System-Wide Accident Prevention: Human Performance Modeling

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Outline of Topics

• Problem, Approach and Goal
  – Errors and accidents in Aviation
  – Model development plan

• Developing Cognitive Modeling Tools for System Design
  – Overview of 5 modeling frameworks
  – Application to taxi-navigation problem
  – Application to approach and landing operations with and without augmented displays

• Developing an Activity Tracking Model for Error Detection and Analysis
  – Overview of CATS (Crew Activity Tracking System)
  – Application to flight test data
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 ($1 \times 10^{-n}$)
- 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

**Goal**

Develop modeling capability to:
- Assess technological and procedural solutions via development of computational models of scenarios and candidate solutions
- Test potential mitigation strategies
**Plan FY00-FY04**

**Two Development Tracks**

- **Human Performance Modeling**
  - Aviation Error Contexts
  - Review of Models
  - RFP Letter (formal review)

- **Error Detection Modeling - Crew Activity Tracking System (CATS)**
  - Taxiway Errors
  - Approach / Landing w/ Aug. Displays
  - Off-line Flight Data Analysis
  - Error Mechanism
  - Multiple A/L Scenarios w/ Aug. Displays
  - Validation
  - Error Simulation with CATS Agents

*Multiple models addressing same operational problem*

**Plan Constraint: limited resources for supporting empirical work**
## Characteristics of selected models

- Operator level, cognitively oriented
- Comprehensive, mature and validated systems
- Integrative frameworks facilitating fast-time simulation
- Output is generative, stochastic, context sensitive

<table>
<thead>
<tr>
<th>Model</th>
<th>Type</th>
<th>Research Team</th>
<th>Demonstrated Sources of Pilot Error</th>
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</thead>
<tbody>
<tr>
<td>ACT-R/PM</td>
<td>Low-level Cognitive with Statistical Environment Representation</td>
<td>Mike Byrne&lt;br&gt;Rice University&lt;br&gt;Alex Kirlik&lt;br&gt;University of Illinois</td>
<td>* Time pressure&lt;br&gt;* Misplaced expectations&lt;br&gt;* Memory retrieval problems</td>
</tr>
<tr>
<td>Air MIDAS</td>
<td>Integrative Multi-component Cognitive</td>
<td>Kevin Corker&lt;br&gt;Brian Gore&lt;br&gt;Eromi Guneratne&lt;br&gt;Amit Jadhav &amp; Savita Verma&lt;br&gt;San Jose State University</td>
<td>* Workload&lt;br&gt;* Memory Interference&lt;br&gt;* Misperception</td>
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<tr>
<td>A-SA</td>
<td>Component Model of Attention &amp; Situational Awareness</td>
<td>Chris Wickens&lt;br&gt;Jason McCarley&lt;br&gt;Lisa Thomas&lt;br&gt;University of Illinois</td>
<td>* Misplaced attention&lt;br&gt;* Lowered SA</td>
</tr>
<tr>
<td>D-OMAR</td>
<td>Integrative Multi-component Cognitive</td>
<td>Stephen Deutsch&lt;br&gt;Richard Pew&lt;br&gt;BBN Technologies</td>
<td>* Communications errors&lt;br&gt;* Interruption &amp; distraction&lt;br&gt;* Misplaced expectation</td>
</tr>
<tr>
<td>IMPRINT/ACT-R</td>
<td>Hybrid: Task Network with Low-level Cognitive</td>
<td>Rick Archer&lt;br&gt;Micro Analysis and Design, Inc.&lt;br&gt;Christian Lebiere, Dan Schunk, &amp; Eric Biefeld&lt;br&gt;Carnegie Mellon University</td>
<td>* Time pressure&lt;br&gt;* Perceptual errors&lt;br&gt;* Memory retrieval&lt;br&gt;* Inadequate knowledge</td>
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Advancing cognitive models into increasingly complex real-world applications
Data Set
T-NASA Full Mission Simulation

Modeling Problem
Reproduce/Explain
Taxiway Navigation Errors

Scenario Specifications

- High-fidelity full motion simulation of taxi-to-gate at Chicago-O'Hare
- 54 trials run by 18 airline crews
- 9 different cleared routes -- all in low visibility (1000 RVR)
- Traffic, hold short, and route changes included in scenarios
- 12 off-route errors committed by crews and specified to modelers
Air MIDAS Simulation of Observed Error

Fixate, Control input stop ac communicate
Fixate, communication, monitor progress
Monitoring, communicating with supervisor

Fixate, Control input stop Aircraft, prepare for right turn
Fixate, communication, consult clearance
CONFIRMATION BIAS EXERCISED
monitoring

Fixate, Control input turn and increase speed
Fixate, communication, monitor progress
Monitoring, communicating

Fixate, Control input accelerate
Fixate, communication
communication monitoring

Fixate, Control input Stop Aircraft, prepare for right turn
Fixate, communication, consult clearance
CONFIRMATION BIAS EXERCISED
monitoring

Monitoring Control input, turn aircraft
scanning, communication
monitoring

Monitoring Control input, increased communication
scanning, increased communication, lost SA
Monitoring, communicating

DECLARATIVE INFORMATION LOSS THROUGH INTERFERERENCE

Fixate, Control input Wait for clearance
Fixate, communication, hear/write clearance, clean up procedure
communication monitoring

ERROR

Captain

First Officer

ATC

Monitoring
(Roll out, autobrake)
Control input
switch alarm off, disasm auto)
verifies thrust levers, monitor ground speed, & communication(speed and sign call out)

Monitoring
(Roll out, autobrake), hearing, Control input (brake) monitor speed, communication (speed and sign call out)

Monitoring Control input
scanning, communication
communication monitoring

Monitoring Control input
scanning, communication
communication monitoring

Monitoring Control input
scanning, communication
communication monitoring

Monitoring Control input
scanning, communication
communication monitoring

Fixate, Control input (AC control), Cognitively missed signage
Clean up head down, Fixate, communication, hear/write clearance, communication and navigation

DECLARATIVE INFORMATION LOSS THROUGH INTERFERERENCE

communication monitoring

Fixate, Control input (AC control), Cognitively missed signage
Clean up head down, Fixate, communication, hear/write clearance, communication and navigation

DECLARATIVE INFORMATION LOSS THROUGH INTERFERERENCE

communication monitoring

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DECLARATIVE INFORMATION LOSS THROUGH INTERFERERENCE

communication monitoring
Data Set
Part-task Pilot-in-loop Simulation
Performance data and Eye-tracking (3 Subjects)

Other Information Provided Modelers
Detailed Cognitive Task Analysis

Modeling Problem
Develop "Normative" Model of Approach & Landing with and without Augmented Display

### Scenarios

<table>
<thead>
<tr>
<th>Display Configuration</th>
<th>Baseline</th>
<th>Baseline</th>
<th>SVS</th>
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</thead>
<tbody>
<tr>
<td>Visibility</td>
<td>VMC</td>
<td>IMC</td>
<td>IMC</td>
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<tr>
<td>Nominal Approach (nominal landing)</td>
<td>Scenario #1</td>
<td>Scenario #4</td>
<td>Scenario #7</td>
</tr>
<tr>
<td>Late Reassignment (side-step &amp; land)</td>
<td>Scenario #2</td>
<td></td>
<td>Scenario #8</td>
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<tr>
<td>Missed Approach (go-around)</td>
<td>Scenario #3</td>
<td>Scenario #5</td>
<td>Scenario #9</td>
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<tr>
<td>Terrain Mismatch (go-around)</td>
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<td>Scenario #6</td>
<td>Scenario #10</td>
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Implementation Plan Status

AvSP SWAP Human Performance Modeling

'01 Modeling Taxi-Navigation Errors
- Technical report on context of aviation errors
- Development of 5 models of surface operations
- Workshop 10/18/01

Proof-of-Concept: replication and causal explanation of various observed pilot taxi-navigation errors committed in high-fidelity simulation

'02-'03 Modeling Nominal Approach/Landing with and without SVS
- 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 (late runway reassignment, system failure, etc.)
- Models of Approach / Landing
  - Initial model development
- Workshop scheduled 3/6/03
- Operator model provided to AvSP ASMM project

Demonstrated: 3 working models of pilot performance during nominal approach/landing: good correlations between simulation outputs and observed pilot eye tracking/visual attention allocation

Objective: prediction of pilot attentional allocation, decisions, and actions during off-nominal operations with & without SVS

'03-'04 Modeling Multiple Off-Nominal Approach/Landing with and without SVS
- Models of Approach / Landing
  - Develop advanced models
  - Investigate off-nominal scenarios
  - Identify error susceptibilities
  - Evaluate mitigation strategies
- Model Verification/Validation Approaches
  - Determine "choke points" (e.g., workload, SA at transition points)
  - Cross scenario
  - Cross model
  - Emergent behaviors
Crew Activity Tracking System (CATS)

Computerized engineering model of correct task performance to predict operator activities and interpret operator actions

- Provides context-dependent knowledge about the operator’s task that can support tutors, aids, and displays to enhance safety
- Supports visualization and analysis of human-automation interaction
Detecting Errors from Flight Data

Current research demonstrates how CATS can analyze flight data from the Langley B757 ARIES aircraft to detect procedural errors

Callantine (2001a, 2001b)

NASA B757-ARIES

On-board Data Acquisition System used to collect flight data

Cockpit observations verified and augmented digital data
Crew receives clearance to climb to 16,000 ft; CATS predicts target altitude setting; crew pushes VNAV switch instead.
CATS uses its model of correct autoflight system usage to detect the error of pressing the VNAV switch before setting the target altitude.
Summary of CATS Development

Demonstrated ability to detect pilot error from in-flight data

- Autoflight misusage in approach/landing operations
- Potential for onboard real-time error detection system

Developed CATS framework into autonomous agent model

- Demonstrated agents that function as air traffic controllers capable of handling flow spacing problems in simulation
- Potential for stand-in for human air traffic controllers in large-scale simulations

Extend CATS agent-based models to incorporate error

- Developing process by which nominal agents will make realistic errors in fast-time simulation
- Potential to conduct "effects analysis" for a given scenario resulting from introduction of a particular error mechanism
Back-up Material
Publications to Date

Journals, Books, Conference Proceedings


Technical Reports


Upcoming


Byrne, M. D., & Kirlik, A. (in prep). Modeling to support error diagnosis in commercial taxi operations. Manuscript to be submitted to The International Journal of Aviation Psychology.


Miscellaneous