HMSE Implementation: Models, Mockups, and Prototypes
The Human-Machine Systems Engineering Process

Needs, Problems, Opportunities

**Evaluation**
- Checklists
- Heuristic Evaluation
- Usability Testing
- Statistical Analysis

**Operation**
- Role Playing
- Simulation
- Full-scale Operation
- Observation
- Data Collection

**Human-Machine System**

**Management**
- Planning
- Scheduling
- Work Assignment
- Monitoring
- Assessment

**Analysis**
- System Analysis
- Environment Analysis
- Personnel Analysis
- Facilities & Equipment Analysis
- Process Analysis
- Task Analysis
- Failure Modes & Effects Analysis

**Requirements Engineering**

**Design**
- Workstation Design
- Equipment Design
- Procedure Design
- Job Aid Design

**Implementation**
- (Computer) Model
- Mockup
- Prototype
- Operational System

**Design Specifications**

**Performance Data, Observations**

OSU Oregon State University
College of Engineering
Implementation and Operation

- Implementation
  - Models
    - Scale
    - Computer
  - Mockups
  - (Electronic) Storyboards
  - Virtual Prototypes
  - Prototypes
  - Operational Systems

- Operation
  - Models
    - Simulation
  - Mockups, Storyboards
    - Scripted Role Playing
  - Prototypes
    - Simulated Scenarios
  - Operational Systems
    - Real Operation
Computer Models: Solid Modeling
Computer Models
Computer Models: MIDAS

- **Man-machine Integration Design and Analysis System**
- Workstation-based simulation system developed by the U.S. Army, NASA, and Sterling Software Inc.
- Used to evaluate candidate crew procedures, controls, and displays before changes become too costly.

**Capabilities**
- graphical equipment prototyping
- dynamic simulation
- human performance modeling
  - kinematic
  - sensory
  - memory, cognition
  - motor

**Applications**
- Air Warrior - 21st Century air crew life support system
- Air MIDAS - assessment of flight management systems, communication, and automation in Air Traffic Control (ATC) aiding
- Short Haul Civil Tiltrotor - crewstation in new vertical takeoff and landing vehicle
- Taxi MIDAS - Preflight Checklist Study (Boeing 747 - 400)
- 911 MIDAS - Emergency Dispatch Console Design Study

**Website:** [http://humansystems.arc.nasa.gov/groups/midas/index.html](http://humansystems.arc.nasa.gov/groups/midas/index.html)
- Air Warrior: [http://humansystems.arc.nasa.gov/groups/midas/application/airwarrior.html](http://humansystems.arc.nasa.gov/groups/midas/application/airwarrior.html)
- Air MIDAS: [http://humansystems.arc.nasa.gov/groups/midas/application/taximidas.html](http://humansystems.arc.nasa.gov/groups/midas/application/taximidas.html)
Mockups: Silicon wafer slicing saw
Mockup framework
Mockup exterior construction
Mockup large features
Mockup display/control details
Mockup operator interface
Mockup: Healthcare Toolkit Instrument Set
Mockup/Electronic Storyboard: ECD Facilitator
Virtual Prototype/Electronic Storyboard: ECD Facilitator

Please choose the appropriate action:

- Facilitate Cesarean Section
- Input Call Team Information
- Customize System Settings
Mockup/Electronic Storyboard: Healthcare Toolkit
Mockup/Electronic Storyboard: Healthcare Toolkit
Virtual Prototype (HTML): DVD-VHS Player
Virtual Prototype: Electronic Checklist

- Full-scale physical mockup (from rapid prototyping machine)
- Simulator (MS Access database)
Virtual/Functional Prototype: Healthcare Toolkit V1
Mockup and Functional Prototype: Healthcare Toolkit Unified Medical Instrument

UMI Mockup

UMI Functional Prototype

iPad Diagnosis Decision Aid

Human Factors Engineering
Rapid Prototyping System: PTD Emulator
Functional Prototype: ECD Facilitator

Emergency Cesarean Delivery Facilitator

Summon Team

Patient:
Status:
Reason for CS:
Assembly Location: OR 1

The following medical personnel will be summoned on the call

Obstetrician: Matthew Olsen
Surgical Assistant: Cathy Falk
Anesthetist: Solomon Graves
OB Nurse: Alice Harbin
Scrub Nurse: Simon Grimble
Circulating Nurse: James Bowers
Family Practice Physician: Chris Bluh
Respiratory Therapist: Joel Hayter

Summons Data

Patient First Name: 
Existing Patient ID: 
Patient Last Name: 

Patient Status: 

<table>
<thead>
<tr>
<th>Summon Team</th>
<th>Summons Information</th>
<th>Team Status</th>
<th>Patient Checklist</th>
<th>Patient Medical Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR Checklist</td>
<td></td>
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</table>
Evaluation:
Verification That Requirements Are Met

- Verification by
  - Inspection
  - Analysis
  - Test
  - Demonstration

- Basis for verification (implementation methods)
  - Design specifications
  - Models
  - Mockups/Electronic Storyboards
  - (Virtual) Prototypes

- Evaluation methods (for Verification by Inspection, Test, Demonstration)
  - Heuristic Evaluation by experts (using checklists, questionnaires, etc.)
  - Usability Testing
  - Human performance measurement
    - speed
    - accuracy
    - training time
    - user satisfaction
Evaluation Experiments: Verification By Test

- Define Objective, e.g., compare
  - baseline (current) vs. new design
  - new design vs competitor
  - design 1 vs design 2 (vs design 3 ...)
- Develop Apparatus, e.g.,
  - mockup
  - prototype
- Identify, recruit participants
- Define independent variables, e.g.
  - design alternatives
- Define and develop controls for extraneous variables
- Define dependent variables
- Design experiment
  - experimental design
  - experimental procedure
- Conduct Experiment
- Analyze Results
AgendaManager Evaluation
Experiment: Simulator with EICAS
AgendaManager Evaluation
Experiment: Simulator with AMgr
AMgr Evaluation Experiment (1)

• Objective: compare AMgt performance (AMgr vs EICAS)
• Apparatus
  – flight simulator
  – AMgr
• Participants: 8 line pilots
• Independent Variable: monitoring and alerting condition
  – AMgr
  – EICAS
• Extraneous Variable: Scenarios
  – EUG to PDX
  – PDX to Eugene
AMgr Evaluation Experiment (2)

• Dependent (Response) Variables
  - AMgr/EICAS Equivalent
    • within subsystems correct prioritization (%)
    • subsystem fault correction time (sec)
    • autoflight programming time (sec)
  - Additional AMgr Functions
    • goal conflicts corrected (%)
    • goal conflict resolution time (sec)
    • subsystem/aviate correct prioritization (%)
    • average number of unsatisfactory functions/tasks
    • percentage of time all functions/tasks satisfactory
    • participant (subject) effectiveness rating (-5 ... +5)
AMgr Evaluation Experiment (3)

- **General Procedure**
  - subject introduction
  - automatic Speech Recognition system training
  - flight training (using MCP)
  - subsystem training (fault correction)
  - EICAS/AMgr training

- **Trials**
  - Run 1 (EICAS/AMgr)
    - experimenter/ATC controller gives clearances, induces faults, induces goal conflicts
    - subject acknowledges clearances, flies simulator, corrects faults, detects and resolves goal conflicts
  - Run 2 (AMgr/EICAS)
## AMgr Evaluation Experiment: Results

<table>
<thead>
<tr>
<th>Response variable</th>
<th>AMgr</th>
<th>EICAS</th>
<th>sig. level</th>
</tr>
</thead>
<tbody>
<tr>
<td>within subsystem correct prioritization</td>
<td>100%</td>
<td>100%</td>
<td>NS</td>
</tr>
<tr>
<td>subsystem fault correction time (sec)</td>
<td>19.5</td>
<td>19.6</td>
<td>NS</td>
</tr>
<tr>
<td>autoflight system programming time (sec)</td>
<td>7.0</td>
<td>5.9</td>
<td>NS</td>
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<tr>
<td>goal conflicts corrected percentage</td>
<td>100%</td>
<td>70%</td>
<td>0.10</td>
</tr>
<tr>
<td>goal conflict resolution time (sec)</td>
<td>34.7</td>
<td>53.6</td>
<td>0.10</td>
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<tr>
<td>subsystem/aviate correct prioritization</td>
<td>72%</td>
<td>46%</td>
<td>0.05</td>
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<tr>
<td>average number of unsatisfactory functions</td>
<td>0.64</td>
<td>0.85</td>
<td>0.05</td>
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<tr>
<td>percentage of time all functions satisfactory</td>
<td>65%</td>
<td>52%</td>
<td>0.05</td>
</tr>
<tr>
<td>mean subject effectiveness rating (-5 to 5)</td>
<td>4.8</td>
<td>2.5</td>
<td>0.05</td>
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