# REDAC Slides

P&I UAS and Innovative Technology Discussion

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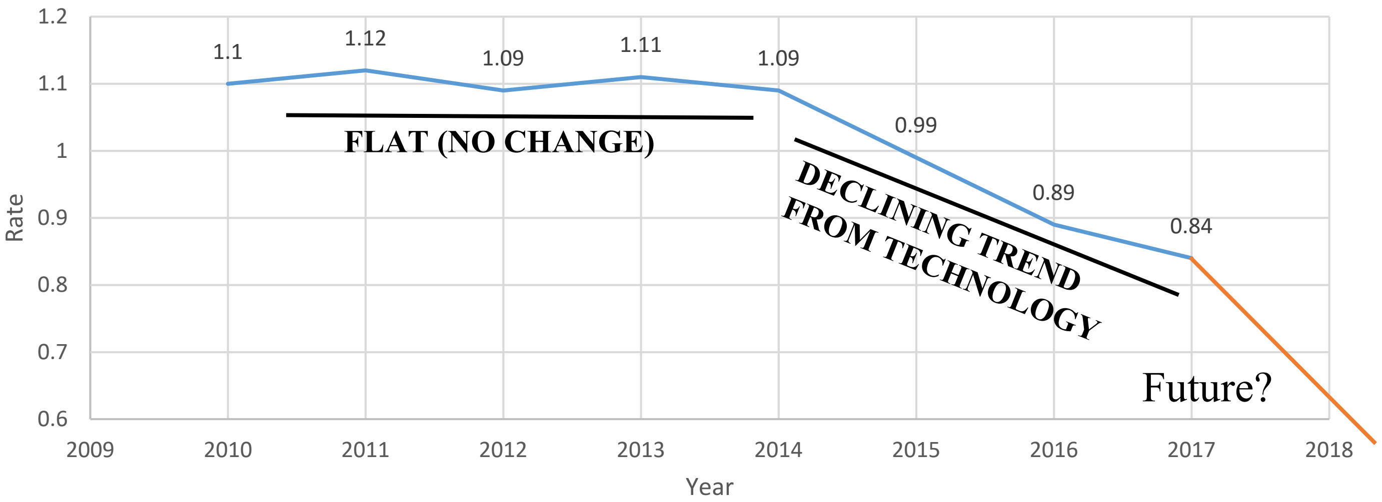
# Using Innovation To Enhance Safety

- History of finding ways to bring new technology into the National Airspace System safely
  - GPS, ADS-B, Glass Displays, Envelope Protection, AOA, Small UAS
- Transformational Flight & Automation Concepts are the Next Logical Progression/Evolution in Technology/Safety
  - Innovation from UAS will work into Small Aircraft, Future UAM, Part 25
  - Culture in FAA is Shifting to Risk-based Innovation & Safety
- Must Foster Innovation While Addressing Current Challenges
  - Further UAS Integration
  - Greater Automation
  - UAM/SVO/EVTOL/ESTOL
- Use Methodical Approach
  - Low risk introduction 1st
  - Build to Higher Risk Uses

**GA Fatal Accidents per 100,000 Hours**



# Future Vision for Innovation/Safety

- Integration of UAS Will Mature Key Technology Enablers
  - Application Will Improve Access To Personal Aviation
  - Attract More Pilots – Automation Will Simplify Flight
- Shared Integration & Future "Traffic Management"
  - UTM Concepts Will Continue To Mature
  - Build to Manage all Trajectories Leveraging UAS Tech
- Prompt Agility Of Airworthiness/Collaboration
  - Part 23 Rewrite,  Industry Standards Development, Others
- Related R&D Must Quickly Feed Policy: Key Enablers – Electric Propulsion, 4D Flight Path Control, Automation

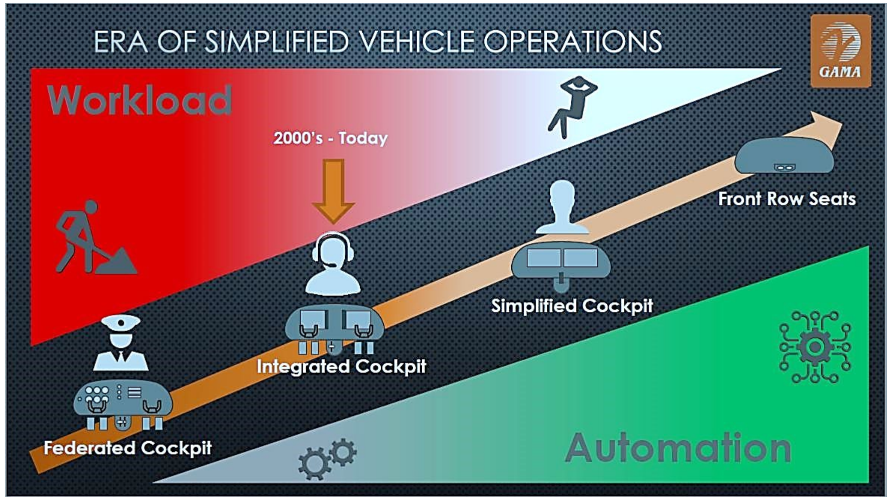


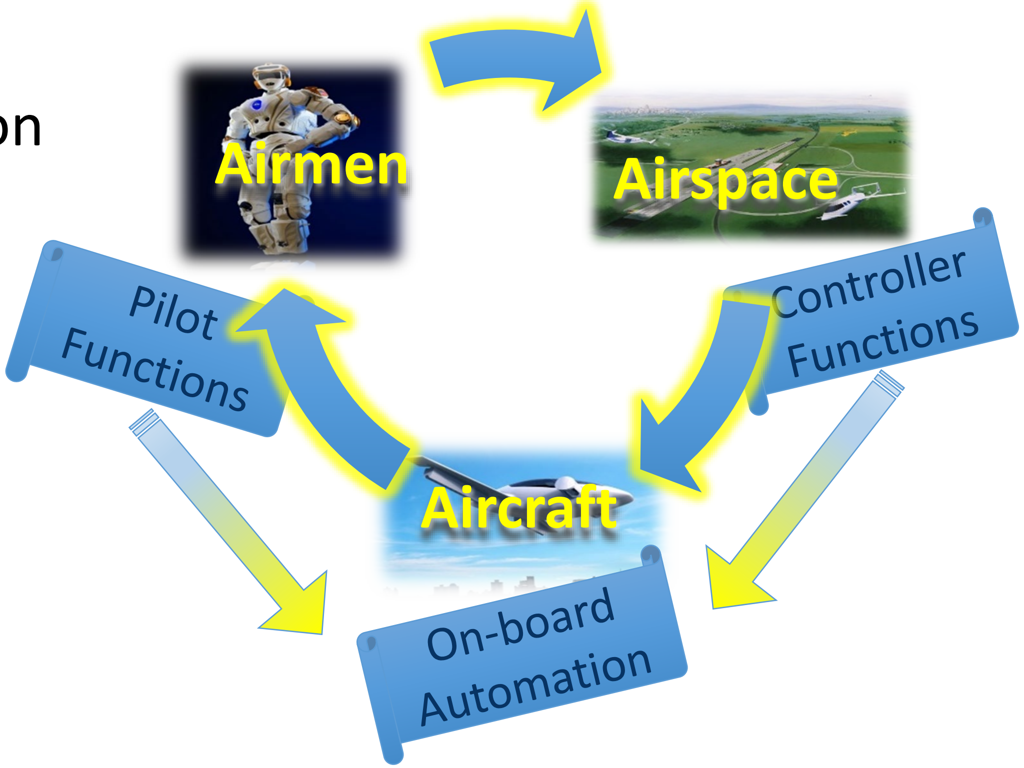
# Electric Propulsion

- Flying Pipistrel Alpha Electro in California
  - Experimental data collection –performing simulated training missions
  - Core lessons learned feeding standards – ASTM & Battery Standards
  - Operational Challenges for a "Pilot of Average Skill" – Suitable for LSA?
  - Energy Management and Indication of Remaining Flight Time (40 min)
- Collaborating with NASA on X-57
  - Part of NASA Design Reviews, Flight Readiness Reviews, and Tests
  - Participation in ASTM Electric Propulsion Standard Development/Validation
- Working with UAS and UAM TC Applicants:
  - Standardized Battery, Motor, Motor Controller Design and Operational Requirements with Methods of Compliance

# Flight Controls & Simplified Ops

- Working R&D for 10+ years to bring affordable augmented flight path control to GA
  - Modern sensors, actuators, processors enabling new systems – UAS provide safe prototyping
  - Real Results - Envelope Protection Autopilots – Certified and in flight for 5+ years
  - Targeting Simplified Vehicle Operations – “Pilot on the loop” simplified flight – Reduce pilot error
- Methodical Buildup from Component to Full System Level R&D Projects Feeding Policy
  - Yielding Real-World Test Results and MOC
  - AOA, Advanced Autopilots, Full Flight Path Management, Resilient Automation, “EZ-Fly” system being tested at Embry Riddle.



# NASA Collaborations


- UAM - Grand Challenge
  - Advance Maturity of UAM Aircraft/Applicants
  - Leverage Combined Expertise of NASA, FAA, Industry
- UAS Integration - SIO – System Integration Operationalization
  - Large UAS Initiative under UAS in NAS program
  - Detect and Avoid and NAS Integration Technology Demonstrations
- Automation - Resilient Autonomy – DOD, NASA, FAA
  - Prove Specific Architecture Can Safely Automate Critical Tasks
  - Robust Autonomy for UAS and Manned Aircraft
  - Run-time Assurance – Key to Safe Automation With Less Human Invovlement
  - Dynamic Consistency Checks (Avoid Issues like 737 Max)

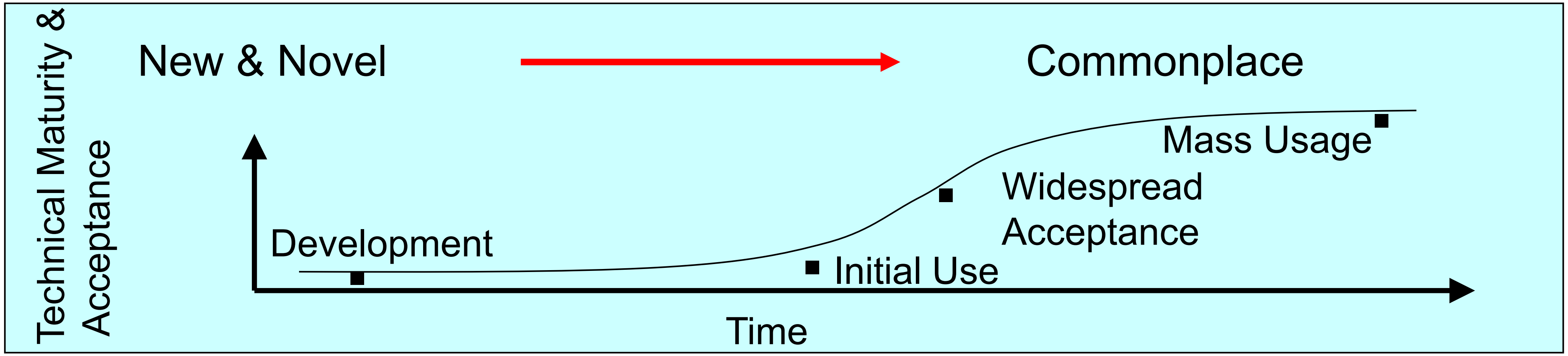
# Supporting Materials

# Cyber Security

- Risk-based Approach to Requirements
  - Exposure of software/system to threats
  - Risk of aircraft to public
- Systems with no connectivity present lower risk
  - Spoofing of GPS sensors still a potential threat
- Greater connectivity = greater exposure
  - Requires partitioning of critical systems from exposed system
  - Procedural and strategic mitigations can be as powerful as design aspects

# Safety From Experience in Innovation

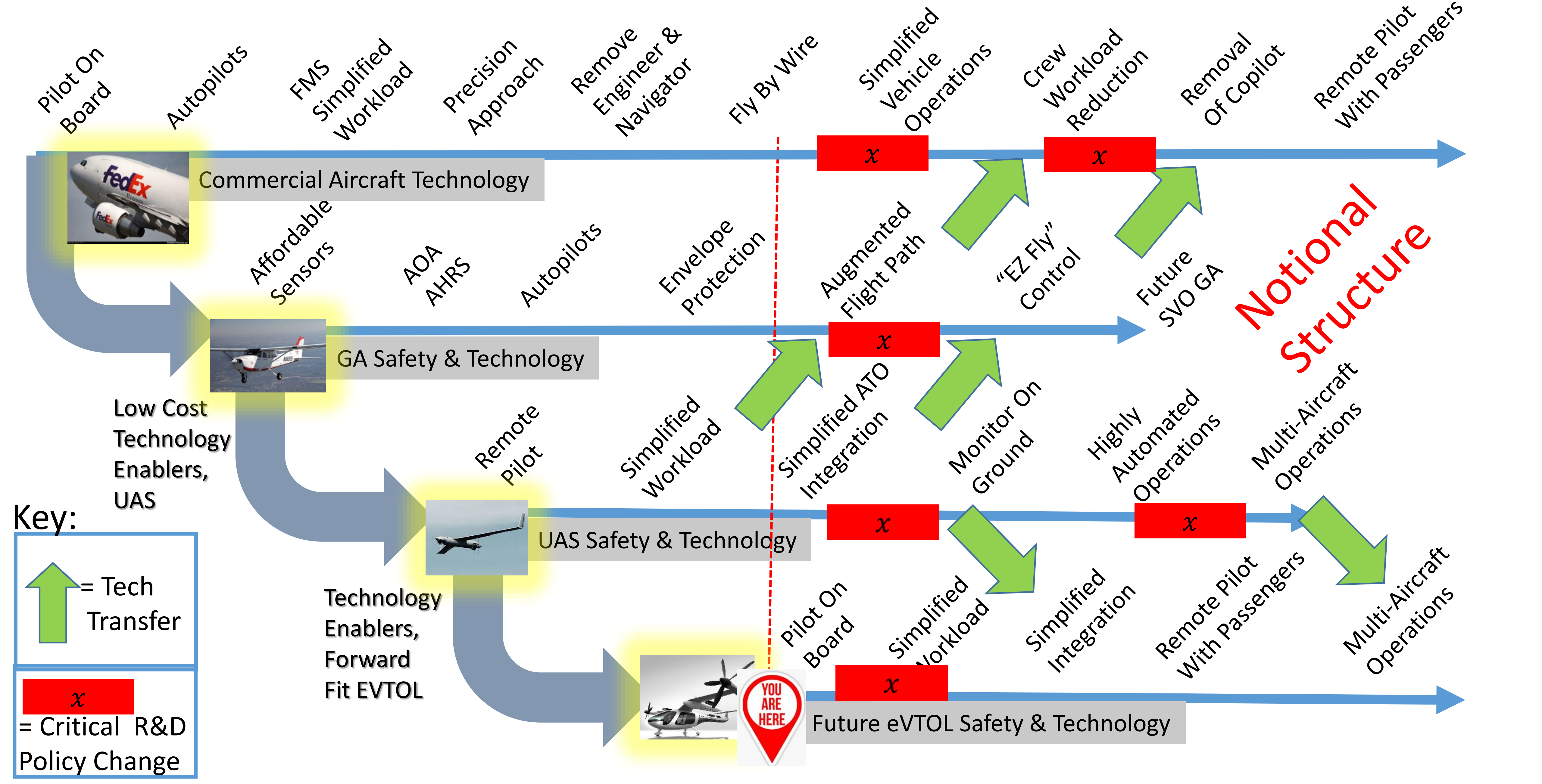
- Using a well-proven risk-based approach to safety
  - Balance FAA Rigor vs. Safety Improvement – Drives cost, time for project
- UAS Certification and our targeted R&D to drive policy to technology benefit all aviation –Urban Mobility and Retrofit/Fwd-fit
- Traditional Certification has primary/secondary, or primary/backup mentality, with human as the safety net – Need New Proven Approach



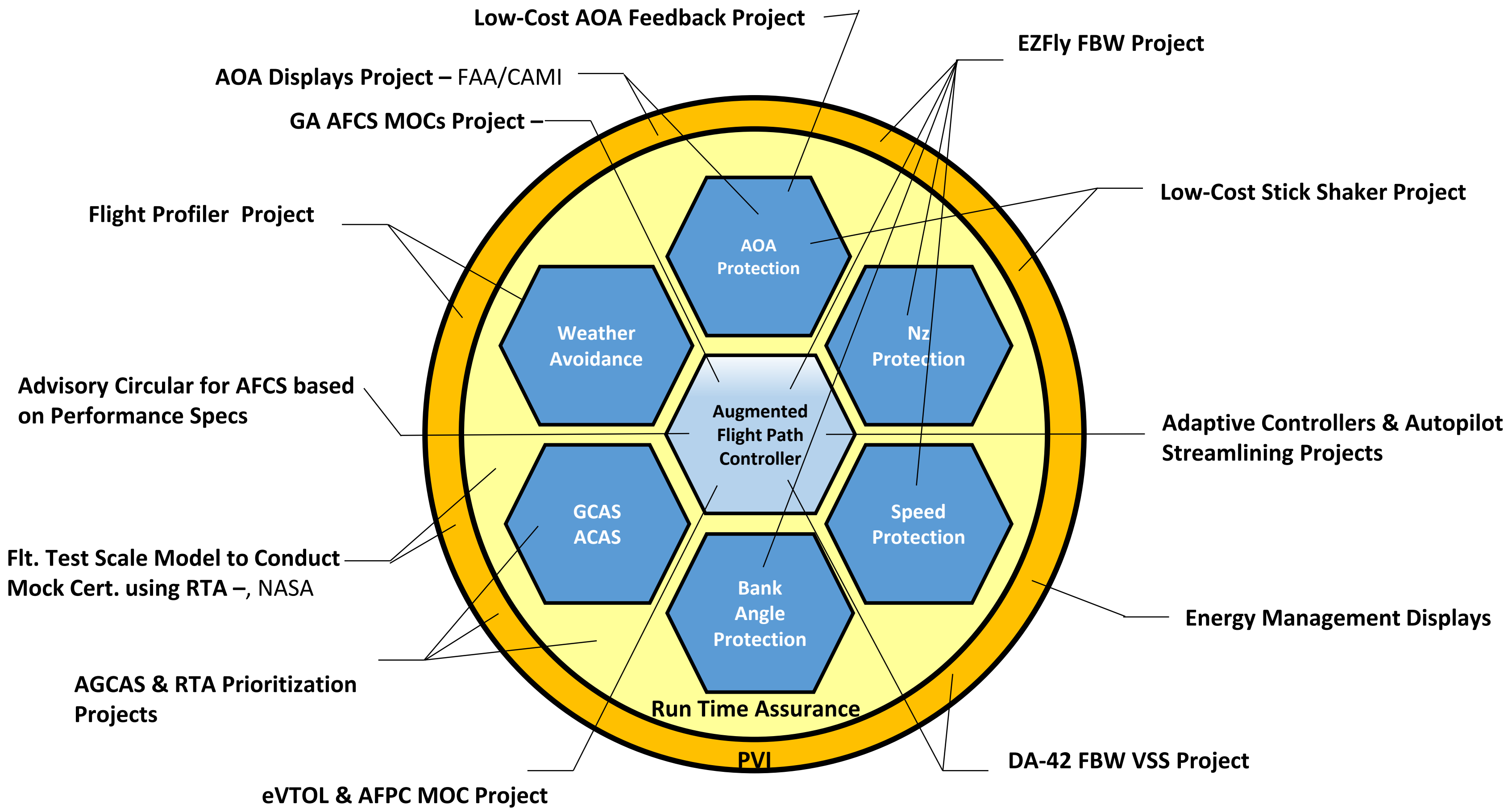

*Abernathy, W.J. and Utterback, J.M. – Patterns of Innovation in Technology, Technology Review 1978

# Gov, Industry + Market Driven Evolution

POLICY ENABLES Tech Transfer

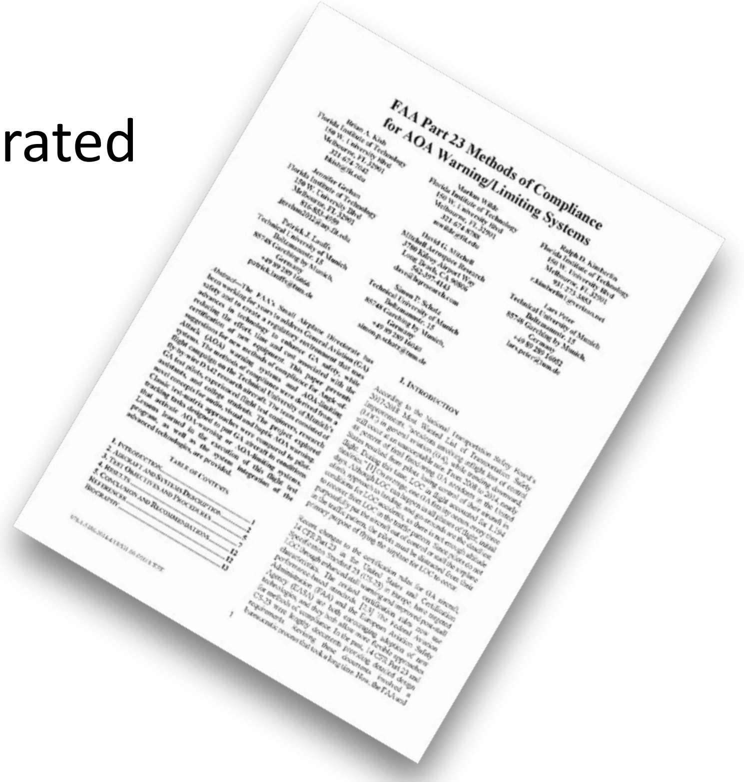


# Ongoing Research Threads



# Research <u>for</u> Policy Development

- Research Projects can be started early focusing on Tech
  - Before applicants apply
- Get Empirical Data to Support Means of Compliance (MOC)
  - Develop first draft of guidance
  - Provide feedback to Industry Stds Committees
- Many advanced VTOL concepts are highly integrated
  - Blend Propulsion, Flight Controls , Autonomy


FAA Part 23 Methods of Compliance
for AOA Warning/Limiting Systems

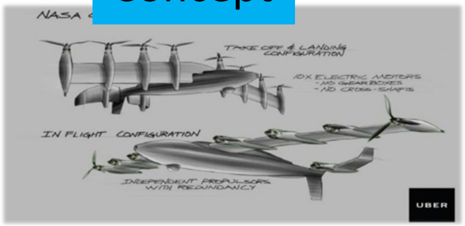
- Research And Policy Integration Team (RAPIT)

  Standards Staffs:
  - Rotorcraft
  - Engine/Propeller
  - Small Airplane
  - Transport

# Our Shared Challenge for Automation

- Discuss Ways to Purposefully/Safely Move from Concept, to Design, to Operation & Integration of Pilotless, Passenger Carrying Aircraft
  - We have the means for conceptual design and sub-scale or full-scale development in flight test of prototypes, BUT
  - We do not have requirements for pilot/automation performance for "autonomous" operations, or automated integration with air traffic

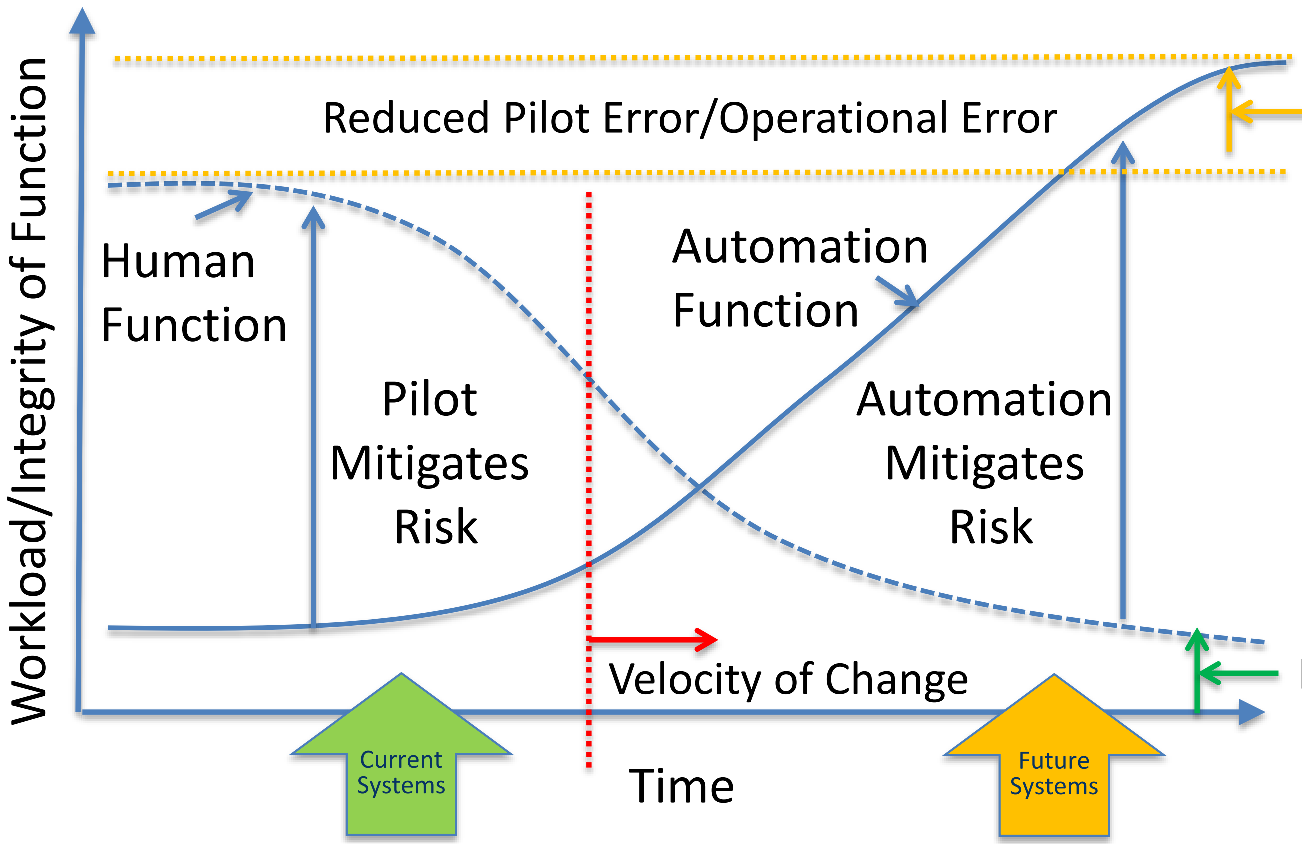
Concept




Development

Operation

# Challenge - Humans/Machines Safely Trading Roles



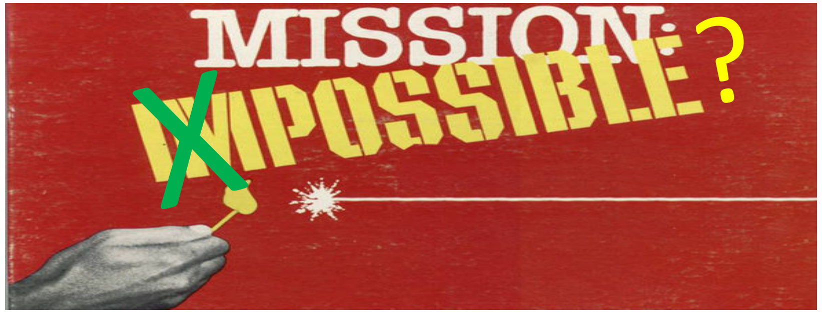

Future Safety Gain?

- Automation Replacing Humans
- Automation May do More Than Human Capability
- What Will Residual Future Roles Be?

# Is Evolution or Revolution the Right Methodology ?

- Some are Convinced they can jump straight to full automation without a human pilot in the loop “flying” the aircraft.
- Others recognize the challenge of replacing the pilot on board with an automated system that is reliable enough to handle all actions typically done by the pilot and the controller for all phases of flight.

# Automation Certification Path

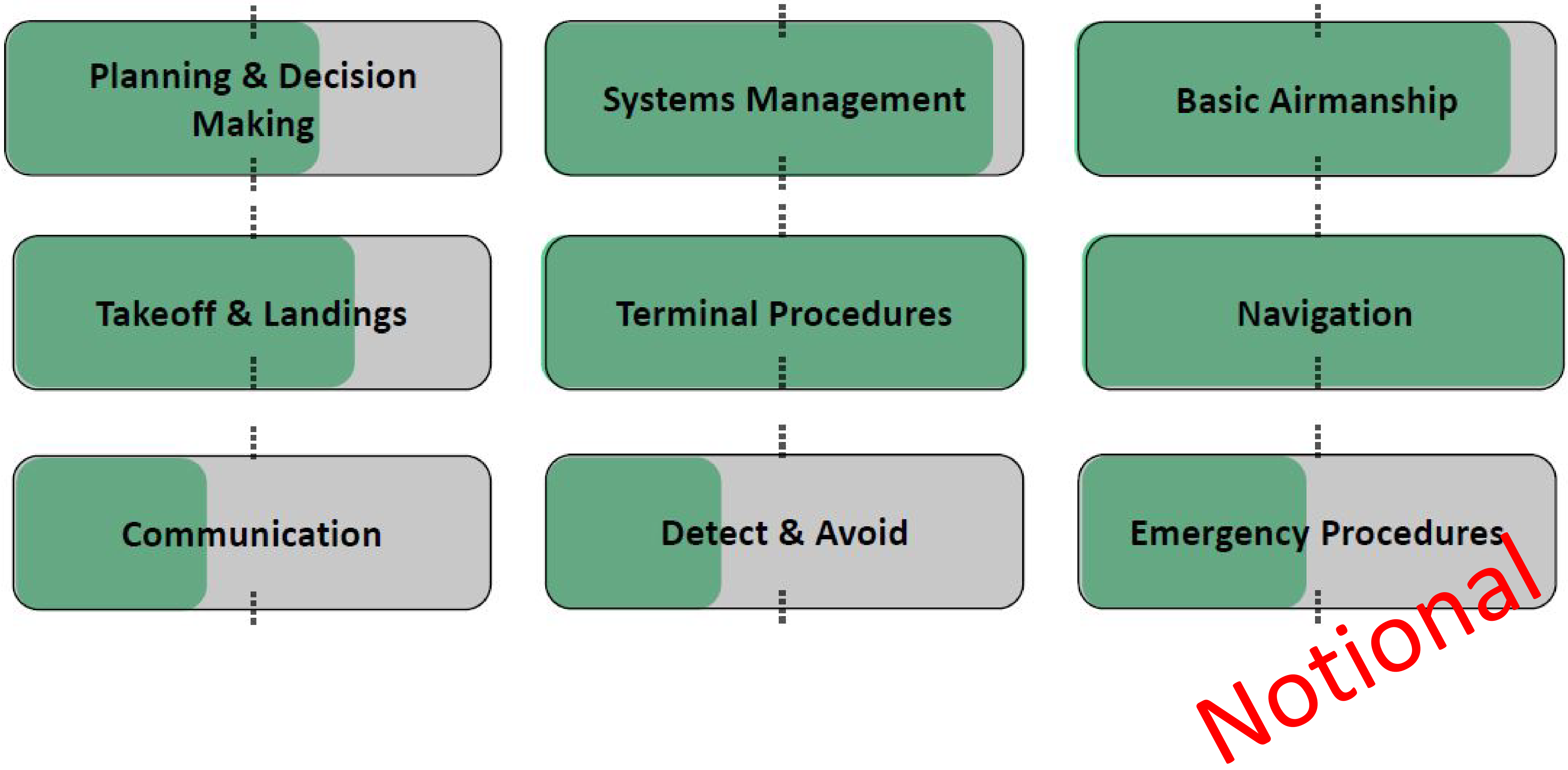



- Logically reduce/replace functions of pilot/controller
  - Deconstruct functions of the pilot and controller to design functions into automation
- Developing "Assured" Automation
  - Bounded Behavior – Safe limitations of authority
  - Expected outcomes – architecture is key – human intention is built in by bounded behavior
  - Fault Tolerant, Fail-Safe – Continue to function after a failure

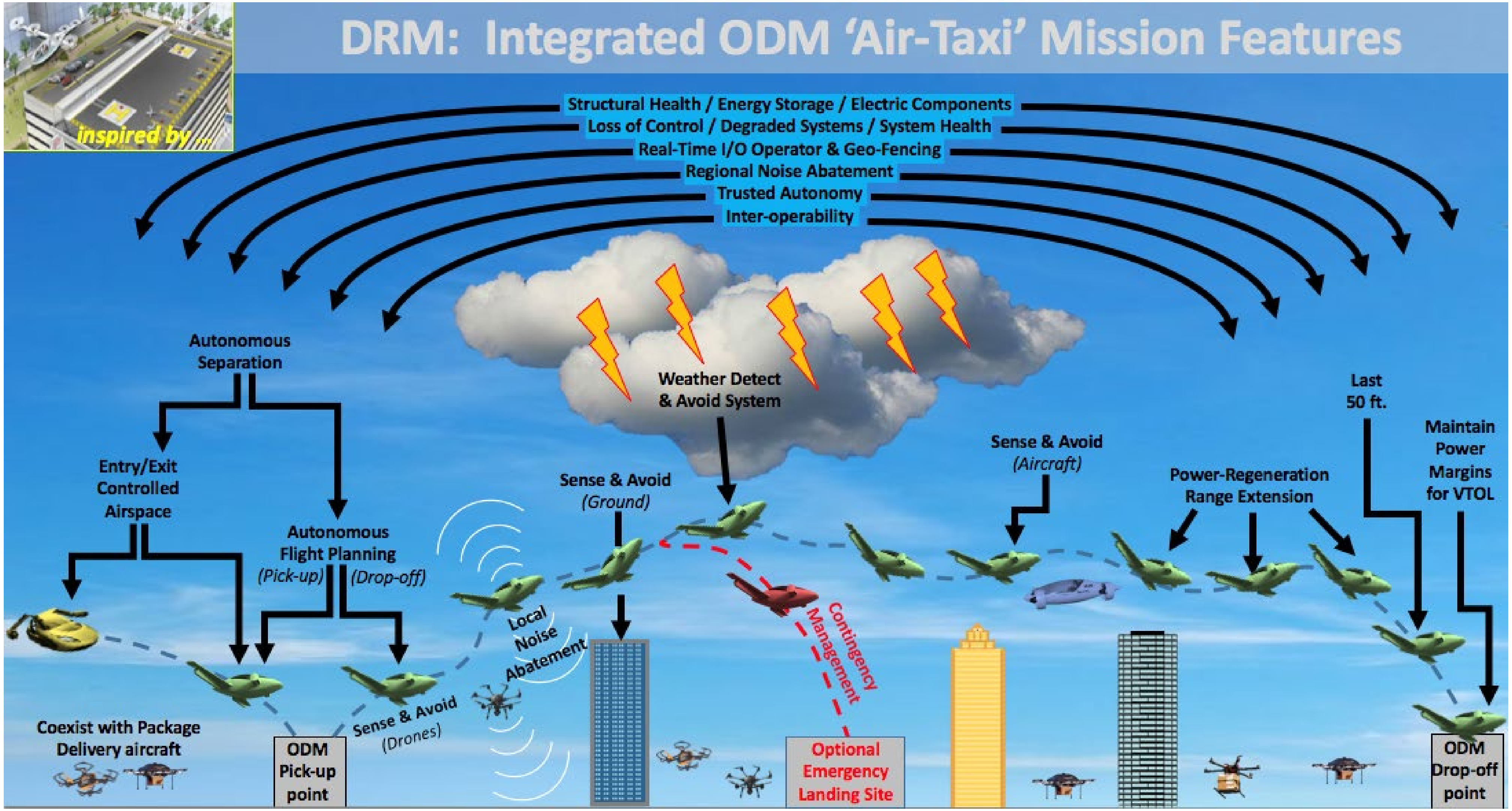
# Deconstruction of Intended Tasks/Functions

- Concentrate on major functions
  - Pilot:
    - Aviate – Flight Path Management of the aircraft states – flying the aircraft
    - Navigate – Flight Path Management of the flight path in national airspace – telling it where to go
    - Communicate – Flight Path Management in context of other aircraft and air traffic expectations
  - Controllers:
    - Locate – Is the aircraft where it is supposed to be?
    - Separate – Is the aircraft avoiding others?
    - Communicate – Can Air Traffic "talk to the airplane" to manage its course?
- Assess Readiness of automation to perform each set of functions – Air and Ground Operations

# Deconstruction of Pilot/Controller Functions

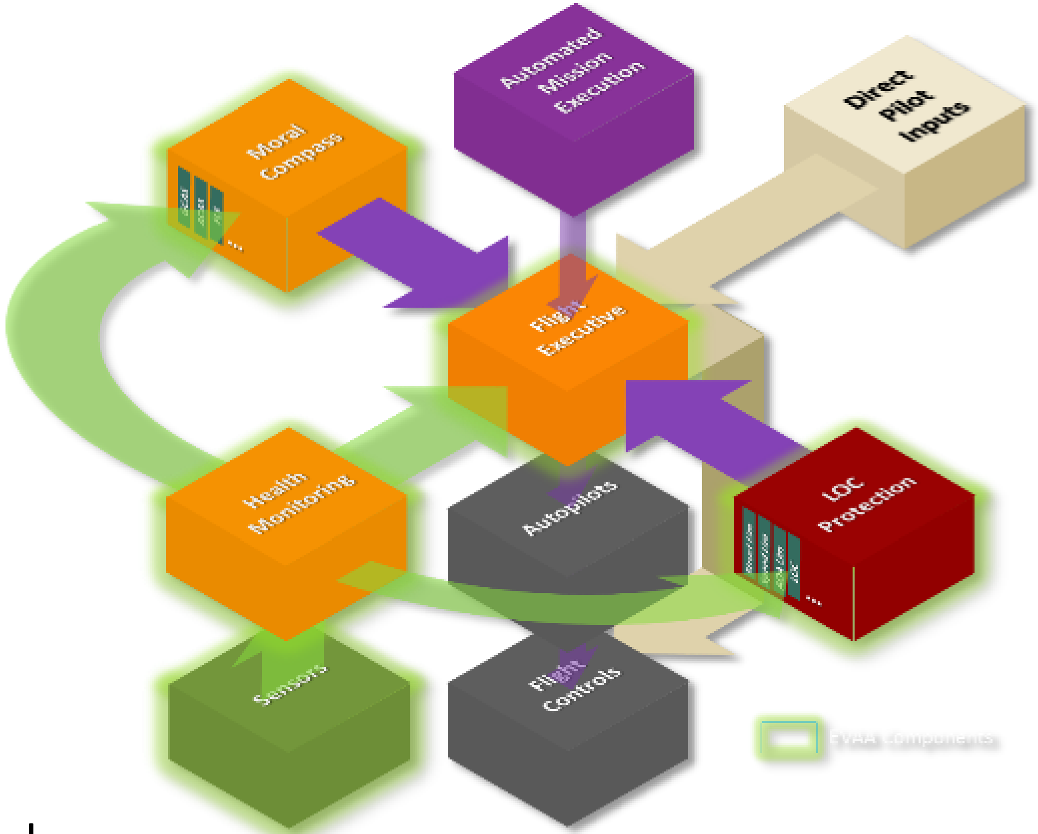


# Piloted vs. Pilotless – Must Design in Functions For All Phases of Flight



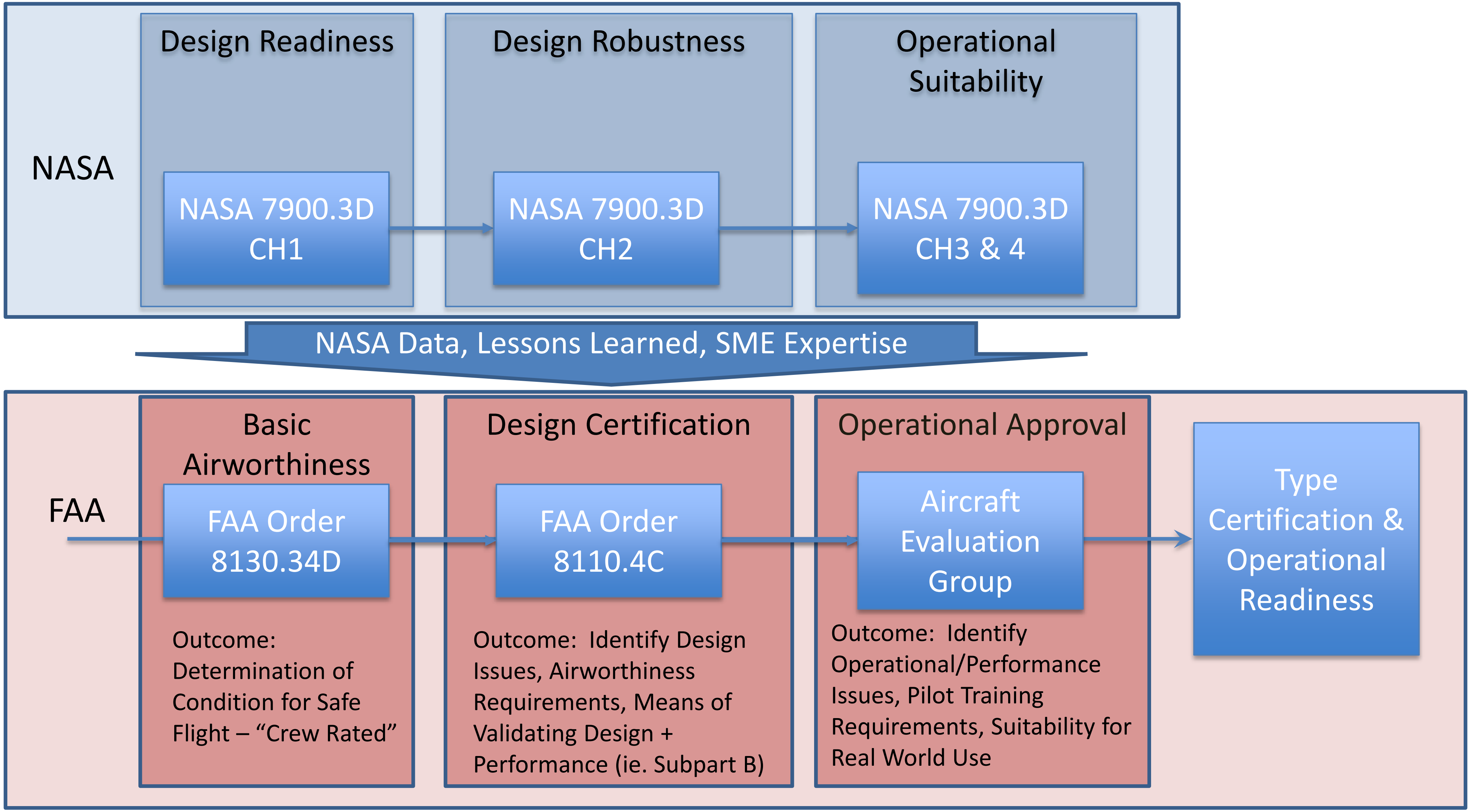
# Keys To “ Trusted” Automation

- Modular Architecture
  - Top down architecture hierarchy with clearly specified interfaces
- Partitioned Functions & Criticality
  - Software/Hardware Isolation
  - Each module limited to a single safety function – Ease of Testing
- Dynamic Consistency Checks
  - Compare Derived and Measured Parameters
  - Measure real time behavior of the system
- Computational Agility
  - Rapid assessment of system/situational hazards with quick and decisive response to those hazards



# Proposed NASA & FAA Process Relationship for Challenge

Grand Challenge "Scenario Roadmap" Rosetta Stone



# FAA Steps for Certification

**Conceptual Design**

- Process Orientation
- Pre-Project Guidance
- Familiarization Briefing
- Top Level Safety Requirement
- Potential Policy Items to Address
- Airspace Integration Challenges

**Requirements Definition**

- UAS Conceptual Design*
- CONOP*
- Risk Classification*
- Certification Plan*
- Conformity Inspection Plan
- Preliminary TCBM
- ORA*
- Proposed Certification Basis *
- Acceptable Means of Compliance
- Detailed Method of Compliance

**Compliance Planning**

- FAA Involvement
- Applicant's Responsibility
- Oversight and Delegation*
- Conformity
- Interim TCBM
- ATO/AFS Coordination*

**Implementation**

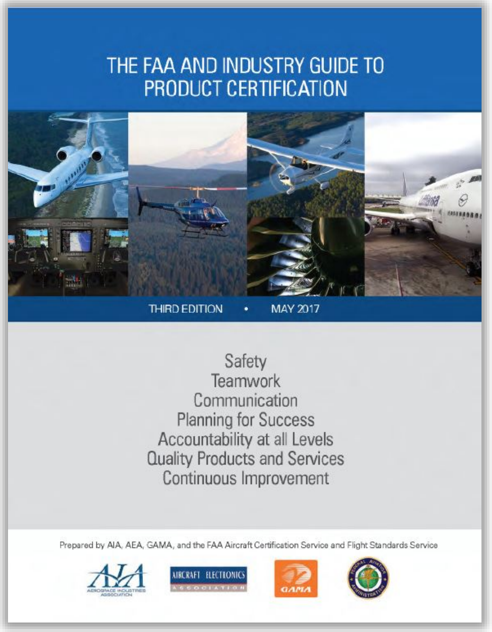
- Compliance Data Generation
- Compliance Substantiation
- Compliance Finding

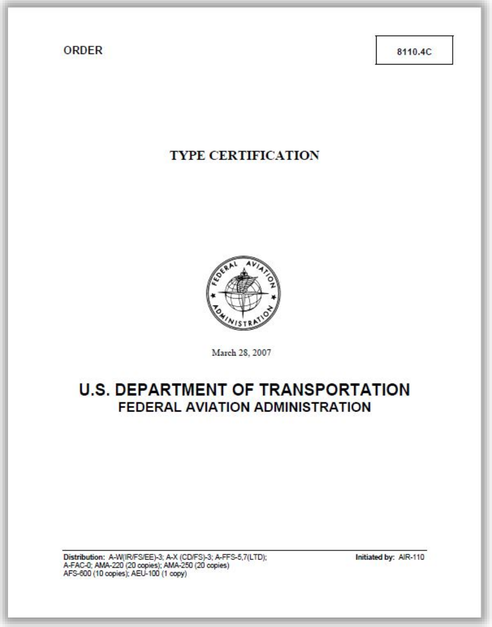
**Post Certification Activities**

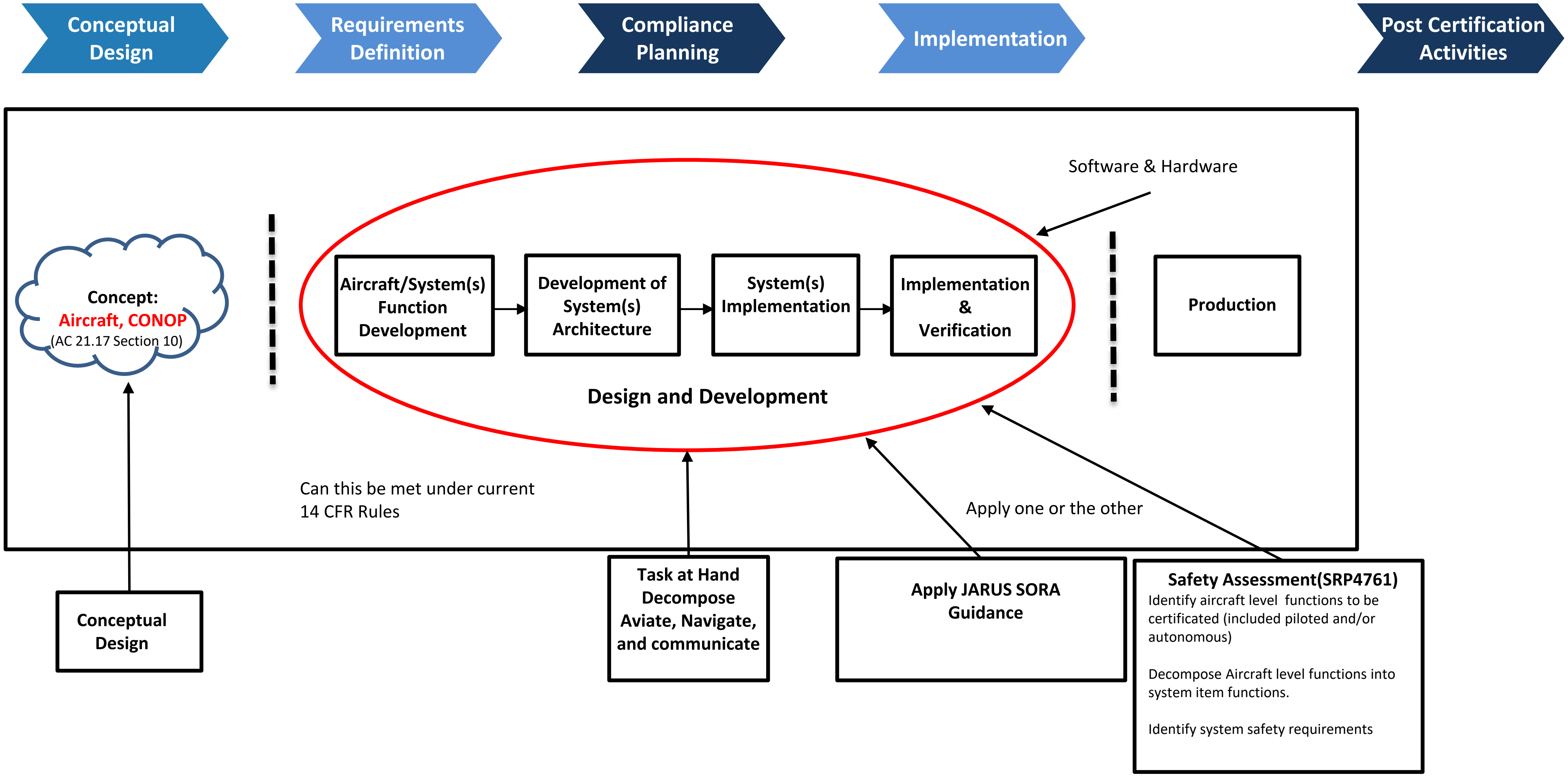
- Type Inspection Report
- Data Retention
- Required Documents at Delivery
- TC Holder Info
- Continued Airworthiness
- ICA Changes
- Post Certification Evaluation

Red Items = Steps Where NASA Resilient Autonomy Will Focus

* Denotes items that are specific to UAS Type Certification, or items that are tailored for UAS certification



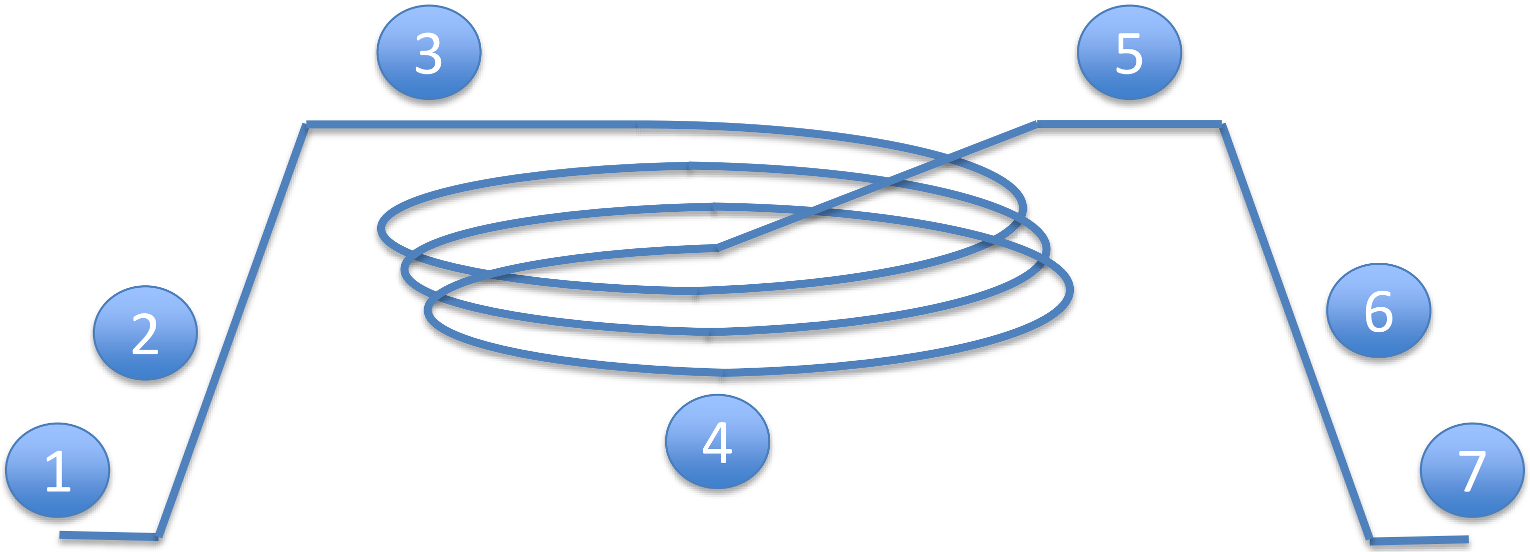





Conceptual Design
Requirements Definition
Compliance Planning
Implementation
Post Certification Activities
Software & Hardware
Concept:
Aircraft, CONOP
(AC 21.17 Section 10)
Aircraft/System(s) Function Development
Development of System(s) Architecture
System(s) Implementation
Implementation & Verification
Production
Design and Development
Can this be met under current 14 CFR Rules
Apply one or the other
Conceptual Design
Task at Hand Decompose Aviate, Navigate, and communicate
Apply JARUS SORA Guidance
Safety Assessment(SRP4761)
Identify aircraft level functions to be certificated (included piloted and/or autonomous)
Decompose Aircraft level functions into system item functions.
Identify system safety requirements

# Mission Task Elements

- Identify what the aircraft is going to do (Concept of operation/mission) and break into mission elements
- Identify tasks automation is intended to do for each mission element
- Identify expected behavior and pass/fail criteria for the automated functions
- Create mission task element testing procedures to validate/verify proper function and behavior



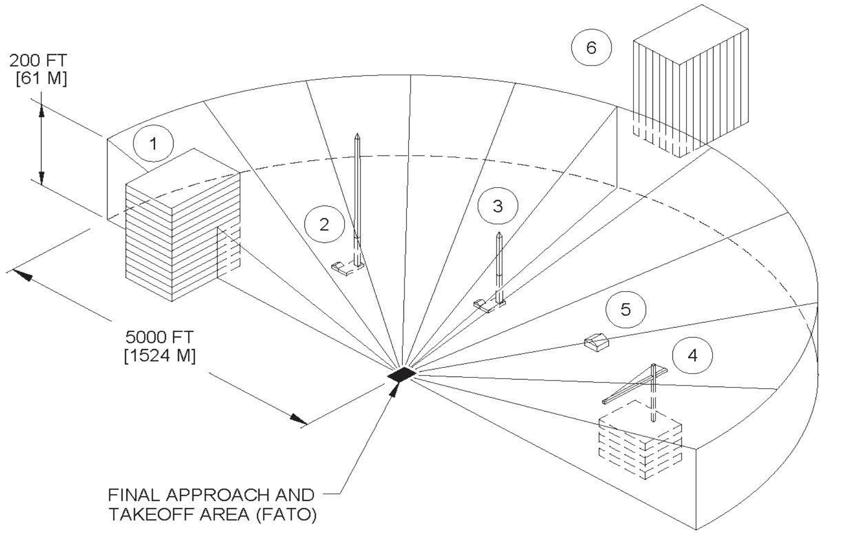

| Task | Description | Behavior | Pass/Fail | MOC |
|---|---|---|---|---|
| 1.a | Pre-flight | Condition for Safe Flt | Configuration | Insp |
| 1.b | Built In Test | System Ready | Sys Parameter Limits | Test |
| 1.c | Flight Plan | Flt Route | As Intended | Test |
| …….. | | | | |

# Grand Challenge Mission Task Elements

Creating Standard Test Procedures, Maneuvers

- Design Basic Airworthiness
- Design Robustness
- Operational Readiness
- GAMA Publication 16 Mission Profile

Goal: Tests and Methods of Compliance for Unique Aircraft Not Currently Covered by our Rules.




Notes:

1. Building is less than 200 ft [61 m] in height, but top will penetrate the 25:1 surface (notice is required by 14 CFR part 77.9).
2. Antenna is over 200 ft [61 m] in height (notice is required by 14 CFR part 77.9 (a)).
3. Antenna is less than 200 ft [61 m] in height, and penetrates the 25:1 surface (notice is required by 14 CFR part 77.9 (b)(3)).
4. Construction crane penetrates 25:1 surface (notice is required by 14 CFR part 77.9 (b)(3)).
5. Building is less than 200 ft [61 m] in height and does not penetrate the 25:1 surface (notice is not required).
6. Building is more than 5,000 ft [1,525 m] from heliport (notice is required if building will be 200 ft [61 m] or more in height).

Note: Notice under 14 CFR part 77 required for all public-use heliports or a private use heliport with at least one FAA-approved instrument approach procedure.

**Figure 1–4. Offsite Development Requiring Notice to the FAA**

# Notional Steps for Certification of Automation

- Identify the aircraft, its intended use, and area of operation
- Identify the functions that are expected to be automated without human backup
- Evaluate risks and severity of those risks based on that CONOP (What if document) (SORA)
- Evaluate mitigations for those risks and whether they are by design, operational limitation, or geographic/airspace limitation
- Evaluate the integrity/assurance needed for the risk mitigations that are by design
- Create certification requirements for the design aspects, and pass fail for those requirements for showing compliance
- Identify functions, definition of expected performance of that function, pass/fail evaluation criteria for the function, and a means to test that functionality to verify reliability, accuracy, availability, and what happens if it fails. (contingencies without human intervention)
- From pass/fail and expected performance for function/design features, identify cert/safety requirement and means to test to show it has been met.
- Collect data, and demonstrate compliance by test, inspection, analysis