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National Aeronautics and Space Administration

Humans, Autonomy and eVTOLs

Dr. Michael Feary

From VTOL to eVTOL Workshop
May 24, 2018

Humans, Autonomy and Safety Challenges for eVTOLs

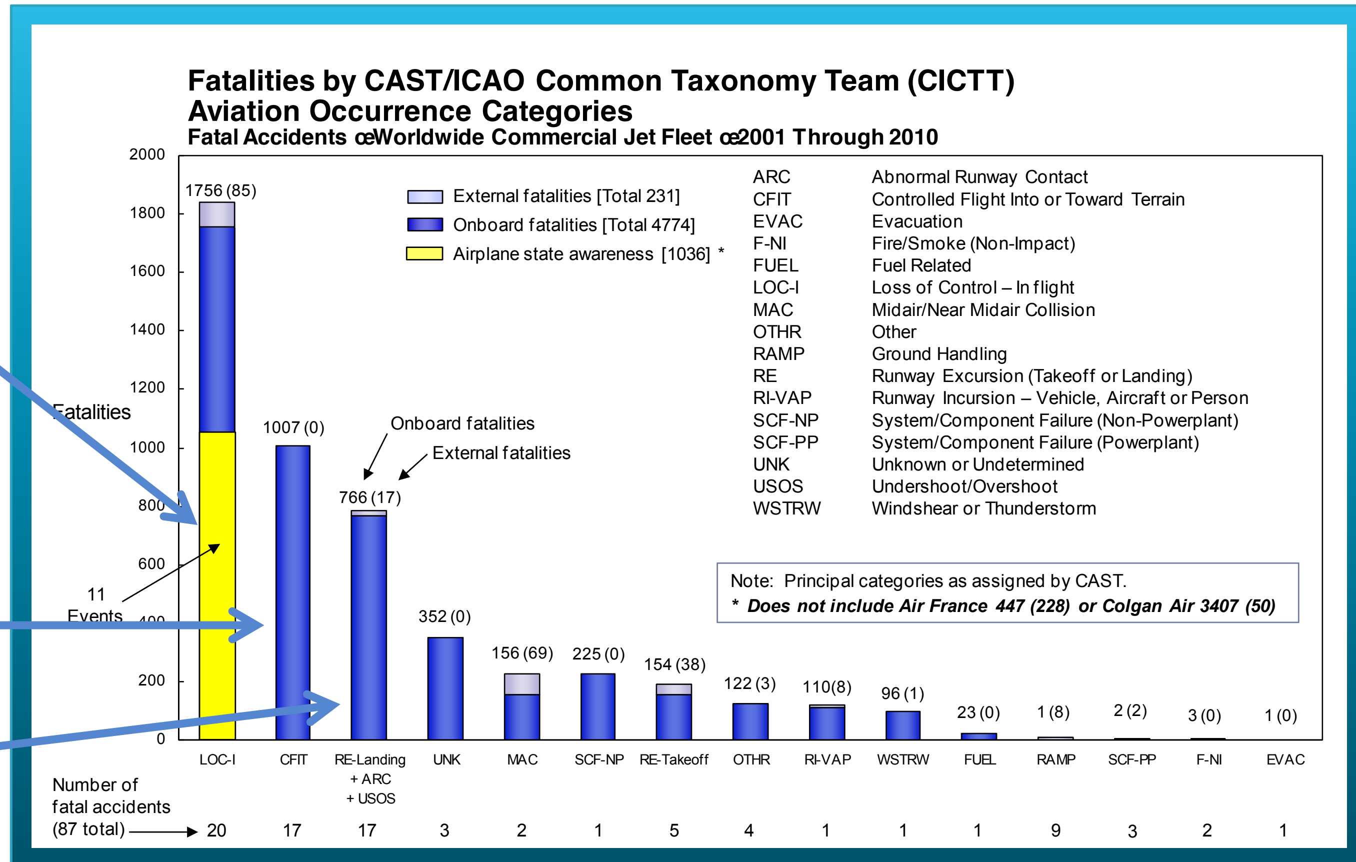
- Current Aviation Safety Issues
- Flight Crew Requirements
- Transition to Autonomy
- eVTOL operations research

Commercial Aviation Safety Issues

Energy management
Attitude Awareness

Controlled Flight into Terrain

Runway Excursion + abnormal runway contact



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

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

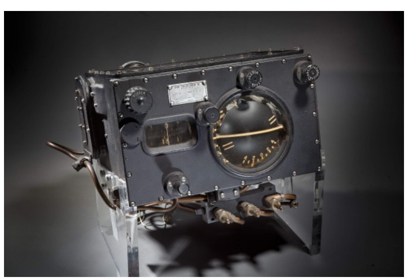
Aircraft Automation: A Brief History

Flight Management System

Fly-by-wire, envelope protection

Automatic Navigation

Autoland



Autopilot

1990 4th generation

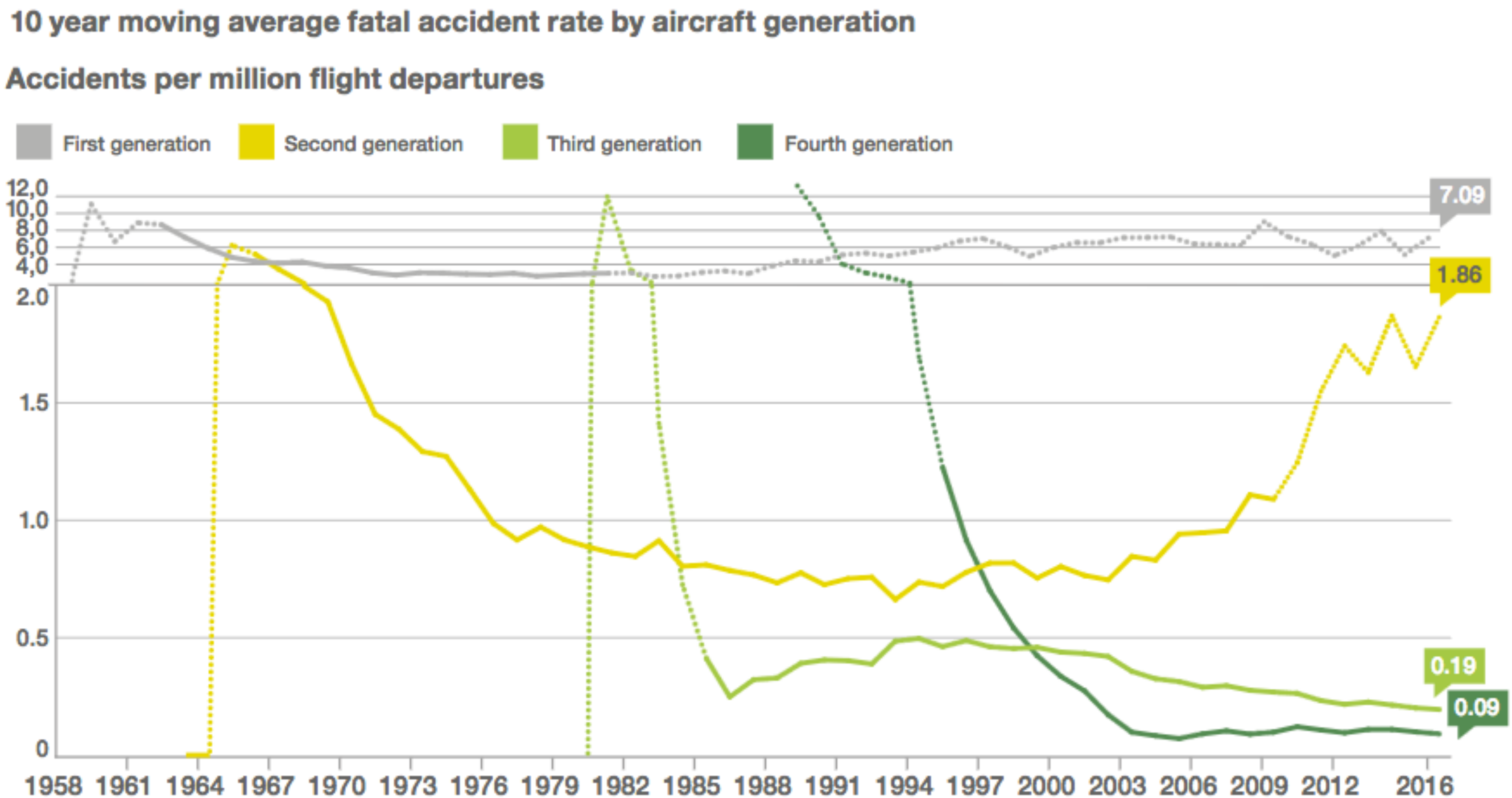
1970 3rd generation

1950 2nd generation]

1930 1st Generation of Jet Airliners

1910

Aviation Automation Fatal accident rate



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

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Feary, AIAA Aviation 2018

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NASA Ames Human Systems Integration

Virtual Environments
for Teleoperation: Robotic Arm and Traffic Management Applications

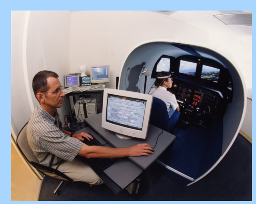
Crew Decision Making and Crew Resource Management for Aviation and Space Operations

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

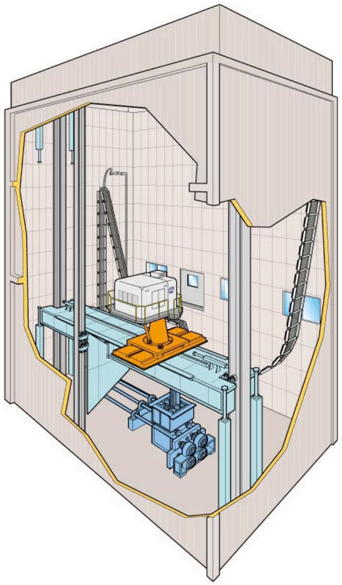
National Aeronautics and Space Administration

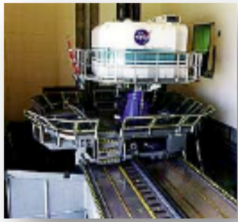
Stall Recovery Guidance

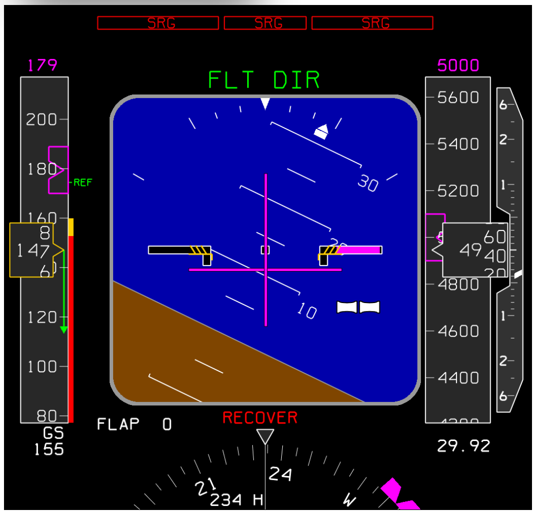
Objective: To develop guidance technology that helps pilots efficiently recover from stall.

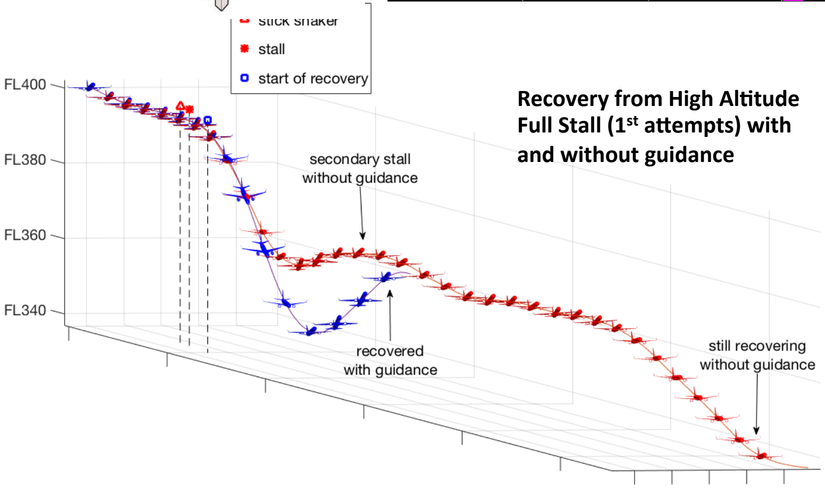
- Developed algorithms that use flight dynamics to determine scenario/aircraft specific recovery guidance.
- Integrated guidance and Boeing/LaRC/ARC developed GTM aircraft model (with extended stall envelope) into the Vertical Motion Simulator (VMS) at Ames.
- Designed experiment with FAA and AFRC pilot 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.
- Final report on NASA Technical Reports Server: NASA/TP–2017–219733

Vertical Motion Simulator (VMS) Facility



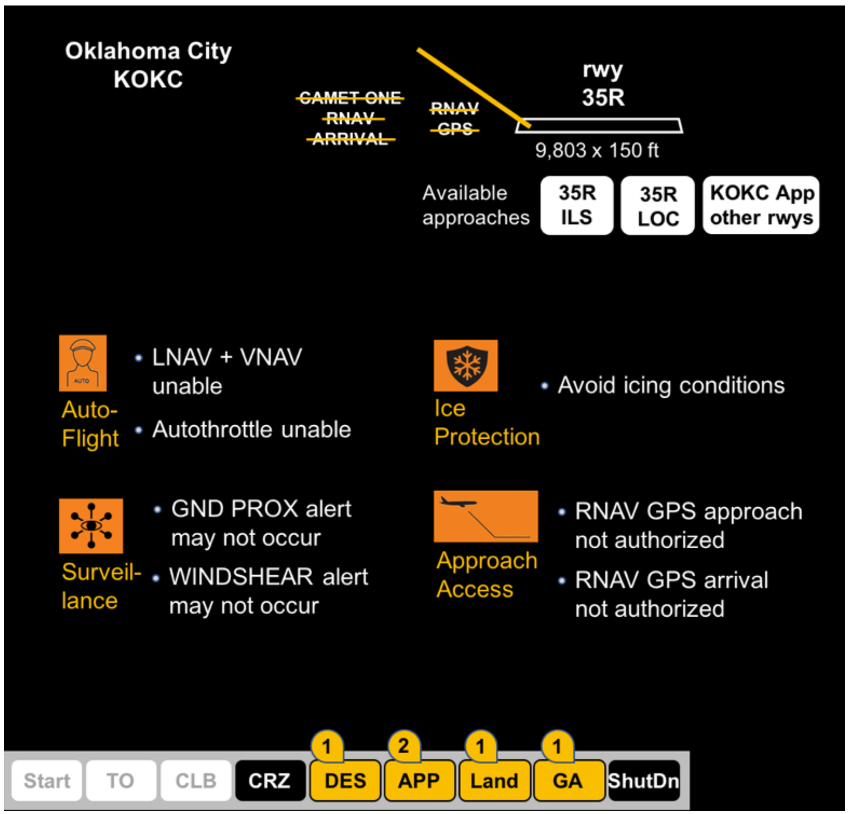






Recovery from High Altitude Full Stall (1st attempts) with and without guidance

Examining Aircraft Capabilities



NASA/TM—2018–219775

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

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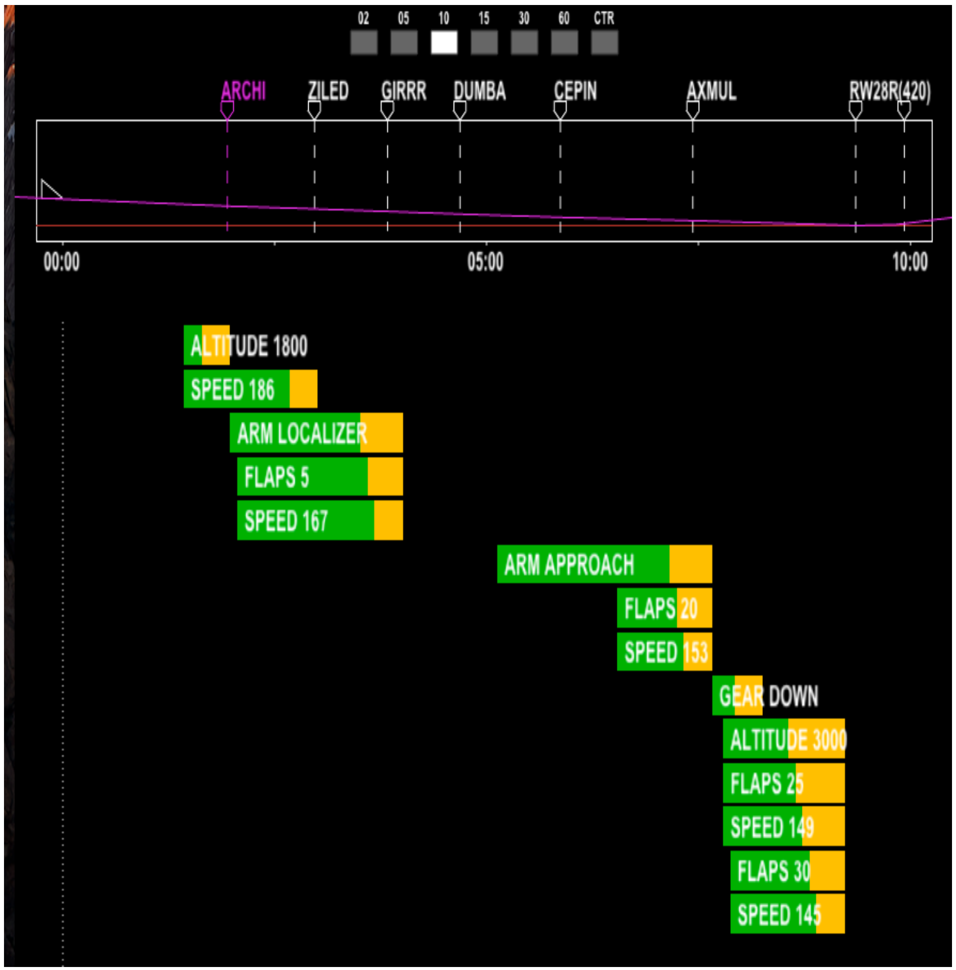
National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, California

March 2018

Cockpit Hierarchical Activity Planning and Execution (CHAP-E)



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Formal Procedure Language

- Possible events
- Pilot Tasks/Actions
- Instrument Monitors/Flight Requirements

```
• Events
    before[ARCHI-2] {CLR: start(Clearance = {ClearedApproach(ILS28R.ARCHI)}}} ;
    before[ARCHI] {F5max: start(IAS <= Vmax5)} ;
    F20: start(Flaps = 20);
    A1000: start[Alt <= 1000 + TDZE) ;
    ...
• Actions

    after[CLR] & between[ARCHI, GIRRR] {ArmLocalizer} ;
    after[CLR] & after[F5max] & between[ARCHI, GIRRR]
        <<SetFlaps(5), SetMCP-SPD(Vref5)>> ;
    between[CLR, ARCHI] {SetMCP-Alt(1800)} ;  // glideslope intercept altitude
    after[F20] & between[AXMUL-2, AXMUL] {Gear: SetGear(Down)} ;
    ...
• Monitors

    throughout[CEDES, RW28L] IAS in [Vref,Vmax] ;
    throughout[LocCap, RW28L] MCP-LMODE = LOC ;
    throughout[CEDES, RW28R] Vmax ≥ IAS ≥ Vref  ;
    throughout[A1000, RW28R] StabilizedApproach ;
    ...
```

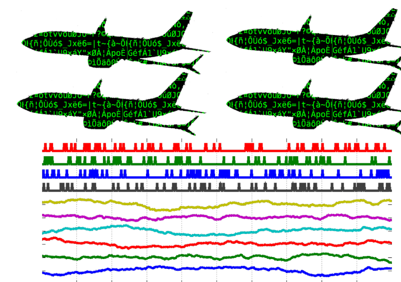
Procedure/Task Windows

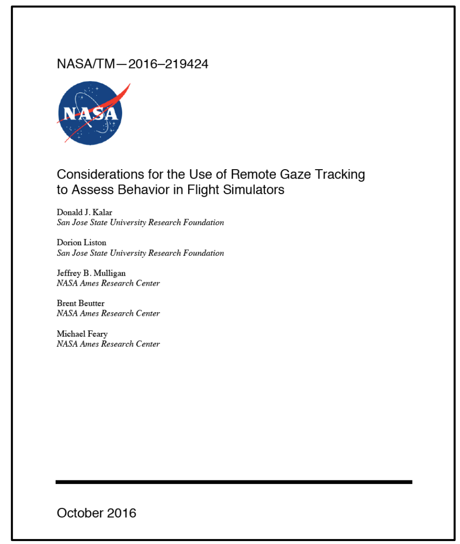
- Easily test VTOL procedures
- Provides predicted aircraft state/configura tion

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)





NASA/TM—2016–219424

Considerations for the Use of Remote Gaze Tracking to Assess Behavior in Flight Simulators

Donald J. Kalar
San Jose State University Research Foundation

Dorion Liston
San Jose State University Research Foundation

Jeffrey B. Mulligan
NASA Ames Research Center

Brent Beutter
NASA Ames Research Center

Michael Feary
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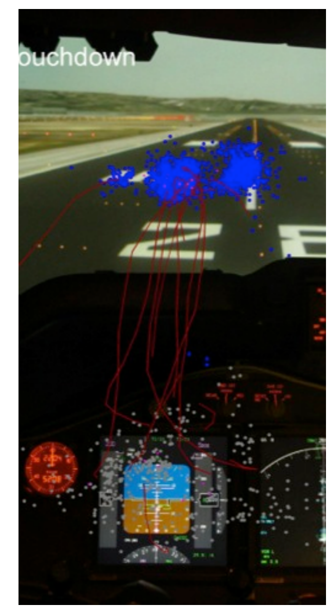
October 2016



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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Back Up

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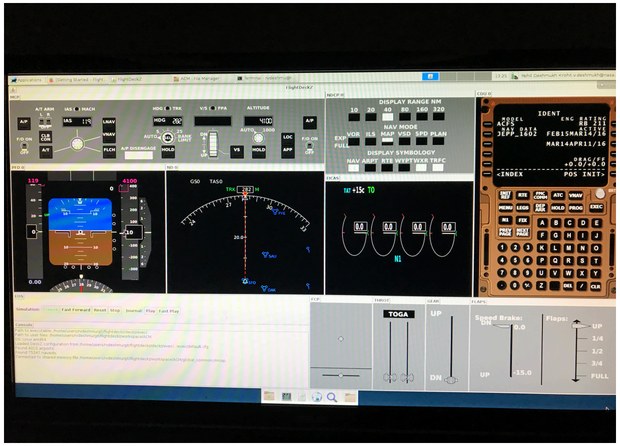
Operational Sim Capabilities for eVTOLs



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

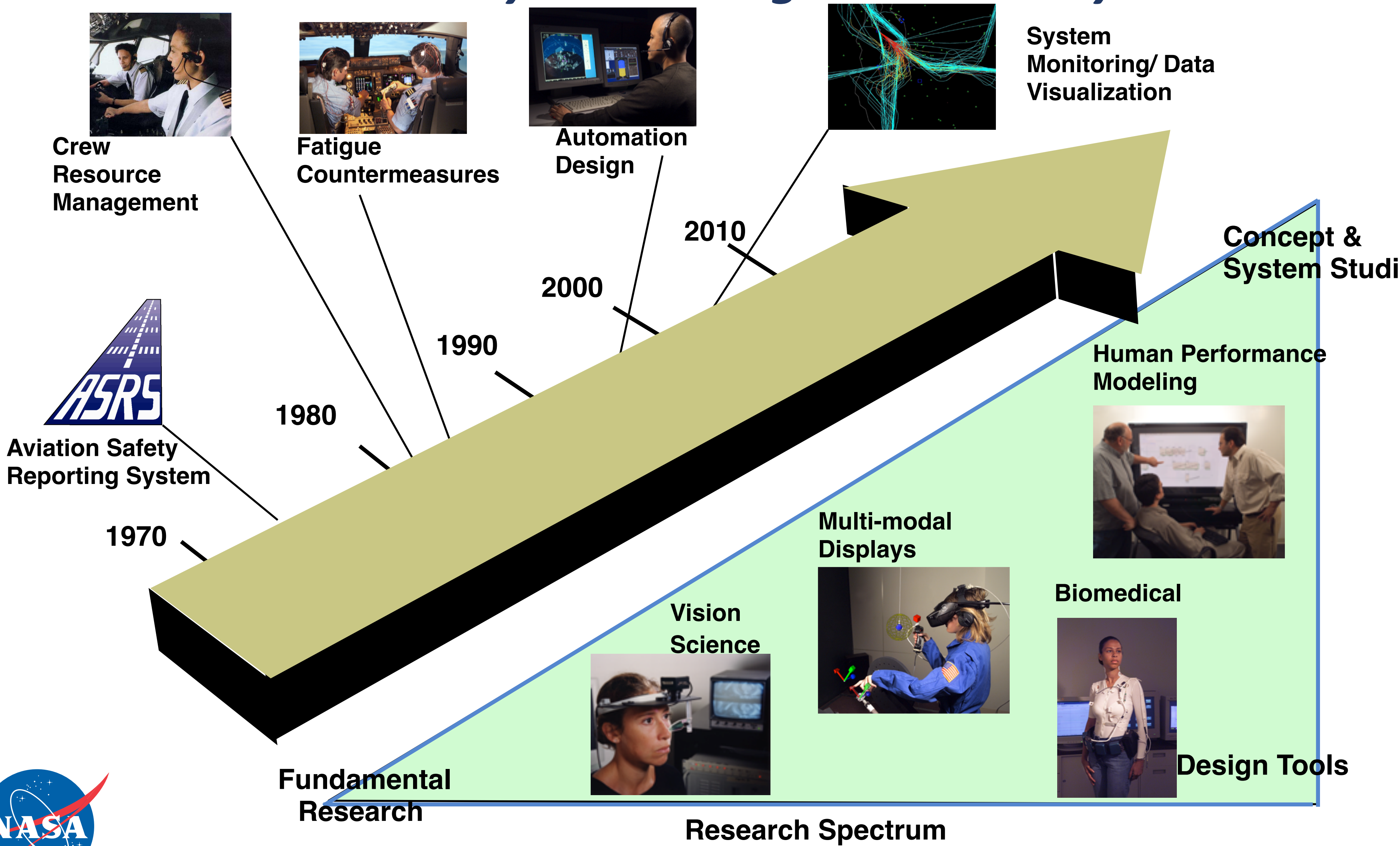
Systems with more shared resources

Interaction:

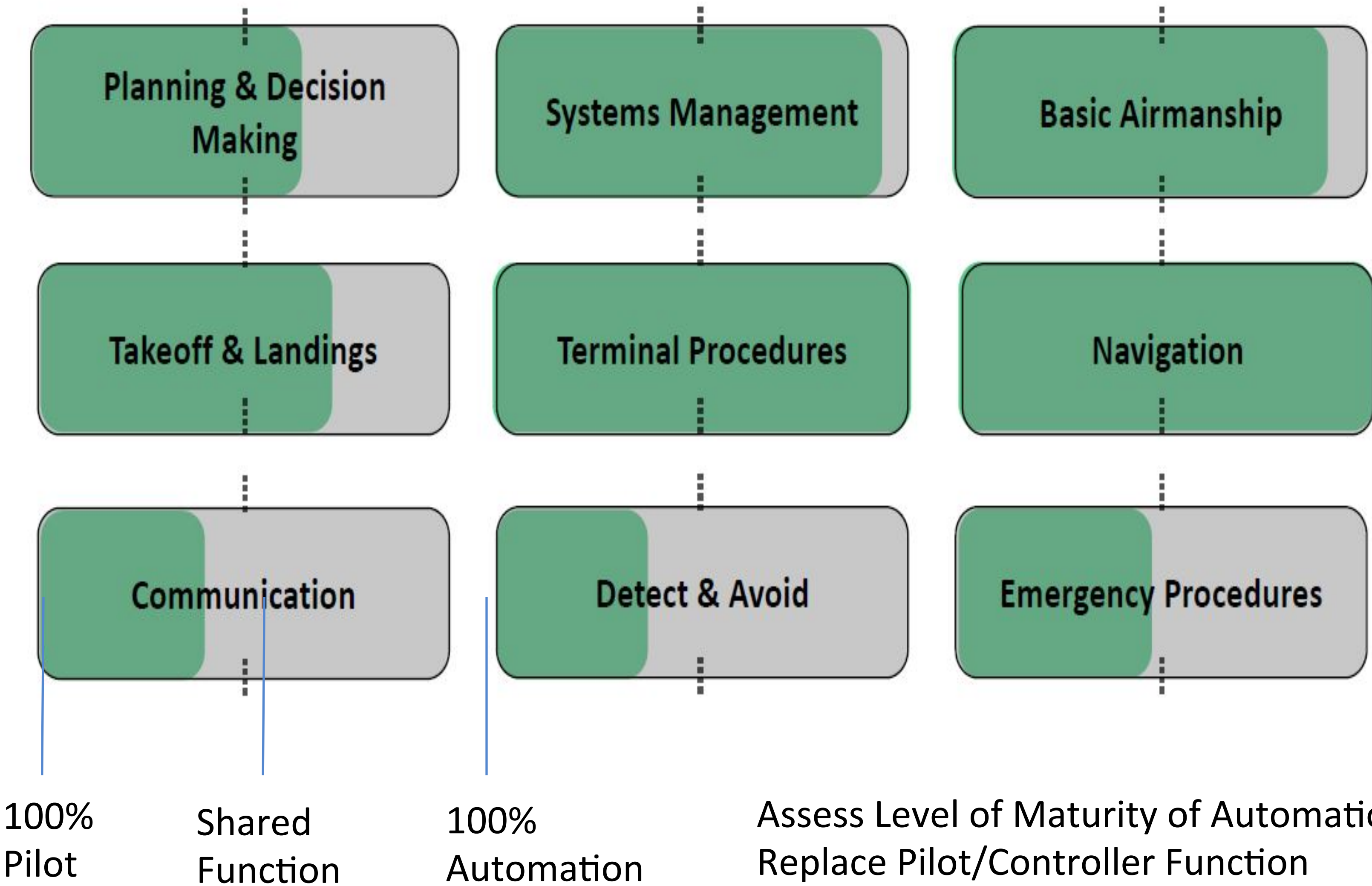
Decision:

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

NASA Ames Human Systems Integration History



Readiness Level



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

Bowles, 2017