Thoughts on Aviation Safety R&D

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6 September 2017

Some Drivers

- **Unmanned Aircraft**
- **Urban Air Mobility**
- **General Aviation Safety**
- **Commercial Aviation**
  - Continued Safety Improvements
  - Automation Complexity
  - Cost reductions
  - Pilot Shortages

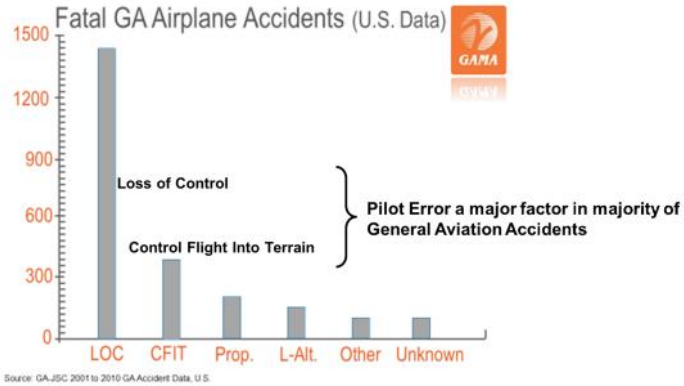

Aurora Flight Sciences


Creative Commons - Dkroetsch


UBS

Q-Series

Flying solo – how far are we down the path towards pilotless planes?

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Concepts

- **Unmanned Aircraft**
- **Urban Air Mobility**
- **General Aviation Safety**
- **Commercial Aviation**
  - Continued Safety Improvements
  - Automation Complexity
  - Cost reductions
  - Pilot Shortages

Accessible Aviation

Simplified Operational Interface

"Easy Button"

Automated Parcel Delivery

Pilotless Flight

Refuse to Crash Technology

Automation as a Safety Net

Reduced Crew Requirements

Single Pilot Ops

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Technology Implications

More Dependence Upon Software for Safe Operations

- **Human-Machine Teaming**
- **Software Assurance**
- **Cybersecurity**
- **Cyber-Resiliency**

Software is both a key enabler and a barrier to operational implementation

- **Certification**

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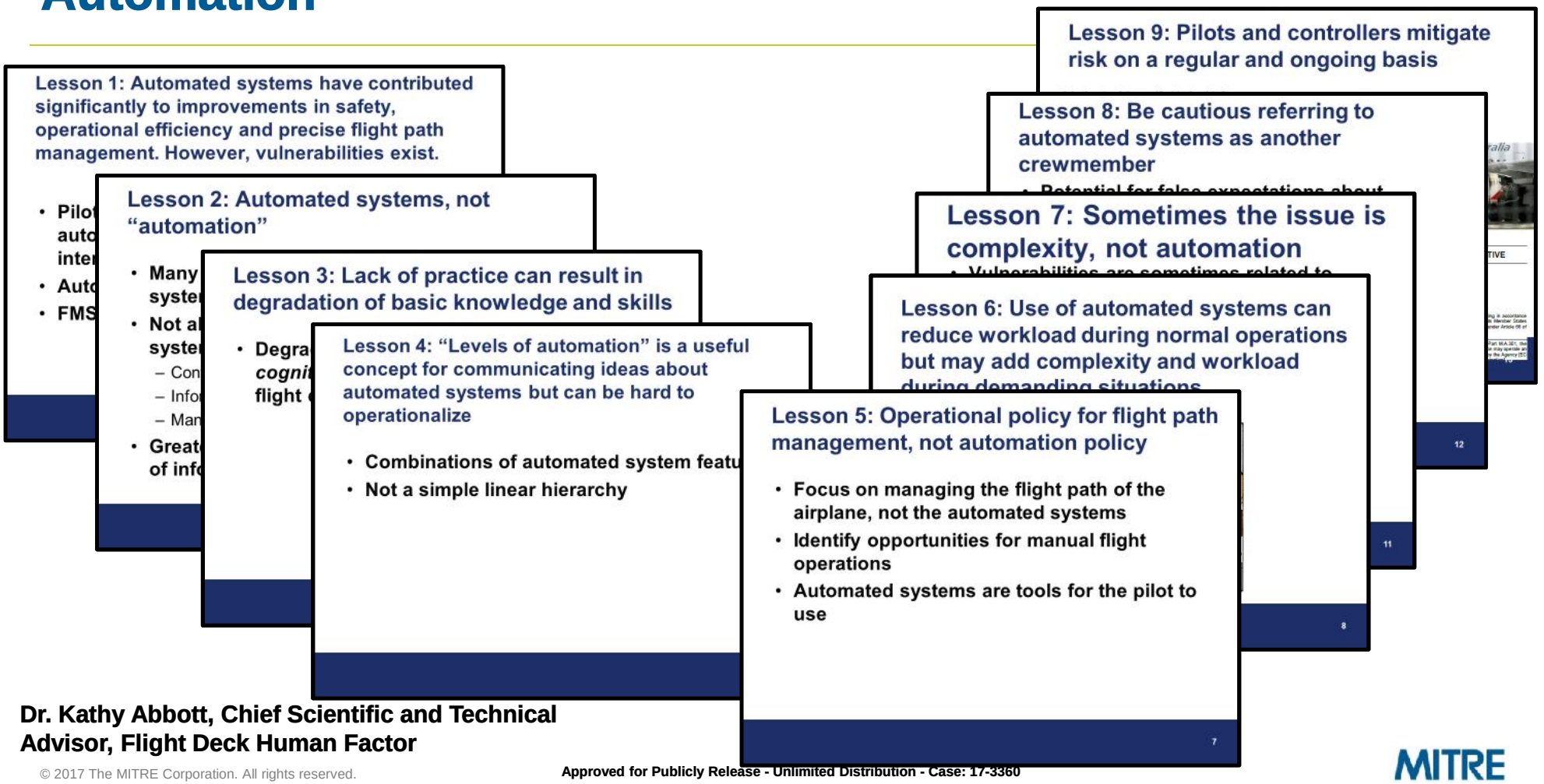
Automated Actions vs. Cognitive Assistance

- **Task Automation under human control**
  - Autopilot; Autoland
- **Human operation with automation assistance (safety net, watch dog, cognitive aid)**
  - Auto-GCAS
  - Digital Co-pilot
- **Pilot-less Flight – Automation is the pilot**

Human-Machine Interface Challenges Associated with Automation



Dr. Kathy Abbott, Chief Scientific and Technical Advisor, Flight Deck Human Factor

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Auto-GCAS: Automatic Safety Net
(Ground Collision Avoidance System)

CFIT & GLOC accidents

Six systems on the F-16 → CFIT rate unchanged

- **Introduced in 2014 – Block 40/50**
- **Maneuver – Roll-to-upright and 5G pull**

Auto-GCAS Keys to Success

- **Design started with the pilot requirements**
  - Nuisance Budget
  - Maximum acceptable maneuver
  - Interface
- **Run-time Assurance Architecture Approach**

CFIT: Controlled Flight Into Terrain
GLOC: G-Force induced Loss of Consciousness
Auto-GCAS: Auto-Ground Collision Avoidance System

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Digital Co-Pilot – Cognitive Assistance

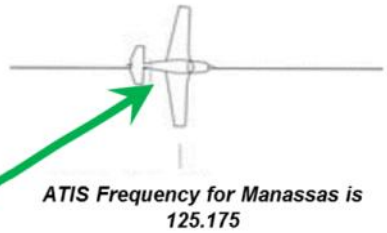
Solo flight is riskier than flight with a crew*

- **Accident rate: ~3x**
- **Fatal Accident Rate: ~13x**

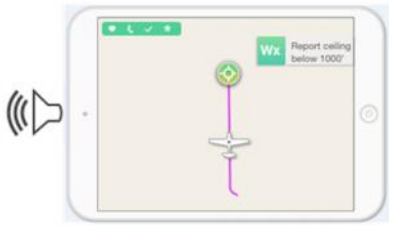
*** Solo pilots also tend to have less training, less experience, and are operating single engine aircraft**

Better Info + Improved Workload + Extra Cognition ➡ Better Decisions ➡ Safer Operations

Right Information



Right Time



Right Format

Pilot Workshops

Lab Studies

Flight Tests

Analytic Modeling

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Old Wine in New Bottles

- **Mature Research Space**
  - **People building systems don't read the research**
  - **People doing research don't understand how to apply it within systems engineering**

Researchers

Developers

Valley of Death

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Human-Machine Teaming – Themes from the Research

Design Content			Design Process
Transparency	**Augmenting Cognition**	**Coordination**	**Design Specifics**
• ***Observability*** Transparency into what an automation partner is doing relative to task progress • ***Predictability*** Future intentions and activities are observable & understandable	• ***Directing Attention*** Orient attention to critical problem features and cues • ***Exploring the Solution Space*** Leverage multiple views, knowledge, and solutions to jointly understand • ***Adaptability*** Recognize and adapt fluidly to unexpected situations	• ***Directability*** Humans can direct and redirect an automation partner's resources, activities, and priorities • ***Calibrated Trust*** Understand when and how much to trust automation partner • ***Common Ground*** Pertinent beliefs, assumptions, intentions are shared	• ***Design Process*** Guidance on the systems engineering processes for HMT • ***Information Presentation*** Format information to support understandability & simplicity

Quenching the Thirst for Human-Machine Teaming Guidance: Helping Military Systems Acquisition Leverage Cognitive Engineering Research - Patricia L. McDermott (MITRE), Katherine E. Walker (MITRE), Cynthia O. Dominguez (MITRE), Alex Nelson (AFRL), and Nicholas Kasdaglis (MITRE).

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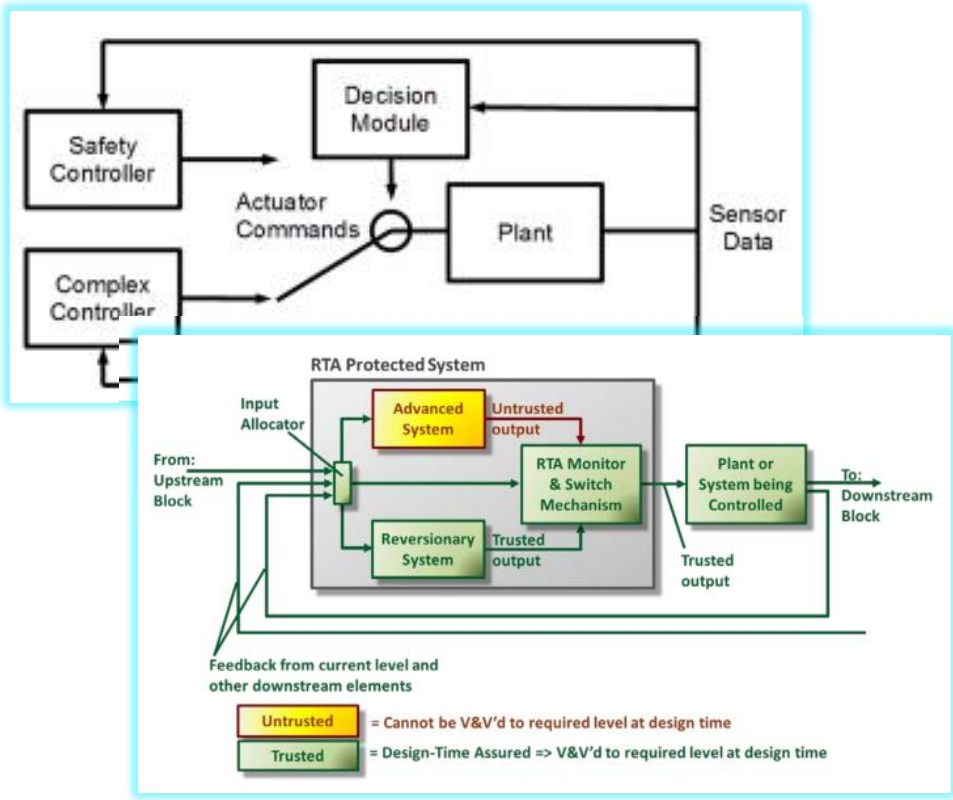
Run-Time Assurance

- **Monitors system behavior during run-time**
- **When specific thresholds are reached triggers bounding behaviors**
- **Variants**
  - Monitor system state
  - Monitor autonomous processes
    - Data outputs
    - Inferred behaviors

From U. of Illinois Study



From AFRL Study

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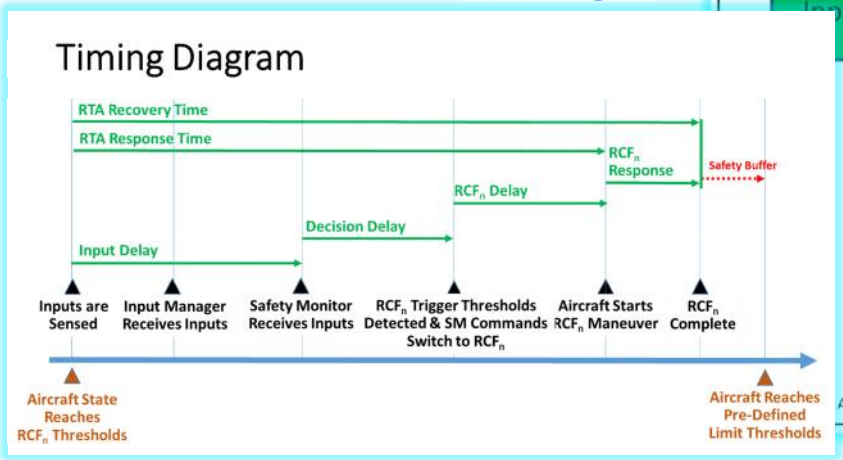
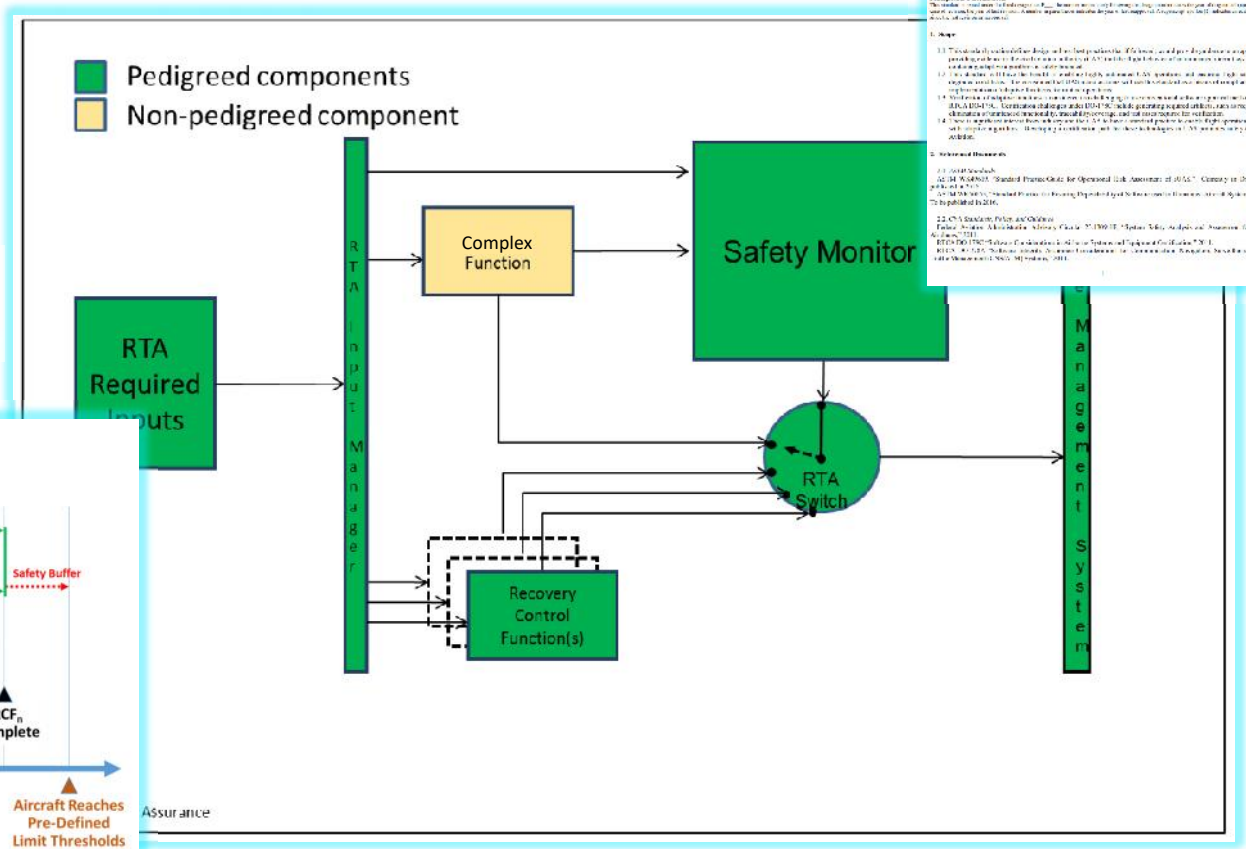
Draft Standard – System State Monitor

- **Guidance on a run-time assurance architecture**
- **Enables applicant to determine implementation**





From Draft ASTM Standard

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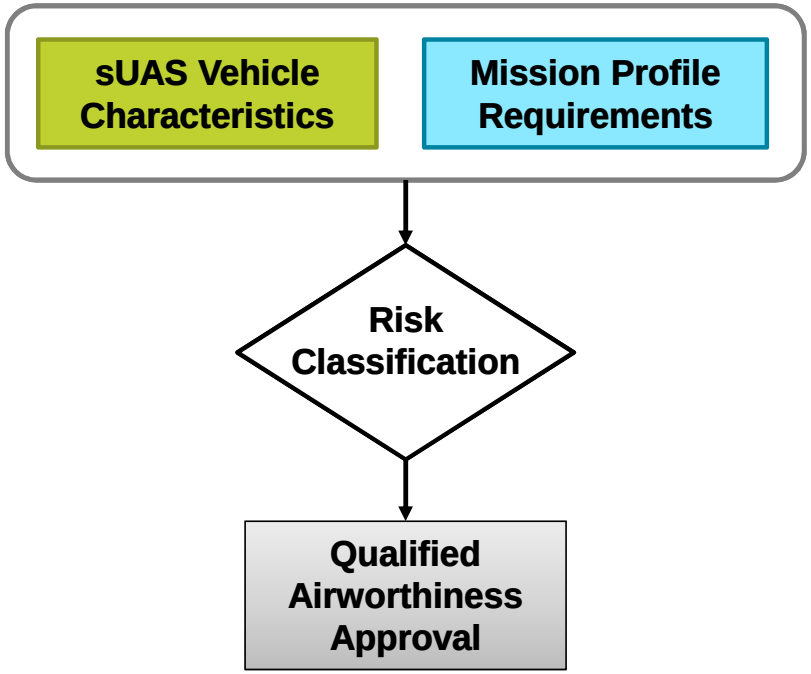
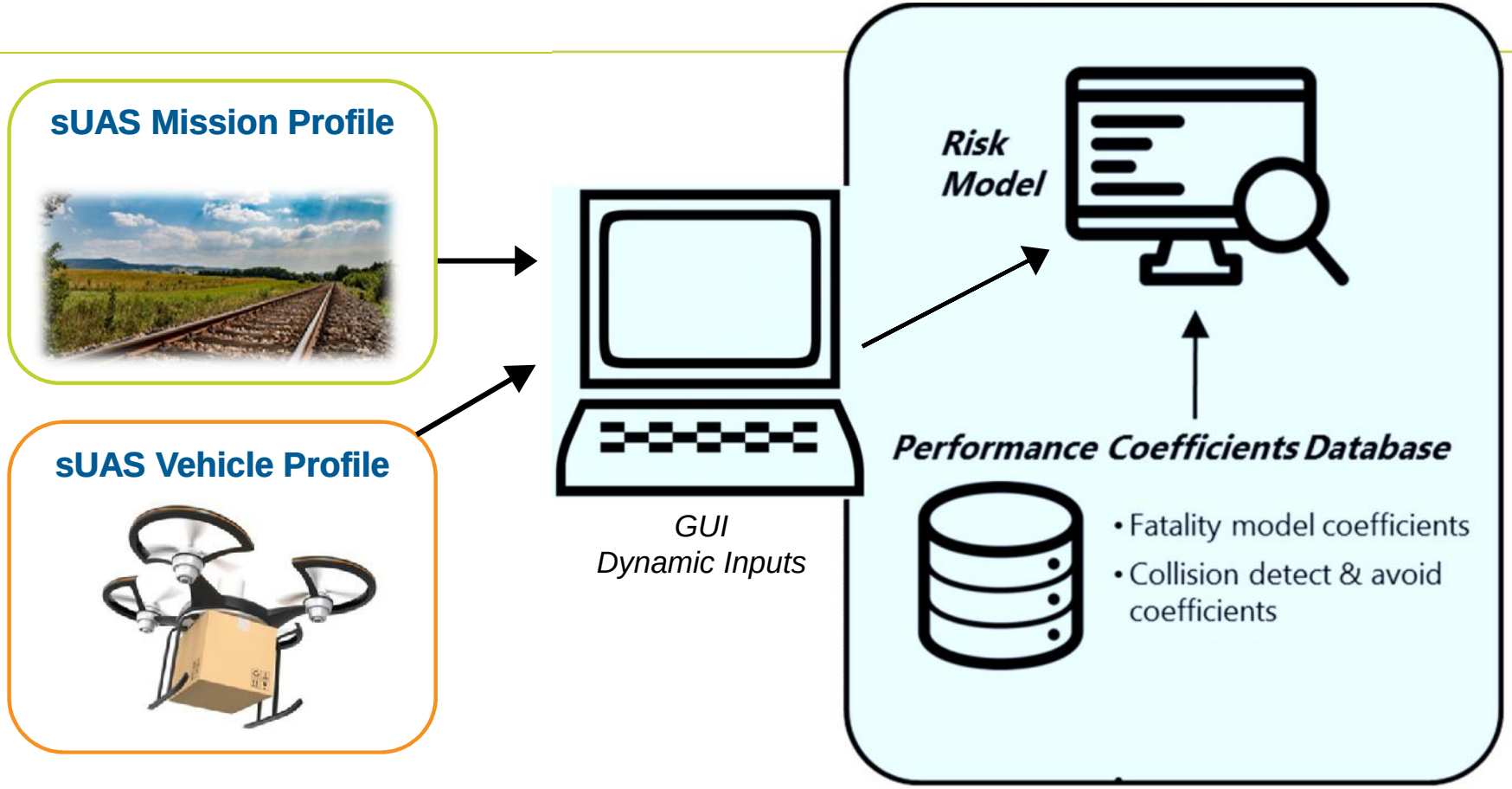
Risk Based Approach for sUAS Operational Approval

A Risk-Based Approach for sUAS operational approval combines the vehicle and mission characteristics to ensure an acceptable level of safety



sUAS Risk Model System



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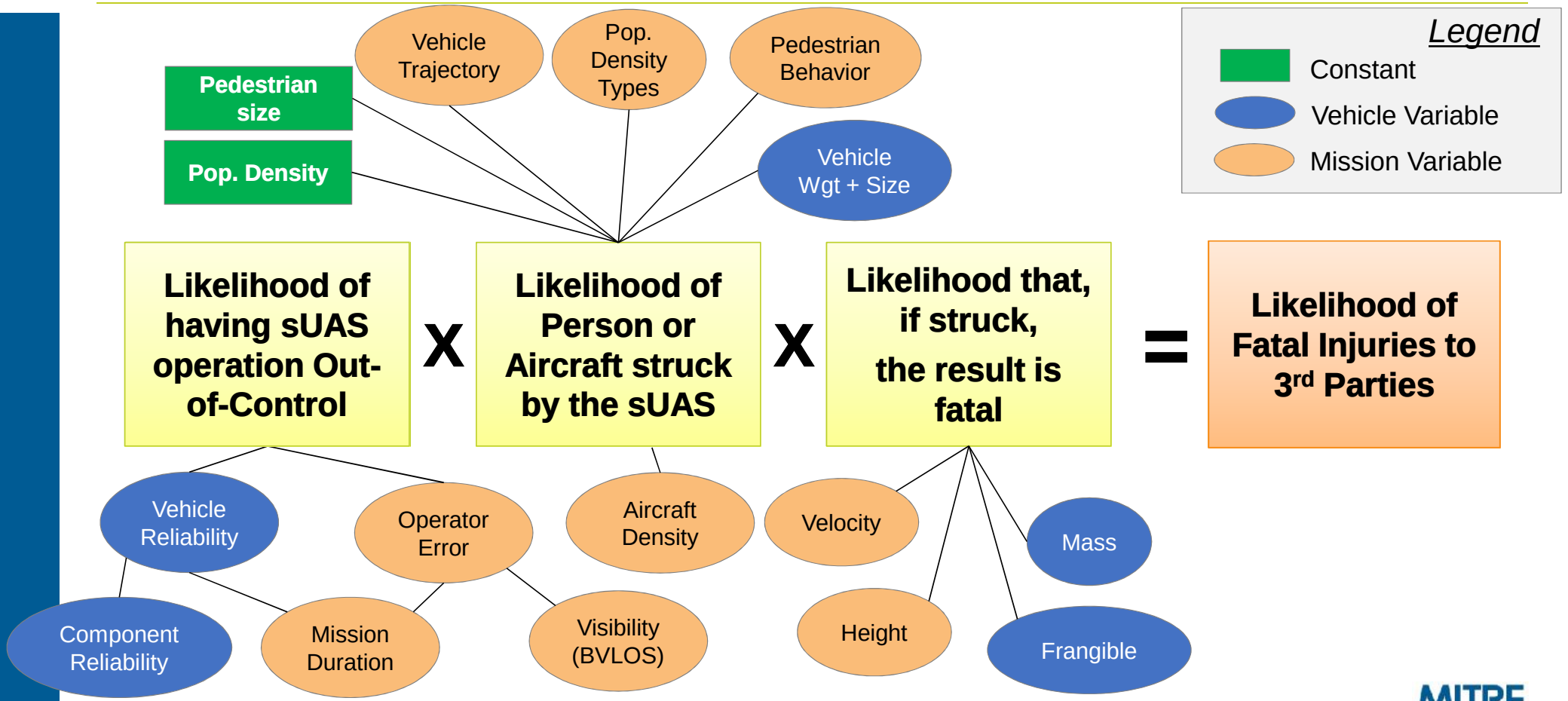
sUAS Risk Model Overview

Modeling Each Node



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Standard Mission Profiles

Each of the Mission profiles have different types of operational risks.

The risk is based on the combination of:

- **Mission profile**
- **Vehicle profile**
- **Operational factors**
- **Environmental factors (such as buildings and obstacles)**

Sparse Operations: Agriculture, Wildlife, Disaster Assessment, etc.

Contained Area Operations: Static Infrastructure Inspection, Real Estate Photography, Temporary Hotspots

Linear Area Operations: Linear Infrastructure, Waterfront Advertising, Traffic, etc.

Public Event Operations: Parades, Sporting Events, Concerts, Static News Coverage, etc.

Network Operations: Small Cargo Delivery, emergency response, etc.

Dynamic Area Operations: Fire and Rescue, search and rescue, police chases, media coverage

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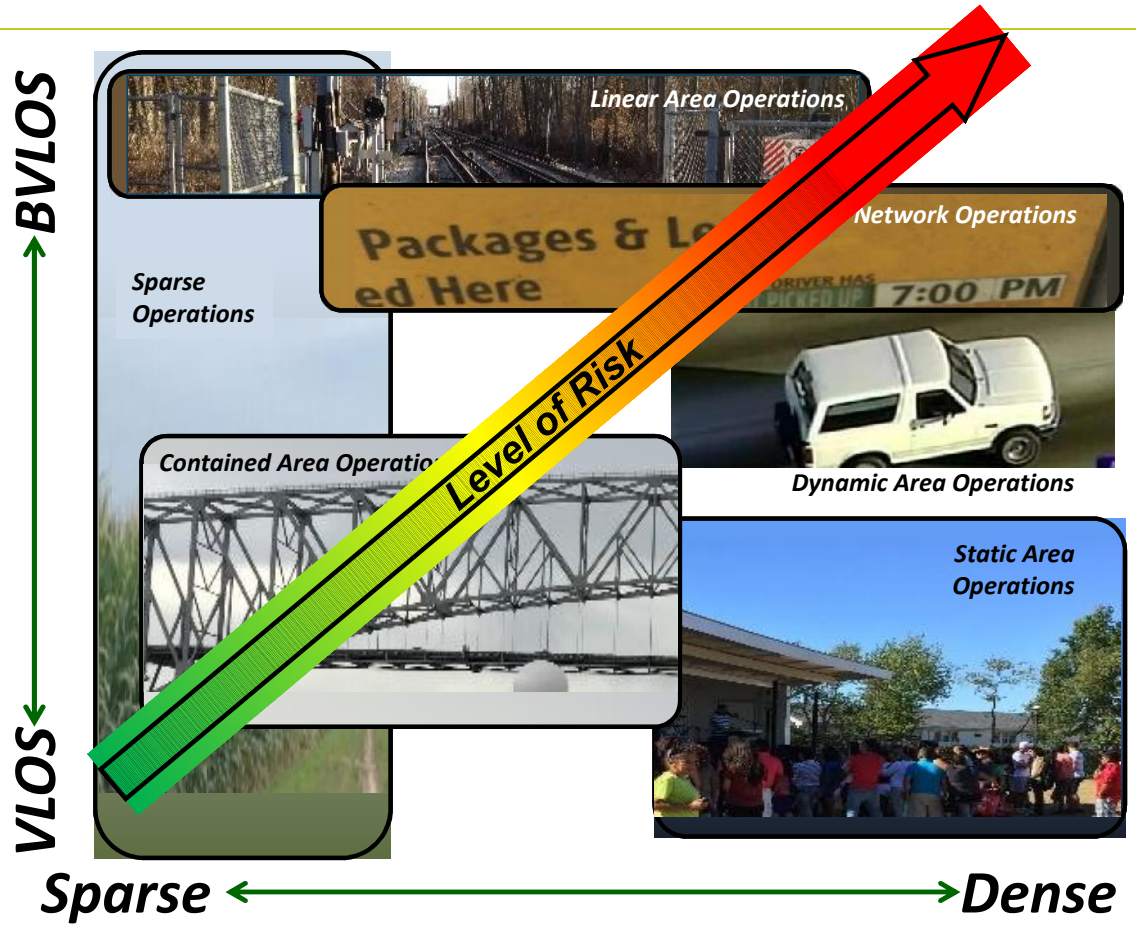
Mapping Mission Profile to Key Risk Variables

- **Sparse Operations** are characterized by low populated areas, but may be near or far from sUAS operator
- **Contained Area Operations** are characterized by operations near structures typically near the operator with controlled population access.
- **Linear Area Operations** are characterized by long distance operations typically over sparse or controlled population areas**.**
- **Public Event Operations** are characterized by operations near the operator over densely packed populations.
- **Network Operations** are characterized by operations traversing wide area networks near or far from populations**.**
- **Dynamic Area Operations:** Fire and Rescue, search and rescue, police chases, media coverage



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Technology Implications

More Dependence Upon Software for Safe Operations

- **Human-Machine Teaming –** ***Automation as a safety net and cognitive assistant***
- **Software Assurance –** ***New architectures – Software watching software***
- **Cybersecurity –** ***New attack surfaces – vulnerabilities at the interfaces***
- **Cyber-Resiliency -** ***Must continue to function safely***
  - ***Despite***
    - **Design defects**
    - **Unanticipated situations**
    - **Missing/corrupt/spoofed/unexpected data**
    - **Deliberate attacks**

Software is both a key enabler and a barrier to operational implementation

- **Certification –** ***Consider operational and system risk together***

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