NASA’s use of human behavior models for concept development and evaluation

Brian F. Gore
San Jose State University in the Human Systems Integration Division
NASA Ames Research Center
Moffett Field, CA
Modeling and simulation are critical to comprehensively study complex human-system designs.

Many different types of models exist at NASA:
- Human behavioral
- Human performance
- Anthropometric, biomechanic, volumetric
- Information processing
- Vision, auditory, memory, and other human processes
- Task network
- Physical structural (space launch vehicle, aircraft, crewstations, CAD/CAEs)
- Airspace system
- Weather
- Airflow and other CFD
- Physiological
- Robotics and automation
- Oxygen and blood flow
- Scheduling
NASA Ames Human Modeling in System Design

System and Environment Design
- Airspace
- Aircraft Trajectories
- Illumination
- Gravitational forces

Physical Equipment Design
- Crewstation
- Flight deck layout
- Loads
- Manual handling
- Fluids and heat transfer models

Operations Design, Evaluation, and Integration
- Procedures
- Training
- Roles & responsibilities
- Scheduling

Technology Design, Evaluation, and Integration
- Displays
- Automation
- Information Requirements

ACES: National Airspace System
FACET: Air traffic management

BRAHMS: Agent-based models
MIDAS: Behavior models
Cognitive process models: Decisions / response to information
SPIFe/SCORE: Scheduling and Planning models

JACK: Anthropometric model
Biomechanic model
MIDAS-FAST ( & BORIS): Robotics Trainer
Volumetric CFD

ADEPT: Human-Automation Interaction
HOP: Human Vision
Basic Process Models: Audition (e.g. threshold models),
MIDAS: Memory & cognitive processing

3/12/12 – BRIMS 201
## NASA Ames HSI Research Areas

http://humansystems.arc.nasa.gov/techareas.tech_areas.php

<table>
<thead>
<tr>
<th>Technical Area</th>
<th>Laboratory</th>
<th>Research Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human Computer Interaction (HCI)</td>
<td>HCI</td>
<td>Contribute to the development of better NASA software through careful application of iterative user research, interaction design, and usability</td>
</tr>
<tr>
<td>Human Automation Interaction</td>
<td></td>
<td>ADEPT provides a tool for prototyping automation and associated interfaces, in an integrated tool that includes analyses to identify potential HAI vulnerabilities early in the design process</td>
</tr>
<tr>
<td>Scheduling and Planning</td>
<td></td>
<td>Scheduling and Planning Interface for Exploration (SPIFe) toolkit for space missions that includes human constraints on mission operations</td>
</tr>
<tr>
<td>Human Performance Research</td>
<td>Advanced Controls and Displays</td>
<td>Research on haptics, speech recognition, visual perception, visual perception in space, adaptation to virtual environments, and acoustics</td>
</tr>
<tr>
<td>Human Cognition</td>
<td></td>
<td>The mission of the Cognition Lab is to develop computational models for assessing throughput and error rates of human performance.</td>
</tr>
<tr>
<td>Flight Cognition Lab</td>
<td></td>
<td>Studies the cognitive, team and organizational processes that underlie the performance of pilots, air traffic controllers, and other skilled professionals</td>
</tr>
<tr>
<td>Intelligent Systems</td>
<td></td>
<td>Enhance mission safety and crew efficiency in next-generation spacecraft by evaluating the operational impacts of environmental stressors and by developing and testing advanced operations concepts and crew-vehicle interfaces.</td>
</tr>
<tr>
<td>Man-machine Integration Design and Analysis System (MIDAS)</td>
<td></td>
<td>Develop human performance models of human-system interaction to predict operator performance along the measures of task performance and times, visual attention, workload, situation awareness</td>
</tr>
<tr>
<td>Integration and Training</td>
<td>Airspace Operations Laboratory (AOL)</td>
<td>Researches roles, responsibilities, and requirements for human operators and automation in future air traffic management (ATM) systems using human in the loop</td>
</tr>
<tr>
<td>Human Centered Systems Laboratory (HC3)</td>
<td></td>
<td>Focuses on mission safety and efficiency by developing innovative display technologies using both HITL and HPM methodologies</td>
</tr>
</tbody>
</table>
Human Performance Models

- Human Performance Models (HPMs) allow system designers the ability to model critical events that cannot be fully studied with empirical simulations.
- Models can be used to provide estimates of human-system performance when the concepts, technologies, or automation are too new, difficult, or dangerous for the human operator.
- Model validity is a paramount concern when predictions are generated to evaluate candidate NextGen operations.
Motivation:

NextGen Technology Design, Evaluation, and Integration

• **NextGen Characteristics:**
  – More data available to the flight deck
    • e.g., weather, wake, traffic trajectory projections, etc.
  – More precise and closely coordinated operations
    • e.g., self-separation, closely spaced parallel operations, RNAV/RNP
  – More tasks are automated
    • Pilot increasingly placed in a monitoring role
  – Potential for increased workload, decreased situation awareness, increased demand for shared attentional resources

• **Evaluating NextGen Concepts:**
  – Must consider pilots’ capabilities when designing / evaluating NextGen procedures, operations, roles / responsibilities and the information requirements
  – Failure to do so will leave the pilots, and thus the entire aviation system, vulnerable to error
MIDAS v5 Structures

MIDAS Input
- Tasks and Procedure Lists (activities and sub-activities)
- Library: Primitive tasks in human model
- Microsaint Sharp
  - Mission Models
  - Workstation Models
  - Anthropometric Models
  - Environmental Models
  - Dynamic Models
  - Flight Profile Models
  - Scenario Objects
- Operator Characteristics
  - Performance Shaping Factors

MIDAS Processes
- Task Manager
  - Schedules
  - Actuates/Triggers
- Physical Simulation
  - Environmental behavior
  - Crewstation behavior
  - Model state movement
  - Model state actions
  - Model state changes
- Commands
- Results

MIDAS Output
- Task Network
- Timeline
- Fit/Reach/Vis envelope
- Dynamic Animation
- Mission Risks
- Mission success
- Performance measures

MIDAS Operator Process Models
- Fits Law: Perception & Attention (SEEV), Multiple Resource Model; Memory, SA, Workload; Operator States (fatigue, gravitational effects); Timeliness

Workload, visual attention
CSPO Project Overview

• Objective
  – Develop valid HPMs of approach and land operations, use these models to evaluate candidate NextGen concepts (Closely Space Parallel Operations, CSPO), develop guidelines regarding flight deck displays and pilot roles and responsibilities

Develop Current Day Model

• RNAV Approach and Land

Validate Model

Extend to NextGen

• 2 Operational scenarios of CSPO concepts

Validate Model

Evaluate impact of CSPO

• Compare CSPO workload, visual fixations to RNAV

Validate Model

“What-if” Investigations

• Off-Nominals
  • Roles, Responsibilities and Flight Deck Displays (2011)

Evaluating NextGen Closely Spaced Parallel Operations Concepts with Validated Human Performance Models

Model Development and Validation
- Develop RNAV model based on task analyses (SME input)
- Validate model inputs, processes and outputs
- Extend RNAV model to two CSPO Concepts
- Evaluate: Pilot-ATC separation responsibility, Wake Information Requirements, Spacing Management Information Requirements
- Implications based on: Pilot workload, visual attention event/alert detection response times

1. Develop and validate model (BRIMS 2010, 2011)
   - RNAV scenario + 2 CSPO operational scenarios
   - Validated model
     - inputs (Focus groups)
     - processes (Literature)
     - outputs (HITL data)

2. Evaluate off-nominal events (BRIMS 2010, 2011)
   - Weather (high wind)
   - RNP Loss
   - FMS Failure
   - Aircraft of runway

3. Evaluate roles and responsibilities (AHFE 2012)
   - Pilot-pilot roles (Allocation of task, monitoring workload)
   - Pilot-ATC roles (Conflict detection and resolution)

4. Evaluate information requirements
   - Flight deck information required to support early conflict detection and safe response
   - Wake format and location
   - Spacing Automation style and format

MIDAS v5, a human performance model of the flight deck environment, pilots’ workflow and cognitive processes.
**Flight Deck Requirements for:**
1. ATC-Pilot Roles and responsibilities: ATC vs Pilot responsibility for separation
2. Alert styles for wake and blunder threats: One-stage vs two-stage alerts
3. Wake display technology: Format (predicted vs real-time), Location (PFD, Nav Display, or Both)
4. Spacing management automation: Style (Current vs NextGen), Location (PFD, Nav Display, or Both)

**Evaluating ATC-Pilot Roles and Responsibility: Separation Delegation**
- Compared Current-day (ATC responsible for separation) with NextGen (Pilot responsible for separation)
- Model predicted slightly faster emergency escape maneuvers when Pilot’s are responsible (.3 sec), BUT...

Higher workload when pilots are responsible for separation

Less balanced pilot scan when pilots are responsible for separation

---

Hooey, Gore, Mahlstedt, & Foyle, (2012); Gore, Hooey, Mahlstedt, Foyle (in process)
Summary

1. HPMs such as MIDAS can be used to evaluate:
   – Pilot/ATC roles and responsibilities and function allocation
   – Technology development and integration
   – Error or safety vulnerabilities
   – Procedures and training needs

2. HPMs such as MIDAS can be applied to other:
   – Phases of flight, (e.g. aviation - arrivals, enroute, departures, taxi and their transitions; space - ascent, descent; ISS operations)
   – Flight deck technologies (e.g., SVS/EVS; CDTI; EFBs; MFDs; )
   – Information requirements manipulations
   – Concept of Operations evaluations
   – Space operations (e.g. ISS and CEV/SLS procedure design and evaluation)
   – Human-automation interaction domains
NASA’s use of human behavior models for concept development and evaluation

Brian F. Gore
San Jose State University in the Human Systems Integration Division
NASA Ames Research Center
Moffett Field, CA