Human Factors in Aeronautics at NASA

Richard Mogford, Ph.D.
NASA Ames Research Center
Moffett Field, CA
Ames Human Factors

- Human Systems Integration Division
  - About 120 people in the division
  - 50 civil servants, about 70 contractors
  - Most with graduate degrees in psychology, engineering, computer science, or other technical disciplines

- Working primarily in three areas:
  - Aeronautics
  - Exploration (space)
  - External collaborations (e.g., Federal Aviation Administration, DoD, Commercial Aviation Safety Team, and international groups)

- Aviation Systems Division
  - Develops and prototypes new concepts for air traffic control and airlines
  - Has a human factors staff
Ames Technical Areas

- Human-machine Interaction
  - Planning and scheduling systems
  - Problem analysis and correction action systems
- Human Performance
  - Visual and auditory interface research
  - Performance modeling (e.g., pilot control strategies to vehicle dynamics)
  - Crew cockpit design and evaluation
  - Perceptual, cognitive, and physiological analyses
- Integration and Training
  - Flight deck display design and evaluation
  - Air traffic management integration
  - Training, procedures, and team coordination
  - Safety analysis and reporting systems
Langley Human Factors

- Largely contained within the Crew Systems and Aviation Operations Branch within Langley’s Research Directorate
  - 45 civil servants
  - Most with graduate degrees in psychology, engineering, computer science, or other technical disciplines
  - Working primarily Aeronautics programs
  - External collaborations include: the FAA, DoD (including DARPA, AFRL, ARL, ONR), Airlines, Industry, Academia
  - Other working groups/participation/leadership: RTCA, CAST, AIAA, etc.

- Additional 5-8 human factors civil servants within the Systems Analysis and Concepts Directorate and the Engineering Directorate, working mostly NASA Exploration Programs
Langley Human Factors Technical Areas

**Human Performance Characteristics and Capabilities**
- Interaction across modalities
- Spatial orientation
- Oculometry and vision perception
- Cognitive processes
- Situational awareness – detection, assessment, and risk mitigation strategies

**Cockpit and display design and development**
- Input devices and controls
- Visual and auditory displays
- Multi-modal, virtual, and augmented reality displays

**Human Computer Interface**
- Natural language Interface and gesture control
- Brain-computer interfaces

**Multi-agent Teaming**
- Human-automation integration - function allocation, trust in automation, adaptive automation
- Crew Resource Management
- Human-machine teaming and collaborative decision making
- Human-system verification and validation and performance metrics

**Training**
- Computer based training development for human machine interfaces
- Crew state feedback for training
Examples of NASA Aeronautics Projects

• Aircrew Checklists
• Dispatch Operations
• Playbook
• Dynamic Weather Routes
• Traffic Aware Strategic Aircrew Requests
• Airplane State Awareness and Prediction Technologies

Note: Most human factors work is embedded in aeronautics tasks. There is only limited basic research.
Checklists and Procedures in Aviation and Medicine: Paper, Electronic, Context-Sensitive and Dynamic
• Conditions, limitations, aircraft status, and operational demands (i.e., constraints) are used to facilitate access and guide autonomous, dynamic presentation and sequencing of information from multiple sources including:
  - normal and non-normal checklist actions
  - instrument procedures
  - enhanced nav displays
  - FMS/autoflight/datacomm information/actions
  - aircraft system status and alerting systems
  - weather conditions
  - current ATM procedures, etc.

• Autonomously helps pilots/remote operators prioritize tasks, minimize overall workload, increase situation awareness, reduce/eliminate errors and better manage overall normal and non-normal flight operations, through:
  - Three completely novel cockpit displays and multi-modal interfaces: visual, aural, haptic/tactile
  - Information that is “pushed” by FAIM (automatically displayed); but FAIM also supports information “pull” through enhanced search/link capabilities to facilitate access to additional information as desired, when/if needed (e.g., FCOM, systems, and training manuals, etc.)

• Supports crewed, RCO, RPA/UAS operations; leads to a fully functioning autonomous vehicle

“Dynamic “ – to change in real-time based on constraints and conditions in response to data gathered through sensors, digital sources, pilot/user input, or a priori selection
Airline Dispatch Operations

- Developing the “Flight Awareness Collaboration Tool” (FACT)
- Concentrates information about winter weather events on one display
- Includes predictive tools
- Supports collaboration between AOC, air traffic control, airport authority, and de-icing operators
- User interface designed completed and web-based prototype under development
- User group at Detroit airport
NASA/Industry Collaboration

• Held an Airline Operations Workshop at NASA Ames in August 2016
  – About 200 attendees
  – Focused on NASA, FAA, and private sector innovations to support the airlines (AOC and flight deck)
  – Identified gaps where research is needed
  – Formed partnerships with airline industry
  – Focused on the airlines and airline software vendors

• Research themes
  – AOC simulation
  – Display/system integration
  – Managing large information database from multiple sources
Playbook: next generation easy-to-use mobile web-based plan & execution tool
Playbook’s Capabilities

• Collaborative self-scheduling with constraint checking and violation visualizations of timeline
• Activity execution status with procedure linking
• Integrated multimedia communications chat functionality (text, photo, video, or files)
• Adding new activities, scheduling task list activities, and rescheduling flexible activities
• Communication availability bands
• Field-tested in more than a dozen different spaceflight analogs for crew and robotic operations, including delayed communication simulation between ground & crew teams.

POC: Steve Hillenius (steven.r.hillenius@nasa.gov)
Playbook Lead, SPIFe Lead, NASA Ames Research Center
Dynamic Weather Routes: Two Years of Operational Testing at American Airlines

Dave McNally, Kapil Sheth, and Chester Gong
NASA Ames Research Center
Moffett Field, California

Mike Sterenchuk
American Airlines, Integrated Operations Control
Fort Worth, Texas

Scott Sahlman, Susan Hinton, Chuhan Lee
University of California, Santa Cruz
Moffett Field, California

Fu-Tai Shih
SGT, Inc.
Moffett Field, California
What's the Problem?

- Convective weather cells, or severe thunderstorms, are leading cause of flight delay in US airspace.
- Flight dispatchers file flight plans 1-2 hours prior to departure utilizing routes with conservative buffers to severe forecast weather.
- Weather changes as flights progress.
- No automation to help operators determine when weather avoidance routes have become stale and could be corrected to reduce delay.
Dynamic Weather Routes (DWR)

Continuous Automatic Search Finds High-value Route Correction Opportunities, Airborne Flights, En Route Airspace
DWR User Interface

DWR Flight List

DWR Route Correction

Flight Plan Route

Potential Savings: 20 min
Potential Benefits Analysis
All Airlines, All Flights, Fort Worth Center 2013

100,000 min for 15,000 flights
Fort Worth Center 2013

Potential Flight Time Savings (min)
Potential savings
Potential savings corrected for observed amendments

AAL  UAL  ASQ  SWA  GA  EGF  FDX  SKW  DAL  AWE  Other
Traffic Aware Strategic Aircrew Requests (TASAR) NASA Flight Deck Application for En Route Flight Optimization

David Wing, TASAR Principal Investigator
NASA Langley Research Center
david.wing@nasa.gov
TASAR Overview, March 2016

Enhanced User Request Process leveraging Cockpit Automation and Networked Connectivity to real-time operational data to optimize an aircraft’s trajectory en route.

Increased flight efficiency

Enhanced ATC request/approval process
Enhanced dispatch/aircrew coordination

ATC = air traffic control
NASA Traffic Aware Planner (TAP)

Flight-Efficiency EFB Application (“Type B”)

Connected to avionics via standard interfaces
  Ownship flight data, ADS-B traffic data

Connected to external data sources via internet
  Latest winds, weather, airspace status, etc.

Computes real-time route optimizations
  - Integrates route optimization with conflict avoidance (traffic, weather, restricted airspace)
    • Powerful pattern-based genetic algorithm
    • Processes 400-800 candidates every minute
  - Produces 3 solution types: lateral, vertical, combo
  - Computes time & fuel outcomes of each solution
  - Displays solutions and outcomes to the pilots for selection and ATC request

Analyzes pilot-entered route/alt changes
  - Touch-screen interface for easy route/altitude entry
  - Displays time & fuel outcomes of entered route/alt
  - Depicts conflicts with traffic, weather, restricted airspace graphically and in text

EFB = electronic flight bag
TAP Auto Mode

Lateral  1937 lbs  16m 10s
WAAHU NASSH

Vertical  2511 lbs (5m 26s)
FL340

Combo  4272 lbs  11m 4s
FL340 / PROTN NASSH

Message  Processing...(60%)

Objective  Fuel
Limit  NASSH
Max WPTS  Two

ATC Approved  ATC Denied
Winds FL 300  Layers
TAP Manual Mode

- FL
- Add WPT
- Rejoin WPT
- Keyboard
- Clear All
- Save
- Delete
- Message
- Outcome
- ATC Approved
- ATC Denied
- Winds FL

RNG: 320
TRK: 270
WX: 350
NEWA

New England Weather Area
Simulation Experiments
Aug 2013, Oct-Nov 2014

Objectives
1. Assess TASAR effect on workload
2. Assess potential interference with primary flight duties
3. Assess TAP HMI design update
4. Assess CBT effectiveness

Results
1. No effect on pilot workload compared to standard flight-deck baseline condition
2. Non-normal event response not adversely affected
3. TAP useful, understandable, intuitive, easy to use
4. Standalone CBT was as effective as live instructor

- Fixed-based commercial transport sim
- 24 eval pilots (left seat, pilot flying)
- 2 simulated flights each, 5-6 use cases
- Two HMI designs (separate sims)

- Rigorous Human Factors experimental design
- Evaluated normal and non-normal flight conditions

CBT = computer based trainer
HITL = human in the Loop
HMI = human Machine Interface
OP = Operator Performance Lab, Univ. of Iowa
Airplane State Awareness and Prediction Technologies
Steven D. Young, PhD
NASA Langley Research Center

(Amended version of presentation given at the AIAA SciTech Forum, January 4-8, 2016, San Diego, CA)
INTRODUCTION

Study Process and Findings (2010-2014)

CAST-recruited gov’t-industry team:

- Analyzed 18 events from ~10 years prior; Identified 12 recurring problem themes; Suggested >270 intervention strategies

- Assessed each intervention strategy for effectiveness & feasibility; Recommended
  - 13 safety enhancements (SEs), no research req’d
  - 5 research safety enhancements (SEs)
  - 1 design SE where research is critical to implementation

- Published plans to achieve each safety enhancement

NASA’s contribution:

- NASA ARMD Airspace Operations & Safety (AOSP) Program
- Airspace Technology Demonstrations (ATD) Project
- Technologies for Airplane State Awareness (TASA) Sub-Project

Desired Outputs

Virtual Day-VMC Displays (SE-200)
Attitude & Energy State Techs (SE-207)
Systems State Technologies (SE-208)
Simulator Fidelity (SE-209)
Flight Crew Performance (SE-210)
Training for Attention Management (SE-211)

5-May-2016 ARMD Technical Seminar

http://www.skybrary.aero/bookshelf/books/2999.pdf
http://www.skybrary.aero/bookshelf/books/3000.pdf
SE-207/208 Research Team
“Green Line” – represents where the automation will take the aircraft if no intervention by the pilot, and no unexpected conditions are encountered.

Circle symbol and label – indicates (1) where a mode switch is predicted and what the new mode will be; or (2) where an energy-related problem is predicted to occur. For the latter, colors/salience will change based on proximity/time to alert (IAW 25.1322)

System Interaction Synoptic

Available on any of these display spaces

1. Mode control panel
2. Display panels
3. Flight-critical information
4. Flight-critical data systems
5. ISFD – standby instrument
   Flight control mode
System Interaction Synoptic

Available on any of these display spaces

EICAS Msg:

- NAV AIR DATA SYS

Non-normal

Associated checklist(s) available on both Electronic Flight Bags (EFBs)

Checklist(s) will be simplified:

1. Removes information now provided on this display
2. Context-relevant data provided rather than lists, or needs to look in reference documents
Research Flight Deck Cab

• Like a B757/B767
  – B757 aerodynamic model and handling qualities
  – Center aisle-stand; throttles
  – Overhead panel
  – FMS/MCP/Autopilot

• Like a B787
  – Four 17” LCDs (vertical)
  – One 17” LCD (horizontal)
  – Dual HUDs and EFBs
  – Narrow CDU keypads*
  – Display control panels

• Like Airbus
  – Sidesticks
  – Rate Command Attitude Hold control law

*with CDU display on LMFD
Status and Next Steps

- **AIME testing completed Jan 28**
  - 12 airline crews participated over 10 wk period; ~250 flights completed
  - Good cross section of airlines, experience, and type-ratings
  - Good system performance in general; detailed analysis underway
  - Generally positive feedback from crews; usability results being tabulated
  - Many many lessons-learned; Findings to be published (Fall 2016)

- **Work on schedule and progressing to remaining milestones through FY19**

- **New collaborations in development**
  - NRA-based awards (3) specific to SE-208 (pending contract negotiations)
  - FAA interagency agreement being drafted (SE-207, SE-208)
Questions?

richard.mogford@nasa.gov