Aviation Safety Program

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Program Director

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Program Goals

By 2016, identify and develop tools, methods, and technologies for improving overall aircraft safety of new and legacy vehicles operating in the Next Generation Air Transportation System.

Determining the Research Plan

- Where is safety research needed?
  - Current safety issues
  - Current constraints imposed by safety concerns
  - Future safety concerns with NextGen aircraft and operations
- What aspects should NASA cover?
  - Fundamental research up to the point of transition to regulatory bodies, other government agencies, and industry
  - Solutions focused on systematic analysis and engineering design methods as applied to aviation technologies and operations

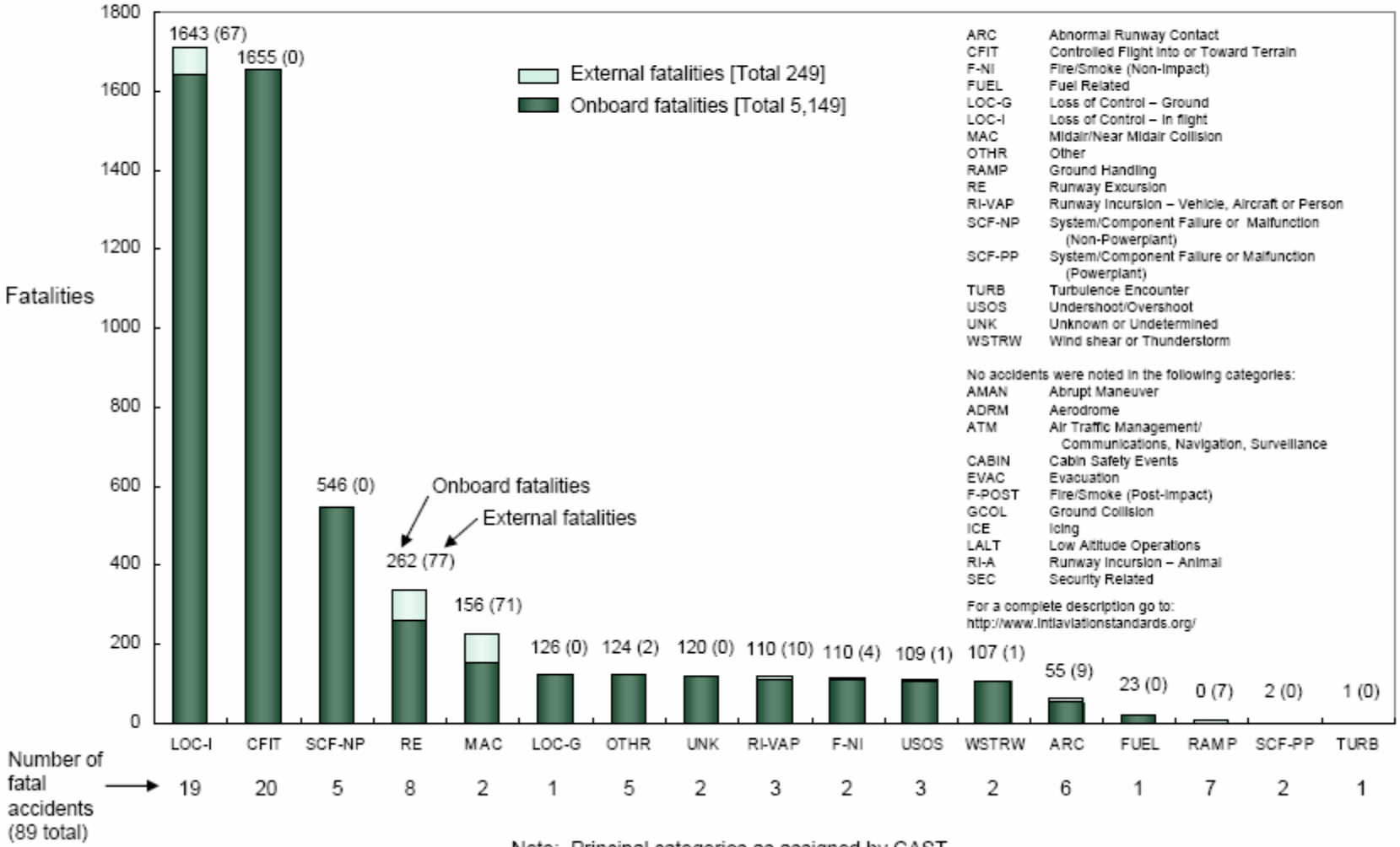
Examining Current Issues: NTSB Most Wanted List

Unacceptable response	**Reduce Dangers to Aircraft Flying in Icing Conditions** **Action Needed by The Federal Aviation Administration**	Use current research on freezing rain and large water droplets to revise the way aircraft are designed and approved for flight in icing conditions. Conduct additional research with NASA to identify realistic ice accumulations and incorporate new information into aircraft certification and pilot training requirements.
Acceptable response, progressing slowly	**Eliminate Flammable Fuel/Air Vapors in Fuel Tanks on Transport Category Aircraft** **Action Needed by The Federal Aviation Administration**	Implement design changes to eliminate the vulnerabilities of flammable fuel/air vapors in all transport category aircraft.
Unacceptable response	**Improve Runway Safety** **Action Needed by The Federal Aviation Administration**	Give immediate warnings of probable collisions/incursions directly to flight crews in the cockpit. Require specific air traffic control clearance for each runway crossing. Require landing distance assessment with an adequate safety margin for every landing.
Unacceptable response	**Improve Audio and Data Recorders/Require Video Recorders** **Action Needed by The Federal Aviation Administration**	Require cockpit voice recorders (CVRs) to retain at least 2 hours of audio. Require back-up power sources so cockpit voice recorders collect an extra 10 minutes of data when an aircraft's main power fails. Inspect and maintain data recorders yearly to make sure they operate properly. Install video recorders in cockpits to give investigators more information to solve complex accidents.
Unacceptable response	**Reduce Accidents and Incidents Caused by Human Fatigue** **Action Needed by The Federal Aviation Administration**	Set working hour limits for flight crews, aviation mechanics, and air traffic controllers based on fatigue research, circadian rhythms, and sleep and rest requirements. Develop a fatigue awareness and countermeasures program for air traffic controllers.
Unacceptable response	**Improve Crew Resource Management** **Action Needed by The Federal Aviation Administration**	Require that Part 135 flight crews receive crew resource management (CRM) training.

Causes of Accidents

Fatalities by CAST/ICAO Taxonomy Accident Category

Fatal Accidents – Worldwide Commercial Jet Fleet – 1997 Through 2006



Note: Principal categories as assigned by CAST.

Examining Current Issues: NTSB Safety-critical Systems Report

Issues called out:

- Structural analysis
- Human-system integration

Noted that design and certification assumptions are not systematically traced out, checked, and relied upon in later modifications

Examining Current Issues: Monitoring Current Operations

- While we strive for predictive methods for identifying and resolving safety concerns, we must still monitor for the unexpected
- Early implementation:
  Aviation Safety Reporting System (ASRS)
  - In 30 years of service, over 700,000 reports provided by pilots, controllers and others
  - Examined to flag research issues
- Potential for much more!
  - Examine for ‘vehicle’ issues and ‘system’ issues
  - Presents a vast data-mining challenge to live up to full potential

IVHM Technical Accomplishment:
Open Sourcing of Software for Classification of Text Reports

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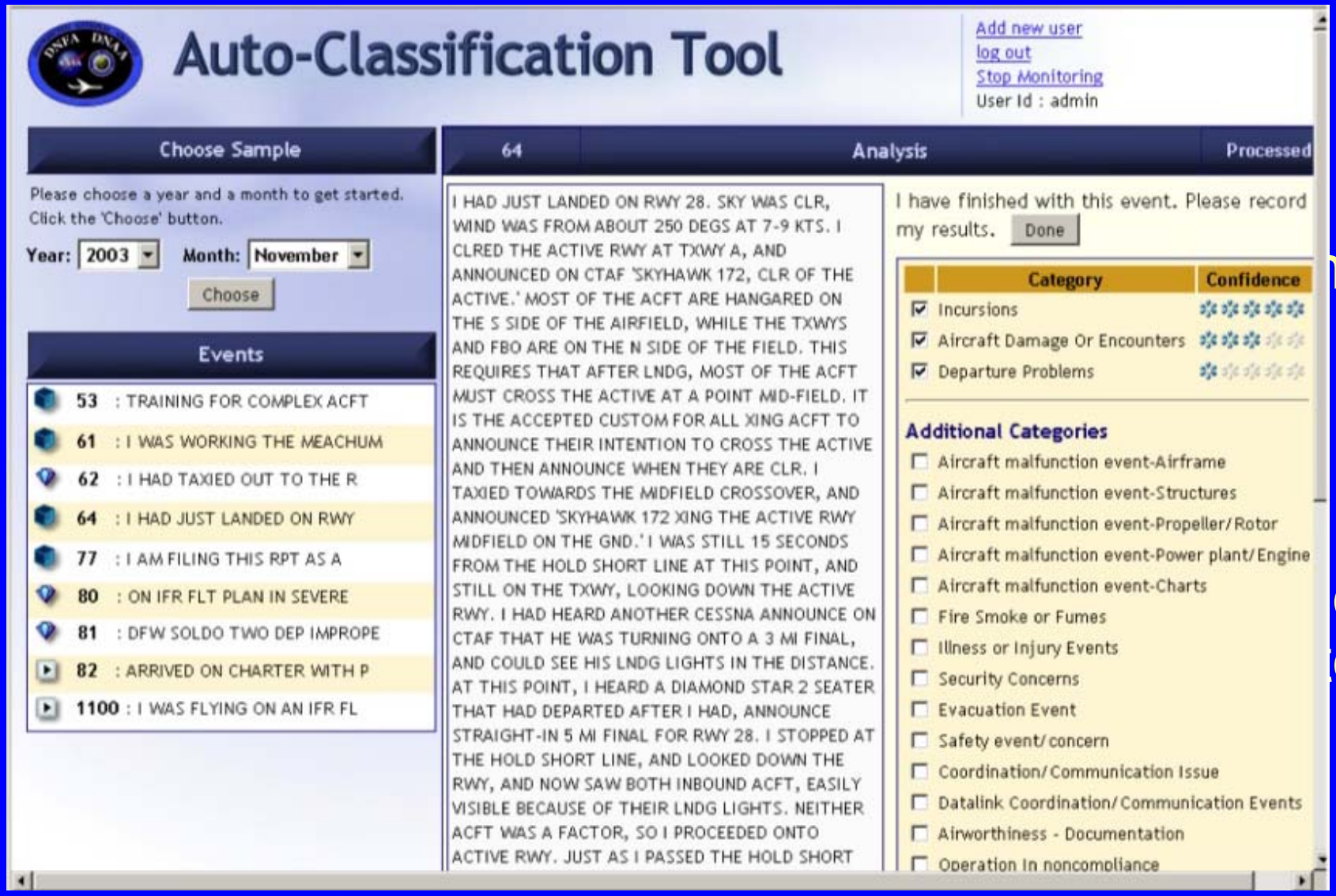


Examining Current Issues: National Research Council

Dependable software identified as critical to many safety-critical systems, especially aviation

Examining Current Issues: Software Cost as a Constraint

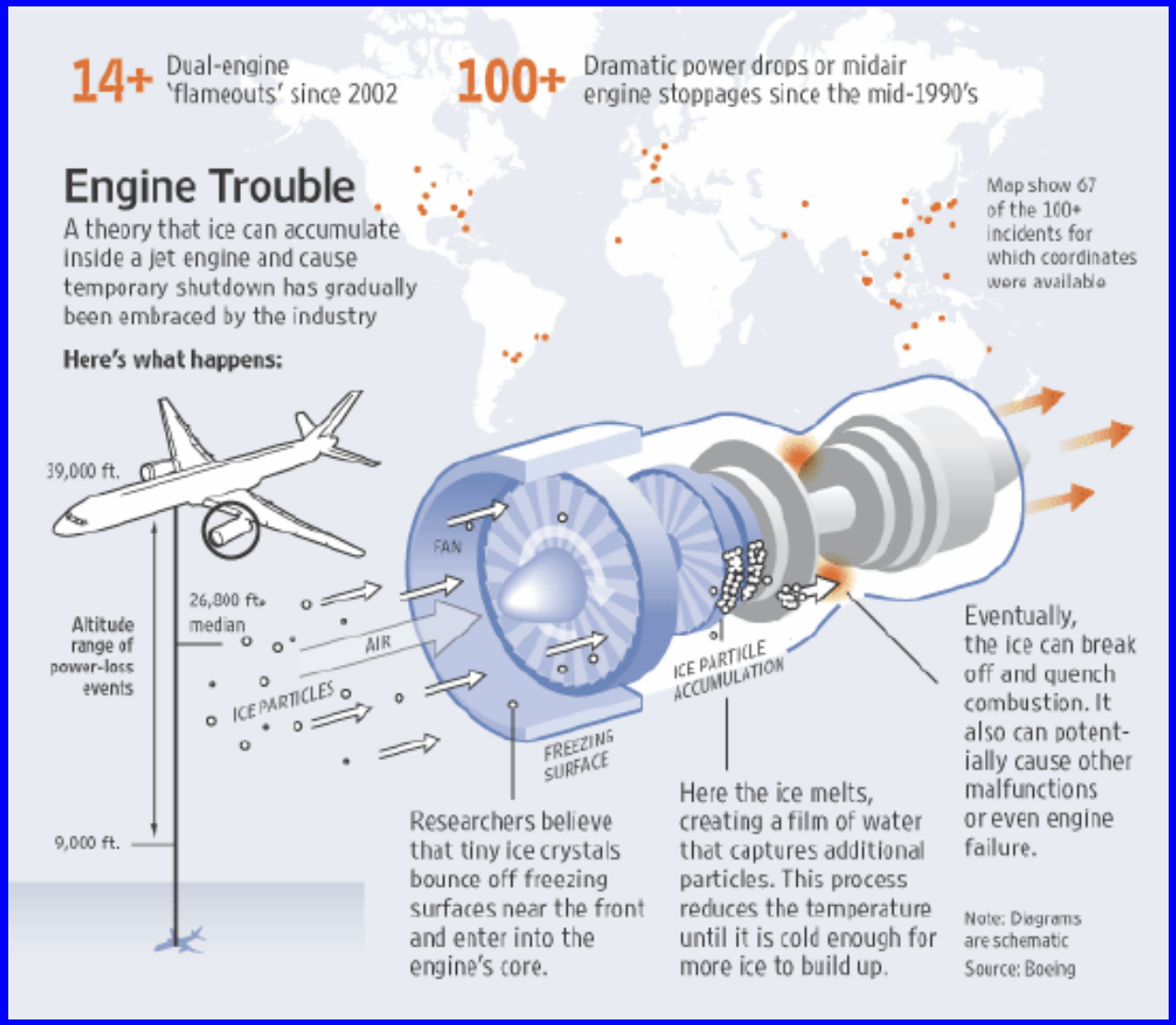
- Software Development Productivity for Industry Average Projects*
  - Cost from requirements analysis through software Integration and test

Characteristic Software Development Productivity	Source Line of Code/Work Month (SLOC/WM)
Classic rates	130-195
Evolutionary approaches	244-325
New embedded flight software	17-105

- Assuming a full cost rate of $150k/year/person the cost for one line of new embedded flight software is between $735 and $119 per line of source code

- * Lum, Karen Et, *Handbook for Software Cost Estimation.* May 30, 2003, JPL D-26303, Rev 0, Jet Propulsion Laboratory

Examining Current Issues: Engine Icing



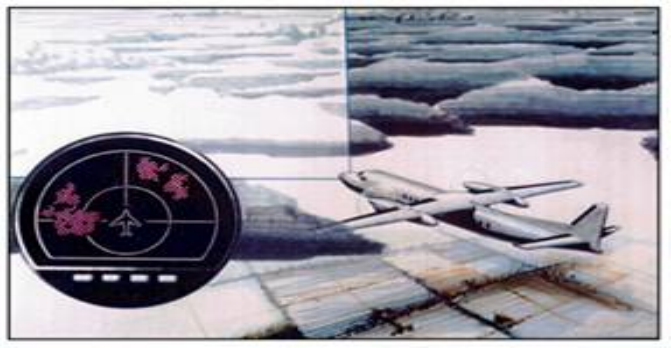
Underlying physics is poorly understood

NPRM in process

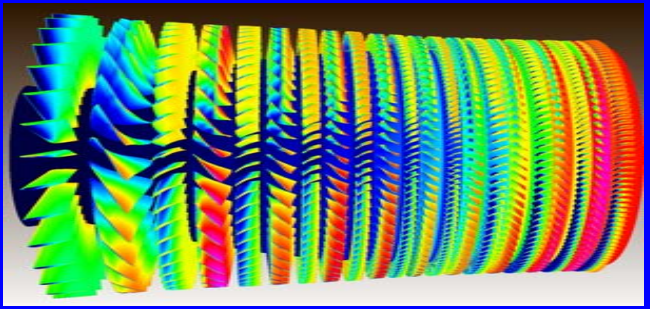
Engine Icing Flight Campaign

The highly instrumented NASA S-3B Viking will be flown into deep convective clouds associated with engine power loss to measure the cloud properties – namely the ice water content and ice particle size and shapes

A flight campaign based in Darwin Australia will provide insight into the cloud properties that cause engine powerloss



Results from the flight campaign will define conditions to improve engine designs and operating points for robustness to this environment.



Additionally, technologies for detecting hazardous conditions will be explored to improve hazard avoidance by the flight crew

Examining Future Issues: New Aircraft

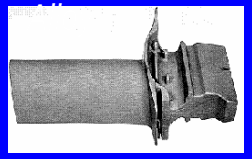
Aerogel

Porous Metal

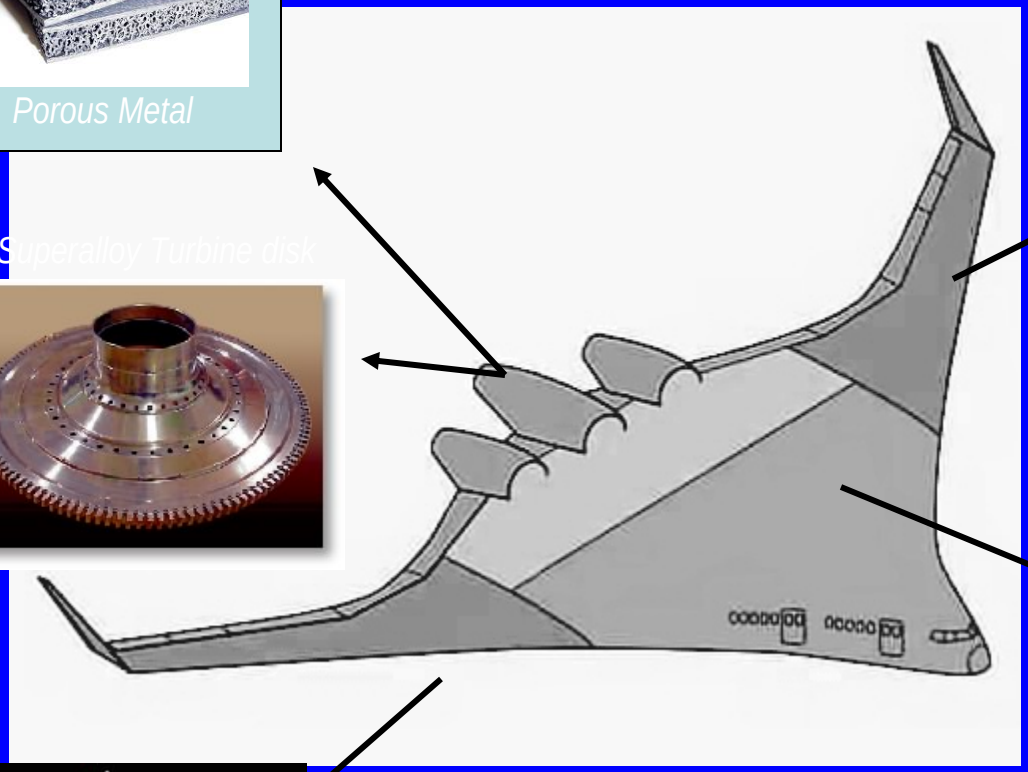
Multifunctional Structures with Porous Materials (Structural +Ballistic Impact + Acoustics)

Direct deposited metallic components

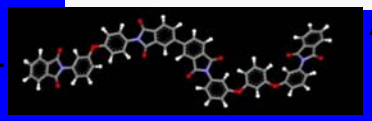
Single Crystal Turbine Blade

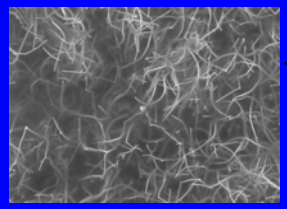


Superalloy Turbine disk



Stitched rod-stiffened composite structures





Computationally-guided multifunctional nanostructured materials development

Examining Future Issues: New Aircraft

- More complex avionics and software
- New stability and control concerns

Examining Future Issues: New Operations

- Emergent concerns in decentralized, tightly-coupled operations
- New roles for humans
- Greater demands for reliability
- Operation closer to hazardous conditions

Addressed early, many improvements to safety can also help efficiency measures (and vice versa)

Left too late, well…

Emergence

- Emergence: Behaviors observed at one level of abstraction which can not be predicted (maybe not explained!) at a different level of abstraction
- Example:
  - An unstable compression wave in a traffic stream in which each aircraft is individually stable
- My hypothesis: Many aspects of complex system safety are emergent phenomenon
  - How does analysis at one level extrapolate to another?

Are Humans the Problem or the Solution?

- Sometimes we make the humans sound like the problem… “the problem with the current system is that it is human-centric”…
- Can anyone name an accident not caused by ‘human error’?
- We don’t even systematically record all the cases where humans ‘saved the day’ – that’s their job

What Should Be the Human Contribution in Next Gen?

- Is it wise to plan for:
  - Automated activity beyond the capability of the human
  - Human supervising the automation for automation failures
  - Human intervening in degraded operations beyond the design limits of the automation

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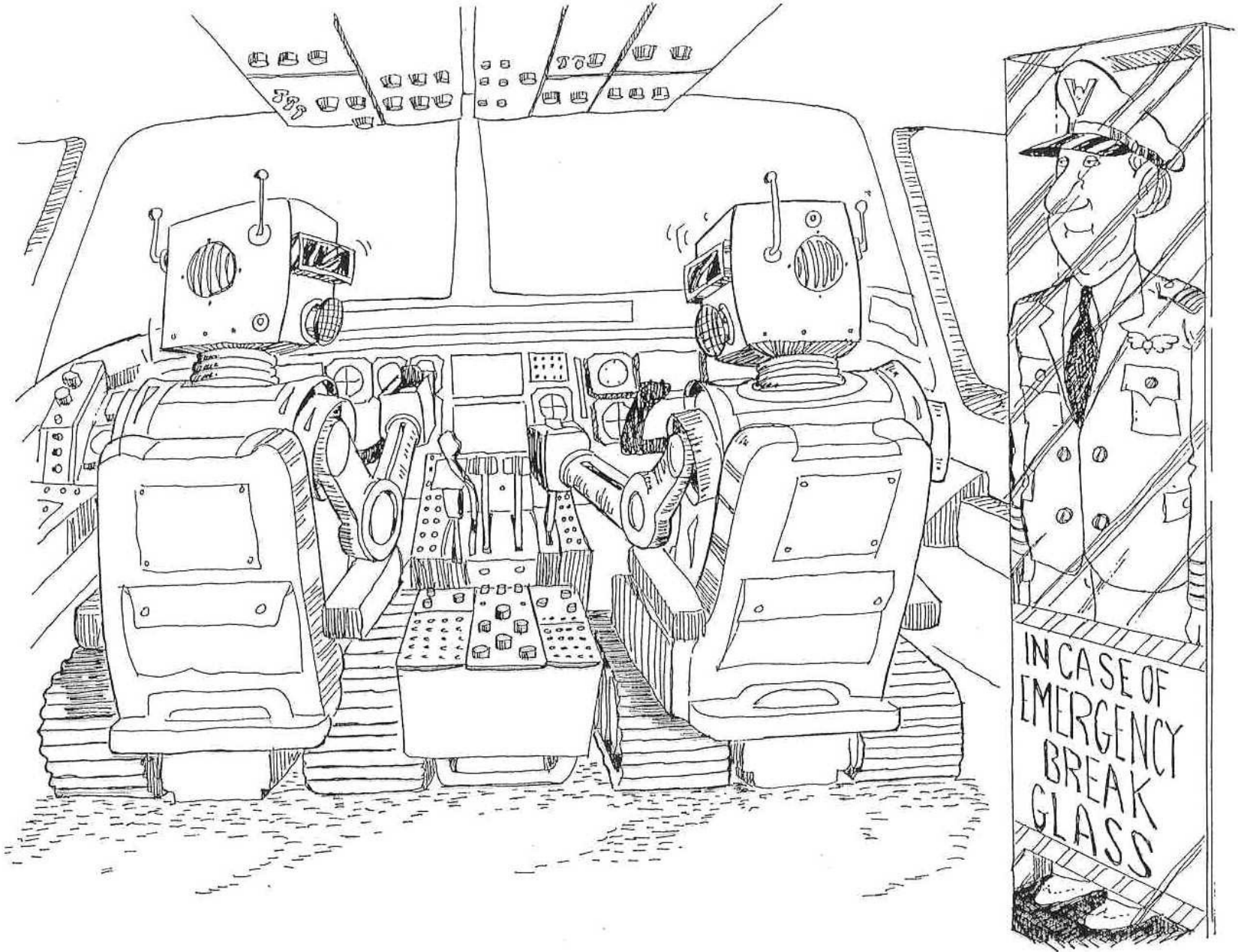
IN CASE OF
EMERGENCY
BREAK
GLASS

Describing Automation

- Robustness: The range of operating conditions with satisfactory performance
- Autonomy:
  - (Engineering): The sophistication of the automation's behaviors when objective and subjective reality overlap – regardless of problems with robustness
  - (Management): The ability to go do any task, no matter how simple, and report back when the manager should know anything

Robustness & Autonomy (management definition) will be our bigger challenges!

Timeline by Design Space

ConOps?
Organizational structure?
Inherent structural safety?

Functions and operations?

Selection of technologies?

Technologies, ConOps Given
Make Them Work

This is an opportunity to make the system safe from the start!

NearGen
Variants on current con ops

FarGen
Transformative, 2-3X

Timeline by Design Space

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Make Them Work

Demands advances on our part:
Envisioning the ConOps
Methods
Scope

NearGen
Variants on current con ops

FarGen
Transformative, 2-3X

Addressing Human Performance

1951 Fitts Report

Human Engineering for an Effective Air-Navigation and Traffic-Control System"

- Research Objective I. Determination of the Relative Abilities of Men and Machines to Perform Critical Functions in Air-Navigation and Traffic-Control Systems.
- Research Objective II. Determination of the Capacities of Human Operators for Handling Information.
- Research Objective III. Determination of the Essential Information Required at Every Stage in the Operation of an Air-Navigation and Traffic-Control System.
- Research Objective IV. Establishment of Criteria and "Indices-of.Merit" for Human-Operator and Man-Machine Performance.
- Research Objective V. Determination of Principles Governing the Efficient Visual Display of Information.
- Research Objective VI. Determination of Optimum Conditions for the Use of Direct Vision.
- Research Objective VII. Determination of the Psychological Requirements for Communication Systems.
- Research Objective VIII. Optimum Man-Machine Systems Engineering.
- Research Objective IX. Maximum Application of Existing Human-Engineering Information.

Our NextGeneration Fitts Report

Our human factors methods need to change!

- From metaphor and guideline to concrete, unambiguous, design guidance
  - Collaborative with tech designers – they need to hear human performance considerations, and we the physical constraints
- ConOps and operating procedures as the subject of rigorous design
- System engineering approach to identifying in and focusing resources on the biggest issues
  - Applying coarse methods at first to capture the 'low-hanging fruit'
- Predictive methods to guide R & D

Summary of Research Needs

- Aircraft aging and durability
  - Full fundamental knowledge about legacy aircraft
  - Start on knowledge about likely emerging materials and structures
- On-board system failures and faults – airframe, propulsion, aircraft systems (physical and software)
  - Early prediction, detection and diagnosis
  - Prognosis
  - Mitigation
- Monitoring for problems before they become accidents
  - Vehicle issues
  - Airspace issues
- Loss-of-control
  - Understanding flight dynamics of current and future vehicles in damaged and upset conditions
  - Control systems robust to unanticipated
- Flight in hazardous conditions
  - Modeling and sensing airframe and engine icing and icing conditions
  - Sensing and portraying environmental hazards
- New operations
  - Design of robust organizational structures
  - Design of effective, robust human-automation systems
  - Information management and portrayal for effective decision making

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Aircraft Aging & Durability

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Integrated Intelligent Flight Deck

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Integrated Resilient Aircraft Control

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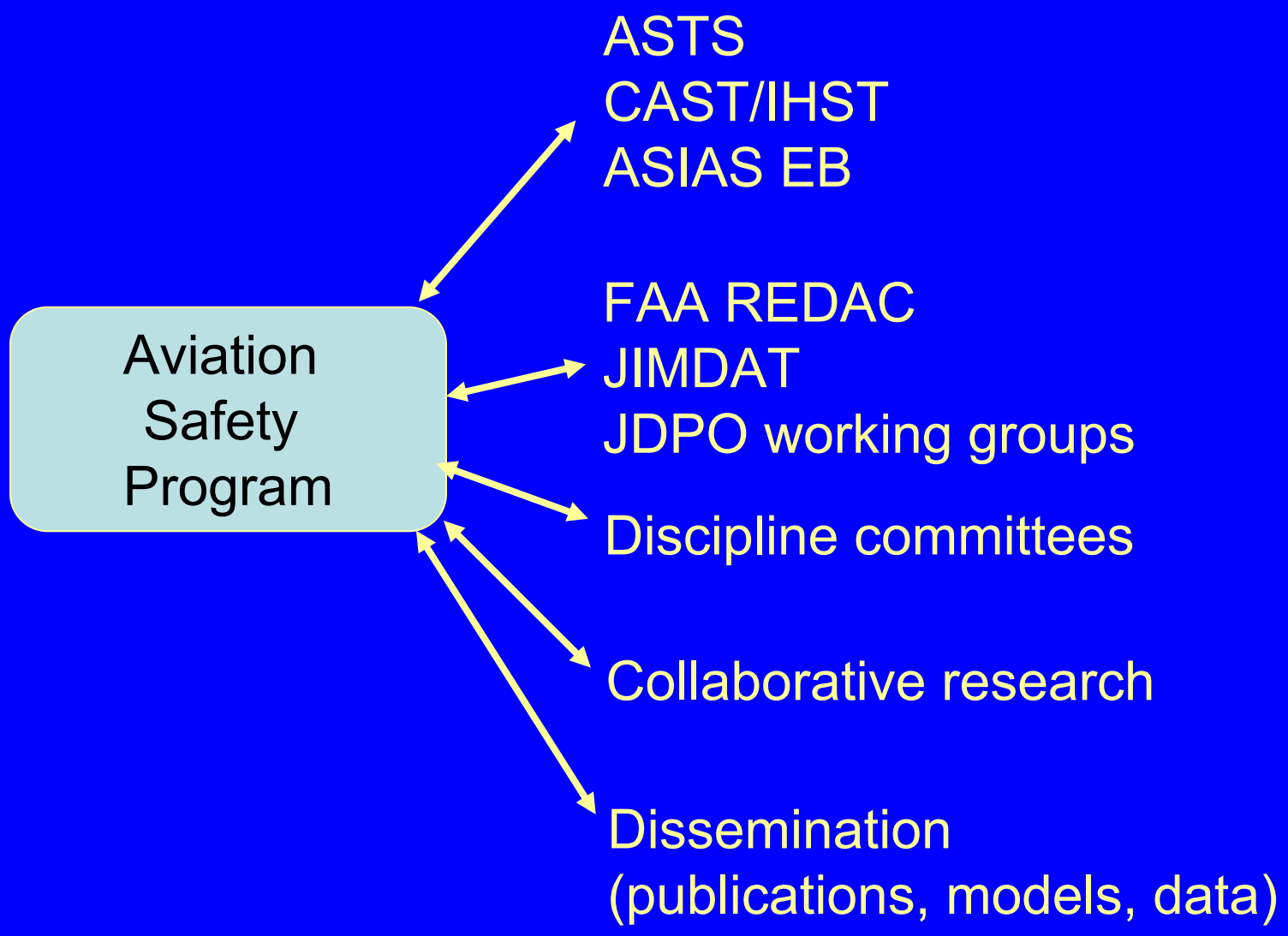
Integrated Vehicle Health Management

Interacting with the Community



Thank You!

Discussion?