NASA Research to Support the Airlines

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ARMD Video
“NASA Is With You When You Fly”
NASA Aeronautics

• NASA aeronautics has made decades of contributions to aviation
• Nearly every aircraft today has a NASA-supported technology on board
• Aeronautics research is managed by the Aeronautics Research Mission Directorate or ARMD
• ARMD starts by asking:
  – How can we help make air travel safer and more efficient?
  – What's the “cleanest, greenest” way to go?
  – How can we innovate?
  – How do we measure results?
• ARMD is helping to create the Next Generation Air Transportation System or NextGen
  • Goals are to increase the capacity, efficiency and flexibility of the national air space and address noise, emissions, efficiency, performance, and safety challenges
Examples of NASA Aeronautics Projects

• **IBM Watson**
  – Application to AOC and flight deck
• **Flight Awareness Collaboration Tool**
  – Winter weather management
• **Dynamic Weather Routes**
  – Efficient deviations around convective weather
• **Traffic Aware Strategic Aircrew Requests**
  – Flight deck tool for optimizing en route trajectories
• **Airplane State Awareness and Prediction Technologies**
  – Analyzed aircraft accidents and incidents
  – Developed and tested interventions

NASA = National Aeronautics and Space Administration
AOC = Airline Operations Center
IBM Watson

• IBM delivered a report to NASA in FY16 on how to apply Watson to the AOC
  – Support dispatch and maintenance in accessing FAA regulations, airline procedures, aircraft manuals, etc.
  – Extend to ACARS messages and Internet data
• NASA Langley is applying Watson to the flight deck
  – Assist pilot to identify risks and determine/prioritize actions needed to mitigate them
  – Identify, evaluate, and trap errors
  – Continually and autonomously maintain safety-of-flight

FAA = Federal Aviation Administration
ACARS = Aircraft Communications Addressing and Reporting System
Flight Awareness Collaboration Tool

- 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
FACT Prototype
FACT Progress

- Web-based prototype will be completed in 2017
- Plan to demonstrate FACT to airlines and airports to seek feedback
- Will make modifications and improvements
- FACT platform will be used to host automation tools (e.g., predicting airport capacity, managing snow removal)
- Developing AOC simulator at NASA Ames to evaluate FACT
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

• Research themes
  – AOC simulation
  – Study dispatcher workload, situation awareness, errors
  – Display/system integration
  – Managing/accessing large information databases from multiple sources
  – Preferred routes
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)

- Flight Plan Route
- Return Capture Fix
- Dynamic Weather Route
- Auxiliary Waypoints
- Maneuver Start Point

Continuous Automatic Search
Finds High-value Route Correction Opportunities
Sample DWR

Sample Flight
A320 Houston/Denver

DWR Route
7.8 min potential savings

Flight Plan Route
DWR User Interface

Potential Savings: 20 min

DWR Flight List

Flight Plan Route

Congestion on Flight Plan

DWR Route Correction

Congestion on DWR

DWR Flight List

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

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TASAR Design

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

Internally sourced data

Avionics Trajectory Application

Navigation Database

Aircraft Performance

Real-Time Trajectory Optimizer Application

Externally sourced data

Traffic
Weather
Airspace

TASAR Overview, March 2016
NASA Traffic Aware Planner (TAP) Auto Mode

- Lateral: 1937 lbs, 16m 10s
- Vertical: 2511 lbs, 5m 26s
- Combo: 4272 lbs, 11m 4s
- FL340 / PROTN NASSH

- Message: Processing... (60%)
- Objective: Fuel
- Limit: NASSH
- Max WPTS: Two

- RNG: 1120
- TRK 283
- MAG

- WAAHU NASSH
- MEVDY
- NASSH
- PROTN
- JUBDI
- AHYOB
- DOGGS
- ALT FL340
- ODLOE

ATC Approved
ATC Denied
Winds FL 300
Layers
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 simulation
• 24 evaluation pilots (left seat, pilot flying)
• 2 simulated flights each, 5-6 use cases
• Two HMI designs (separate simulations)

Rigorous human factors experimental design
Evaluated normal and non-normal flight conditions

Route, KJFK - KLAX
ATC Station
EFB Mounted in Simulator
U.I. Operator Performance Lab 777 Simulator

HMI = human machine interface
CBT = computer based trainer
U.I. = University of Iowa
TASAR Flight Trials
November 2013, June 2015

Objectives
1. Verification of live data interfaces and TAP functionality in flight
2. Pilot and controller assessments of TAP and TASAR operations
3. Partner airline risk reduction

Results
1. TAP processed live avionics, ADS-B, and internet data, and functioned properly
2. Pilots rated HMI usability high; workload low
3. ATC provided extensive feedback on user request acceptability factors; found most TASAR requests acceptable
4. Airline deployment risk areas reduced: hardware, connectivity, accuracy, human factors

NOAA = National Oceanic and Atmospheric Administration
SAA = Special Activity Airspace

Reference AIAA-2014-2166
Airplane State Awareness and Prediction Technologies
Steven D. Young, PhD
NASA Langley Research Center ARMD
Technical Seminar, May 5, 2016

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

Study Process and Findings (2010-2014)

Commercial Aviation Safety Team (CAST) - recruited from government & industry

- 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 required
  - 5 research 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 Program
- Airspace Technology Demonstrations Project
- Technologies for Airplane State Awareness Sub-project
- 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)

ARMD = Aeronautics Research Mission Dir.
VMC = Visual Meteorological Conditions

5-May-2016

ARMD Technical Seminar
Trajectory & Mode Change Prediction

“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

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

ISFD = Integrated Standby Flight Display
Non-normal

Associated checklist(s) available on both EFBs

Checklist(s) will be simplified:

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

EICAS = Engine-indicating & Crew-alerting System
AFDS = Autopilot Flight Director System
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” displays (vertical)
  – One 17” display (horizontal)
  – Dual HUDs and EFBs
  – Narrow CDU keypads
  – Display control panels

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

FMS = Flight Management System, MCP = Mode Control Panel
HUD = heads up display, CDU = Control Display Unit
Status and Next Steps

• Simulation testing completed January 28, 2016
  – 12 airline crews participated over 10 week 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 lessons-learned; findings to be published (Fall 2016)

• Work on schedule and progressing to remaining milestones through FY19

• New collaborations in development
  – NASA Research Agreement-based awards (3) specific to SE-208
  – FAA interagency agreement being drafted (SE-207, SE-208)
Questions?

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