Human Factors in Aerospace: Examples from projects at NASA Ames

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Agenda

• Overview of NASA and NASA Ames
• What is ‘human factors’?
• Applied examples of HF in NASA Ames research
• Future HF research initiatives
• Summary: Why is human factors important?
• Challenges to HF
• Time for questions and discussion
Overview of NASA
NASA Ames: Human-system integration division

• Division dedicated to research focusing on Human-System integration
• Human Factors is a dominant consideration
• Human Factors research takes place within both aviation and space domains
• The following research was all conducted within the human-systems integration division at NASA Ames
What is human factors?

- “Aims to make technology work for people” - Wickens
- Incorporates elements of engineering, psychology, cognitive sciences etc.

<table>
<thead>
<tr>
<th>Information processing</th>
<th>Cognitions</th>
<th>Performance-influencing factors</th>
<th>Display design - HCI</th>
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</thead>
<tbody>
<tr>
<td>1. Visual sensory system</td>
<td>1. Attention &amp; perception,</td>
<td>1. Workload</td>
<td>Workstation design</td>
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<td>2. Processing</td>
<td>2. Resources</td>
<td>2. Fatigue</td>
<td></td>
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<tr>
<td>3. Perception, including meaning of colour</td>
<td>3. Memory</td>
<td>3. SA</td>
<td>Automation &amp; monitoring</td>
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<td>5. Tactile</td>
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<td>6. Vestibular inputs</td>
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Human factors & Human-Systems integration

• Historically, human factors emerged to increase productivity of employees
• Increased focused on human error – still dominant today
• Research at Ames tends to focus on the human-systems integration approach (prevention vs retrospective)
• Appears to be the most applicable approach, considering rapid increases in automation
Human Factors:
Applied examples from NASA Ames Research
Air traffic control overview

- Manage sectors of airspace
- Maintain safety
  - Ensure separation
  - Conflict detection and resolution
- Provide efficient user service
  - Airlines, flying public
- Track aircraft on radar – speed, flight level, heading (direction)
- Usually work in teams
Phases of air traffic control

- Approach
- Tower
- En-route
- Sector
- Sector
- En-route
- Approach
- Tower
Prestwick Ops room
Airborne Reroute Advisories
Predicting the Operational Acceptance of Route Advisories
Approach

• Use machine learning to build a predictor of ATC operational acceptability for route advisories:
  – Accuracy of 74%

• Relevant model features:
  – Historical usage of route
  – Timing/location of request in maneuver start sector
  – Number of downstream sectors
  – Direct routing or via auxiliary waypoints
  – Demand to capacity levels in maneuver start sector

• (Best performing model is Random Forest with 40 trees)
Concept Video

https://youtu.be/Rlf3lkpsbTA
Ramp Traffic Console Display

- **Arrival Flights**
- **Departure Flights**
- **Terminal E in KCLT**
- **Pushed back Flight**
- **Arrival parked without Flight Strip**
- **No Flight?**
Prediction of Demand to the Runways

Predicted Excess Demand that would require a gate hold

Target of delay on the Active Movement Area
Objective motion criteria for pilot training simulators

• Currently, the motion of pilot training simulators is based on opinion
  – No standardization
• Research aims to develop a standardized criteria for most realistic simulator motion
• With the wrong motion, pilots possibly learn to fly the simulator instead of the aircraft, leading to pilot error in hazardous situations in flight (e.g. during a stall)
• The study uses measures of pilots’ performance and self-reported workload, as well as motion ratings, to developed standardized criteria
• Video
Simplified pilot go-around criteria

• Runway excursions, abnormal runway contact, and undershoot/overshoot are the third leading category of fatal accidents in the worldwide commercial jet fleet

• The leading cause of these type of accidents is “go-around not conducted”
  – Most pilots are of the opinion that current go-around criteria are too complex and restrictive
  – Procedure problem or overestimation of abilities?

• This project aims to develop simplified universal criteria indicating when a go-around should be performed

• Aircraft dynamics and performance are important to develop these criteria, as well as workload, fatigue, and pilots’ perception of risk
Human-systems approach to graceful degradation

Degradation cause
- System fault or failure
- Environment events
- Human Operator (Air traffic controller)

Identification

Prevention and mitigation of degradation:
- Preventative measures to generate graceful degradation
- Active at different stages

System design e.g.
- Fault tolerance
- Redundancy
- Automation

Environment e.g.
- Airspace design
- Traffic flows
- CONOPS
- Procedures

Human Operator e.g.
- Training
- Human-centered interface design
- Decision support tools

Predominantly human operator
Can be supported by all previous pre-degradation measures

Post-degradation: Recovery

Output

Graceful degradation
The operational envelope

Normal operations:
ATC is working effectively within this workload and scenario space

At edges, due to difficulty, complexity, overload etc., performance/safety may be temporarily compromised; but situation normally recovered before loss of separation event

Here a loss of separation will occur

Individual envelopes that interact to determine the overall system envelope

Operational maximum

Operational optimum

Tolerance

System

Environment

ATCO
A notional UTM world

- UTM = UAS traffic management
  - UAS = unmanned aircraft system

- UTM Concept:
  - Flexibility where possible and structure where necessary

- The objective of UTM is to inform the needs and requirements for enabling low-altitude UAS operations
  - Services, roles & responsibilities, information architecture, data exchange protocols, software functions, infrastructure, performance requirements, etc.
# Examples of Observations to Guide Future Studies

<table>
<thead>
<tr>
<th>Topic</th>
<th>Comment volunteered by a participant</th>
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</thead>
<tbody>
<tr>
<td>Team structure</td>
<td>Human-in-the-loop was a critical component of the conformance alerting capability. Communication protocols were established and exercised. This combined with the audio alerts and geospatial displays provide an effective alerting mechanism for all levels of operators from the mission director to the pilot.</td>
</tr>
<tr>
<td>Workload levels permitting message handling</td>
<td>Outside of the test environment, during a real lost link / non-conformance event, the pilot workload would be too great such that the pilot may never submit a message to UTM, or the message may be considerably delayed. The expectation that a pilot would message during an emergency procedure is not feasible.</td>
</tr>
<tr>
<td>Level of situation awareness</td>
<td>The [interface] does not query and visualize any associated operation volumes, constraints, or other UTM aircraft in the event of alerts or negative UTM responses (e.g. rejected). These kinds of visualizations will become increasingly important to provide as much situational awareness as possible to the user.</td>
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Note: although these are quotes from single individuals, similar comments were gathered from multiple teams, which is why this topic has been flagged for further investigation

**HF note:** Look how much information from how many sources team members are having to check during a flight

**HF note:** Look at the variability in workload due to the dynamic nature of operations. Sometimes responding to a message will be fine, but sometimes it will be overload

**HF note:** Look that some users think they need information about other flights – how can this all be integrated on one display?
Example Communications Flow

From an early flight test study

HF considerations at this stage of concept development

- Team organization
  - Team member coordination
- Team verbal communication
  - Operators have different backgrounds and perspectives
- Messaging
  - Universal understanding of short messages
  - Workload levels permitting message handling
- Level of situation awareness
  - When is in-vehicle awareness enough vs. SA of local flying area?
- Procedures for emergency actions
  - Can universal procedures be implemented?

GCS = ground control station (home base)
VO = visual observer
UTM rep = UTM system operator
OC = observer controller
PIC = pilot in command
GCSO = ground station operator
Future initiatives

• Urban air mobility
  – Automated environment
  – Human roles – monitor or operator?
  – Airspace design
  – Tools design

• UTM
  – Design of manager station
  – Teamwork
  – Communication
  – Role of human

• TBO
  – Precision and flexibility in the system
  – Tool design
  – Function allocation - automation

• ‘Playbook’
Challenges to HF

• Will HF still be relevant in the future with increasing automation?
• HF as a barrier to implementation
• Does HF identify problems and not solutions?
• Trouble with metrics related to HF contribution
Summary:
Why is human factors important?

• Safety (e.g. challenger, deep water horizon)
• Efficiency
• Prevention of incidents/accidents
• Supporting human performance
• Guidance for usable and acceptable design
Conclusions and future directions

• HF can enhance safety and efficiency in safety-critical systems.
• It is therefore essential to consider HF in any technological design or development.
• Human systems integration and Human-automation teaming.
• HF will still be needed and contribute to safety and efficiency in highly automated environments.
• Need to encourage a cross domain communication and research to support optimum systems performance.
Thank you!
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