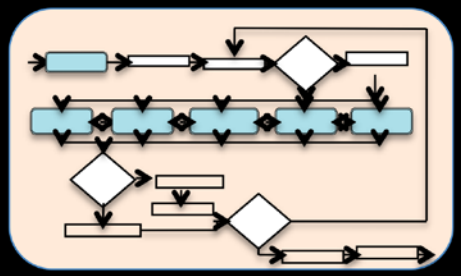
How well can we describe the work?

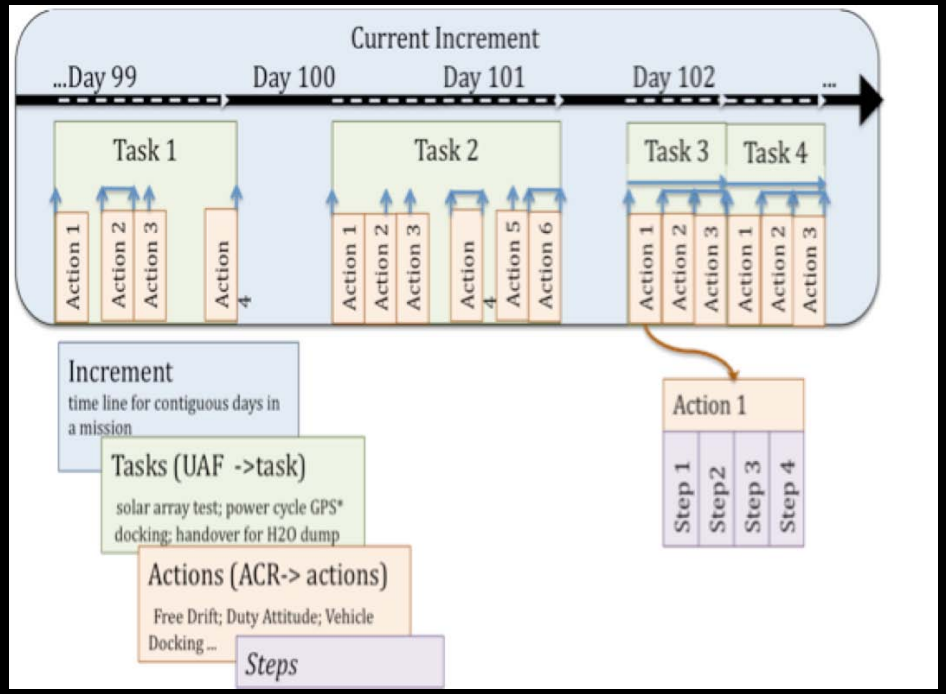
- **Background:**
  - Difficult problem (CTA 15+ year history)
  - Time with domain experts is expensive and limited
  - Accurate task descriptions are critical
  - Current task analysis methods request detailed action sequence information, which is time consuming, and problematic

- **Focus Issues:**
  - How can we involve domain experts in the task analysis process most efficiently?
  - How can identify work structures and prioritize important work themes?
  - What level of description detail is necessary?
    - Need performance metrics/utility functions

Work Domain Analysis

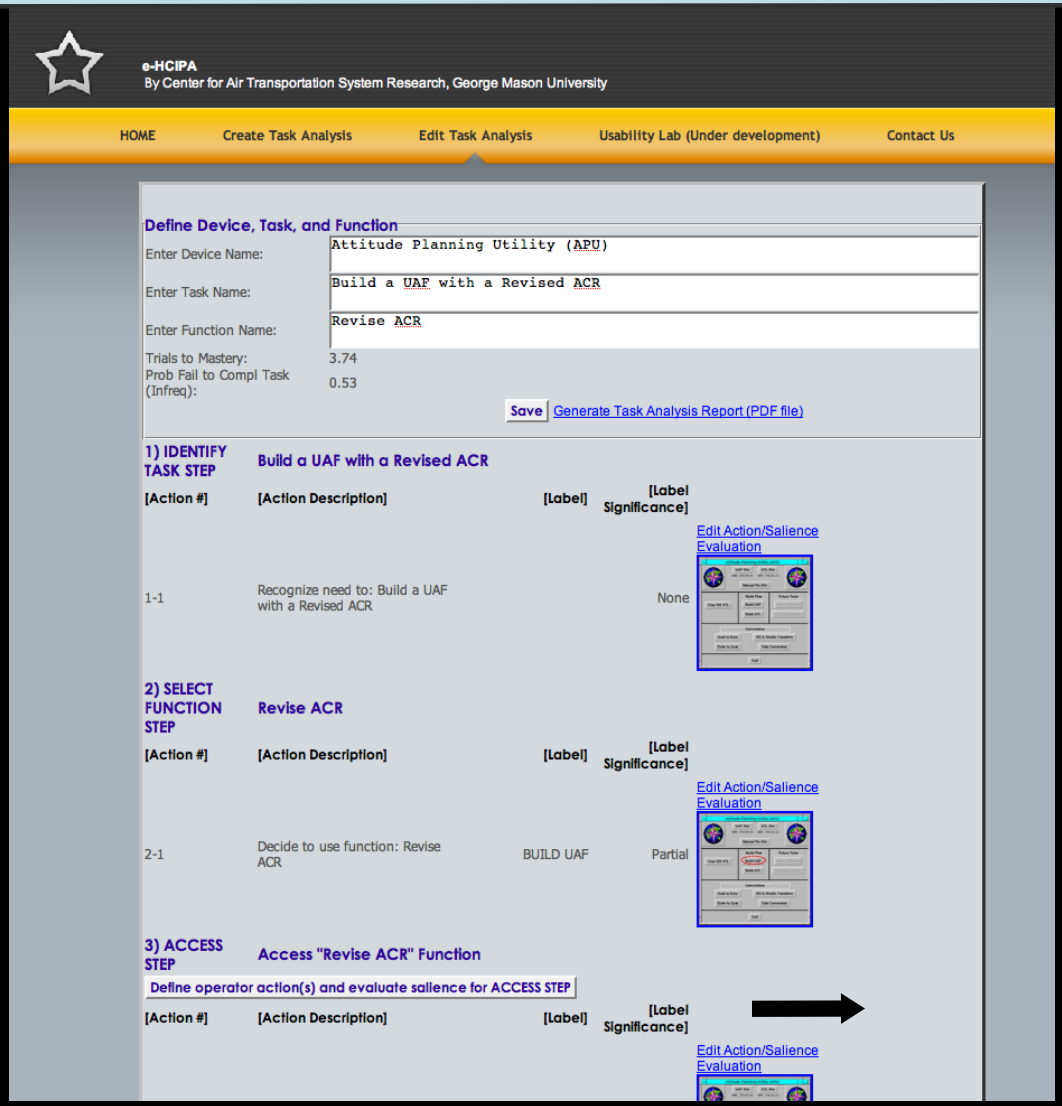
Minimum Information: Description of tasks/products, and utility functions





Product diagrams (Billman, Feary, Schreckenghost, Sherry,)

Task Analysis Tools



Medina, Sherry, Feary (2008)

Research Approach

- **Understanding the Problem**
  - Domain Characterization and Representing the Work Context
  - Visualization of the problem and solution space

- **Evaluating Human-System Performance**
  - Human Performance Analysis
  - Formal Verification of Integrated Human-Automation Systems

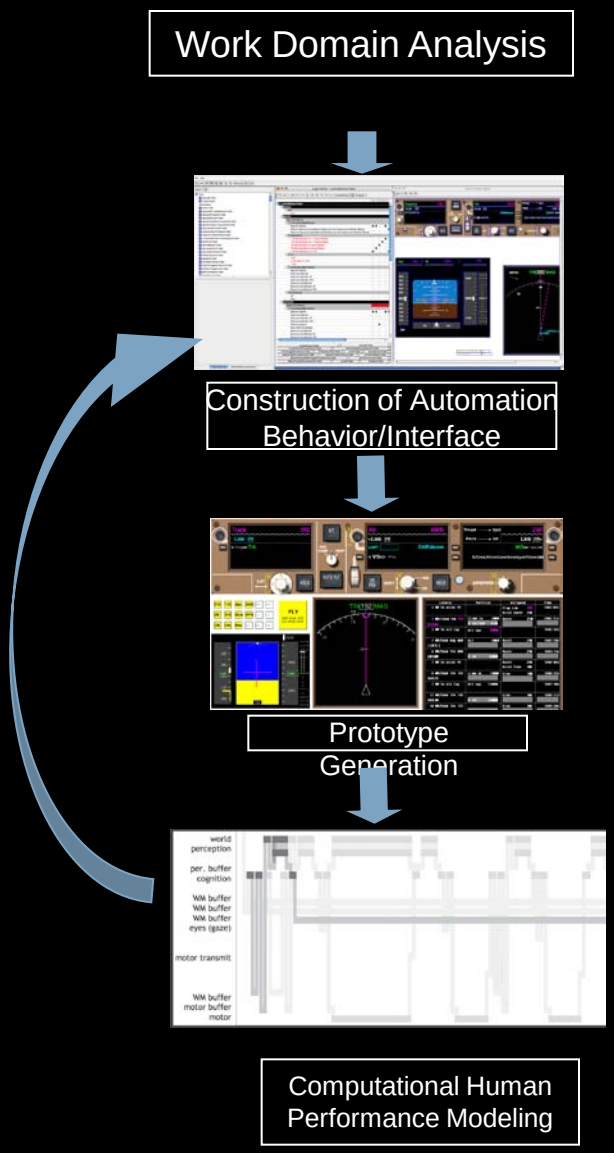
Visualization

See Chuck's talk

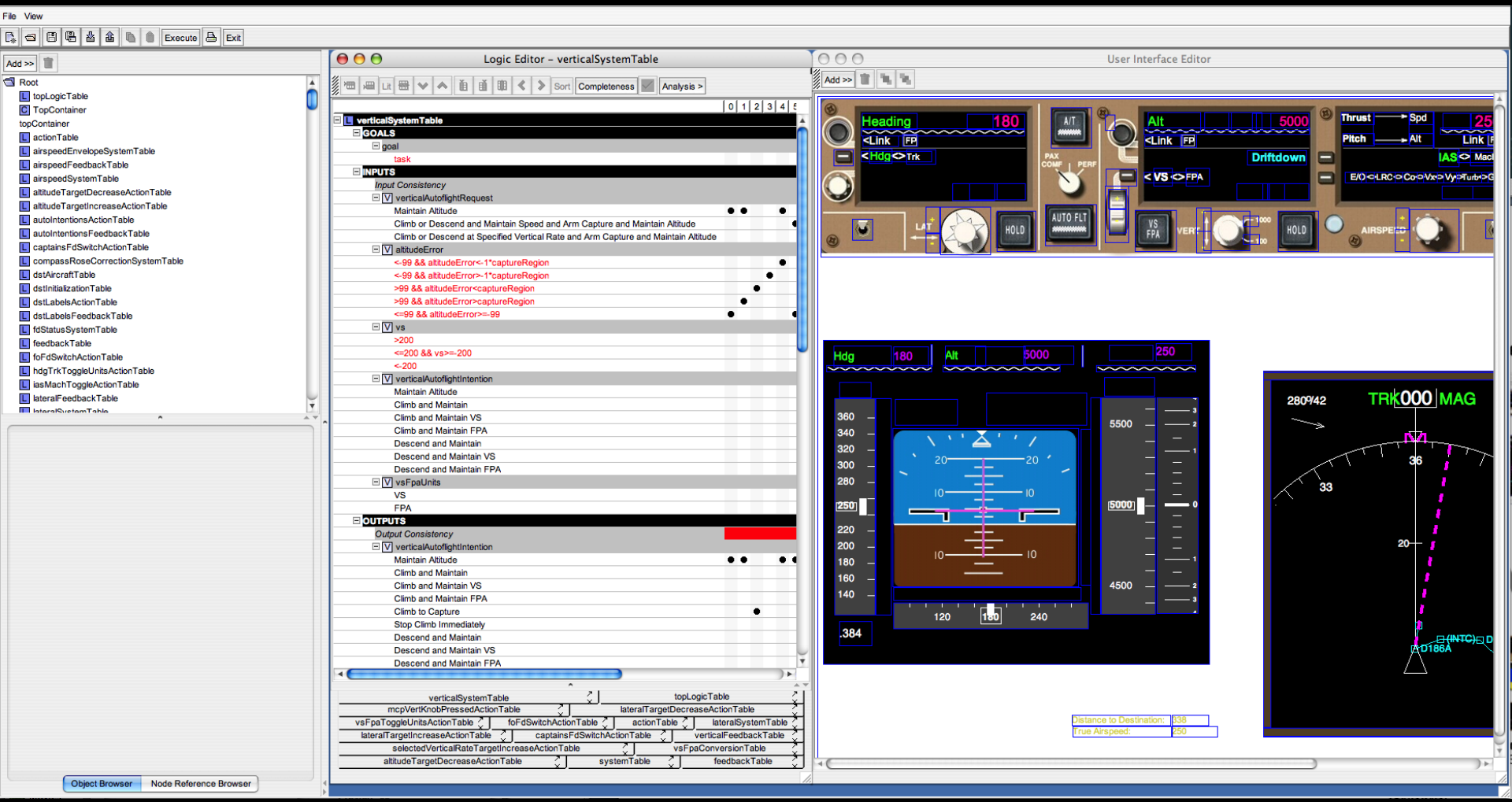
Human – Systems Analysis

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

- **Challenges:**
  - What development work needs to be done to enable human performance modeling optimize a design in the design process timeframe?
  - Can provide metrics and parameters that are directly applicable to design issues?
  - Can we provide methods and tools usable within design process constraints?
  - Can we computationally optimize strategies/action sequences?
  - Need the utility functions
  - Procedure generation can be seen as a reachability (and hence model checking) problem.



Specification of Automation and Interface Behavior in ADEPT



Logic Editor

User Interface Editor

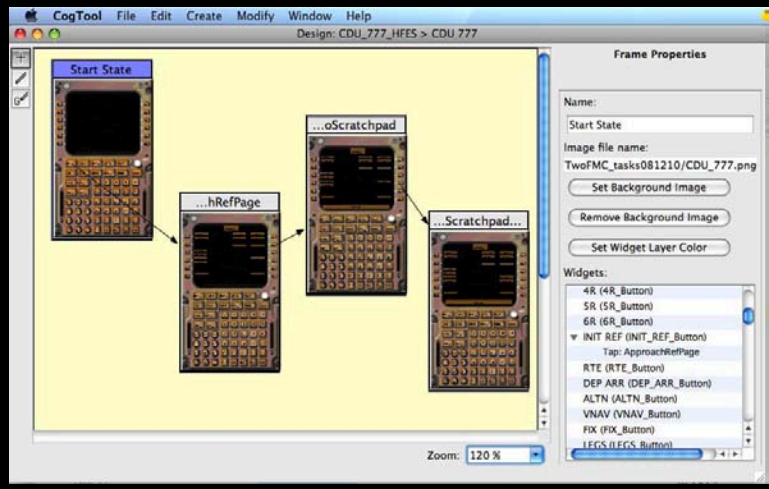
Human Performance Analysis

Aviation CogtoolExplorer with SemanticAnalysis (Carnegie-MellonUniv.)

•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 anaviation “corpus” database that simulatestheknowledge of typicalairline 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

END

Thank you

For more info: Michael.S.Feary@nasa.gov