Humans, Autonomy and eVTOLs

Dr. Michael Feary

From VTOL to eVTOL Workshop
May 24, 2018
Humans, Autonomy and Safety Challenges for eVTOLs

- Current Aviation Safety Issues
- Flight Crew Requirements
- Transition to Autonomy
- eVTOL operations research
### Commercial Aviation Safety Issues

**Recent increase in opportunities for major trauma:**
- uncontained engine failure, explosion, bird or drone strike

**Fatalities by CAST/ICAO Common Taxonomy Team (CICTT)**

<table>
<thead>
<tr>
<th>Category</th>
<th>External Fatalities</th>
<th>Onboard Fatalities</th>
<th>External Fatalities + Onboard Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOC-I</td>
<td>1756 (65)</td>
<td>1007 (0)</td>
<td>2763 (65)</td>
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<tr>
<td>CFIT</td>
<td>766 (17)</td>
<td>352 (0)</td>
<td>1118 (17)</td>
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<tr>
<td>RE-Landing + ARC + USOS</td>
<td>352 (0)</td>
<td>352 (0)</td>
<td>704 (0)</td>
</tr>
<tr>
<td>UNK</td>
<td>156 (69)</td>
<td>156 (69)</td>
<td>312 (69)</td>
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<tr>
<td>MAC</td>
<td>225 (0)</td>
<td>225 (0)</td>
<td>450 (0)</td>
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<tr>
<td>SCF-NP</td>
<td>154 (38)</td>
<td>154 (38)</td>
<td>308 (38)</td>
</tr>
<tr>
<td>RE-Takeoff</td>
<td>122 (3)</td>
<td>122 (3)</td>
<td>244 (3)</td>
</tr>
<tr>
<td>OTHR</td>
<td>110 (8)</td>
<td>110 (8)</td>
<td>220 (8)</td>
</tr>
<tr>
<td>RAMP</td>
<td>96 (1)</td>
<td>96 (1)</td>
<td>192 (1)</td>
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<tr>
<td>RE-Takeoff</td>
<td>23 (0)</td>
<td>23 (0)</td>
<td>46 (0)</td>
</tr>
<tr>
<td>F-NI</td>
<td>1 (8)</td>
<td>1 (8)</td>
<td>2 (8)</td>
</tr>
<tr>
<td>EVAC</td>
<td>1 (8)</td>
<td>1 (8)</td>
<td>2 (8)</td>
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<tr>
<td>SCF-PP</td>
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<td>4 (2)</td>
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<td>6 (0)</td>
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<tr>
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<tr>
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<td>2 (0)</td>
<td>2 (0)</td>
<td>4 (0)</td>
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<tr>
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</tbody>
</table>

**Note:** Principal categories as assigned by CAST.

*Does not include Air France 447 (228) or Colgan Air 3407 (50)

**Controlled Flight into Terrain**

**Runway Excursion + abnormal runway contact**

**Energy management**

**Attitude Awareness**

ICAO/CAST, 2015
Loss of Control/Energy Management

Diversity in eVTOL design and operational paradigms
Who will pilot the eVTOLs?

- Long-term vision is no onboard pilot
- Short-term will require pilots
- Regional Airlines are cancelling flights and routes due to pilot shortage
  - At least one airline failure is blamed on pilot shortage
- Training is a challenge
  - Majority trained by military
    - Difficult for civilian helicopter training schools to stay in business. Some helicopter training schools are closing due to lack of instructors (part 61) (How many 141 helicopter schools are there? Any?)
    - Civil airlines are transitioning helicopter pilots for 121 airlines
Aircraft Automation: A Brief History

- **Autopilot**
- **Autoland**
- **Automatic Navigation**
- **Flight Management System**

- **1st Generation of Jet Airliners** (1910)
- **2nd Generation** (1930)
- **3rd Generation** (1950)
- **4th Generation** (1970)
- **1990**

- **1910**: Fly-by-wire, envelope protection
- **1930**: 1st Generation of Jet Airliners
- **1950**: 2nd Generation
- **1970**: 3rd Generation
- **1990**: 4th Generation
Aviation Automation Fatal accident rate

10 year moving average fatal accident rate by aircraft generation

Accidents per million flight departures

- First generation
- Second generation
- Third generation
- Fourth generation

Airbus, 2017
Flight Crew Functions

Cross cutting

- Information Integration
- Planning
- Guidance and Control
- Navigation
- Communication

- Inspection and Test
- Environmental Factors
- Risk Assessment and Decision Making
- Hazard Detection and Avoidance

Vehicle and Operation Specific

- Systems Operation
- Emergency Procedures
- Special Procedures
- Security Procedures
- Company Procedures

Feary, AIAA Aviation 2018
Flight Crew Functions

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Feary, AIAA Aviation 2018
NASA Ames Human Systems Integration

**Virtual Environments**
for Teleoperation: Robotic Arm and Traffic Management Applications

**Crew Decision Making** and
Crew Resource Management for Aviation and Space Operations

**Automation Design** for
Air-Ground Operations, Boeing 7E7, Shuttle, CEV, Mission Operations

**Procedures and Document Design**
for Aviation Maintenance and Shuttle Maintenance

**Fatigue Studies**
for Ultra Long-Haul Flights, MER Ground Operations, and ISS Crew work schedules

**Cognitive Models**
of Attention and Information Processing in Air Traffic Control and Shuttle Range Operations

**Training**
for Line Oriented Flight Operations, Emergency Situations, Crew Interaction

**Vision Science**
and Visual Technologies for Flight Deck and Ground Control Displays
Stall Recovery Guidance

Objective: To develop guidance technology that helps pilots efficiently recover from stall.

- Developed algorithms that use flight dynamics to determine scenario/aircraft specific recovery guidance.
- Integrated guidance and Boeing/LaRC/ARC developed GTM aircraft model (with extended stall envelope) into the Vertical Motion Simulator (VMS) at Ames.
- Designed experiment with FAA and AFRC pilot feedback.
- Tested the guidance across four scenarios, simulating different stall entry conditions:
  - High altitude full stall
  - Final approach, descending
  - Low altitude with initial bank
  - Low altitude with bank and excessive nose-up trim
- 30 commercial pilots from multiple carriers, and 10 NASA AFRC test pilots participated.
- Received overall positive feedback, and quantitative results.
  - In particular, with almost no training the guidance helped pilots avoid secondary aerodynamic stalls in their recoveries at high altitude.
Examining Aircraft Capabilities

Oklahoma City KOKC

- LNAV + VNAV unable
- Autothrottle unable
- GND PROX alert may not occur
- WINDSHEAR alert may not occur
- Avoid icing conditions
- RNAV GPS approach not authorized
- RNAV GPS arrival not authorized

Available approaches: 35R, ILS, LOC, KOKC App, other rwys

NASA/TM—2018–219775

Managing Complex Airplane System Failures through a Structured Assessment of Airplane Capabilities

Randall J. Minnau
San Jose State University Foundation

Michael Fezry
NASA Ames Research Center

Lars Fricks
Dahlin Aerospace

Michael Stewart
San Jose State University Foundation

Randy Riegseger
San Jose State University Foundation

Alex Pogorelic
San Jose State University Foundation

Rohit Deshmukh
San Jose State University Foundation

National Aeronautics and Space Administration
Ames Research Center
Moffett Field, California

March 2018
Cockpit Hierarchical Activity Planning and Execution (CHAP-E)

Formal Procedure Language
- Possible events
- Pilot Tasks/Actions
- Instrument Monitors/Flight Requirements

- Events
  - before([ARCHI-2]) (CLR: start(Clearance) 
    
  - after([CLR] & between([ARCHI], [GRIR]) ARM/localizer);
  - after([CLR] & after([Fmax]) & between([ARCHI], [GRIR])
    
- Actions
  - between([CLR], [ARCHI]) (SetMCP Alt(1800)) ; // glideslope intercept altitude
  - after([F20]) & between([AXMUL-2], [AXMUL]) (Gear: SetGear(Down));

- Monitors
  - throughout([CLDLY, RW28]) IAS in [Min, Max];
  - throughout([CLDLY, RW28]) MCP LMCGS = LOC;
  - throughout([CLDLY, RW28]) IAS > IASRef;
  - throughout([A1000, RW28]) StabilityApproach;

Procedure/Task Windows
- Easily test VTOL procedures
- Provides predicted aircraft state/configuration
Flight Crew Performance Research

Research for the Commercial Aviation Safety Team (CAST)

- ASIAS data analysis
  - Supporting development of alerting metrics

- Methods for assessing attention issues
  - Coordination with FAA on alerting guidance
  - Report on state of the art attention evaluation methods

- Technologies for detecting attention issues
  - Data analysis from studies to understand and mitigate channelized attention
  - Tech transfer through requests for expertise from industry (airlines, pilot orgs.) and government (FAA, DOT, ICAO)

23 publications * 5 journal articles listed on “most read” list
Operating in Urban Environments

Some issues:
- Required Navigation/Actual Navigation Performance
- Environmental Conditions
- Traffic Detection and Avoidance
Summary

- This is just a sample of some Human – Automation Interaction Challenges for eVTOLs

- Humans will remain important components of complex systems
  - Successful efforts going forward will be those that wrap new machine intelligence capabilities around human competencies in order to get the most out of each

- There are new safety challenges for operation of eVTOLs
  - Current safety issues will still be relevant

- There is a need to reduce requirements for pilot expertise, skill and proficiency

- Behavior across highly-integrated, dynamic and tightly coupled systems is a research challenge

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From VTOL to eVTOL Workshop, May 24, 2018
Back Up

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Operational Sim Capabilities for eVTOLs

Flight Deck Z Modular simulation software
   Extendible for different aircraft types
   Integrated avionics: Autopilot, Flight management system
Current Aircraft Automation Issues

Identification:
- Energy management
- Attitude Awareness

Info acquisition
- Info analysis
- Decision and action selection
- Action implementation

Assessment:
- Highly interconnected and integrated airplane systems
- Systems with more shared resources

Interaction:

Decision:
- Recent increase in opportunities for major trauma: uncontained engine failure, explosion, bird or drone strike
NASA Ames Human Systems Integration History

1970

1980

1990

2000

2010

Aviation Safety Reporting System

Aviation Safety Reporting System

Crew Resource Management

Fatigue Countermeasures

Automation Design

System Monitoring/ Data Visualization

Research Spectrum

Vision Science

Fundamental Research

Multi-modal Displays

Concept & System Studies

Human Performance Modeling

Biomedical

Design Tools
Readiness Level

- Planning & Decision Making
- Systems Management
- Basic Airmanship
- Takeoff & Landings
- Terminal Procedures
- Navigation
- Communication
- Detect & Avoid
- Emergency Procedures

100% Pilot
100% Automation
Assess Level of Maturity of Automation to Replace Pilot/Controller Function

Bowles, 2017