

National Aeronautics and Space Administration

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## South African CAA National Aviation Conference Crossing the chasm: Technology in Aviation

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[www.nasa.gov](http://www.nasa.gov)

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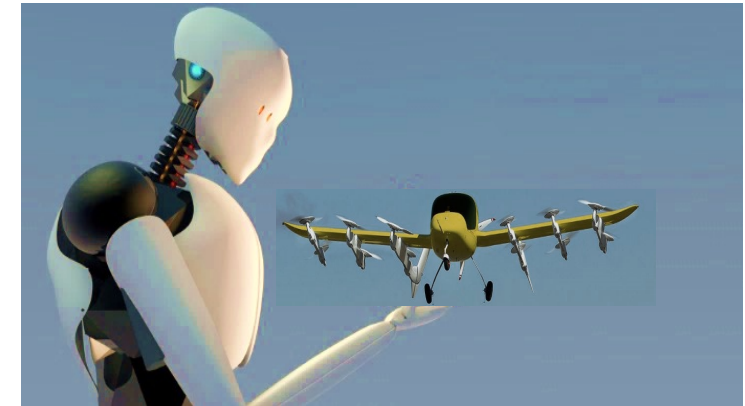
# Technology in Aviation

- Trend: Greater “Personalization” of Aviation Services
  - Safer Aircraft - Package Delivery & Future Air Taxi
- Trend: Trust & Reliance on Automated Systems - Emerging Automation Concepts
- Trend: Healthy “Creative Tension” Between Industry and Safety Regulated Industries – “Why can’t we.....?” vs. “Can it be done safely?”
- Need: Integrated Solutions - **Must** Consider the Aircraft, Automation, Operation, and Airspace for Integration for Future Concepts to be Viable



# Technology Challenges

- Move From Sub-Scale Technical Demonstration to Civil Readiness
- Need Proven Readiness for Safe Public Use i.e. “Civil Trustworthiness” – Mature Capabilities
- “Supply Chain” of New Capabilities & Products – DAA, C2, Flight Path Management, etc.
- Current Certified Systems & Procedures Require Human to Manage Safety – Can We Remove?
- Risk-based/Model Based Capabilities - Assistive Uses or Low Risk Uses First
- Design and Certification May Need to Evolve – Smarter Architectures
- AI/ML Safely Introduced, Certified, Managed



# Vision Includes Entire Ecosystem



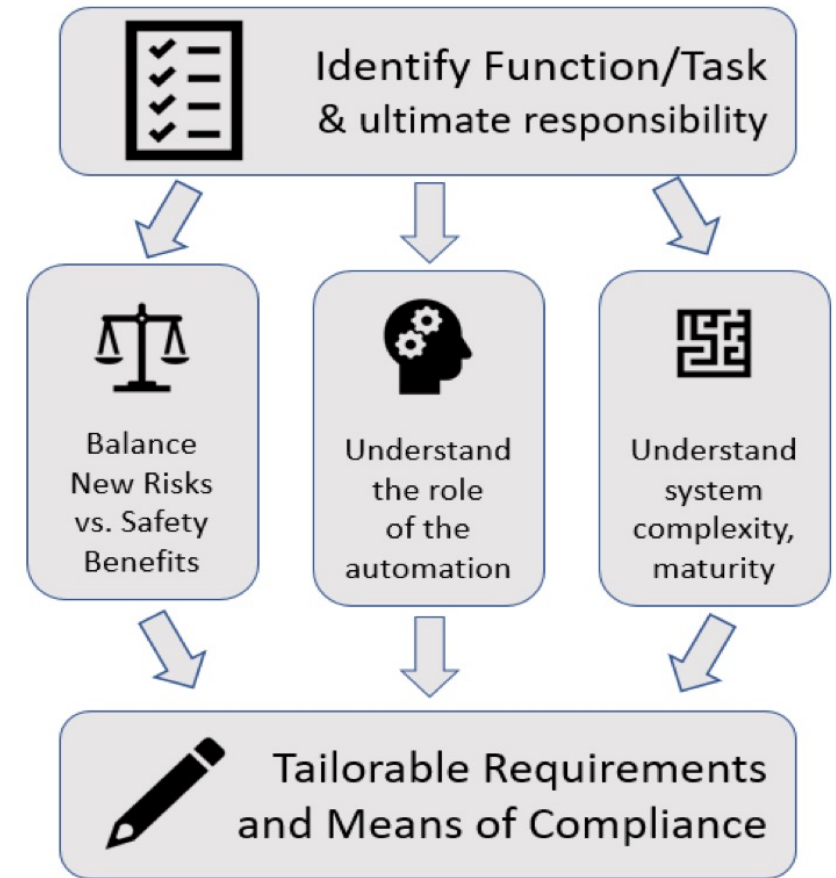
- How Can NASA Assist Industry/FAA to Bridge Gaps Between Future Vision for UAM/AAM and Current Capability?
- Industry Has Many, Independent Efforts, Different CONOPS, and Business Plans – Individually Working with FAA
- Seeking Common Approach to Define and Accelerate New Capabilities for Aircraft, Ops Integration, and Airspace Mgmt



# Risk Based & Model Based Integration



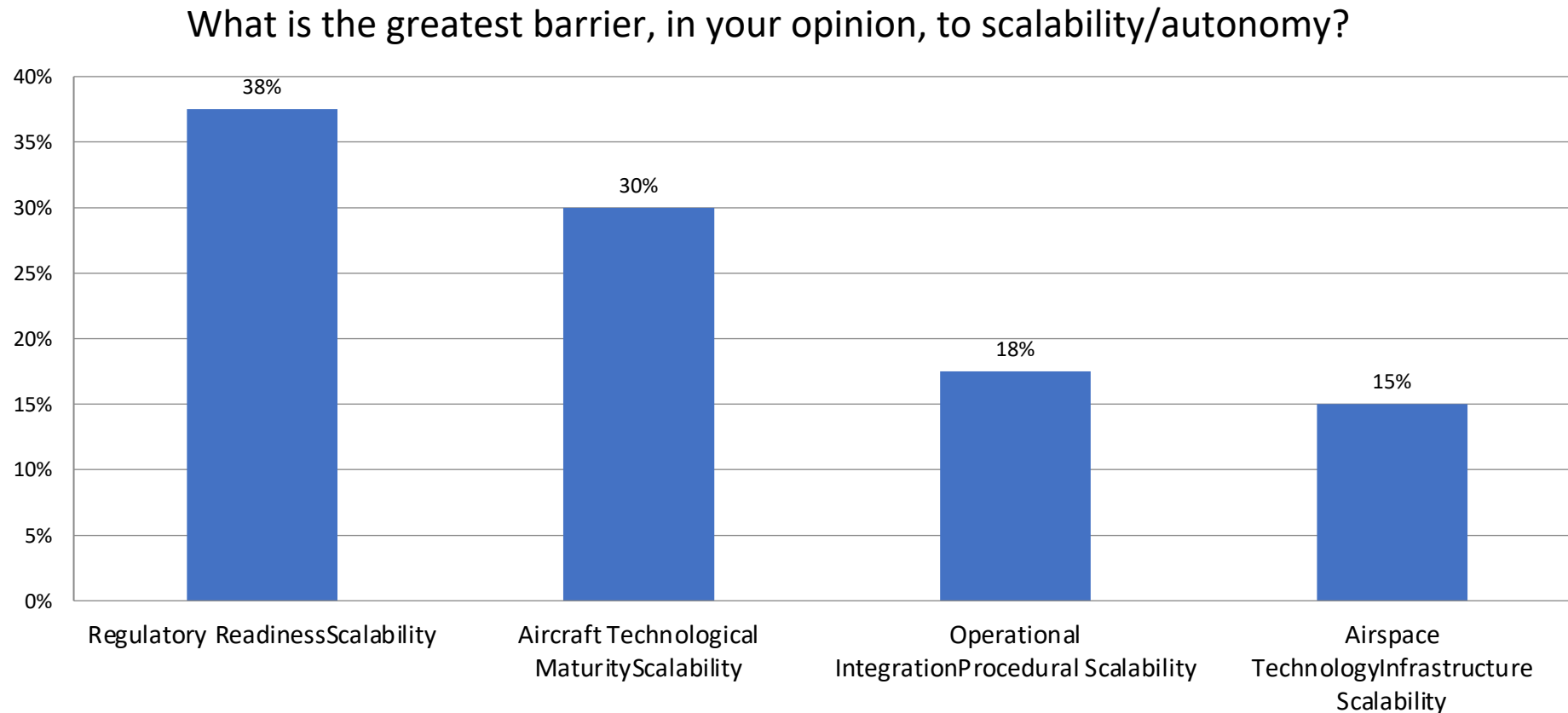
- Introduce Current Technology In Low-Risk Use Cases First, Where Appropriate
- Collect Data & Use Data to Develop/Validate Models
- Analyze Models for Higher Risk Safety Cases to Evolve
- “Build a Little, Test a Little” - Iterative Loop
- Models for Physical Problems Easier to Develop/Mature Than Models for Decision Making and Perception Functions
- Move Technical Maturity Forward for Specific Functions – Combine to Reach Specific Operational Goals for Autonomy



From ASTM AC 377 TR

# Shared Regulatory and Technology Challenge

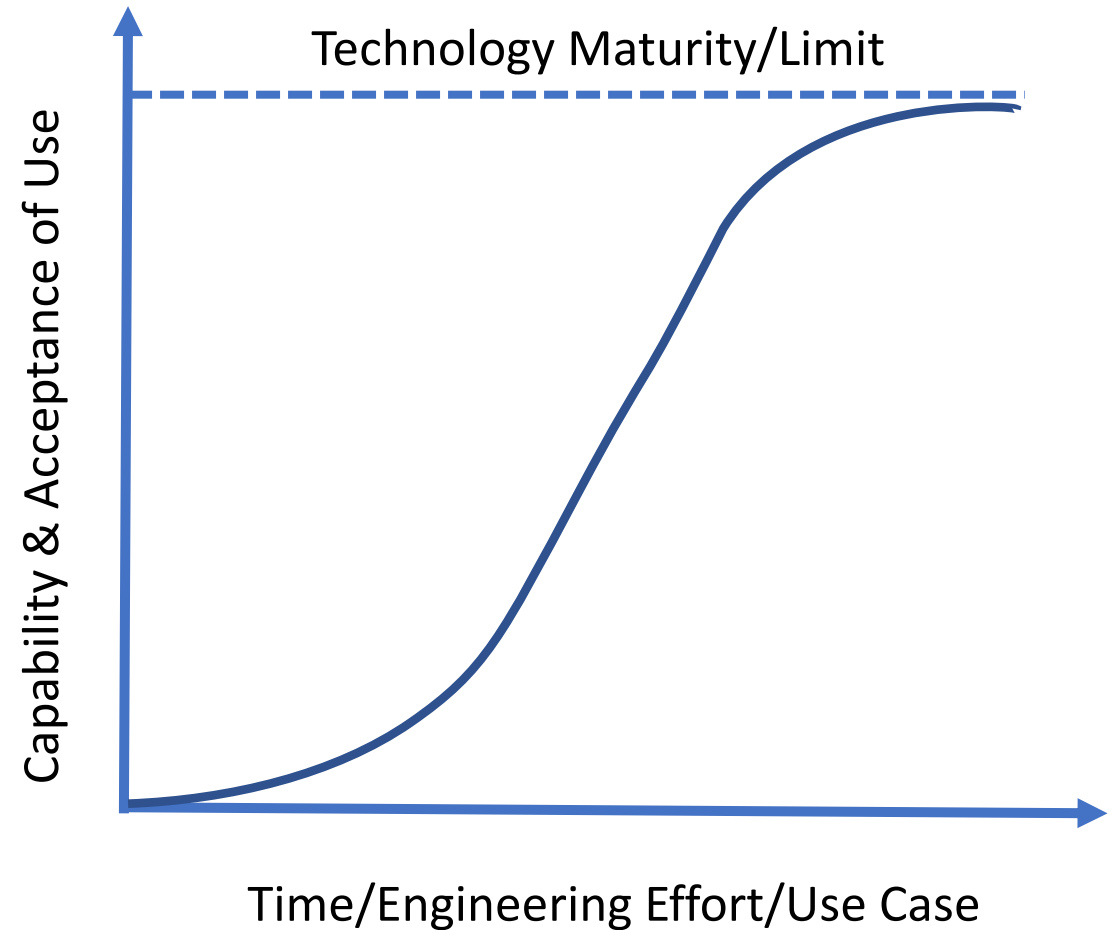
- 5/27/21 Workshop for Scalable Autonomy Indicated the largest barriers to scalability/autonomy were:



# S-Curve of Technology Maturation



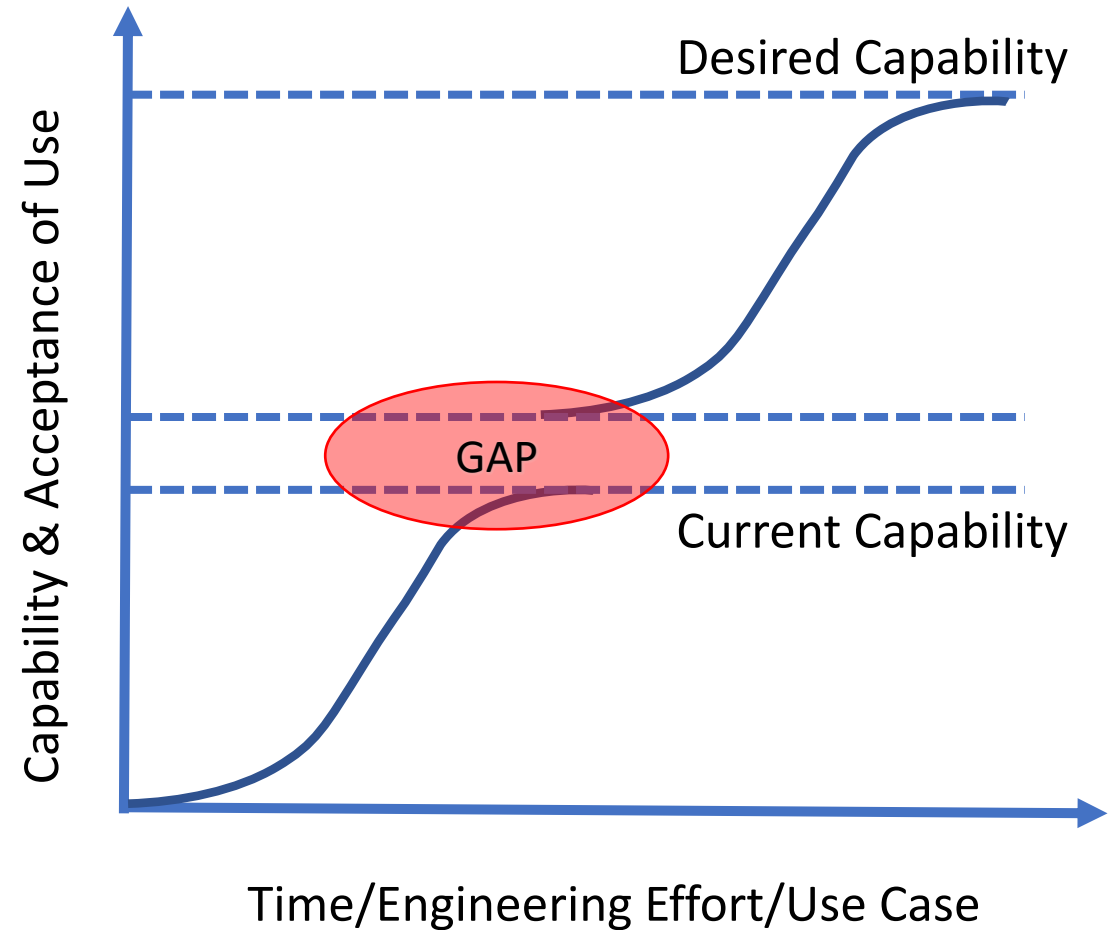
- Initial Development/Capability Slow
- Build Lessons Learned and Experience
- Maturity Leads to Greater Capability and Accepted Use
- Technology Reaches a Limit of Capability
  - Based on Assumptions for Development
- Capability Limits Spawn New S-Curves for Next Generation and/or Expanded Development for New Use Cases



# S-Curve Epochs – Maturity & Discontinuity



- Gaps in Capability May Limit Growth Towards Ultimate Goal/Use Case
- Gaps Can Exist in Technology, Regulation, and/or Operational Capability
- Consider the Level of Expected Integration vs. Demonstrated Capability
- Technology Gaps Must be Overcome by Data Collection and Demonstration in Real-World Scenarios – Catch 22
- Regulatory Gaps Present Similar Challenge - Overcome by Data



# Notional Automation Capability Maturity Model



## Capability

New ability, expertise, or proficiency

## Functions/ Services

Task, role, and/or system effects which enable a *Capability*

## Technology/ Human

Equipment including HW/SW which provide *Functions/ Services*

Human contributions to provide *functions/ services*

## Data/ Knowledge

Information sources used by *Technology* and/or *Humans*

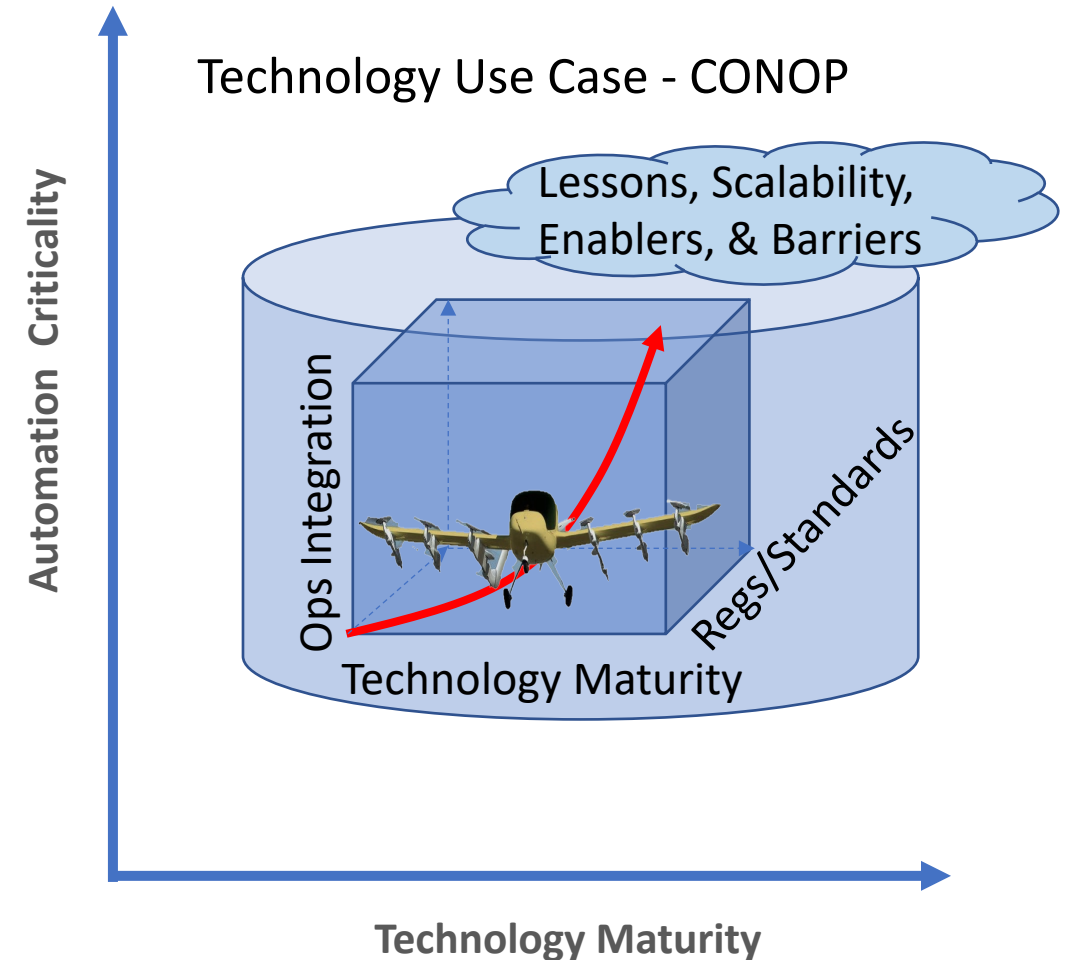
*Human* knowledge

**Must assess maturity, integrity, reliability, availability, etc. of data sources & technology to implement an intended function in support of a new capability**

# Capability Maturity Model – CONOP Focus



- Each Use Case Has Different Capabilities/Needs for Technology and Data – AAM, UAM, UAS, Remote Cargo
- Scalability of Technology & Technology Limits Inform Barriers & Enablers for Next “Epoch” or Expanded Use Case
- Lessons Learned Could Inform Other Use Case Evaluations and Technology Maturation/Integration Strategy
- Expanded Use Case Must Consider Technology and Data Gaps
- Regulatory Readiness and Standards Informed by Data

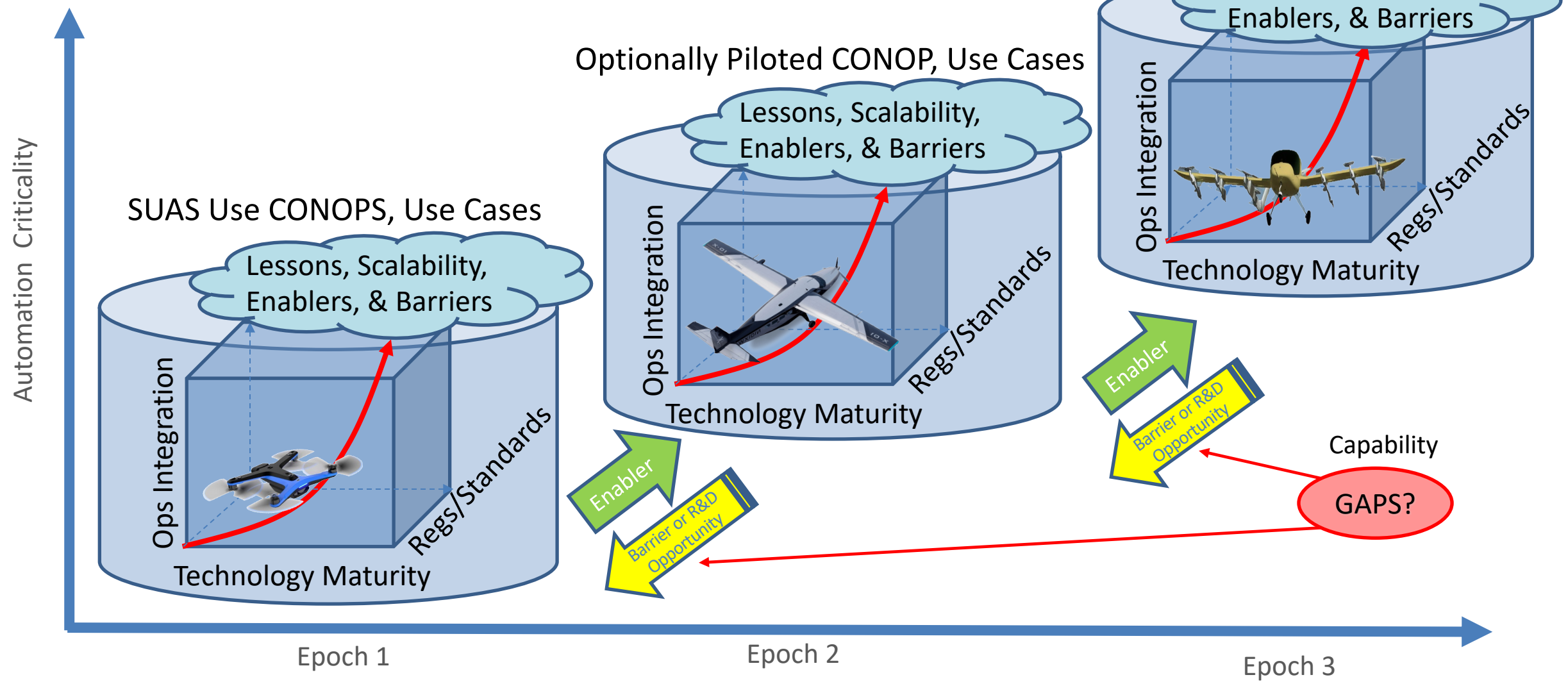




# Potential Reference mission Capability Maturity Path (Epochs)

Consider Technical & Regulatory Maturity + Aircraft/Ops

Remotely Piloted CONOP, Use Cases



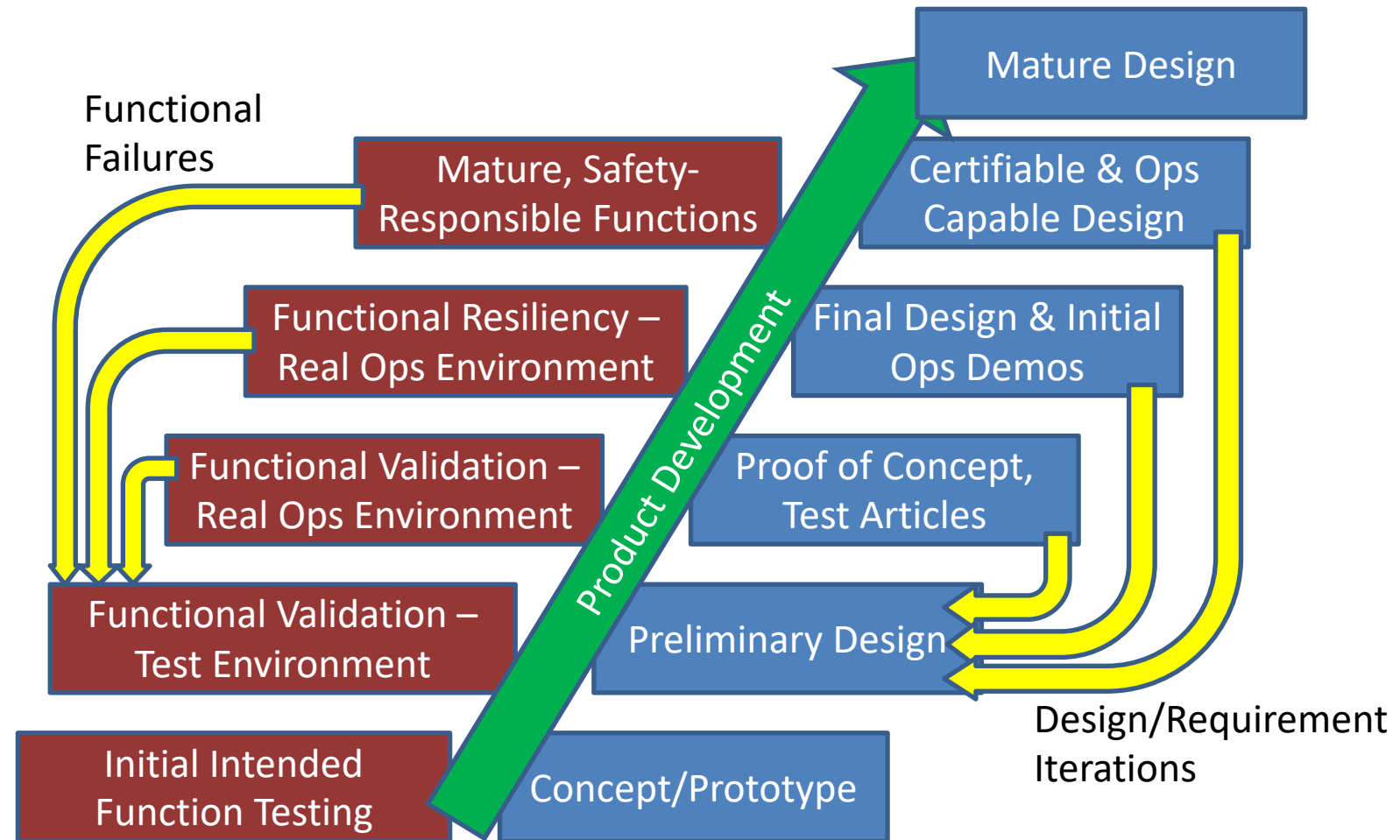


# Supporting Slides



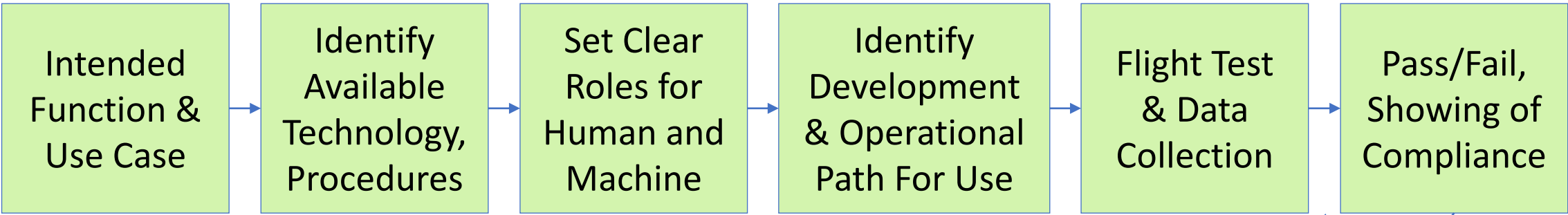
# Benefit of Using CMM Concept for Technology

- Methodical Progression from Prototype, to Initial Function with Human Monitoring/Backup, to Safety Responsible Function
- Common Framework for Analyzing Each Step Towards Proven Technology/Capability

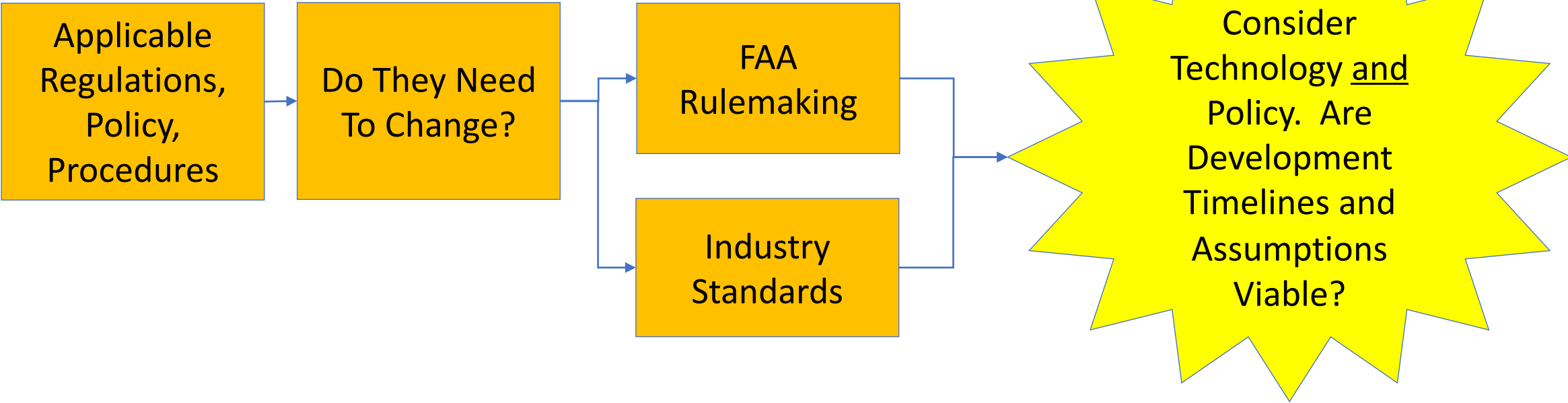


# Deconstruction of Functional/Technology Capability

## Functionally Based Approach to Product Development



## Functionally Based Approach to Policy & Regulation

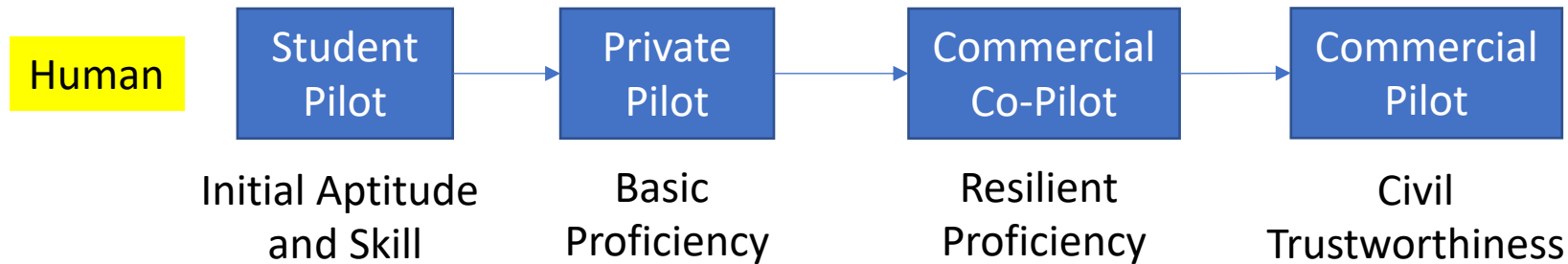


# Building-in Robust Safety Assurance

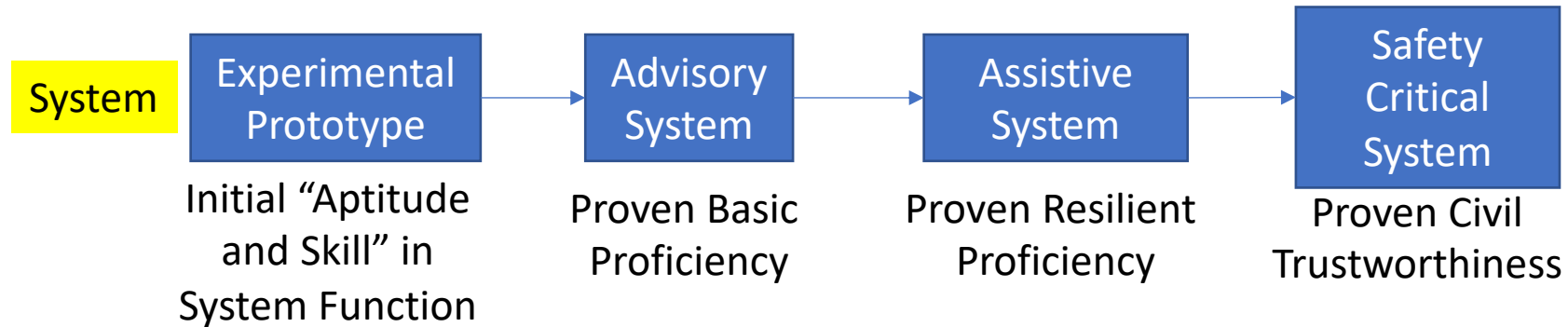


- Compare Risk-based, Model Based Automation Development to Pilot/Crew Development Process
- How Do We Build In Proficiency, Robust Function?

Scenario-based Training With Instructor + Repetition + With Expected Outcomes/Behavior

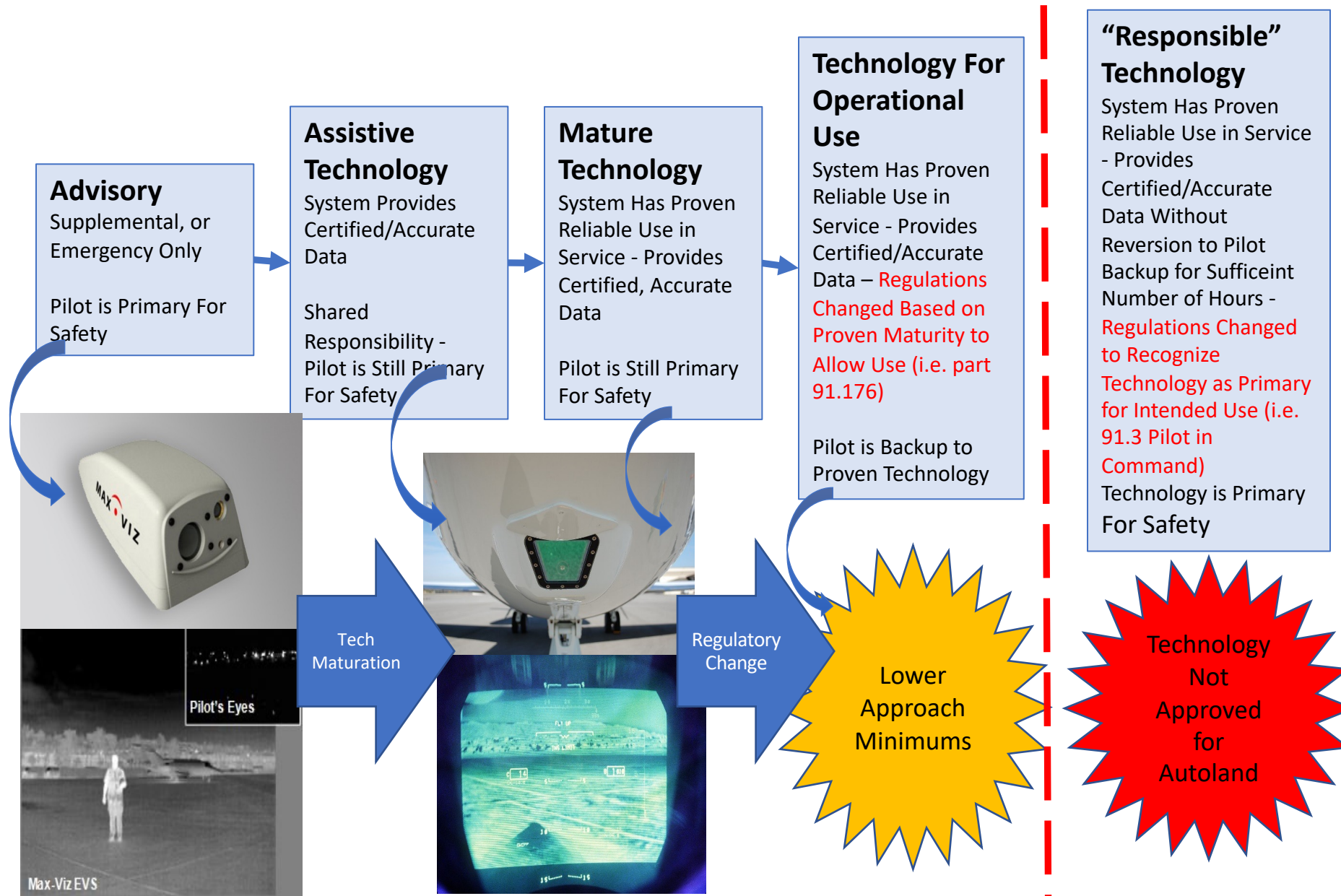


Simulation & Flight Test to Demonstrate Readiness for Intended Use, Type of Operation, Task Criticality



Must Work-up to Resilient/Robust Assurance in Automation Designs

# Automation Example – Technology Maturation



# Advisory, Assistive, and Responsible Functions – When Will AI/ML Be Ready?

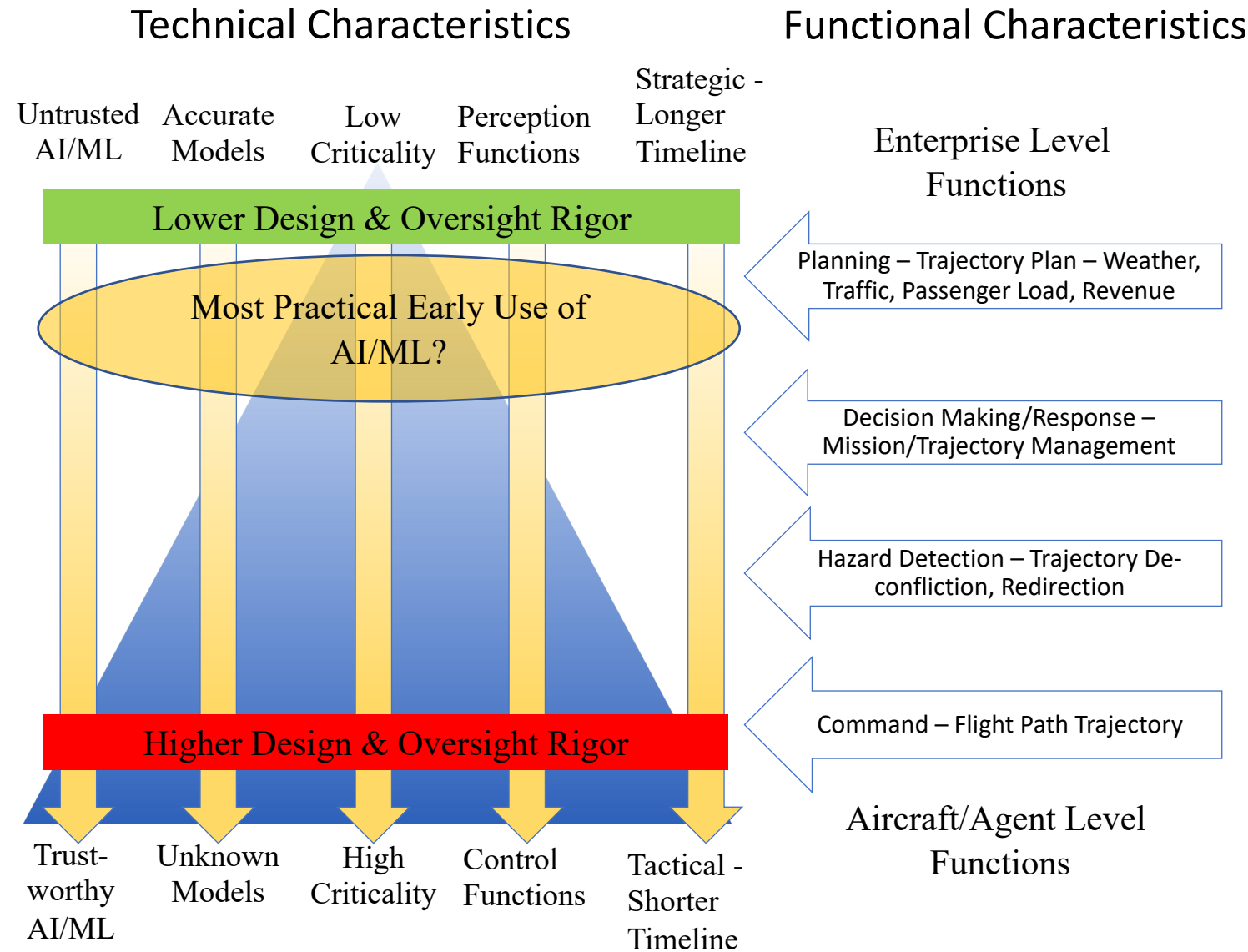


- Starting with Advisory Functions or Assistive Functions Allows for Human Intervention for Safety Critical Conditions
- Responsible Functions Require “Civil Trustworthiness” to be Proven
- How Do We Build in the “Aptitude” and “Resilient Proficiency” into AI/ML and Automation System?
  - Aptitude Measures Ability of the System to Perform its Function
  - Resilient Proficiency is the Ability of the System to Perform Repeatedly in Foreseeable Conditions
  - Civil Trustworthiness is the Ability to Show the System is Proficient to a Level the Public Trusts

# AI/ML Classification Construct



- Perception Functions Difficult to Model, Less Bounded by Known Model/Physics
- Control Functions Well Understood, Governed by Flight Dynamics and Physics of Aircraft/Trajectory Models
- Tactical Decisions Have Shorter Timeline, Greater Urgency
- Strategic Decisions Have Longer Timeline, Less Urgency
- Where Should We Focus AI/ML in the Near Term, Mid Term, Long Term? Safety Critical or Route Efficiency Improvement Functions?
- What Risks/Challenges Do We Face for Moving AI/ML from Tactical to Strategic Decision Making, or From Control Functions to Perception Functions?



# What Is Safety Assurance?

- The Process By Which A Product is Deemed Safe for Repeatable, Reliable, Civil Use
  - Not Just Software Development Assurance
  - System safety, airspace, ops, maintenance, & pilot performance all feed into operational safety
  - Cannot try to fix ops safety target with increasing  $10E^{-x}$  for system failures
  - Must Account For Other Factors

