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Autonomy as an Operational Enabler: Why do we need autonomy?

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Panelists



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Autonomy as an Enabler – Panel Flow



Why do we Need a High Level of Automation Towards Autonomy?

– Skydio, Zipline, Wing, and Others

- UAS Ops Enabled by Existing Regulations for Limited Operations – Seeking expansion
- Specific Assumptions about Airspace, Operating Limitations, Integration/Segregation, Risk to the Public, etc.
- Use Cases Already Depend on, and Demonstrates, a High Level of Automation

– Reliable Robotics, Xwing, and Expanding Use Cases

- Rely on Technology Maturation and Regulatory Expansion for Flight Path Automation, Detect and Avoid, Command/Control, etc.

– How NASA Research & Flight Demos Can Enable Technology Maturation and Inform Future Use Case Expansion

- Wildfire Mitigation, Autonomy Flight Demos, Technology Development Programs to Enable Automation, V&V of Complex Systems, Traffic Management, etc.

– Future for AAM

- Wisk, Joby, Overair, and many others are depending on technology and regulatory maturation to succeed.

Food for Thought for Panel



Industry Pace - Industry is heavily investing in early prototyping that can be tied to proposed UAM Maturity Levels (UML), and desires to move quickly towards initial commercial operations

Industry Challenge – Technology Maturity and Regulatory Readiness are at the heart of operations that are enabled today and indicate which require further collaboration to enable in the future. Many proposed use cases outpace current technology and regulatory maturity levels, so we must bridge those gaps to enable the future

NASA Leadership – NASA must lead in the areas of noise, autonomy, safety, and airspace integration, getting out in front of industry

NASA, FAA, USAF, and Industry focus – Partner to do the research industry needs to mature their operational concepts & achieve scalable operations that benefit the general public and maintain international leadership

Standards + Behavior-Based Outcomes – Define Pass/Fail Behavior Expected for Each Intended Function to be Automated – Enable Outcomes-based Approach to Certification



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Thank you
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Successful Paths to Autonomy Will Require:



- Holistic Consideration of Human Role in All Aspects of Existing Operations
- Implement Risk Leadership vs. Risk Management – Risk Vs. Reward
- Foster Key Partnerships to Mature Technology
- Focus on Data Collection to Feed Standards & Regs
- Need Methodical Scalability From Autonomy Demos to Safe Civil Use
- Consider “New” Airspace, Operations, Design, Architecture, & Certification Methods/Concepts
- Leverage Model-Based Engineering & Simulation



Regulatory vs. Technology Functional Focus



Goal of Moving Towards Remote-piloted Autonomy

- Requires Technology For Safe Function & Operational Integration To Be Mature And Accepted By The FAA – (I.E. DAA To Meet Intent Of 91.113 And Many Others)
- If Regulatory Basis For Acceptance Does Not Exist Yet – FAA Needs Data – NASA Can Help
- Catch 22 - Can't Collect Data Unless You Fly, Can't Fly Unless Technology Is Safe - NASA Can Help

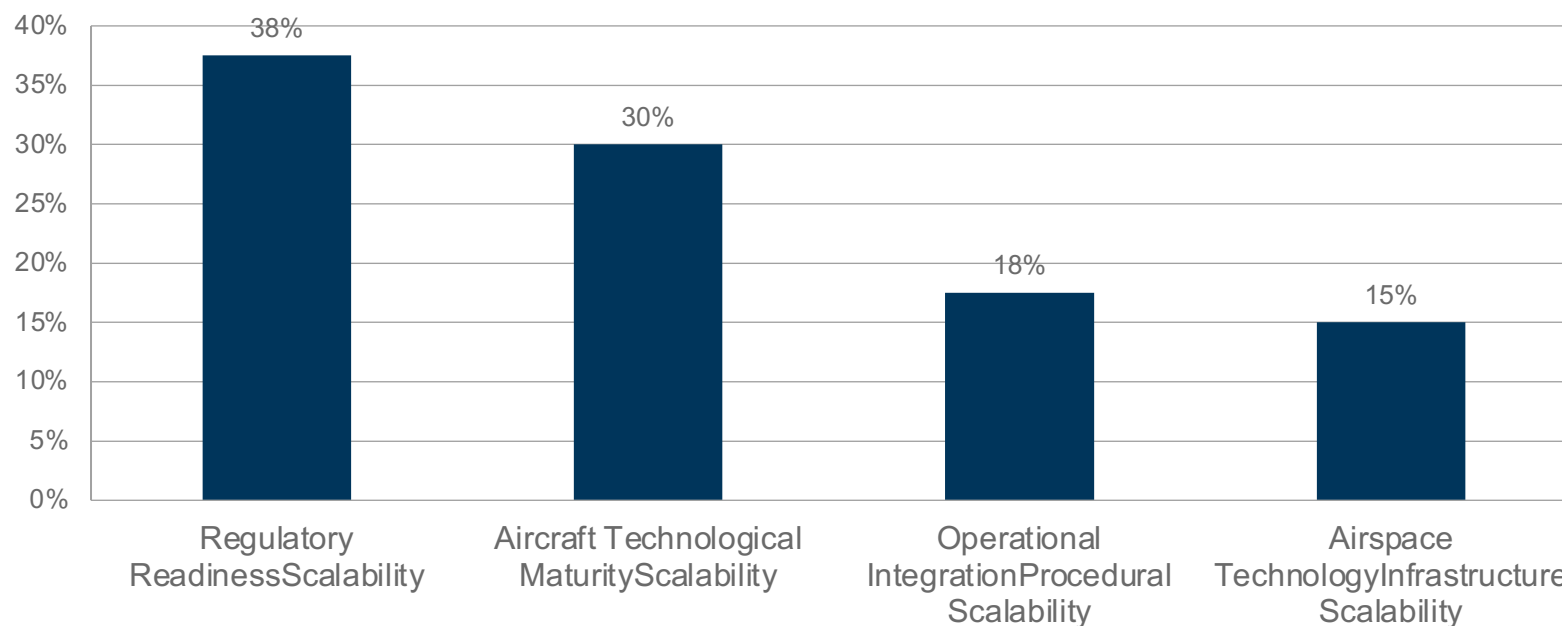
The Logical Path For Technology Development May Or May Not Match Logical Regulatory Path and Vice-Versa
Technology and Regulations Evolve Following “S-Curves”

Shared Regulatory and Technology Challenge



Results of 5/27 NARI Workshop for Scalable Autonomy Indicated the largest barriers to scalability/autonomy were:

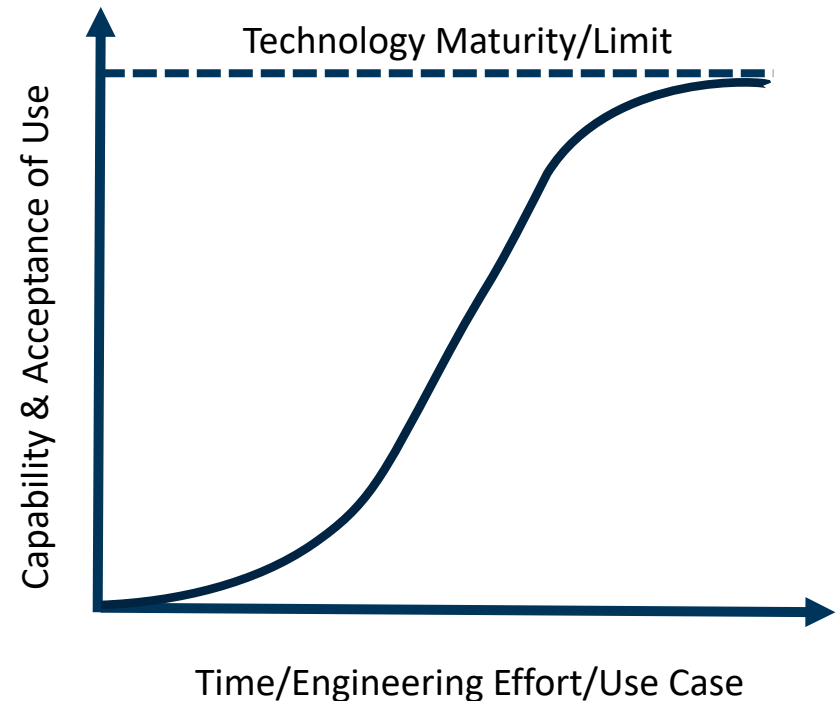
What is the greatest barrier, in your opinion, to scalability/autonomy?



S-Curve of Technology Maturation



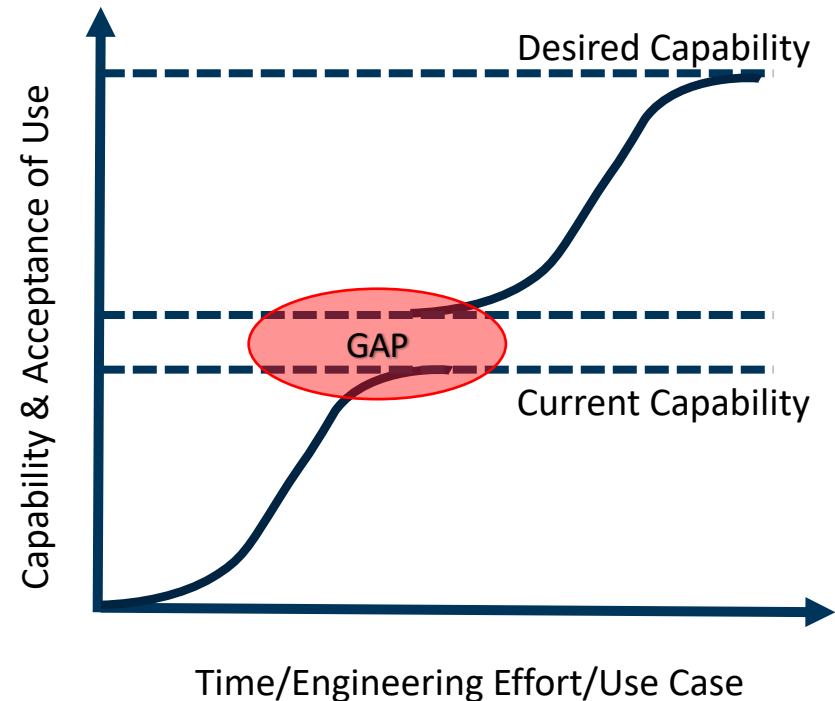
- Initial Development/Capability Slow
- Build Lessons Learned and Experience
- Maturity Leads to Greater Capability and Accepted Use
- Technology Reaches a Limit of Capability
 - Based on Assumptions for Development
- Capability Limits Spawn New S-Curves for Next Generation and/or Expanded Development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



S-Curve Epochs – Maturity & Discontinuity



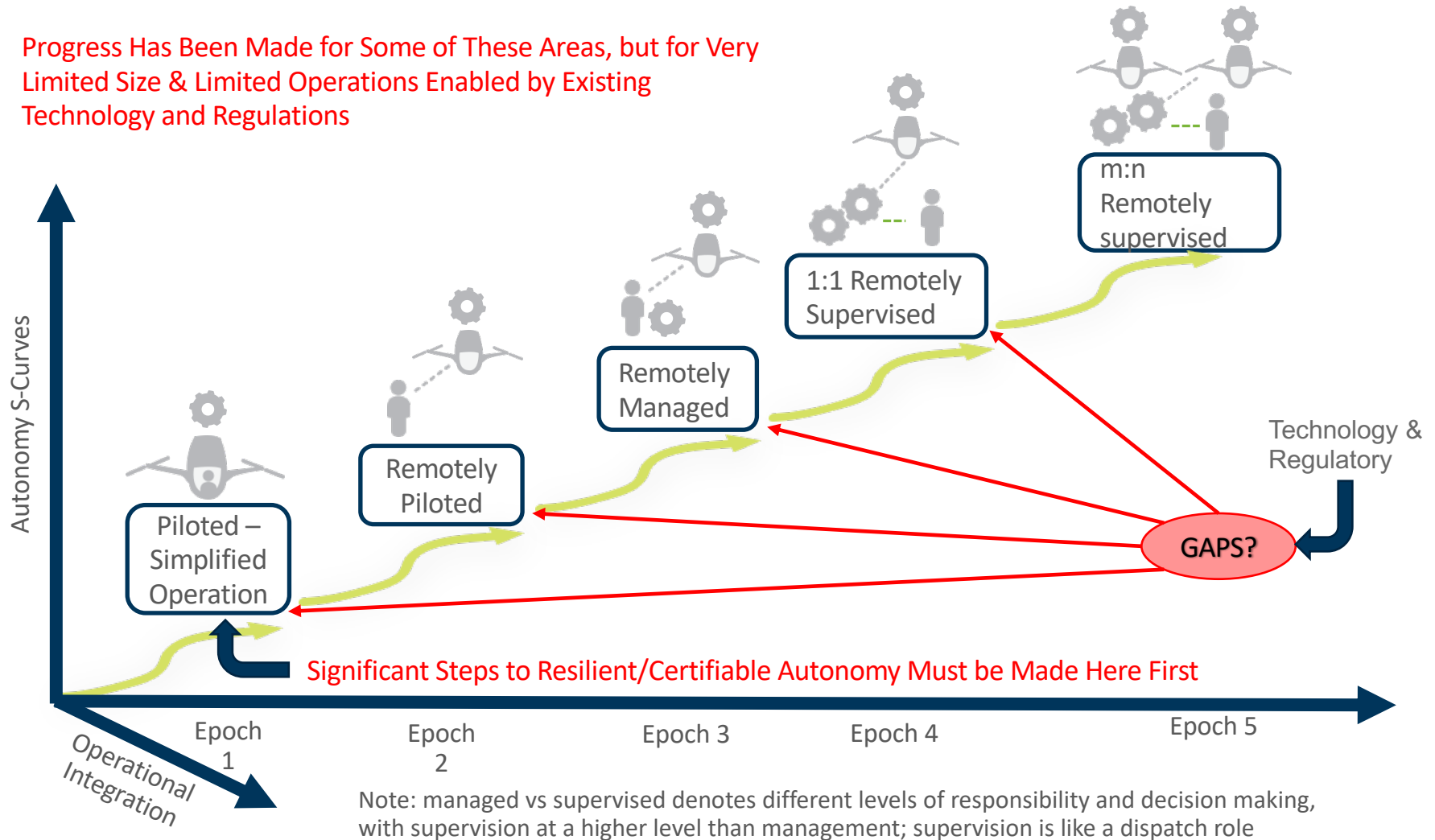
- Gaps in Capability May Limit Growth Towards Ultimate Goal/Use Case
- Gaps Can Exist in Technology, Regulation, and/or Operational Capability
- Consider the Level of Expected Integration vs. Demonstrated Capability
- Technology Gaps Must be Overcome by Data Collection and Demonstration in Real-World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



Notional Epochs for Automation Maturity



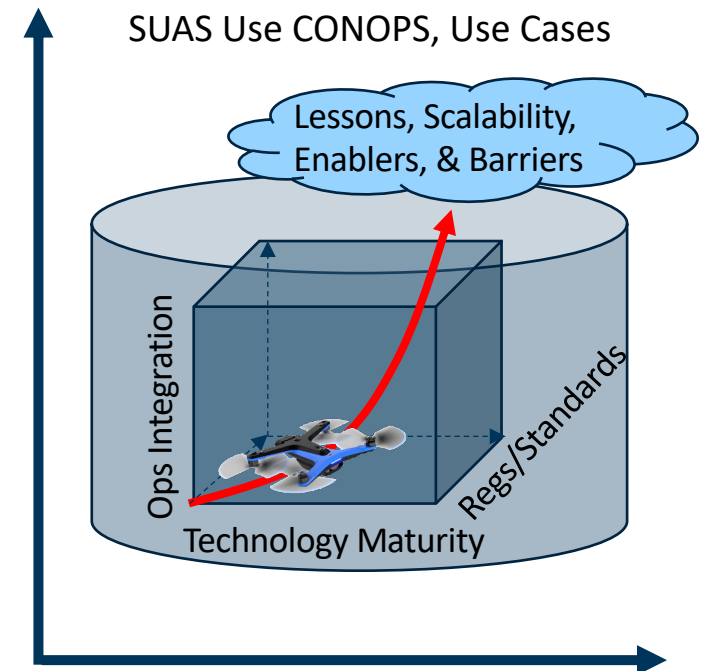
Progress Has Been Made for Some of These Areas, but for Very Limited Size & Limited Operations Enabled by Existing Technology and Regulations



S-Curves and Technology Maturity/Regulatory Gaps By Use Case



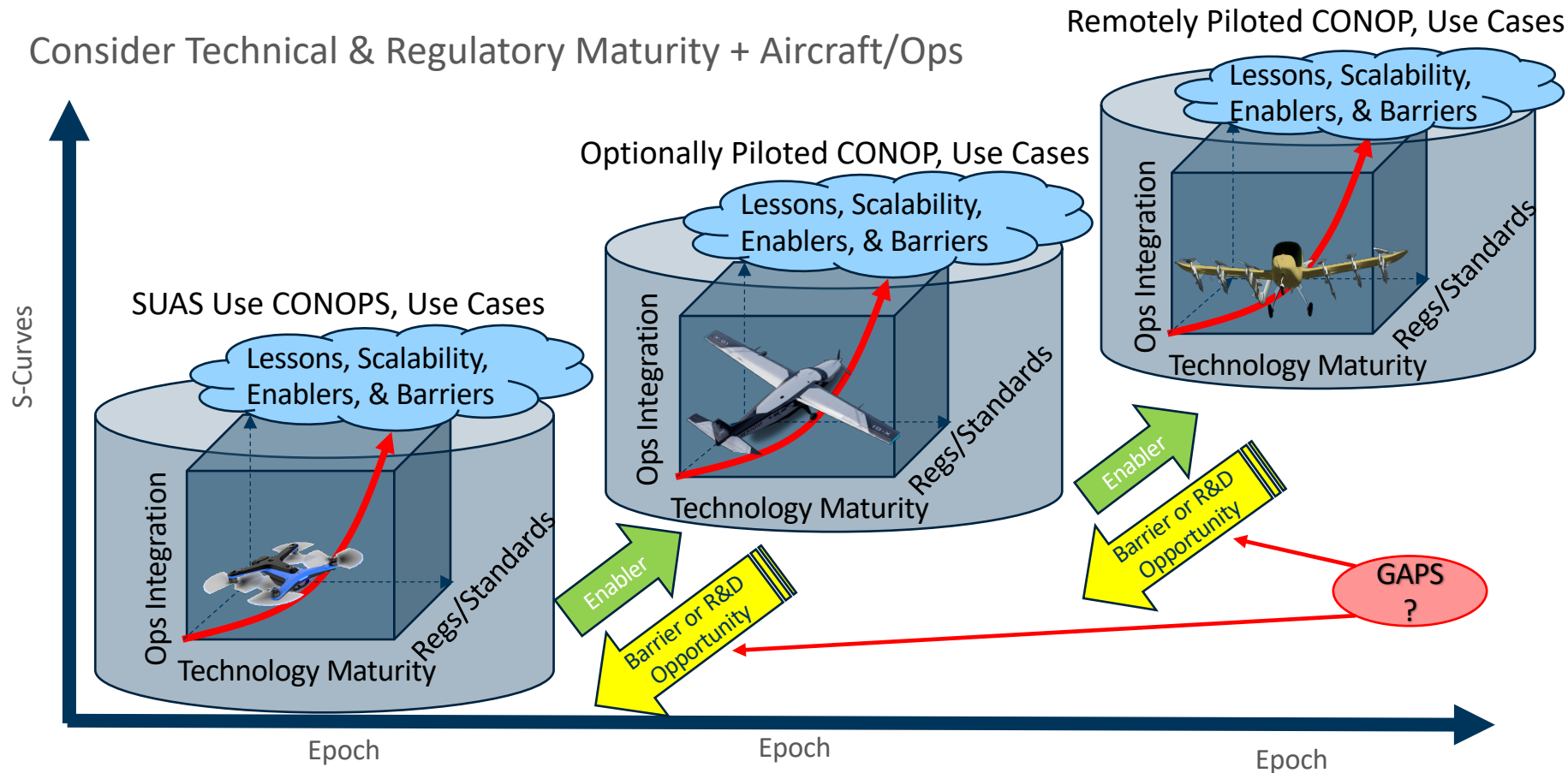
- Consideration for Technology, Regulatory, and Ops Integration Level of Maturity – Must Have Proven Capability
- Learn By Doing – Traverse S-Curve With Lesson Learned From Real-World Operations
- Scalability of Technology & Technology Limits Inform Barriers, Enablers, & R&D Opportunities for Next “Epoch” or Expanded Use Case
- Regulatory Needs to Enable Next “Epoch” or Expanded Use Case Must Be Considered With Technology Gaps
- Regulatory Readiness and Standards Informed by Data



Notional Epochs Between Use Cases



Consider Technical & Regulatory Maturity + Aircraft/Ops



Gaps Identify Needs for R&D, Technology Maturation, etc.

Assumptions & Enablers/Barriers/Opportunities - Epochs - SUAS to GA-Sized OPA



Epoch – Small UAS	Enabler, Barrier, R&D Opportunity	Epoch – GA-Sized OPA
Automation Concepts for Nominal Control/Behavior	Tech Enabler	Design Redundancy and Architectural Lessons Learned – Behavior-based Outcomes/Rules
Automation Concepts for Safe Reversionary Control/Contingency	Tech Enabler	Design Redundancy and Architectural Lessons Learned – Behavior-based Outcomes/Rules
Part 107	Reg Barrier	Part 91
Segregated Airspace	Reg Barrier	Integrated Airspace
No Airworthiness	Reg Barrier	Part 21 Airworthiness
VLOS & Obstacle Masking	Tech & Reg Barrier	91.113 Required
Sensors – Close Proximity to Objects	Tech Barrier	Sensors for Tactical Detection
Small Size – Low Ground Risk	Tech & Reg Barrier	Must Mitigate Ground Risk
Small Sphere of Influence/Risk Exposure	Tech & Reg Barrier	Contingency Management for Greater Risk
Sensor Range vs. Speed of Vehicle	Tech Barrier	Closure Rates/Distances - Sensors Not Ready

Assumptions & Enablers/Barriers/Opportunities - Epochs

- GA-Sized OPA to Remotely Piloted GA Aircraft

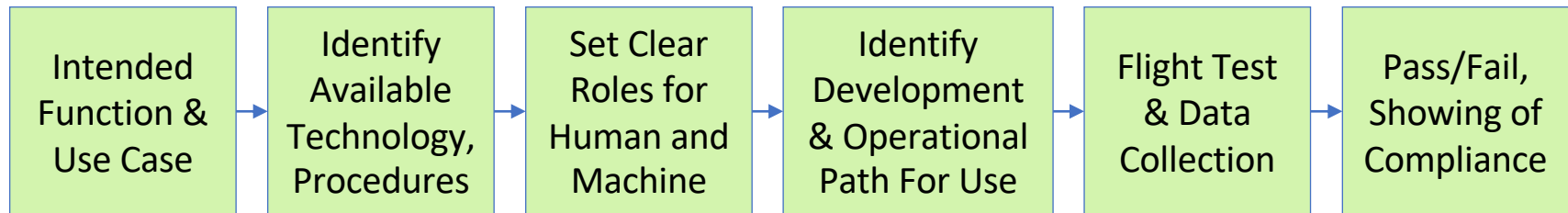


Epoch – GA Sized OPA	Enabler, Barrier, R&D Opportunity	Epoch – GA-Sized Remotely Piloted Aircraft
Automation Concepts for Nominal Control/Behavior	Tech Enabler	Design Redundancy and Architectural Lessons Learned – Behavior-based Outcomes/Rules
Automation Concepts for Safe Reversionary Control/Contingency	Tech Enabler	Design Redundancy and Architectural Lessons Learned – Behavior-based Outcomes/Rules
Part 21 OPA Airworthiness	Reg Enabler	Part 21 Airworthiness
Automation Concepts for Nominal Control/Behavior	Tech Enabler	Design Redundancy and Architectural Lessons Learned – Behavior-based Outcomes/Rules
Part 91, Pilot Mostly On Board or Visual Observer Requirement if Off-Board	Tech & Reg Barrier	Part 91 – 100% Remote Pilot – 91.113 compliance and acceptable MOC to AFS/ATO
Integrated Airspace – Pilot on Board & OPA Procedures Meet 91.113	Tech & Reg Barrier	Integrated Airspace – Remote Pilot & Technology Must Meet 91.113
Sensors for Assistive Tactical Detection - Pilot Primary for 91.113 Compliance	Tech Barrier	Sensors for Safety Critical Tactical Detection – Remote Pilot 91.113 Compliance Unclear
Must Mitigate Ground Risk – Optional Pilot May Play into Mitigation	Tech & Reg Barrier	Must Mitigate Ground Risk – Remote Pilot Role Undefined for MOC for Mitigation
Large Aircraft Risk to Airspace/Others Mitigated by OPA Procedures and/or Pilot On Board	Tech & Reg Barrier	Contingency Management by Remote Pilot in Manner Acceptable to AFS/ATO
Closure Rates/Distances - Sensors Not Ready for Safety Critical Use	Tech & Reg Barrier	Sensors Expected to Replace Pilot Vision for 91 Compliance – MOC Acceptable to AFS/ATO

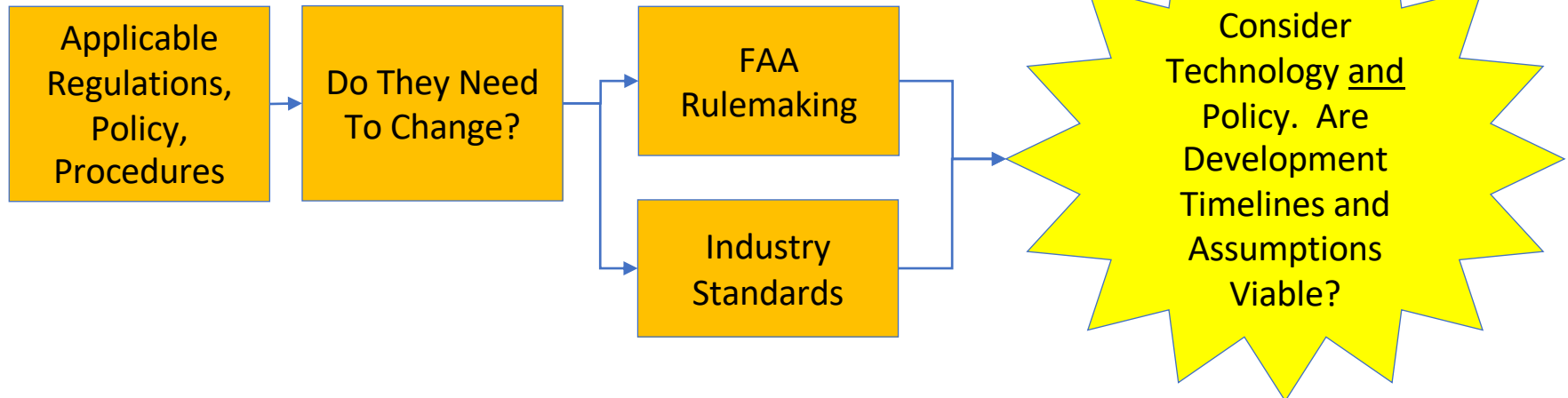
Functional (Task-Based) Evaluation Steps



Functionally Based Approach to Product Development



Functionally Based Approach to Policy & Regulation



Gates Help Identify Gaps/Needs for R&D, Technology Maturation, Reg Change, etc.

FAA/NASA AAM – Vehicle Automation WG

Proposed Gates for Evaluating Functions



Gate	Action/Evaluation
0	Identify an intended function for automation including the context – Intended use (e.g. operational context and/or phase of flight, and functional interfaces/dependencies)
1	Explain the potential benefits or incentives of automating the proposed function (e.g. safety enhancement, operational enhancement, and economics). Identify any potential risks, limitations, or barriers to automating the proposed function
2	Define how the intended function is currently completed/accomplished in operations and describe how it would be completed/accomplished once automated. Include human responsibilities and authority and how they could change and other system interfaces or dependencies when comparing.
3	Define the required information, processing, and outputs necessary to automate the function.
4	Identify candidate example technology products that may be capable of automating the function
5	Identify gaps in the current technology products to perform the function, and what operations the current technology could enable now
6	Identify the required maturity level of a technology product for it to achieve the intended function. Describe any differences in the level of maturity that may be appropriate depending upon aircraft size (i.e., normal category, transport category), kind of operation (i.e., cargo, passenger-carrying), or any other appropriate risk consideration.
7	Identify a path from current technology capabilities to the future technology capabilities necessary to achieve the identified maturity level(s).
8	Identify the applicable regulations/policy/standards/guidance (i.e., aircraft certification, operational, airman, ICAO) related to the current function.
9	With reference to Gates 2 and 8, identify what regulations/policy/standards/guidance may need revision and where new regulations/policy/standards/guidance may need to be developed to certify an aircraft with the technology and authorize/enable its use in operations.