

AUTOMATED TOOL FOR TASK ANALYSIS OF NEXTGEN AUTOMATION:

ACCELERATING AIRLINE DEPLOYMENT OF
NEXTGEN WITH TASK ANALYSIS TOOLS

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Outline

1. Problem Statement
2. Research Objectives
3. Research Approach & Enabling Technologies
 - Industry Reqs for Tool
 - Operator Performance Model
 - Executable Models
 - Empirical Models
4. Example Application
5. Conclusions and Future Work

(1) Problem Statement – Life-cycle Costs

- Airline cost of deployment of cockpit automation (e.g. data-link, ADS-B, 4-D trajectory) = 5X-10X cost of equipment
 - Procedure redesign and testing
 - Training redesign and testing
 - Training and Proficiency Checks

(1) Problem Statement – Airline Cost Pressures

- Airline lean-processes, low-cost business models placing cost pressure on operator training and operational efficiency
 - Not acquisition costs (only)
 - Boeing CAG (Boorman, 2007; Castor-Peck, 2007), Rockwell-Collins, Smiths, Honeywell, Airbus Industries,
 - Southwest Airlines, United Airlines, Boeing – CAG/Flight Safety
 - Google, MOD – International Space Station (ISS) – Attitude Direction and Control (ADCO) (Ward, et al, 2007)
- Operator training/operational efficiency determined by Human-Computer Interaction (HCI)

(1) Problem Statement – Sub-optimum Designs

- Existing HCI methods applied in industry fail to meet the training/operational efficiency criteria
 - Surveys have revealed that majority (~ 75%) of device functions are not optimized for training/operational efficiency (Sherry, Feary, LeGoullon, Yaacoubi, Medina, 2002 – 2007)
 - Infrequently used functions tend to be buried
- HCI methods tend to focus on ergonomics and expert time-on-task (not training and op efficiency)
 - State-of-the-art in cognitive modeling is expert time-on-task

(1) Problem Statement – Methods Cost Prohibitive

- Current methods cannot meet demand for HCI analysis across the contractor-base
 1. HCI is not required by SDRL, certification
 2. Subject User Testing – cost prohibitive, late in life-cycle
 3. Inspections, Walkthroughs – earlier in life-cycle, but poor inter-rater reliability
 4. Comprehensive reviews of all mission tasks
 - Reviews – cost prohibitive to review all mission tasks
 - Infrequently performed safety/critical tasks
 - “Corner-cases”
 5. Distributed development teams
 6. Many decisions made in the software design “trenches”
 - No time/place for inspections/reviews
 7. “Affordable” Operator Performance Models are immature (focus on expert time-on-task)

(2) Research Objectives

Objective:

“Provide standardized analytic methods and tools, which enable deployment teams to make informed decisions about Human - Automation Interaction (HAI) at critical times in the design process. “

Research Requirements:

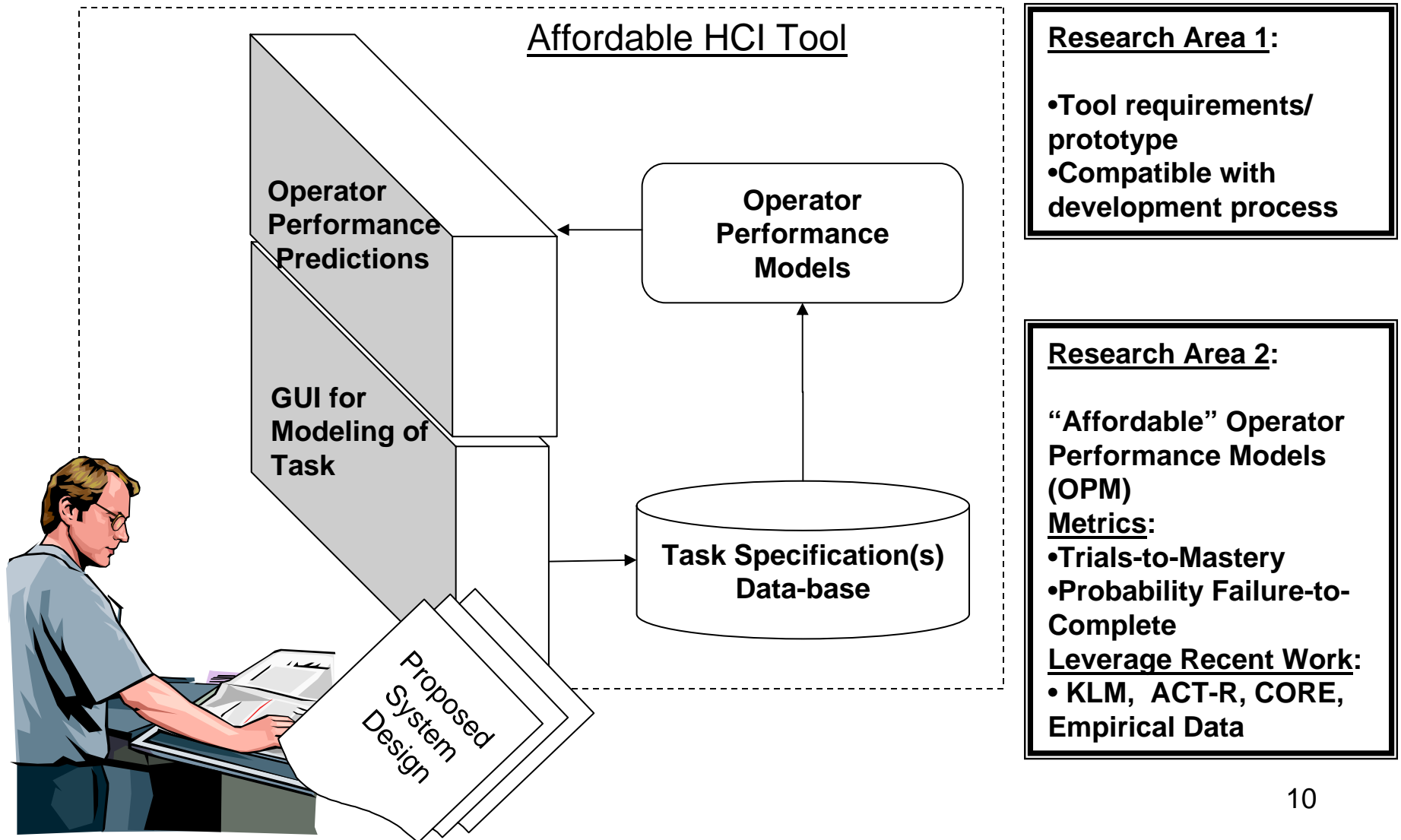
- 1. Provide methods and tools which are usable by designers without extensive training or expertise**
- 2. Provide performance metrics and parameters that are directly applicable to design issues**
- 3. Focus on cognitive aspects of Human-Automation Interaction that drives performance**
- 4. Compatible with business processes**

(2) Research Objectives

Payoff:

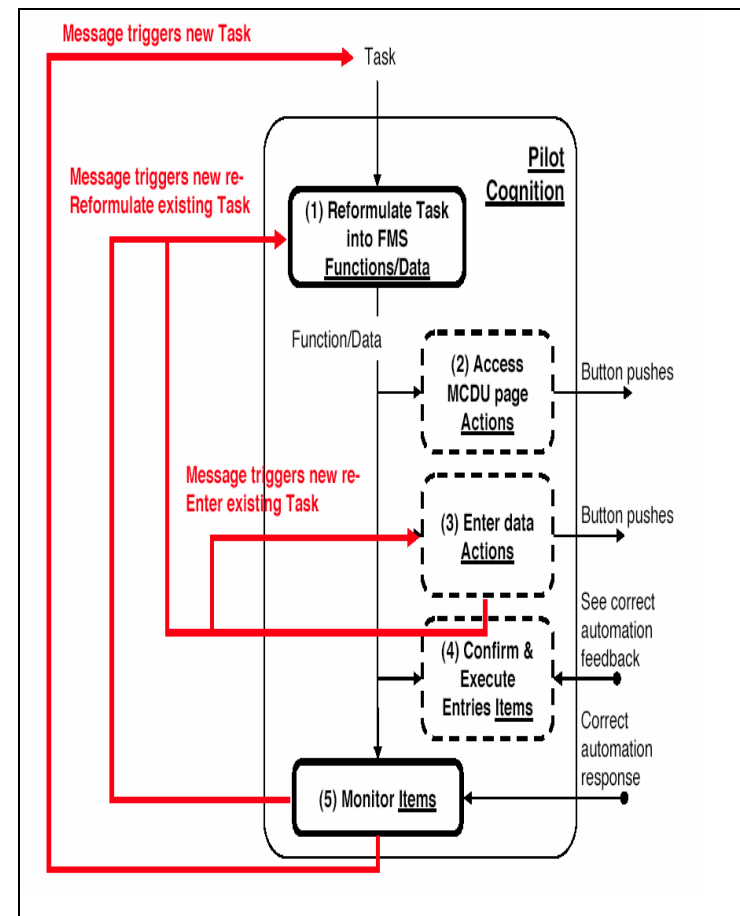
- **Successful tools will help enable cost-effective deployment of NextGen technologies**

(3) Research Approach



(3) Research Approach – HCIPA Method

- Theoretical basis in Cognitive Complexity Theory (Kieras, Polson)
- Structure derived from Cognitive Walkthrough (Lewis, et al)
- Field tested (C-130, B777, Desktop Apps, ...)



(3) Research Approach “Affordable Operator Performance Models”

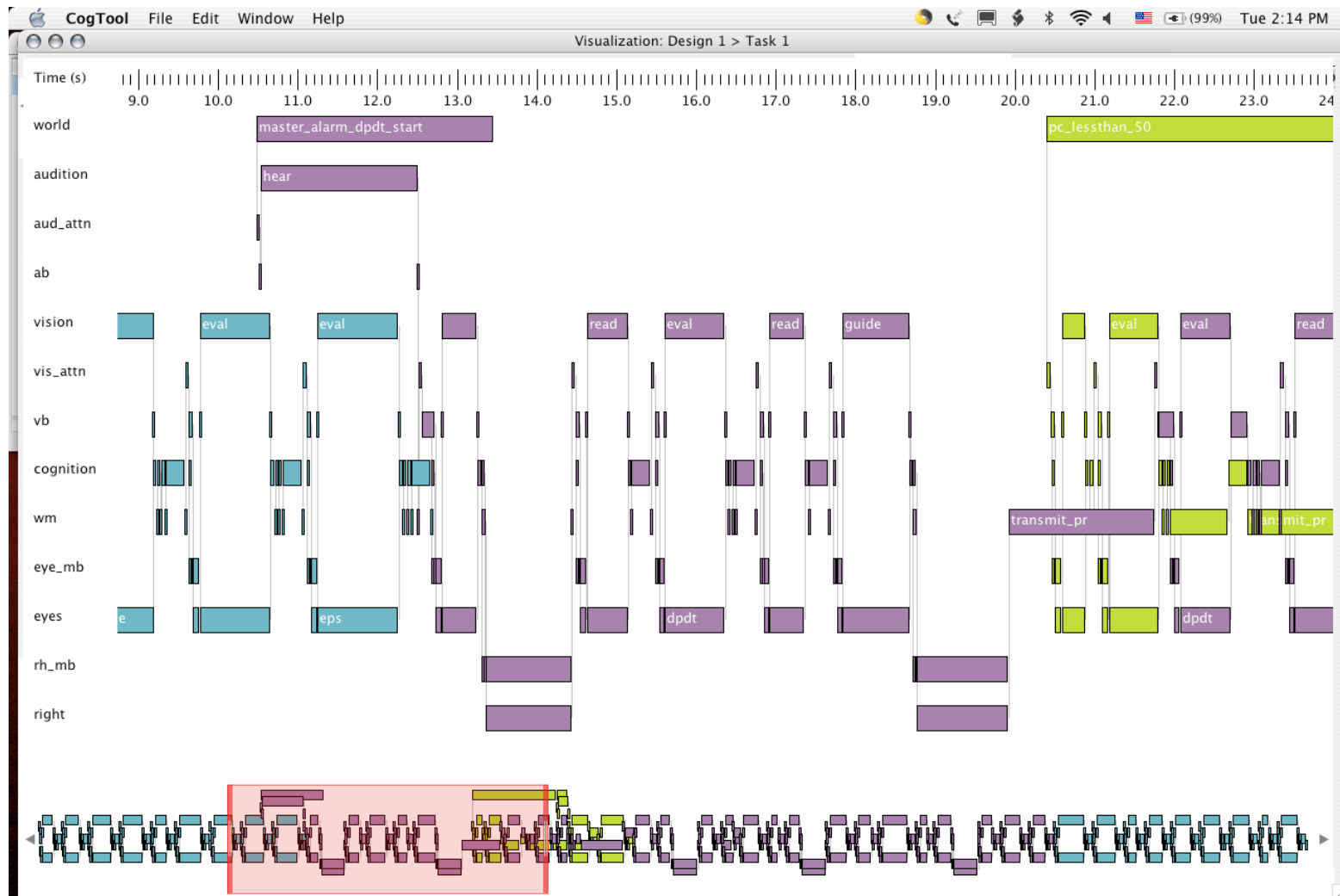
- Recent advances in Operator Performance Models (ACT-R, CORE, ...) have yielded tools for automation of HCI analysis (e.g. Cog Tool, John et al 2004)
- Opportunity to:
 - Conduct reviews early in life-cycle
 - Low cost
 - Accurate/Good inter-rater reliability
 - Available across distributed contractor-base

(3) Operator Performance Models – Executable Models

- ACT-R (Anderson, 1973, 1990, 1998)
 - ACT-R is a cognitive architecture
 - John Anderson at Carnegie Mellon University
 - Defines basic and irreducible cognitive and perceptual operations that enable the human mind
 - Human task consists of a series of these discrete operations
- CORE (Howes et al., 2004)
 - multiple tasks in tandem, operators interleave
 - basic cognitive, perceptual and motor processes are ordered
 - explore range multitasking strategies.

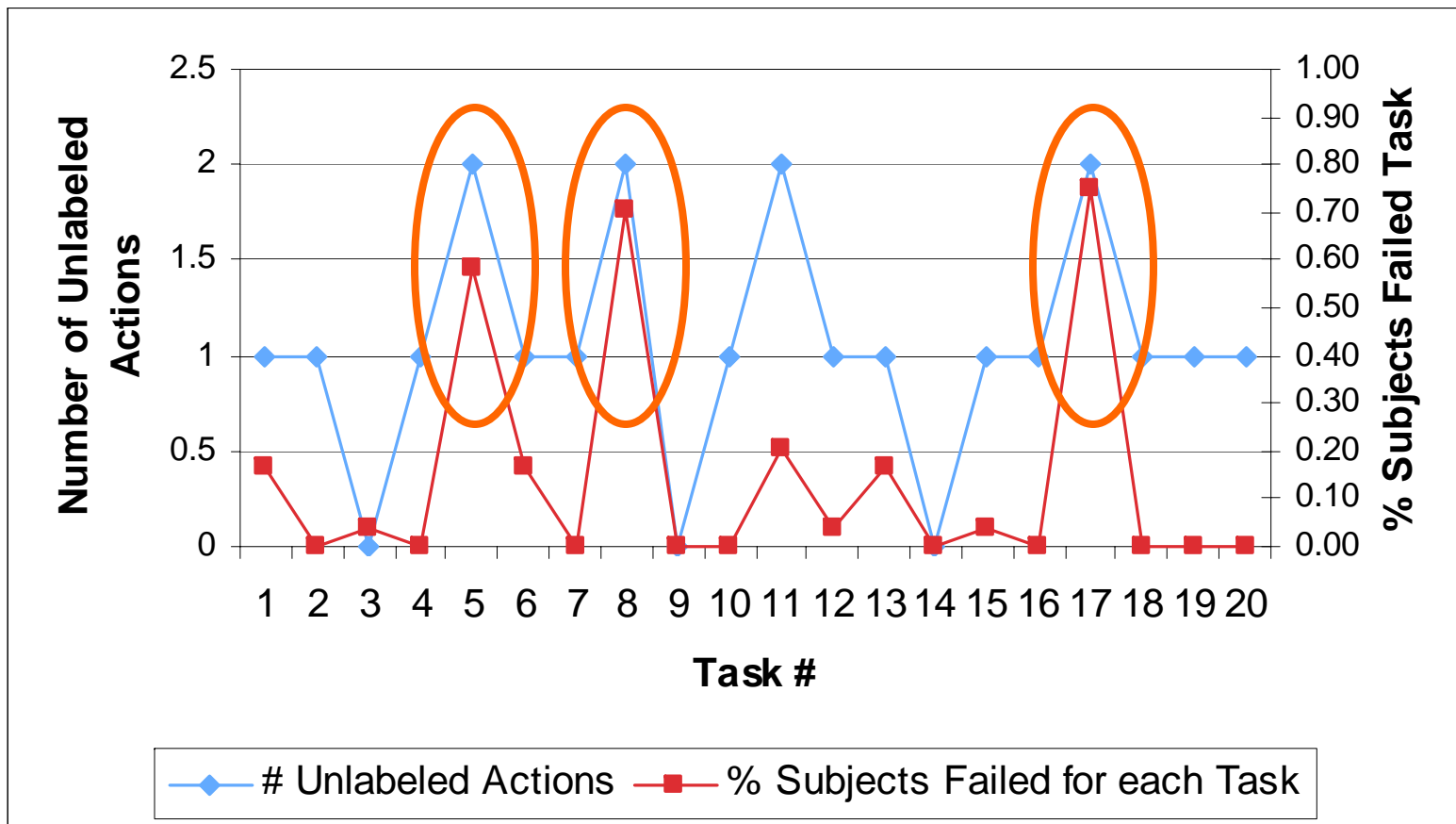
(3) Operator Performance Model - CORE

Cognitive Steps required to perform a task (cognition interleaving shown)



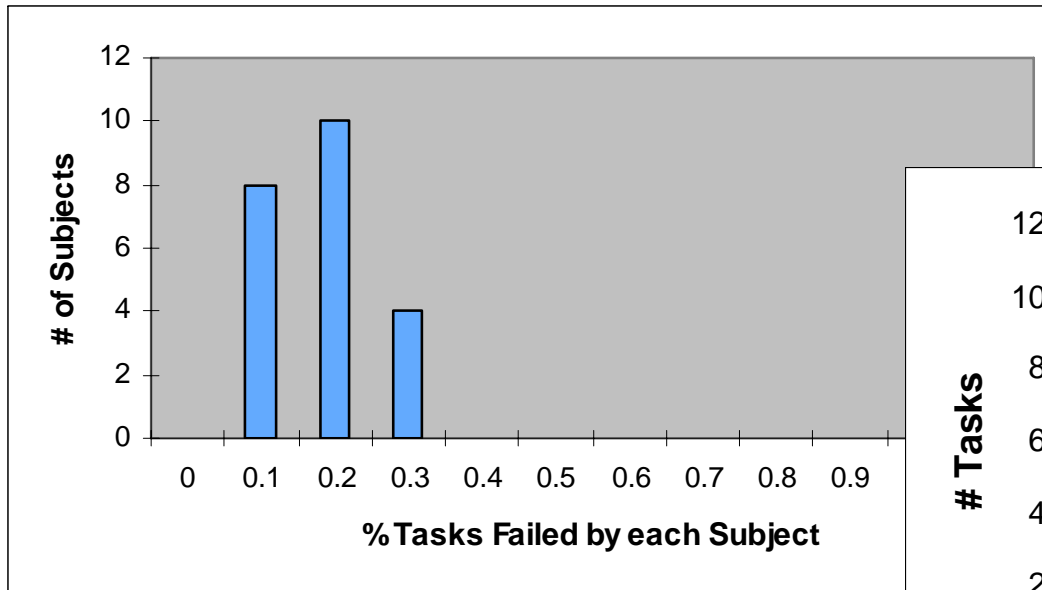
(3) Operator Performance Models - Empirical

Empirical subject data – C-130



(3) Operator Performance Models - Empirical

C-130



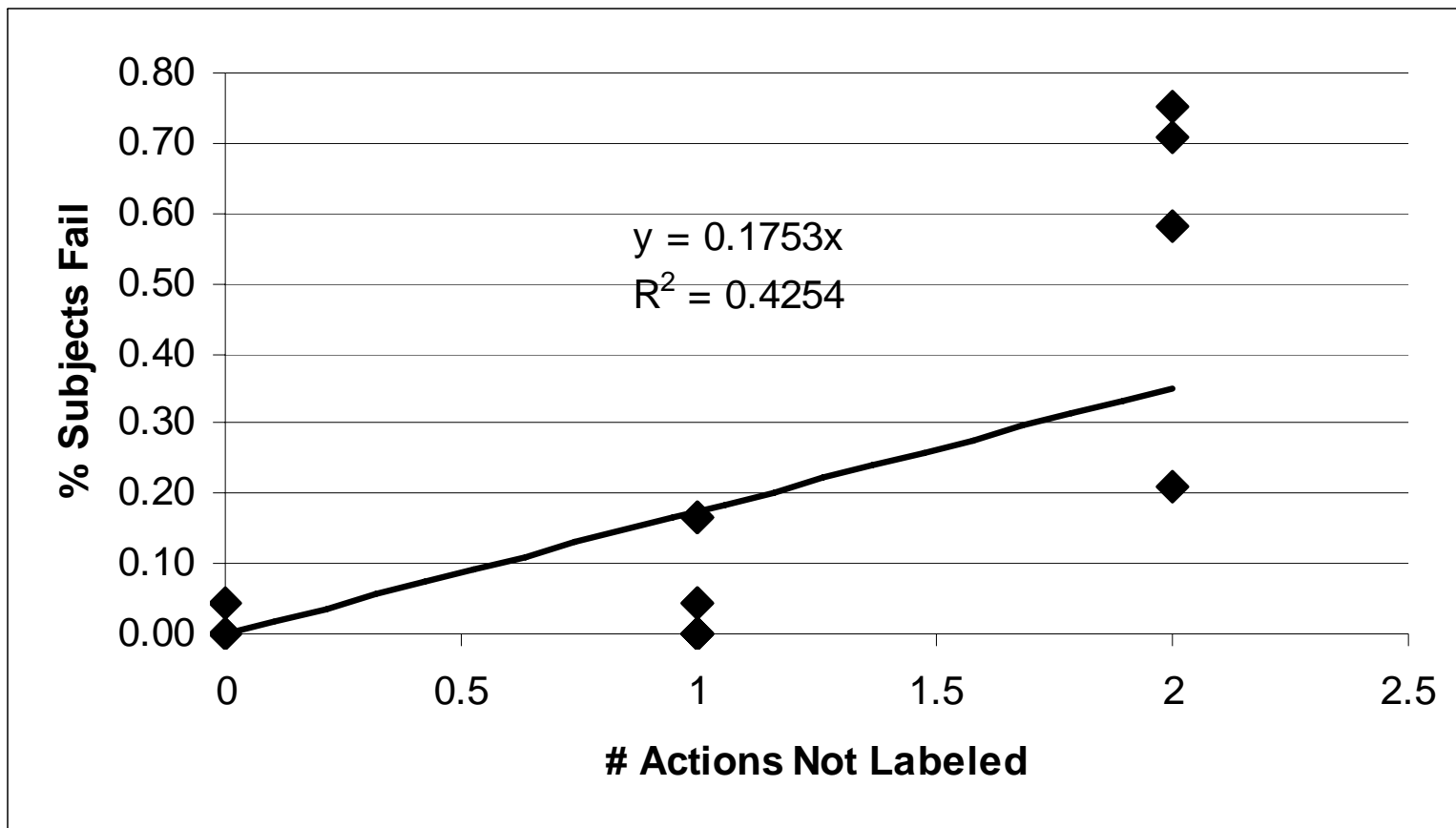
Operators equally likely to fail to complete a task



Some tasks more likely to not be completed than others

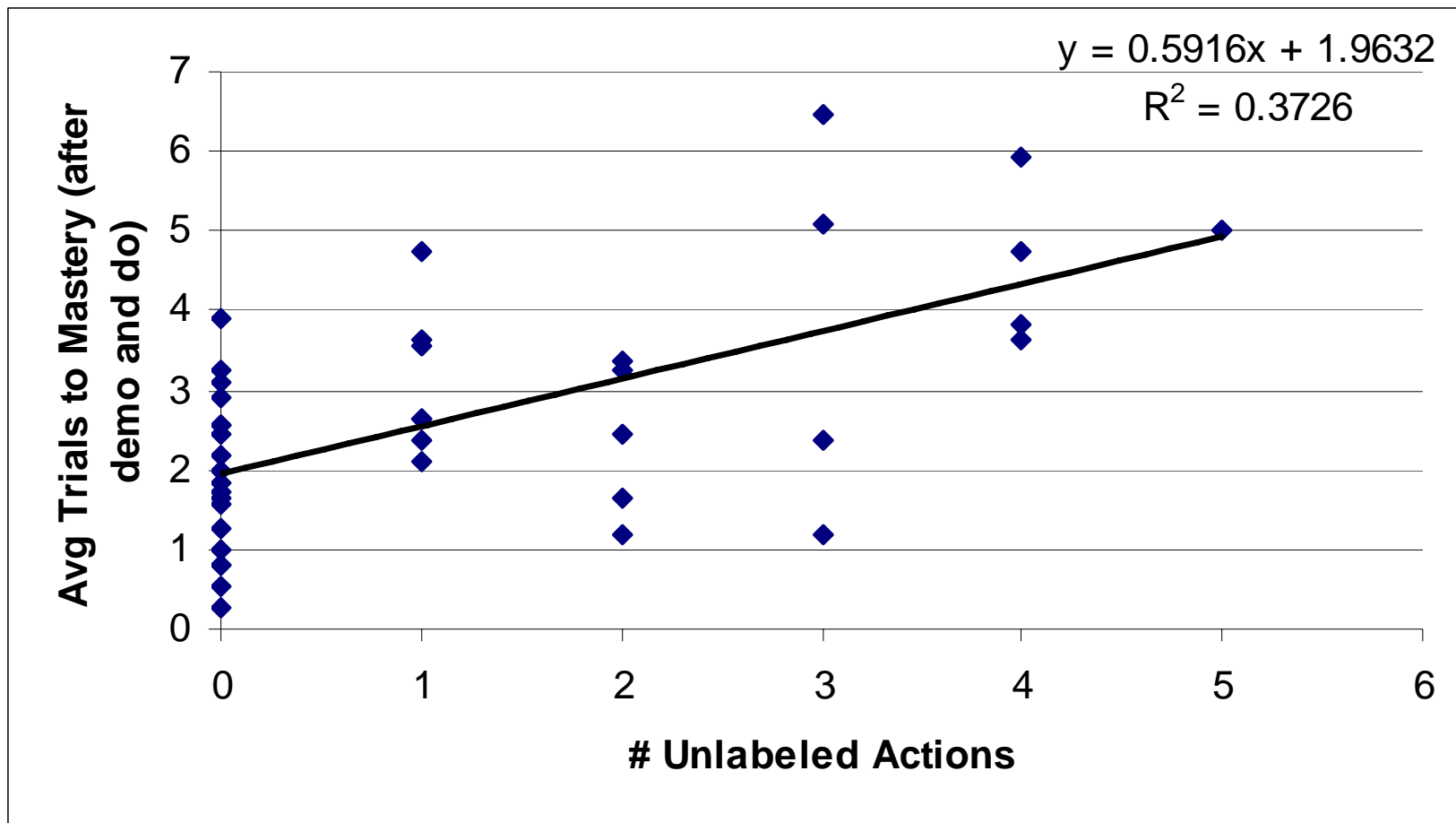
(3) Operator Performance Models - Empirical

C-130



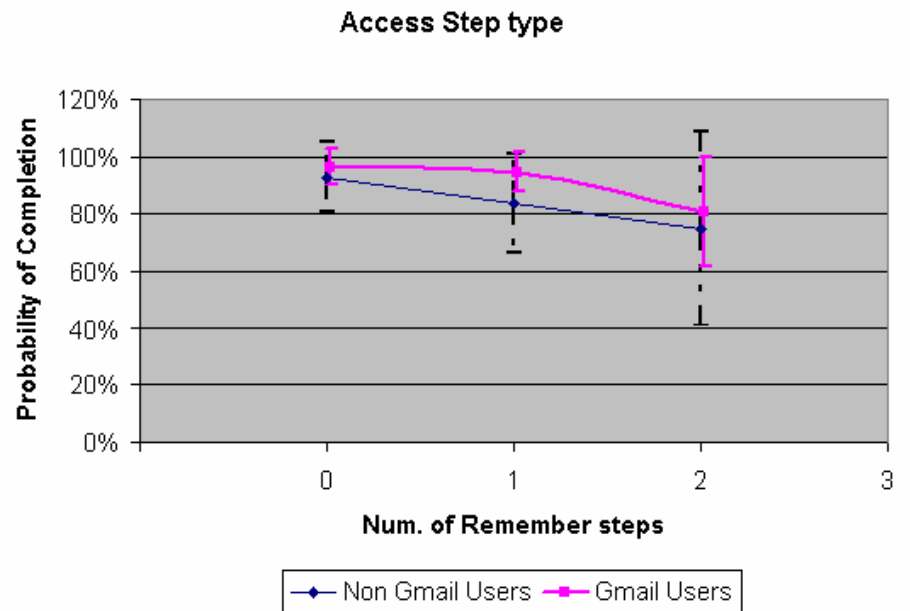
(3) Operator Performance Models - Empirical

B-777



(3) Operator Performance Models - Empirical

- Google migrating into development of Decision Support Tools
- Human-in-the-loop study of Google design practices
 - large variance in performance as unlabeled steps > 1



(4) Prototype Task Analysis Tool

The screenshot shows the 'Create Task Analysis' page of the tool. The navigation bar includes 'HOME', 'Create Task Analysis', 'Edit Task Analysis', 'Usability / Training Lab (Under dev)', and 'Contact Us'. The main form is titled 'Define Device, Task, and Function' and contains the following fields:

- Task #: 32
- Enter Device Name: Attitude Planning Utility (APU)
- Enter Task Name: Build a UAF with a Revised ACR
- Enter Function Name: Revise ACR

Below these fields are two statistics: 'Trials to Mastery: 3.74' and 'Prob Fail to Compl Task (Refers): 0.53'. There are links for 'Task Analysis' and 'User Guideline', and a 'Generate PDF Reports' button.

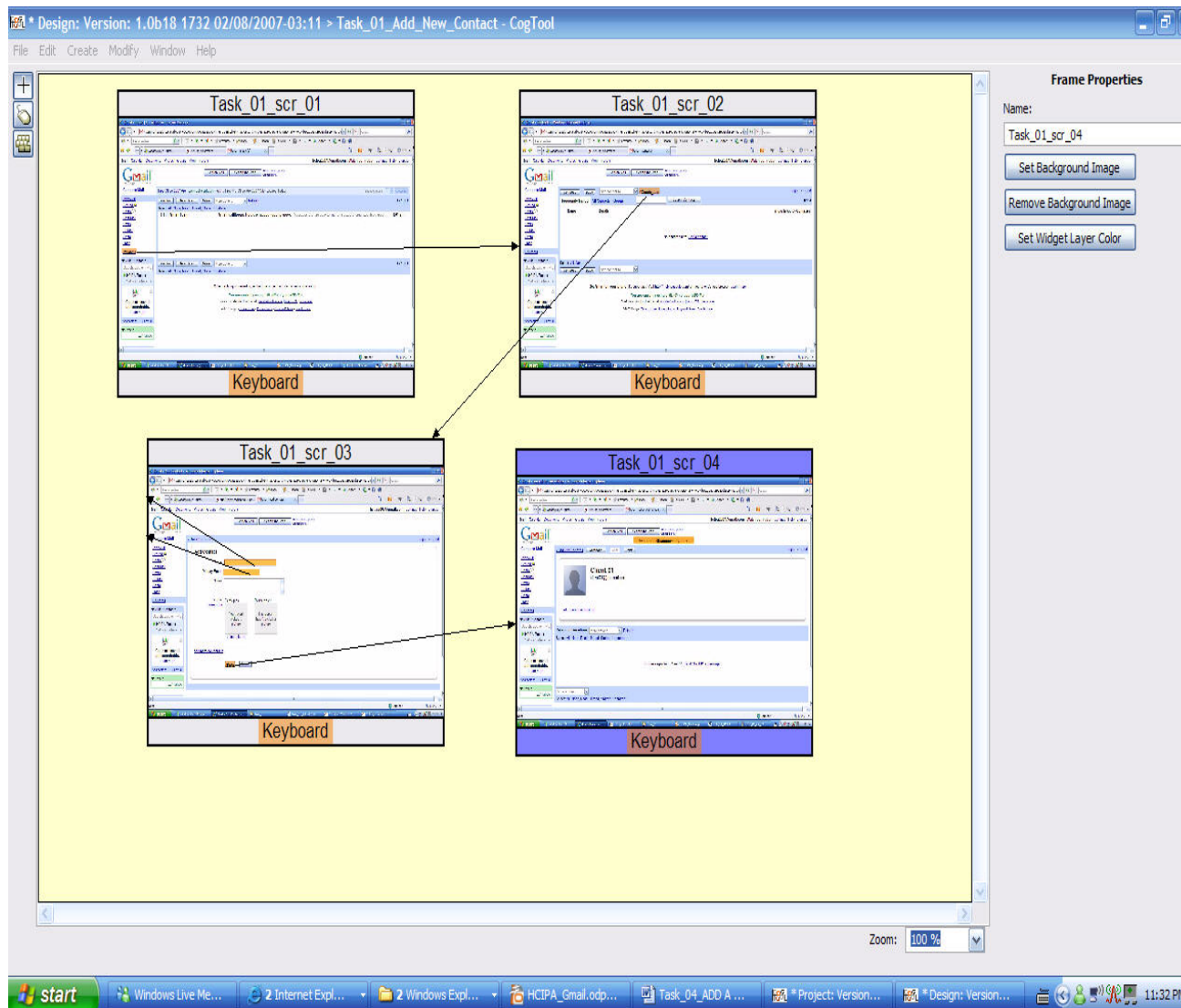
The '1) IDENTIFY TASK STEP' section shows a table with columns for '[Action #]' and '[Action Description]'. The first entry is 'Build a UAF with a Revised ACR'.

An inset window titled 'CONFIRM & SAVE STEP: Confirm & Save data using "Revise ACR" Function Action #: 5-1' is shown. It includes an 'Edit Next Action' link, an image selection area, and a 'UAF Generation Window' with a table of actions. The 'UAF Generation Window' table has columns for 'Author', 'GMT', 'Year', 'Rev', 'Activity', 'Day', and 'ACW'. The 'Revise ACR' button in this window is circled in red.

Callouts provide the following information:

- Designer specifies Task, Function(s), Operator Actions, and Visual Cues**: Points to the task and function name fields.
- Estimates from Operator Performance Model:**
 - (1) Trials-to-Mastery
 - (2) Probability Failure-to-Complete
- Automatic Report Generation**: Points to the 'Generate PDF Reports' button.

(4) Prototype task Analysis Tool



- CogTool Storyboard Task 01: Add a contact
- John et.al. (2004)

7. Airline Flight-deck Example #4

TASK:

- During pre-flight taxi-out, ATC changes the departure runway



REFORMULATE

- **REMEMBER** DEPARTURES “function” allows pilot to insert RUNWAYS, SID, and SID TRANSITION into LEGS (Note: Not RTE or LEGS “function”)

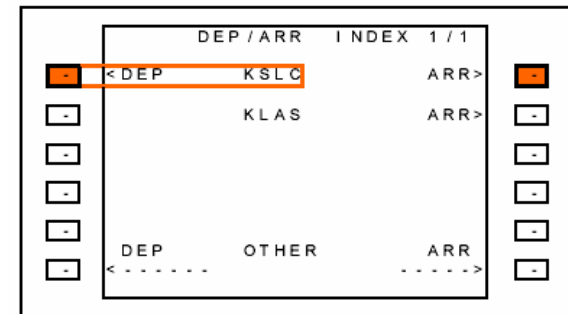
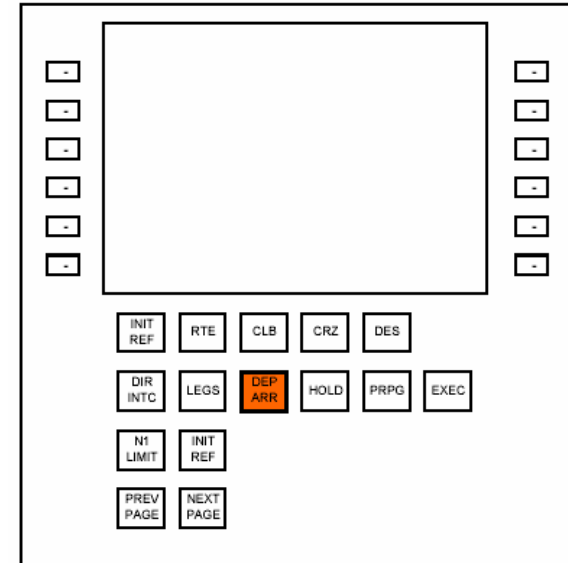


7. Airline Flight-deck Example

#4

Access

- **SEE** Mode Key labeled “DEP ARR” to access DEP/ARR INDEX menu (Press)
- **SEE** LS 1L labeled < DEP KSLC to access KSLC DEPARTURES (Press)



7. Airline Flight-deck Example #4

ENTER:

- **INFREQUENT REMEMBER** “CHANGE ONE, CHANGE ALL” When changing SID, Runway or SID Transition reselect each one again (even though displayed <ACT>. This avoids losing waypoints in the LEGS
- **SEE** List of eligible SIDS listed under 1L field labeled SIDS
- **SEE** List of eligible Runways listed under 1R field labeled RUNWAYS
- **REMEMBER** List of eligible SID TRANSITIONS is displayed only after SID and RUNWAY have been selected
- **SEE** List of eligible SID TRANSITIONS listed under 2L field labeled TRANS

KSLC DEPARTURES 1 / 1		
SIDS	RUNWAYS	
<input checked="" type="checkbox"/> FFV6 <ACT>	14	<input type="checkbox"/>
<input type="checkbox"/> SEVYR1	<input checked="" type="checkbox"/> <ACT> 16L	<input type="checkbox"/>
<input type="checkbox"/>	16R	<input type="checkbox"/>
<input type="checkbox"/>	17	<input type="checkbox"/>
<input type="checkbox"/>	32	<input type="checkbox"/>
<input type="checkbox"/> <INDEX	ROUTE>	<input type="checkbox"/>

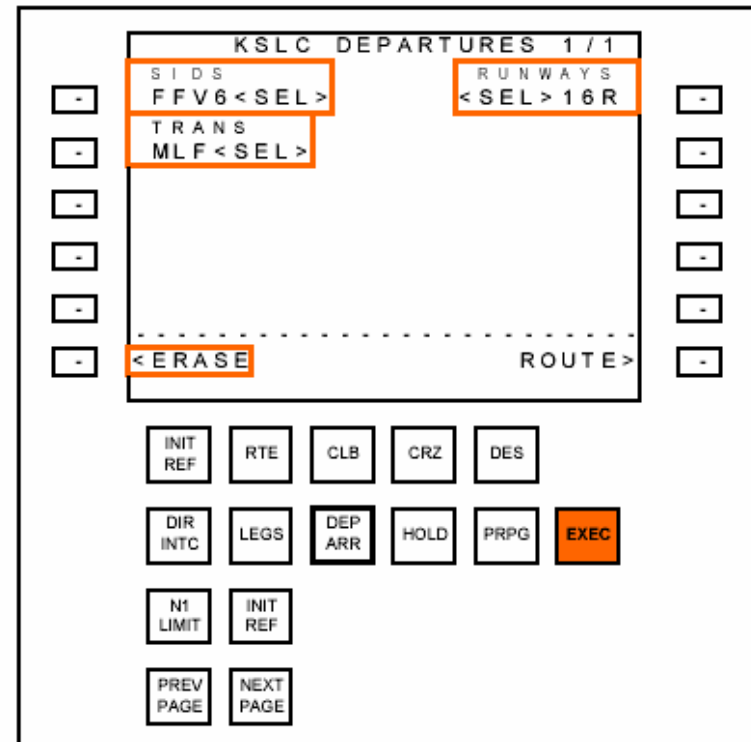
KSLC DEPARTURES 1 / 1		
SIDS	RUNWAYS	
<input type="checkbox"/> FFV6 <SEL>	<input checked="" type="checkbox"/> <SEL> 16L	<input type="checkbox"/>
<input type="checkbox"/> TRANS		<input type="checkbox"/>
<input checked="" type="checkbox"/> MLF		<input type="checkbox"/>
<input type="checkbox"/> ZYX		<input type="checkbox"/>
<input type="checkbox"/>		<input type="checkbox"/>
<input type="checkbox"/> <INDEX	ROUTE>	<input type="checkbox"/>

7. Airline Flight-deck Example

#4

VERIFY

- **INFREQUENT REMEMBER** “CHANGE ONE, CHANGE ALL” When changing SID, Runway or SID Transition reselect each one again (even though displayed <ACT>. This avoids losing waypoints in the LEGS
- **SEE** <SEL> indicates selected
- **SEE** <ERASE prompt is displayed after selection of SID, Runway, or SID Transition
- **SEE** EXECute Mode Key is illuminated
- **REMEMBER** Confirm changes when EXECute Mode Key is illuminated
- **SEE** EXECute Mode Key is illuminated, press EXECute key



7. Airline Flight-deck Example #4

MONITOR:

- **SEE LEGS** includes desired Runway, SID waypoints, and SID Transition waypoints.
- **SEE LEGS** does not include a –ROUTE DISCONTINUITY – between SID or SID Transition waypoints
- **SEE ND** shows desired course and sequence of waypoints

ACT	RTE	LEGS	1 / 2
1 6 1*		3 2NM	
FFU		2 93 / FL 2 0 7	
1 7 0*		4 9NM	
LODUY		. 7 0 2 / FL 3 4 4	
1 7 3*		2 0NM	
URNUW		. 7 0 2 / FL 3 7 0	
2 0 9*		6 3NM	
MLF		. 7 0 2 / FL 3 7 0	
1 9 0*		1 1 0NM	
KSI NO		2 8 0 / FL 1 8 8	
RNP / ACTUAL		-----	
1. 0 0 / 0. 0 5NM		RTE DATA>	

7. Airline Flight-deck Example #4

HCIPA Analysis:

- 15 Actions
- 4 Remembers
 - 1 Infrequent
- 11 Sees

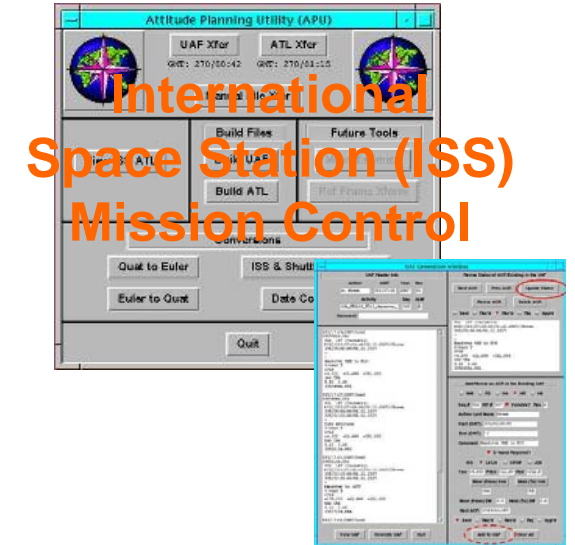
Notes:

- FMS not well designed, despite regulatory requirements and industry intentions
 - 25% of 101 mission tasks satisfied minimum criteria for learnability & usability
 - 64% of error messages satisfied minimum criteria for learnability & usability

- Graphical User-interfaces are not “silver bullet”
 - Simply transfer Remembers for Entry to Access steps
 - Do not solve Reformulate problems
- Granularity of tasks
 - Use Mission Tasks, create hierarchy if necessary
 - Typing of entry is too small granularity

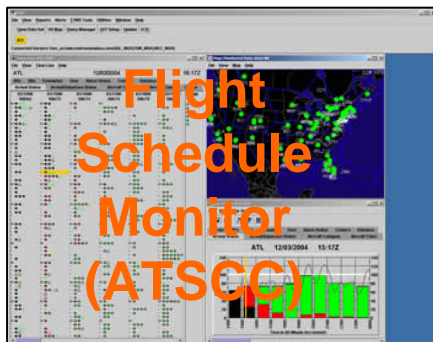
(5) Conclusions & Future Work

- NASA NextGen Data Comm
- Boeing 787 Design
- Boeing 787 Training
- Boeing Flight Deck of the Future
- SWA RNP Procedures
- United Airlines TK

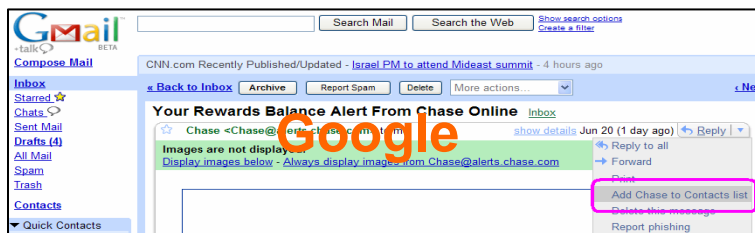
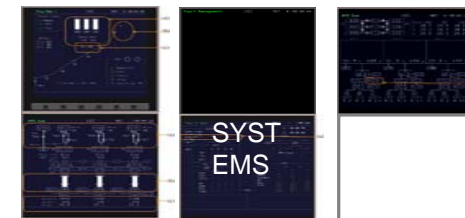
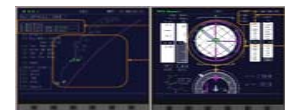


International Space Station (ISS) Mission Control

Space Shuttle/Constellation Cockpit Design



Flight Schedule Monitor (ATSCC)

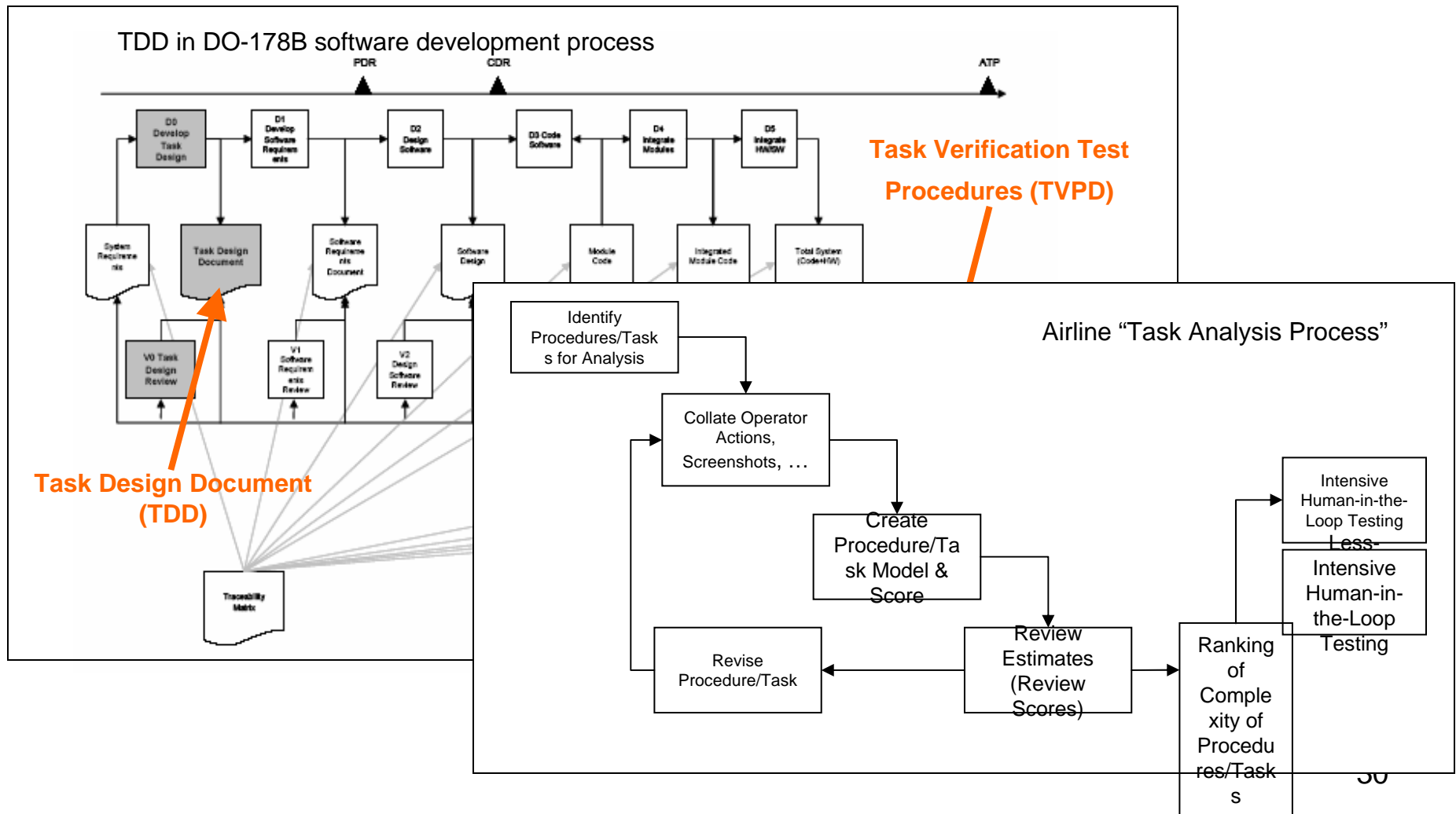


Google

(5) Future Work

- Future Work
 - Test prototype tool on SWA, UAL, others
 - Configure and calibrate Operator Performance Models
 - Work with industry to integrate into development processes
 - Automate salience assessment process to improve inter-rater reliability

(5) Future Work – Integrate into Industry Process



(5) Future Work Assessment of Saliience of Visual Cues

- Big issue is inter-rater reliability (Hertzum, et al, 1997)
- HCIPA – designers must rate Saliience of each Visual Cue
- Proposal to automate this assessment using results from Latent Semantic Analysis (Landuaer, Blackmon)/SNIF-ACT (PARC) literature

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- <http://catsr.ite.gmu.edu/HCIPA>

- www.ICRAT.org (June 2-6)