FAA – NASA PNT* Workshop

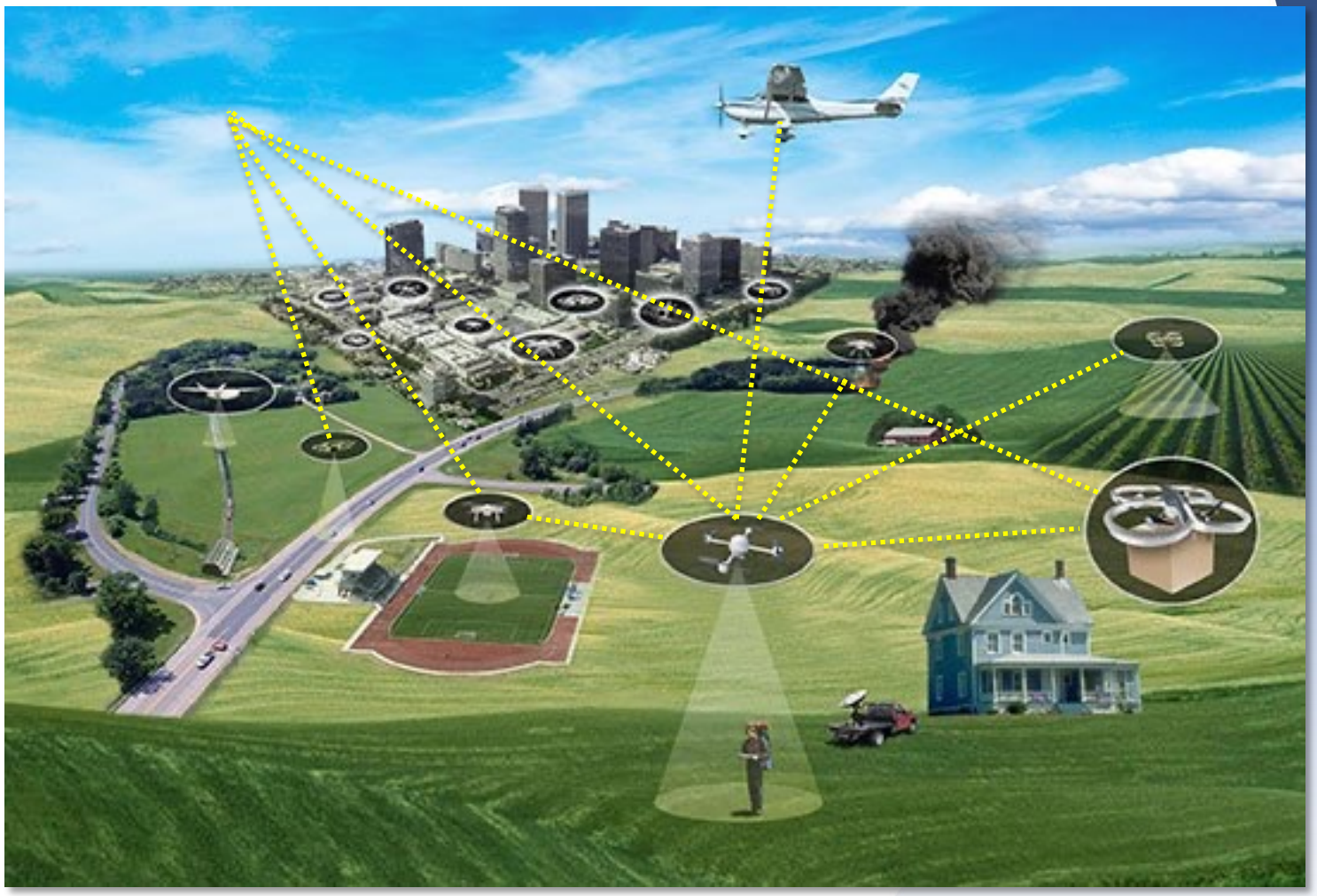
Addressing the Need for

→ *Resilient PNT Services*

in *Challenging* and

***Under-Served Airspace* to**

→ *Enable New Capabilities*



Wes Ryan, NASA NARI
Lannie Herlihy, FAA

*PNT=Positioning Navigation and Timing

May 24-25, 2022

Agenda – Day 1 – May 24 – Pacific Time

Time	Item	Presenter	Purpose
8:00-8:15	Welcome	Wes Ryan and DR. Parimal Kopardekar, NARI Director	Logistics - Opening Comments – Why Complementary PNT, why Now?
8:15-8:30	FAA Comments	Steve Bradford	FAA Statement of Need - R&D Efforts Regarding PNT
8:30-8:45	Workshop Purpose/Goals	Wes Ryan, NARI Program Manager Lannie Herlihy, FAA	Clear Purpose and Expected Outcomes
8:45-9:15	Overview of FAA/NASA PNT Work	Corey Ippolito, NASA Ames Evan Dill, NASA Langley Ken Alexander, FAA - TBD	Existing FAA/NASA Efforts for PNT R&D and Existing Approvals vs. Denied Uses
9:15-9:30	Break		
9:30-10:30	Description of PNT Needs and Vision for New Capabilities – Sean Memmen - FAA Moderator	Industry Panel • uAvionix – Ryan Braun • NextNav – Ganesh Pattabiraman • Spirent - Jeremy Bennington • Satelles – Mike O'Connor • Near Earth Technologies – Sanjiv Singh • BNSF – Jim Barrett	What new missions are desired & where is technology now to meet that vision? Emerging Technology – How can sensor fusion systems meet the need?
10:30-11:15	Sample use Case Intro	Wes Ryan, NARI Program Manager, NARI	Low Altitude Rotorcraft Logistics Low Altitude Fixed Wing Logistics
11:15-12:00	Lunch	Open Mic or Lunch Speaker	
12:00-1:30	Mural Collaboration Session	Breakout 1a – Use Case 1 – Capability & Performance Breakout 2a – Use Case 2 – Capability & Performance	Explore Barriers and Opportunities for PNT Needs for Mission Elements
1:30 – 2:00	Regroup - Discussion from Breakouts	Recap/Report out of what each breakout learned (Top 5)	Identify actionable steps and areas for future work

We will be in this MS Teams room and using the microphone, chat, and "Raise your hand" features to interact directly with the hosts.

- **Please remain on mute unless you are speaking.**
- **Be prepared to turn on your webcam *only* when speaking.**
- **Say your name and affiliation before you begin speaking**
- **Enter comments/questions in the chat function on the right side of the screen**
- **We will also utilize Conferences.io for polling and any additional questions and comments**

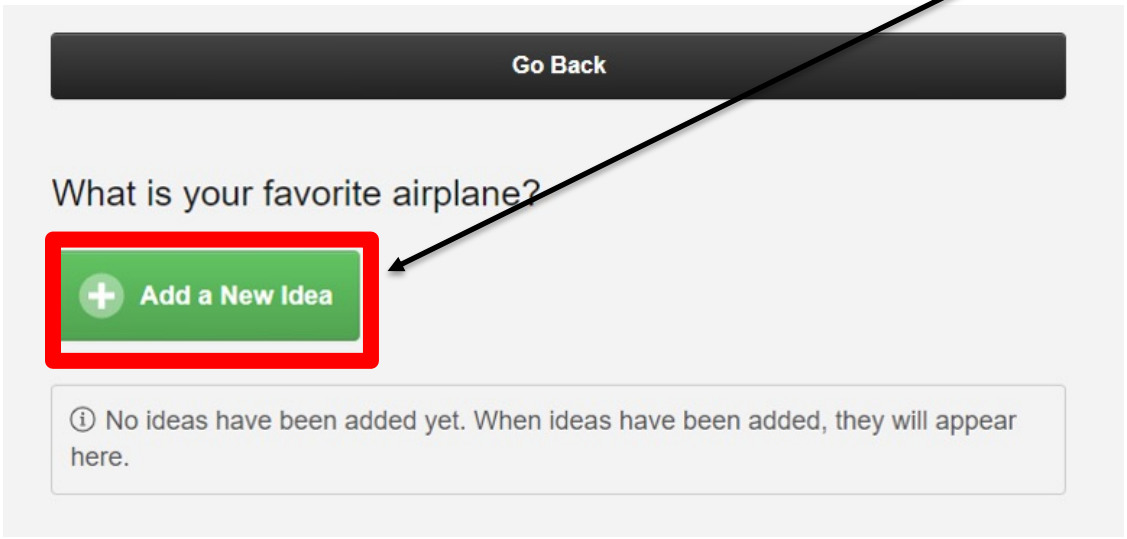
Conferences.io

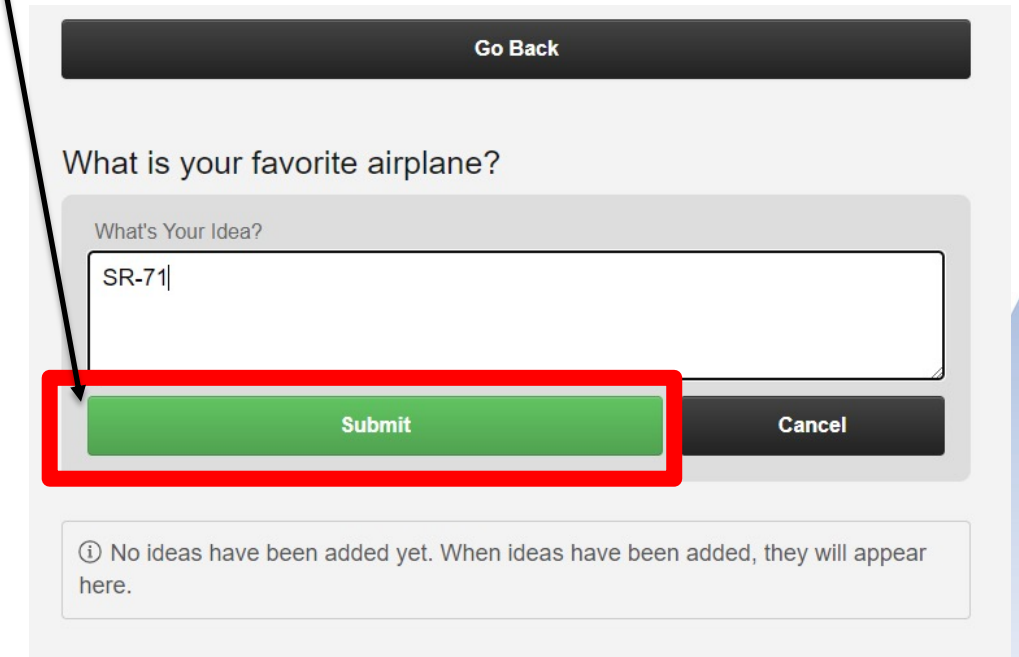
Web Address: https://arc.cnf.io/
Event Title: PNT Workshop

- Throughout the event, facilitators will direct you to conferences.io to respond to polling questions.
- Responses to these questions will be used for post-event analysis and reporting.

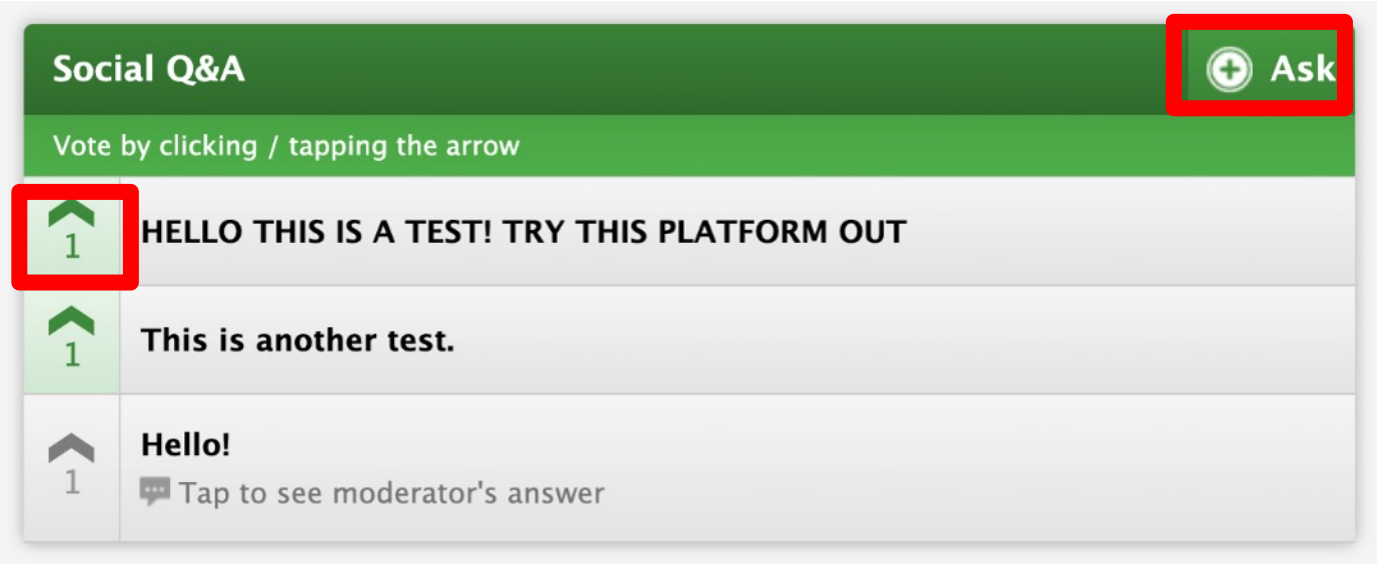
Answering Polling Questions

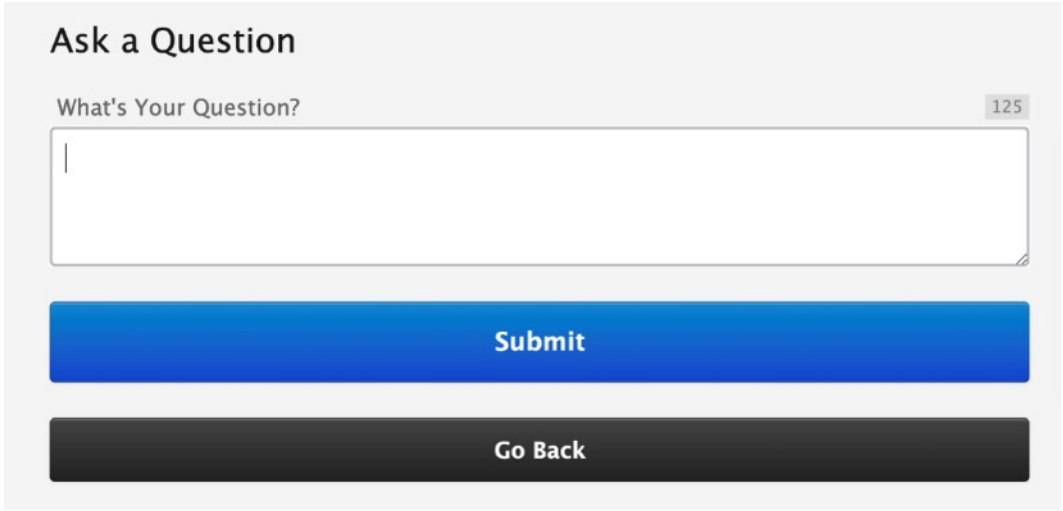
1. When a polling question is unlocked it will appear under “Polls”. Click on the question to answer.
2. Click “Add New Idea”.
3. Type in your response and click “Submit”





Social Q&A





Below the Polls there is a "Social Q&A" section for additional questions.

Please use this feature to capture questions not directly related to the current discussion for follow up at the end of the event.

- **A video stream of this event is being recorded for NASA internal use only.**

- **Responses to polling questions and discussion over Teams and in chat will not be attributed to individual persons or organizations in final reports.**

Welcome

Parimal Kopardekar (PK), Director

NASA Aeronautics Research Institute

FAA Opening Comments

Steve Bradford, FAA

Chief Scientist

NextGen Architecture

Workshop Purpose and Goals

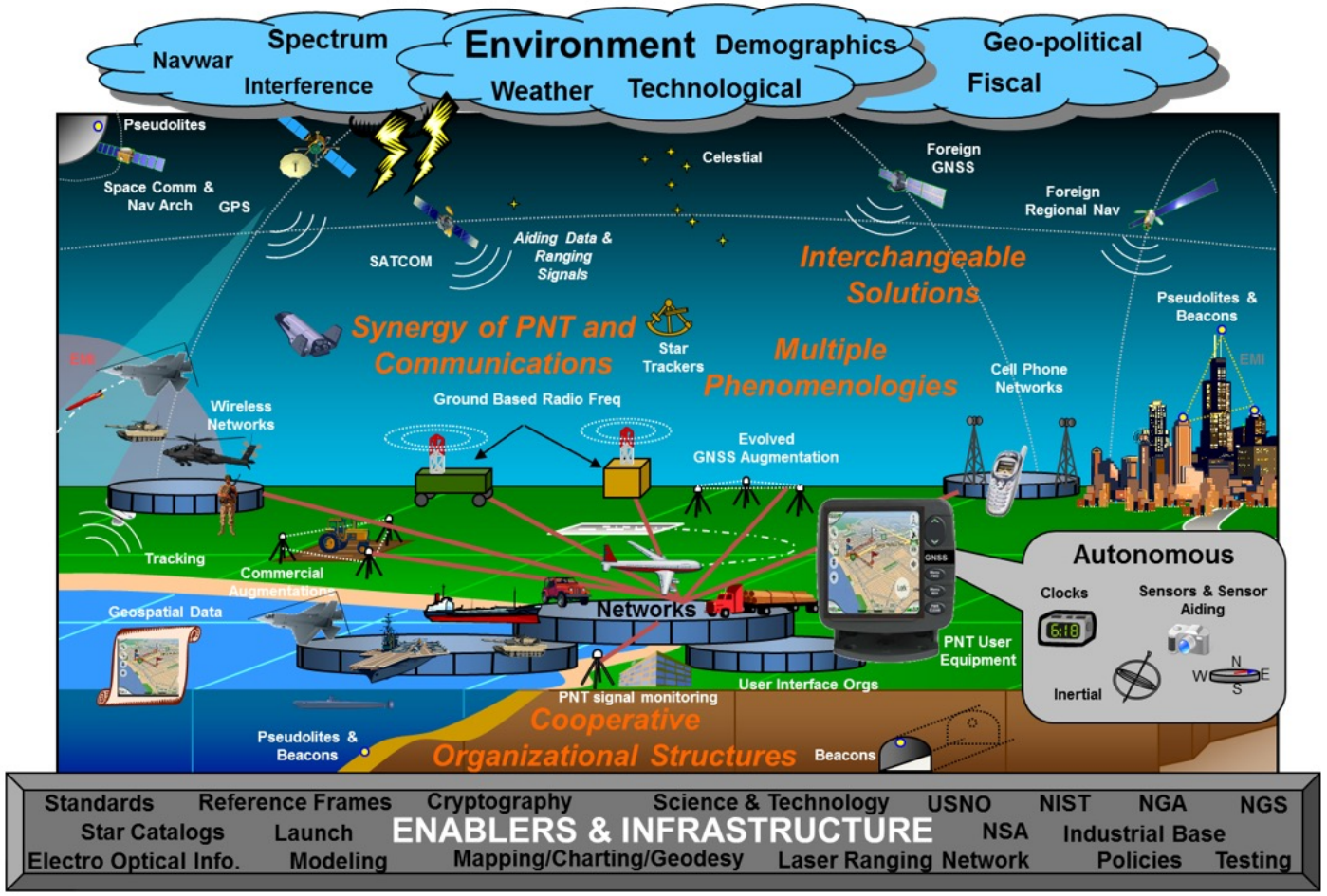
Wes Ryan, Program Manager
NASA Aeronautics Research Institute
NASA Ames

Lannie Herlihy, FAA NextGen
Systems Engineer
Navigation Enterprise Architecture Lead
FAA

Why Are We Here?

- Existing PNT is Vulnerable
- May Not Serve Expanded Low Altitude Ops for UAS & Adv. Air Mobility
- GPS, VOR, DME, other Nav Aides Insufficient for Low Altitude & Urban Canyon
- Need PNT and Localized Relative Positioning/Precision

National PNT Architecture



https://www.transportation.gov/pnt/what-positioning-navigation-and-timing-pnt

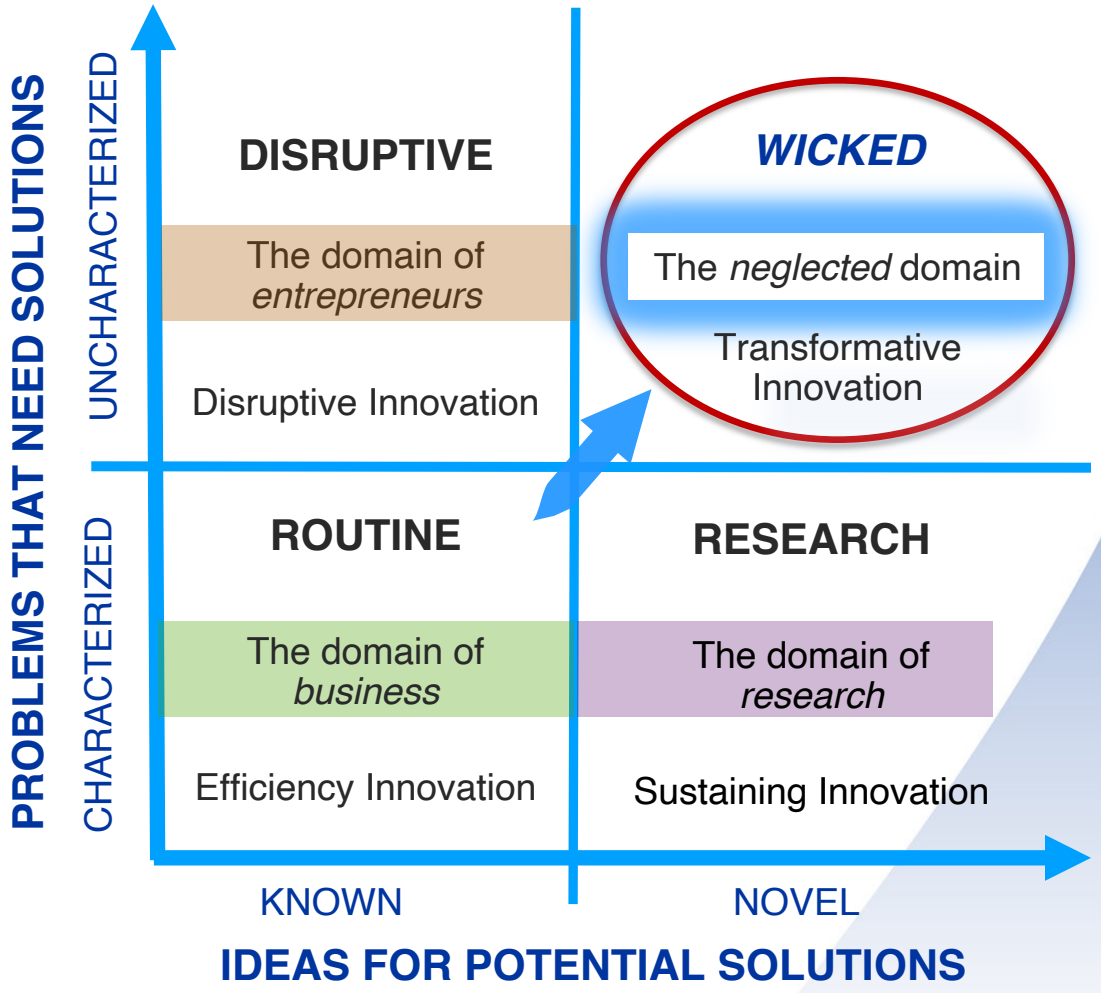
The “Big Picture”

- **NASA and the FAA Collaborating on Future PNT**
  - **PNT Services are *Key Enablers* for AAM, Automated Flight Rules, Tactical/Strategic Conflict Management, 4D Trajectory Management, etc.**
  - **Identifying PNT Service *needs and sources* are an important part of identifying the paths to New Future, Safe, and Scalable Operations**
  - **We need to identify the role of New PNT Technology to support paths to Future Capabilities in alignment with the Performance Based NAS Navigation Strategy**
  - **GPS PNT Services are subject to interference – both denial of service (jamming) and manipulation (spoofing). We need to address complementary PNT to address vulnerabilities/outages**
- **Goal: Workshops – Identify Ways to Collaborate and Inform Certification Paths for New/Complementary PNT Technology – Set Requirements for CPNT**

Complementary PNT Solutions – A *"Wicked"* Problem

In the sense that "Wicked" means:

A difficult or seemingly impossible problem to define and to solve because of incomplete, contradictory, and changing requirements, and where no single solution appears to be adequate.



Goals: Exploring PNT Technology Concepts

- **Use complementary and resilient PNT technology to replace or augment GPS PNT below 1000 ft to support UAS/AAM**
  - **Vehicle-based Visual/IR/Lidar/Radar Mapping for "Visual" Navigation**
  - **Ground-Based Surveillance (primary and/or secondary)**
  - **Ground-Based Radio Navigation**
  - **Others?**
- **Can Complementary PNT systems be developed to aviation-level metrics (accuracy, availability, integrity, continuity, coverage) yet be affordable for wide-scale deployment?**
  - **What PNT metrics are needed for different "phases of flight" – especially in "challenging" operational areas <1000 ft AGL?**
  - **What is the role of Charting in these expanded operational areas?**

Need for Complementary PNT

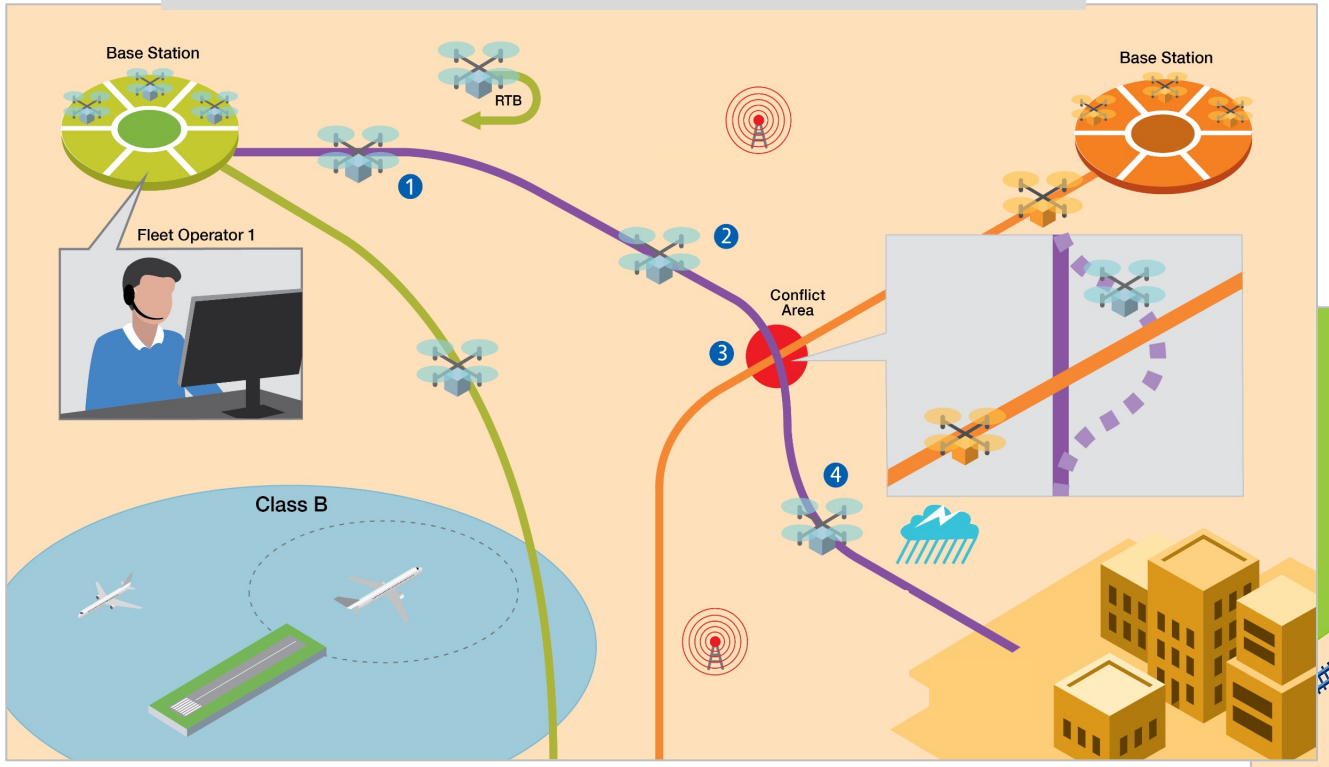
- New/Expanded Ops Capabilities/Functions Desired
  - Automated Flight Operational Concepts
  - “Underserved” Use Cases/Airspace
- Improved Availability/Intended Function of Current Sources
  - Precision and Data Sharing for AAM/Future Use Cases
  - Size, Weight, Power – UAS Cannot Carry Current Certified Equipment
- Address GPS Risks – Cannot Serve as the Sole Source means of PNT for Med/High Risk Ops
  - Mitigations of Jamming, Spoofing, Cyber Concerns
  - Current Requirement in FAA Waivers to Cease Ops for Small UAS for GPS Outage, Signal Degradation, etc.
  - Fail-safe? Fail-soft? Continue operations using resilient PNT alternatives?

Our Proposal

- **Complementary/New PNT Sources are Needed to Enable New/Safer Ops and UAS/AAM Use Cases – NASA Plays Key Role in Maturation**
  - **Rather than Wait on Core PNT Development for all potential use cases, determine how use cases could be enabled NOW using existing resilient PNT alternatives providing required safe, secure, PNT services**
  - **Establish performance-based requirements with specific requirements set by use case and intended function**
- **Expanding UTM Services for:**
  - **Low Altitude Use in Emergency Services, In TFR for Wildfire, etc.?**
  - **First/Last 500 - 1000 ft to/from vertiports – Augmenting existing RNAV approach and departure procedures**
- **Integration and Maturation Data Collection**
  - **Consider NASA/FAA/AFWERX Industry Flight Demos/Ops**

Workshop Overview - Deep Dive Two Use Cases

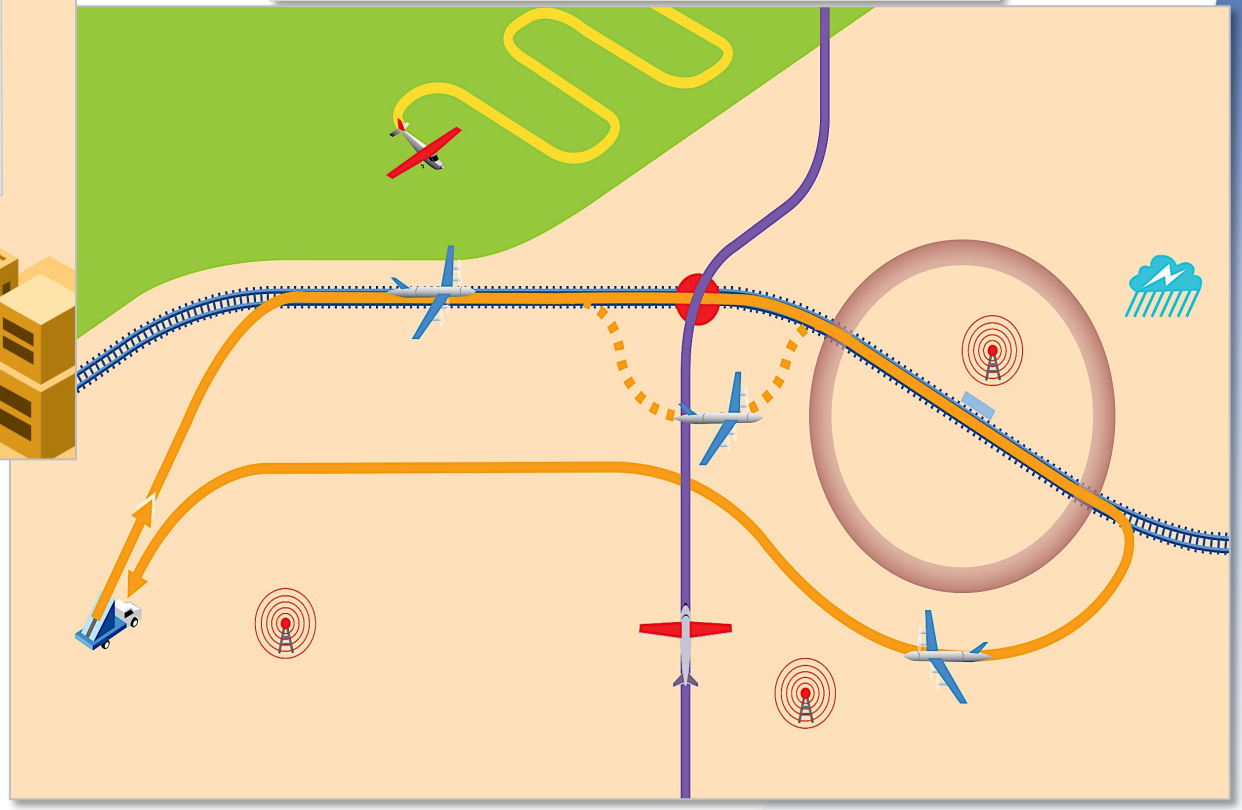
Low Altitude Rotorcraft Logistics



Breakout Group 1

Breakout Group 2

Low Altitude Fixed Wing Logistics



Breakout Overview: Plan Mural Board Breakouts

Day 1: Two Parallel Breakouts: Rotor Wing and Fixed Wing Logistics Missions

Goal: Identify Capabilities and Functions
Assess Barriers and Opportunities for PNT Maturation

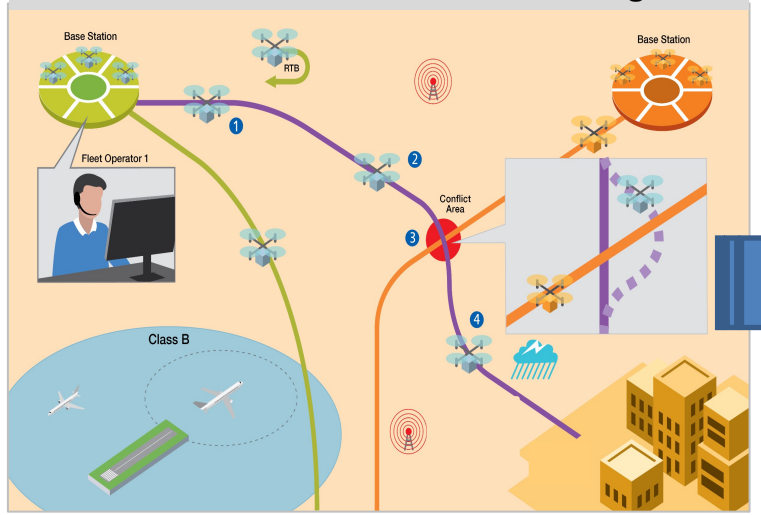
Day 2: Two Parallel Breakouts: Continue Rotor Wing and Fixed Wing Logistics Mission Evaluations

Goal: Identify Candidate Technologies per Function
Identify Data Sources and Requirements per Technology

Separate Mural Board For Each Mission
Day 2 Sessions Build on the Day 1

Board Layout - Breakout Group 1 – Day 1 and 2

Breakout 1 - Low Altitude Rotorcraft Logistics



PNT Opportunities, Capabilities, Technology, Data, Metrics for Low Altitude Rotorcraft Logistics Mission

Need For Specific Mission Element/Segment

Pre-Flight Planning	Takeoff & Landing	Enroute Flt Path Mgmt.	Conflict Avoidance	Mission Objective Delivery	Return Home	Contingency
Built -in Test	Radio Nav	ADS-B				

Need for All Mission Elements

Accuracy | Integrity | Govt Private Partnership | Tech Maturity | UTM

Day 1

Day 1 & 2

Day 2

Opportunities

Barriers

Day 1

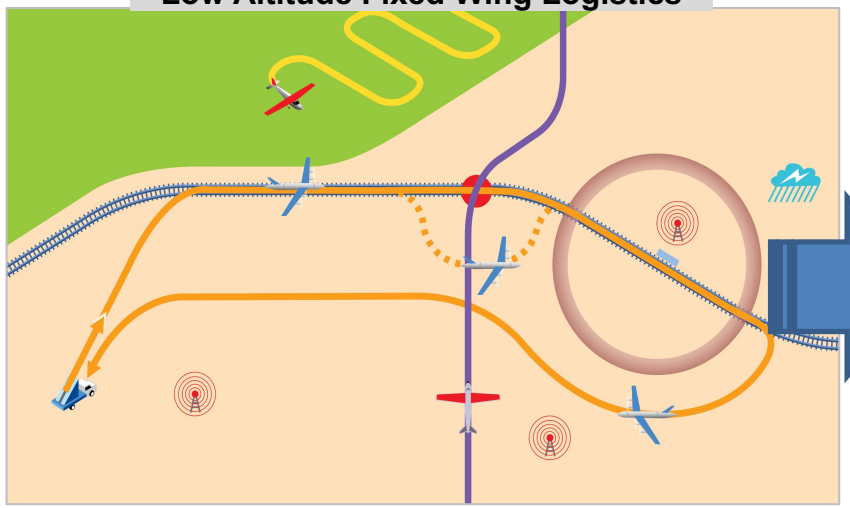
Capability/Function

Enabling Technology/Data Source

Metric/Performance Measure

Board Layout - Breakout Group 2 – Day 1 and 2

Low Altitude Fixed Wing Logistics



PNT Opportunities, Capabilities, Technology, Data, Metrics for Low Altitude Fixed Wing Logistics

Need For Specific Mission Element/Segment

Pre-Flight Planning	Takeoff & Landing	Enroute Flt Path Mgmt.	Conflict Avoidance	Mission Objective Delivery	Return Home	Contingency
Built -in Test	Radio Nav	ADS-B				

Need for All Mission Elements

Accuracy | Integrity | Govt Private Partnership | Tech Maturity | UTM

Opportunities

Barriers

Day 1

Day 1

Day 1 & 2

Day 2

Capability/Function

Enabling Technology/Data Source

Metric/Performance Measure

NASA Presentation: Past/Existing NASA PNT Work

Corey Ippolito, NASA Ames

Evan Dill, NASA Langley

Ken Alexander, FAA

–

Summarize Past NASA UTM, Cyber Work for PNT

Highlight Needs, Gaps, and Path Forward

Focus on Their View of ”Top 3” Remaining Challenges

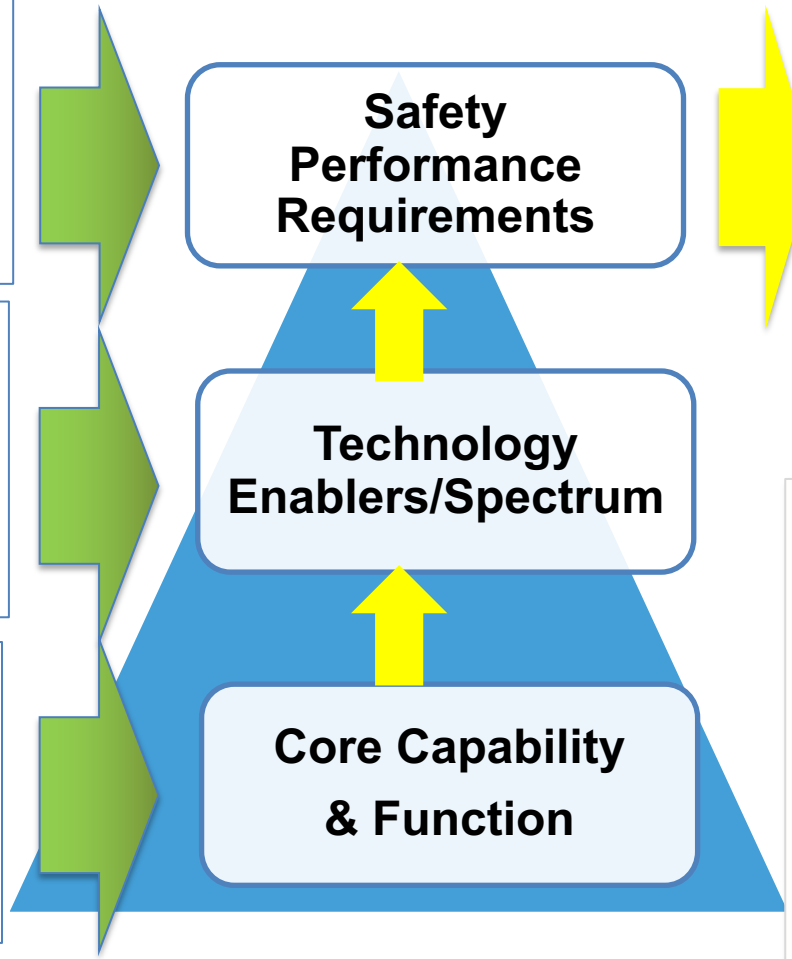
Break 0915 – 0930 PDT

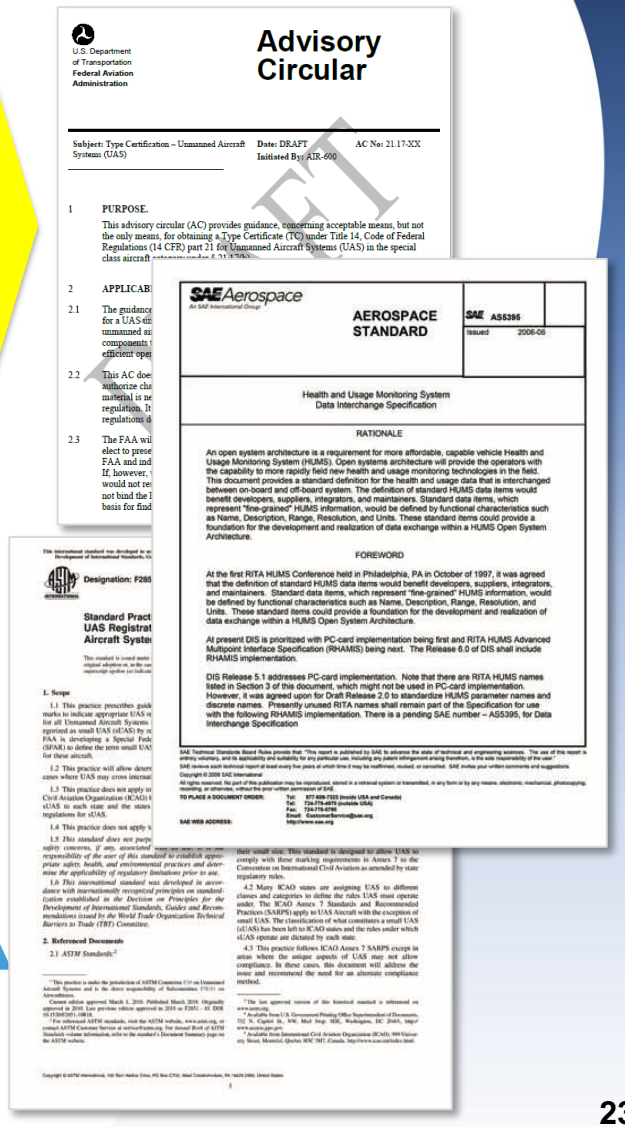
Complementary PNT Maturation

- Performance Based Requirements for Technology, Function, and Capability

- Core Technology and Data Needs to Enable Functions and Capabilities
- Functional Performance
- Role of the Human

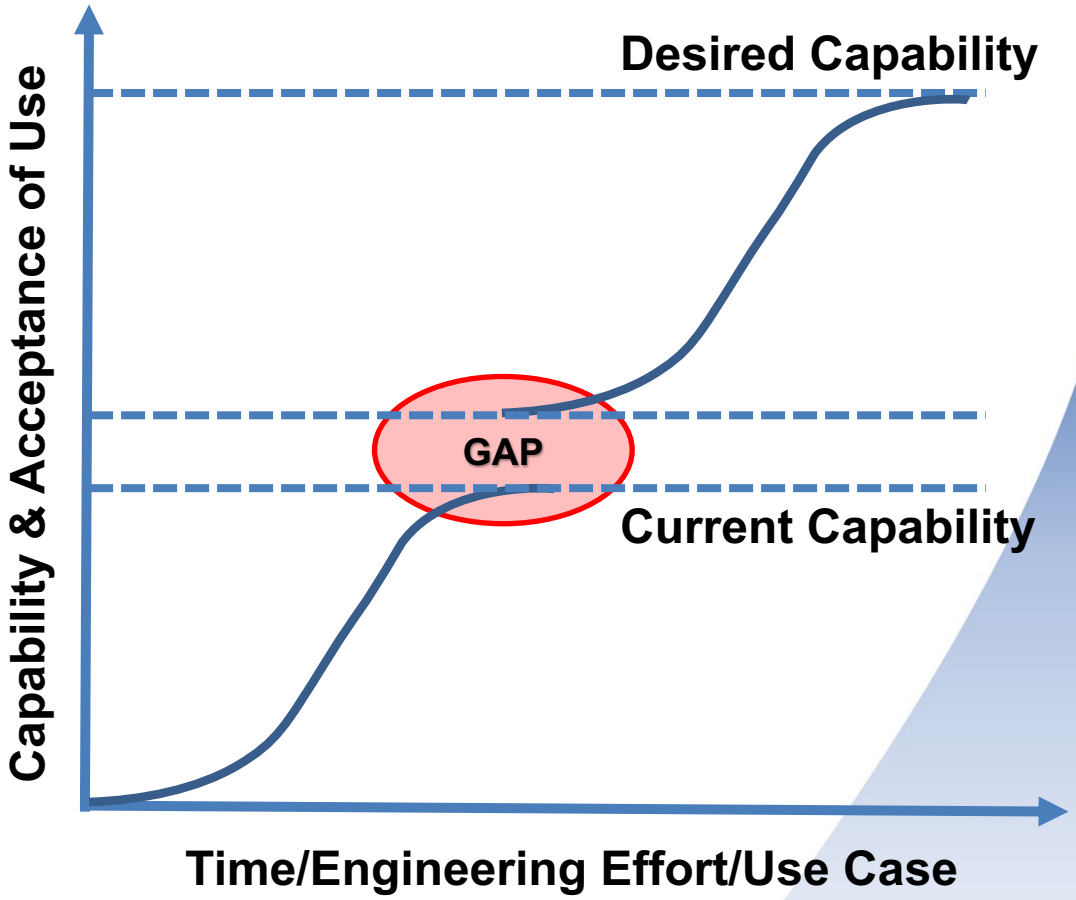
- Sample Use Cases
- Core Capability & Functional Identification/Development
- Data Collection/Demo Flights





S-Curve Epochs – Maturity & Discontinuity

- Desired PNT Capabilities May Enable Growth Towards Ultimate Goal/Use Case
- Gaps in Technology, Regulation, and/or Operational Capability Can Be Addressed by R&D
- 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



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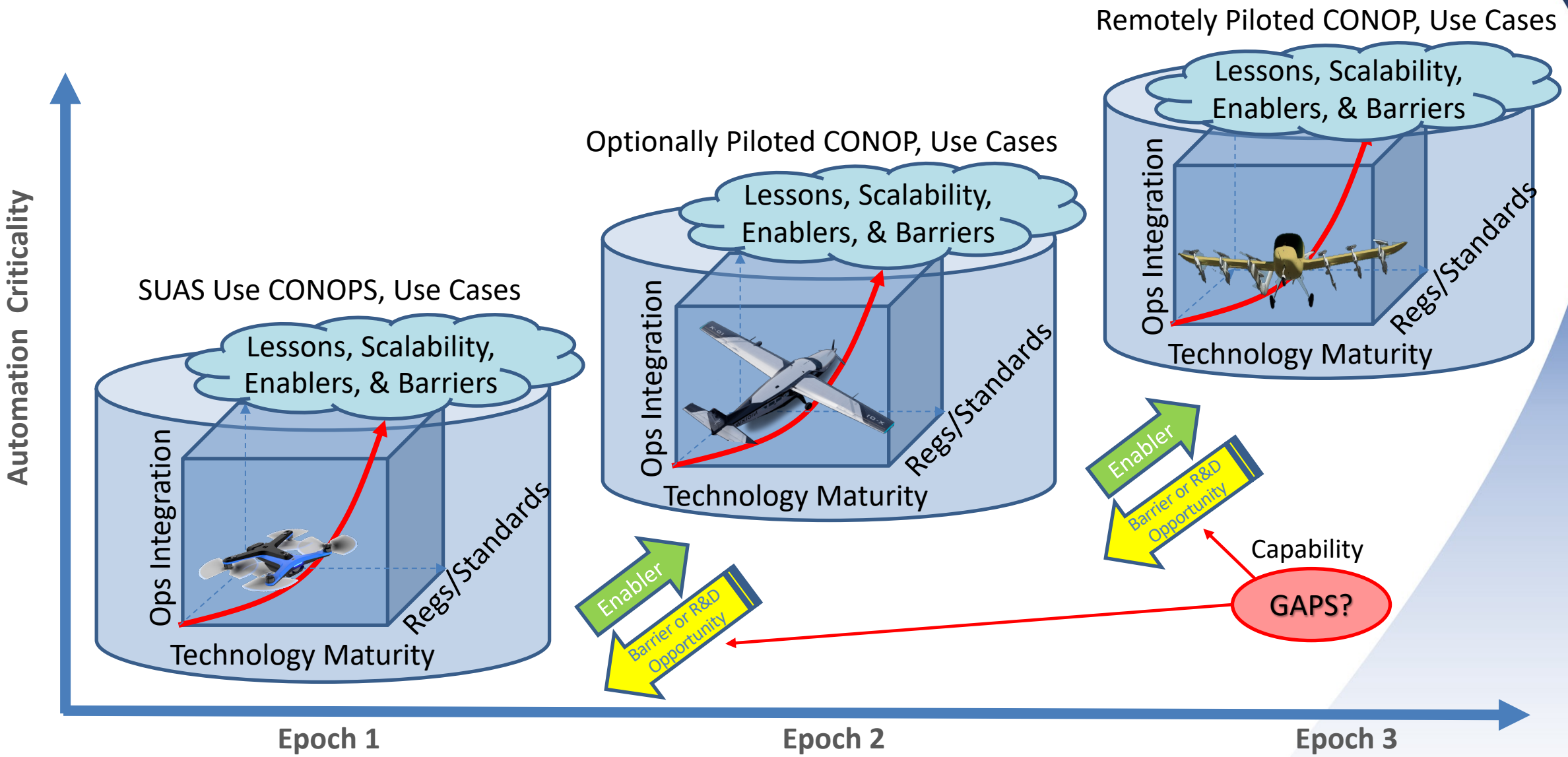
Potential Reference Mission Capability Maturity Path (Epochs)

Consider PNT Technical and Regulatory Maturity + Aircraft/Ops



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Industry Panel Discussion

Ryan Braun
COO
uAvionix

Ganesh Pattabiraman
Co-founder, CEO
NextNav

Jeremy Bennington
VP of PNT Assurance
Spirent Communications

Mike O'Connor
CEO
Satelles

Sanjiv Singh
CEO
Near Earth Autonomy

Jim Barrett
Sr. Consulting Systems Engineer
BNSF

Moderated by Sean Memmen, FAA

Poll #1

From the Discussion:

What New Key Capabilities/Functions Will Complementary PNT Enable?

☐	Auto-land, Auto-takeoff
☐	Relative Positioning Between Aircraft
☐	Location of Fleet for M:N Operations
☐	Location of Suitable Landing Site/Obstacle
☐	Others

Sample Use Case #1 Intro

UAS Rotorcraft Logistics
Industrial Parts Delivery
Mission Objectives and Overview

Mission Briefing

- Fleets of multi-rotor UAS are used for “last mile” delivery of time-critical cargo (e.g., parts, tools, supplies) from urban distribution centers to factories, maintenance centers or construction sites
- All flights are autonomous, typically 500’ – 1000’ AGL and below, operating in Class B, C, D, E, and G airspace
- Deliveries are made to designated landing spot at an industrial customer’s location – rooftop, parking lot, or other purposed landing area
- Delivery aircraft return to distribution centers for servicing, recharging, inspection, and prep next mission
  - What PNT Technologies are Needed to Enable Capabilities/Services to:
    - *Safely and Efficiently* Navigate an intended route
    - Avoid Geofenced Airspace, Fixed and Mobile Obstacles, and Other Aircraft With Degraded GPS
  - What Requirements/Performance metrics are Needed?

AGL Above Ground Level

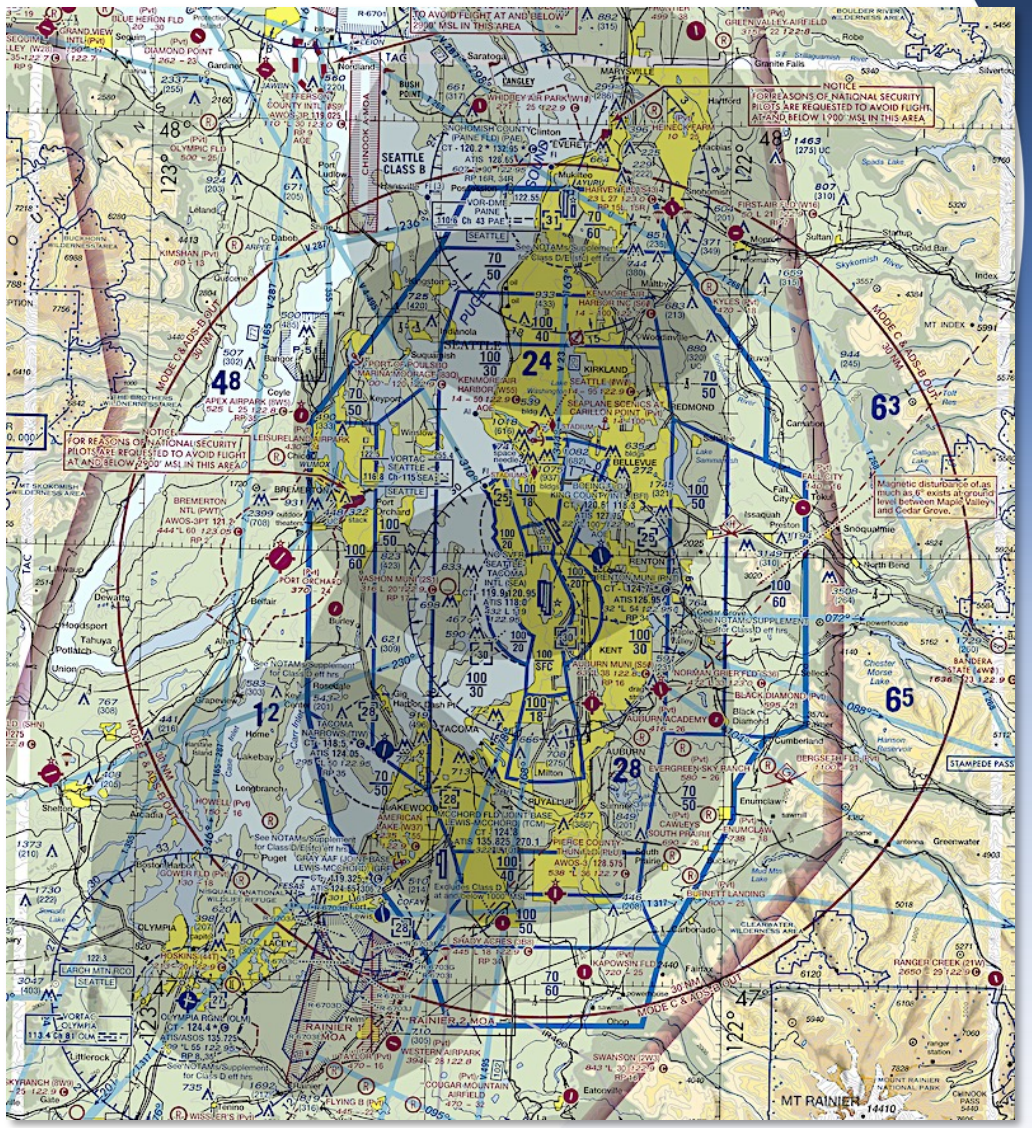
Notional Aircraft For Use Case #1

- Multirotor VTOL-capable aircraft
  - GW less than 500Kg, payload 50 – 100 Kg
  - Type certified for Part 135 operations
- Remote operator of each fleet authorizes and initiates multiple, simultaneous missions
  - Each aircraft accomplishes mission and performs all safety functions automatically
- Nominal range
  - 30 NM round trip in 20 kt wind with payload delivery and return on single charge
- Runway-independent - Could require special launch or recovery equipment (On Board Sensing or Potential PNT Portable Technology?)

GW Gross weight
VTOL Vertical Take-Off and Landing

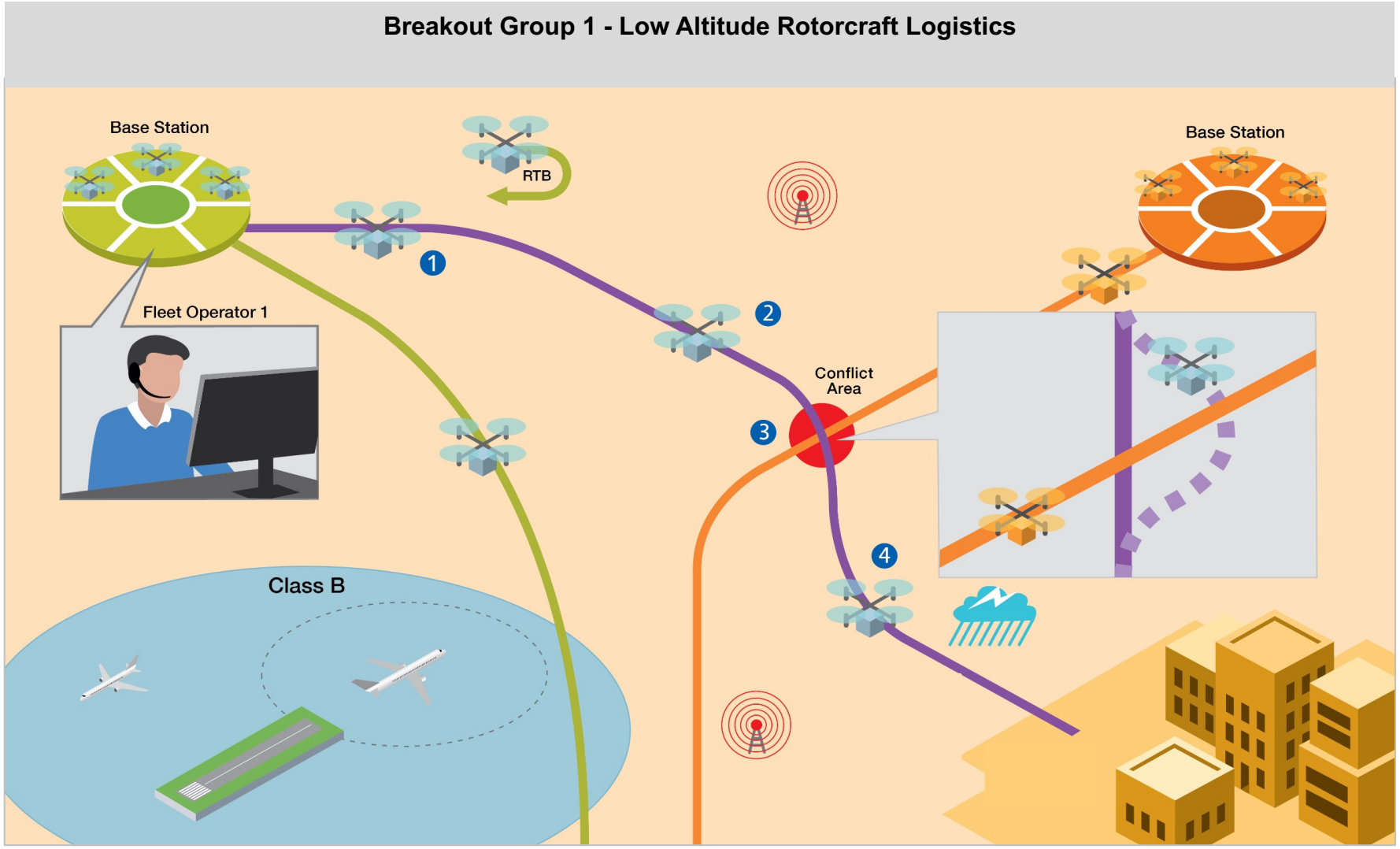
Delivery Coverage Area

- Four delivery centers cover entire Seattle metro area
  - 10 to 50 delivery aircraft at each center
- Other delivery companies have similar coverage
- From Everett to Olympia, with redundant coverage in areas of highest population density
- Each coverage circle requires 30-mile out and back range



https://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/vfr/

Breakout Group 1: PNT Needs/Barriers



Sample Use Case #2 Intro

Low Altitude Fixed Wing Logistics Inspection, Monitoring, Delivery Mission Objectives and Overview

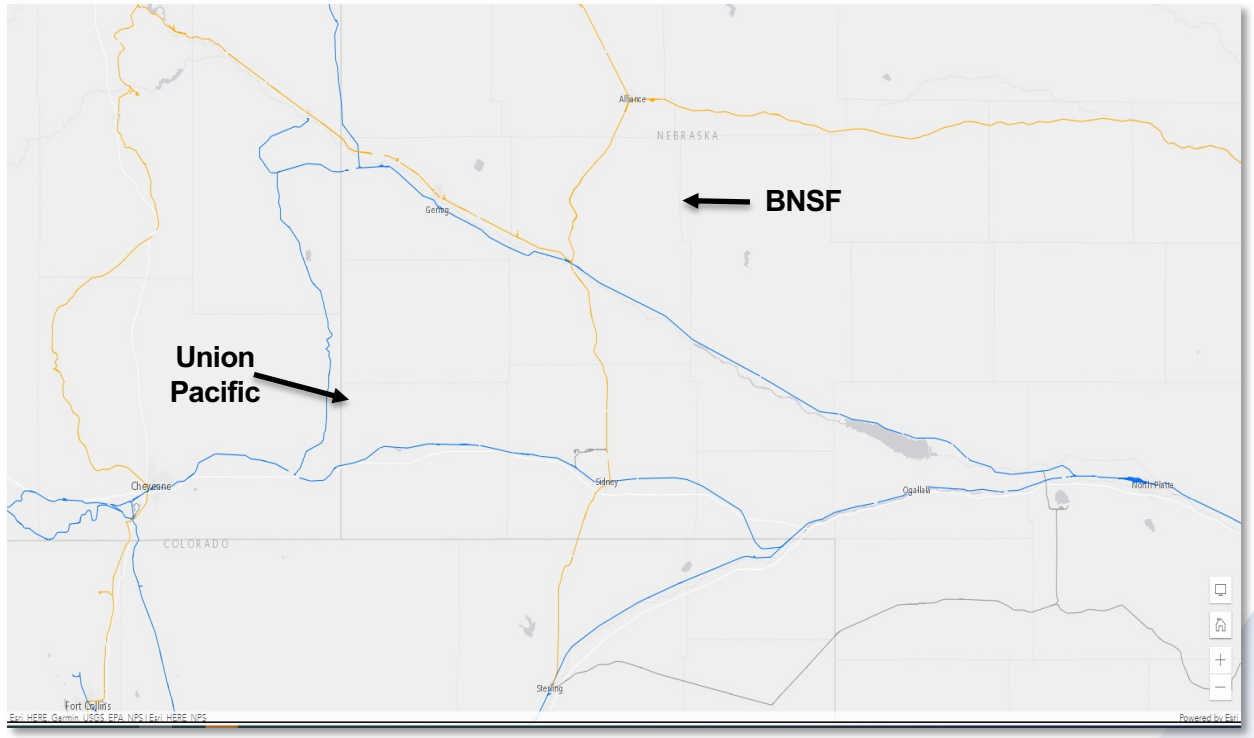
Mission Briefing

- Fleets of fixed wing UAS (up to Light Sport Sized conventional aircraft), converted to remotely piloted configuration, are used to carry cargo between rural airports and hub airports
- All flights are remotely operated and largely autonomous, on segments typically less than 100 miles at altitudes below 1,000 feet
- Must integrate with other aircraft

Mission Overview

- **<100 Mile Logistics (e.g., linear infrastructure (i.e., railroad right-of-way) using a remotely operated unmanned aircraft flying >400' AGL**
  - Wildfire Inspection
  - Delivery of Retardant

Photo: A. Lacher

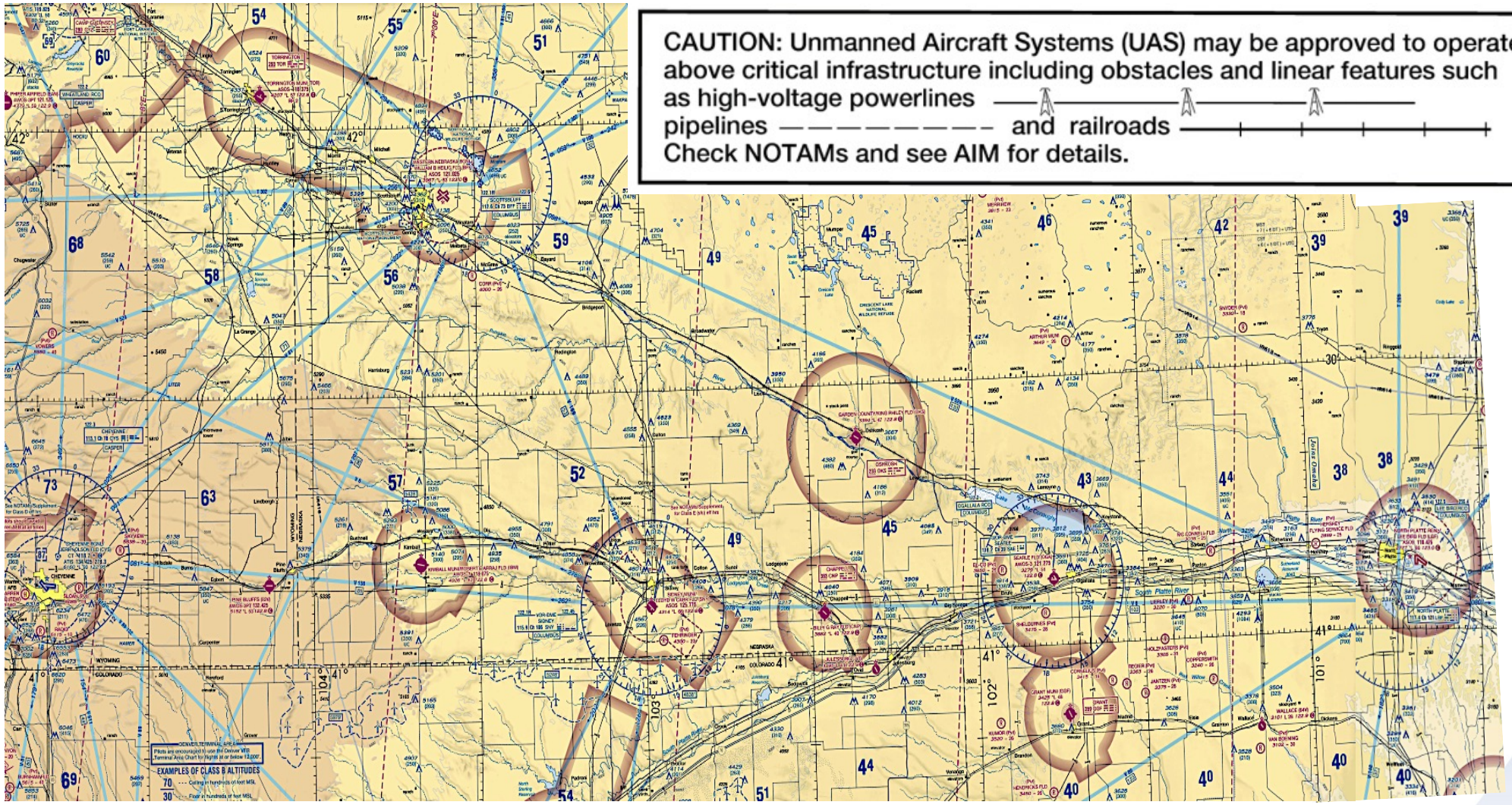


Web Map by Joshua Wayland (US DOT Surface Transportation Board) using US Government data

Example Mission Overview

- **Aircraft to fly directly over railroad right-of-way**
  - **Gather data regarding condition of the bed and any misalignment of ties/rails that could lead to unsafe conditions**
- **Perform a high-resolution "visual" inspection**
  - **Routine – Periodic inspections to ensure no deterioration**
    - **Allows for advanced flight planning**
  - **On Demand – Inspections after an event: flooding, landslide, heavy rains, windstorms, temperature extremes**
    - **Ad hoc operations**
- **Electro Optics and other sensors collect data that is georeferenced and automatically analyzed for issues**

Environment Overview



[FAA VFR Raster Charts]

Environment Overview Continued

- **Mostly Class G airspace**
- **Airports with Class D, E, and G airspace**
- **Manmade obstructions (antennas, powerlines, wind farms in the area)**
- **Rural areas with agricultural (ranching and farming)**
  - Expect agricultural aircraft operations nearby
- **Visual Meteorological Conditions**
  - Enables “visual” inspection
  - Deteriorating toward IMC over parts of route above 2000’ AGL


Photo: A. Lacher


Photo: A. Lacher


Photo: A. Lacher

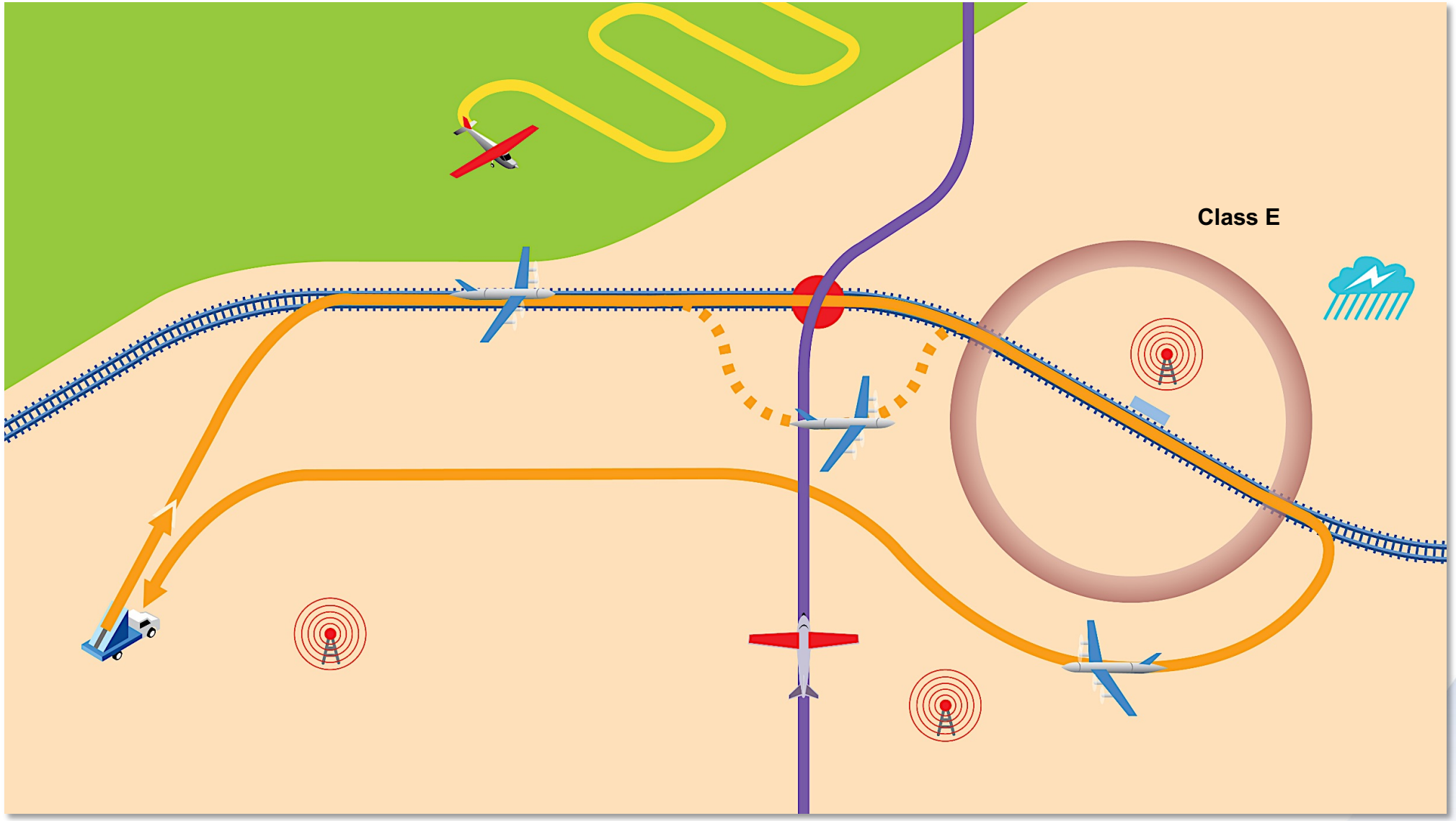
Aircraft Overview

- **Remotely piloted**
  - Remote PIC: Situation awareness & operational control
    - Remote PIC can affect the path of flight
    - Robust Command and Control (C2) communications
  - Onboard automation has “direct” flight control
    - Actuation, rotational, and translational control
- **Fixed Wing**
  - Linear inspection often involves long flight duration
- **Airworthiness**
  - Through the emerging FAA Dependability and Reliability (D&R) process
- **Runway independent**
  - Does not require launch and recovery equipment
  - Capable of both VTOL precautionary landings and wing-borne emergency landings

Example For Illustration Purposes Only: L3Harris FVR–90 VTOL

Endurance	8-16 hrs
Dash Speed	65 kts
Cruise Speed	50 kts
Max Wind Speed	30 kts
MTOW	120 lb

Breakout Group 2: PNT Needs/Barriers



LUNCH 11:15 – 12:00 PDT

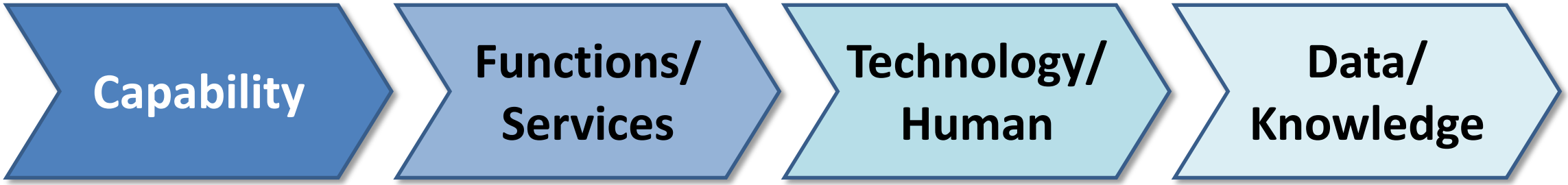
Workshop Overview: Plan Mural Board Breakouts

Day 1: Identify Capabilities and Functions
Assess Barriers and Opportunities for PNT Maturation

Day 2: Identify Candidate Technologies per Function
Identify Data Sources and Requirements for Technology

Mural Board For Each Mission
MS Teams Room for Each Mission
Day 2 Session Builds on the Day 1

Notional Automation Capability Maturity Model



Capability	Functions/ Services	Technology/ Human	Data/ Knowledge
New ability, expertise, or proficiency	Task, role, and/or system effects which enable a *Capability*	Equipment including HW/SW which provide *Functions/ Services* Human contributions to provide *functions/ services*	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

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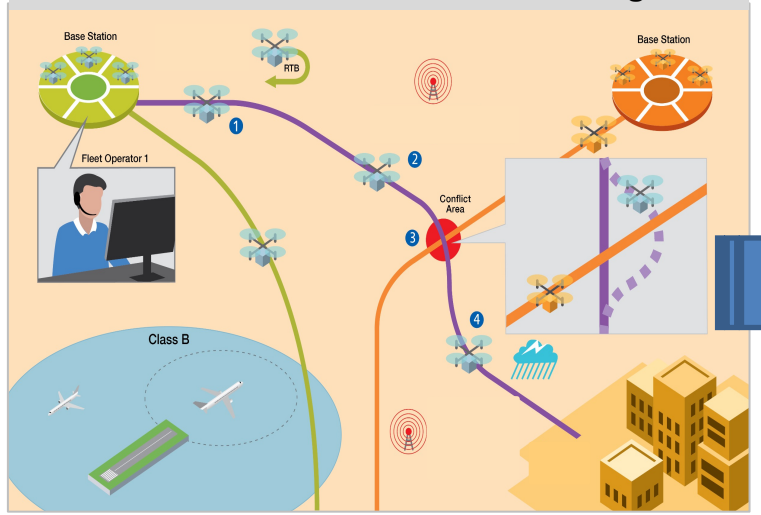
Board Layout - Breakout Group 1 – Day 1 and 2

Breakout 1 - Low Altitude Rotorcraft Logistics



PNT Opportunities, Capabilities, Technology, Data, Metrics for Low Altitude Rotorcraft Logistics Mission

Need For Specific Mission Element/Segment

Pre-Flight Planning	Takeoff & Landing	Enroute Flt Path Mgmt.	Conflict Avoidance	Mission Objective Delivery	Return Home	Contingency
BIT	RNAV	ADS-B				

Need for All Mission Elements

Accuracy | Integrity | Govt Private Partnership | Tech Maturity | UTM

Day 1

Day 1 & 2

Day 2

Opportunities

Barriers

Day 1

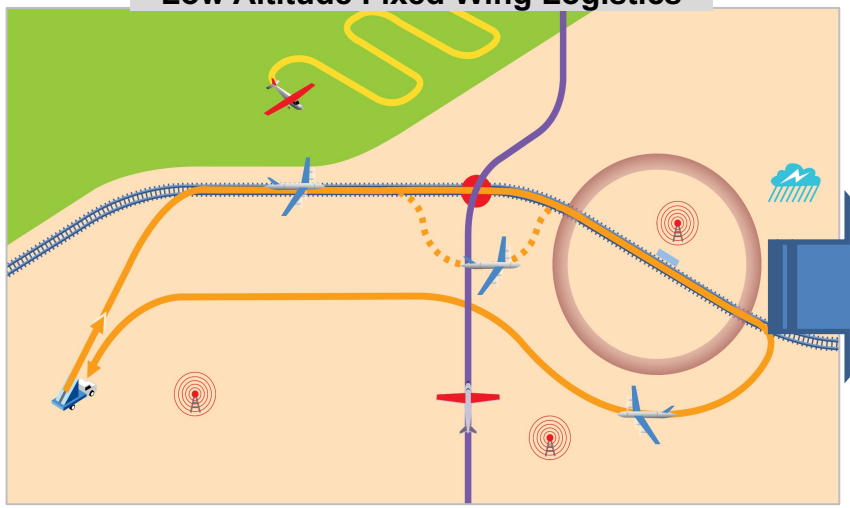
Capability/Function

Enabling Technology/Data Source

Metric/Performance Measure

Board Layout - Breakout Group 2 – Day 1 and 2

Low Altitude Fixed Wing Logistics



PNT Opportunities, Capabilities, Technology, Data, Metrics for Low Altitude Fixed Wing Logistics

Need For Specific Mission Element/Segment

Pre-Flight Planning	Takeoff & Landing	Enroute Flt Path Mgmt.	Conflict Avoidance	Mission Objective Delivery	Return Home	Contingency
BIT	RNAV	ADS-B				

Need for All Mission Elements

Accuracy | Integrity | Govt Private Partnership | Tech Maturity | UTM

Opportunities

Barriers

Day 1

Day 1

Day 1 & 2

Day 2

Capability/Function

Enabling Technology/Data Source

Metric/Performance Measure

Go To Breakouts

Regroup - Discussion from Breakouts – DAY 1

- Perform Second Poll
- Review MURAL Board Results in Real-Time With Participants Together
- Summarize Barriers/Opportunities for PNT
- Identify Major Findings from Mural Sessions
- Actions for Day 2
- Recap/Report out of what each breakout learned (Top 5)
- Identify actionable steps and areas for future work

Poll #2

From the Breakouts:

Please Make Suggestions for Improvement, What Was Missing, Confusing, or Could be Improved

☐	Layout of Boards
☐	Sample Use Cases
☐	Mural Facilitation/Content
☐	Board Layout, Process
☐	Add Your Own Suggestion

Adjourn Day 1 – 1400 PDT

Day 2

- Welcome and Thank you
- Summary of Day 1
- Plans for Day 2

Agenda – Day 2 – May 25 – Pacific Time

8:00-9:00	Recap of Day 1	Wes Ryan, NARI Program Manager Lannie Herlihy, FAA	Summary of the prior day and review of agenda for 5/25
9:00 – 10:00	Mural Collaboration Session #2	Breakout 1a – Use Case 1 – Technology & Metrics Breakout 2a – Use Case 2 – Technology & Metrics	Explore Barriers and Opportunities for PNT Needs for Mission Elements
10:00- 10:30	Break		
10:30- 11:30	Regroup - Discussion from Breakouts	Recap/Report out of what each breakout learned (Top 5)	Identify actionable steps and areas for future workshops
11:30- 12:15	Lunch		
12:15-12:45	Summary of Findings	Capture of “top ten” areas that could inform future work in SDOs, future collaboration, etc.	Partnerships with Industry, NASA & FAA to Mature PNT Technology
12:45-1:30	Next Steps & responsibilities	Team – Wes & Lannie – What do we need next?	What did we learn and what comes next? Who is doing it? What partnerships can we generate?
1:30-1:45	Break		
1:45-2:15	Workshop Critique	Wes Ryan, NARI, Mich Narins	For Future Detailed Dives into PNT Capabilities, What could have been done differently
2:15-2:30	Closing Remarks	Dr. Parimal Kopardekar, NARI Director	

Workshop Overview: Plan Mural Board Breakouts

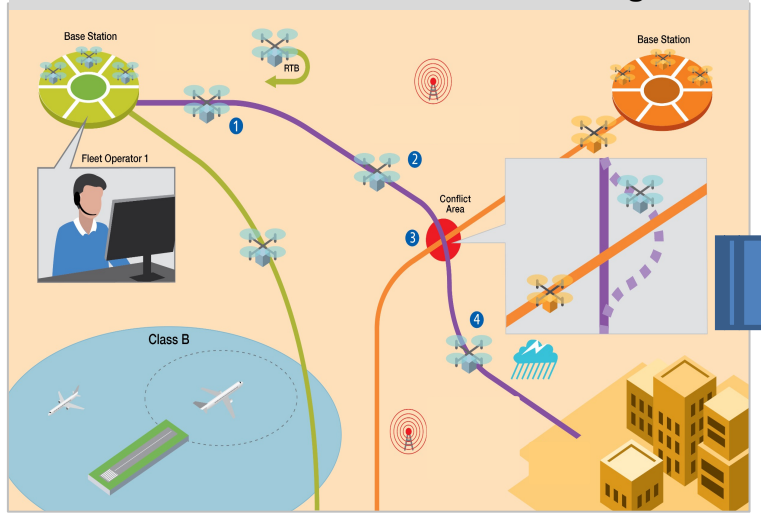
Day 1: Identify Capabilities and Functions
Assess Barriers and Opportunities for PNT Maturation

Day 2: Identify Candidate Technologies per Function
Identify Data Sources and Requirements for Technology

Mural Board For Each Mission
Day 2 Session Building on the Day 1

Board Layout - Breakout Group 1 – Day 1 and 2

Breakout 1 - Low Altitude Rotorcraft Logistics



PNT Opportunities, Capabilities, Technology, Data, Metrics for Low Altitude Rotorcraft Logistics Mission

Need For Specific Mission Element/Segment

Pre-Flight Planning	Takeoff & Landing	Enroute Flt Path Mgmt.	Conflict Avoidance	Mission Objective Delivery	Return Home	Contingency
Built In Test	Radio Nav	ADS -B				

Need for All Mission Elements

Accuracy | Integrity | Govt Private Partnership | Tech Maturity

Opportunities

Barriers

Day 1

Day 1

Day 1 & 2

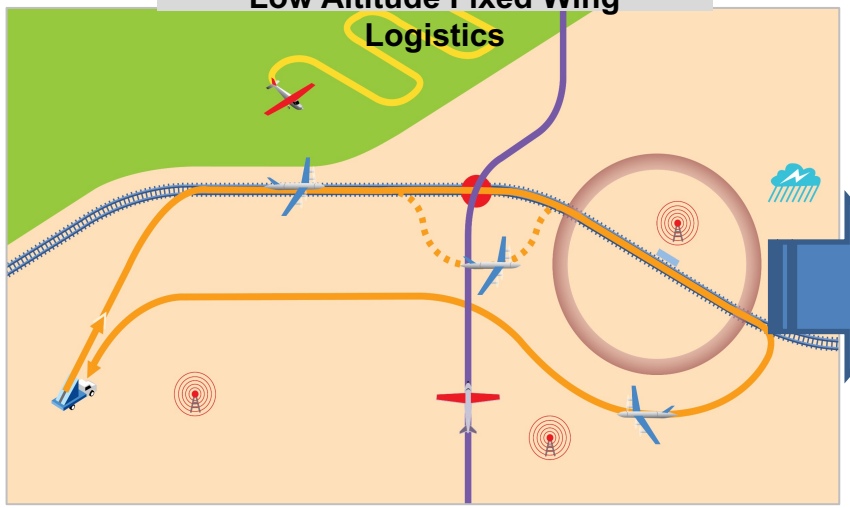
Day 2

Capability/Function

Enabling Technology/Data Source

Metric/Performance Measure

Board Layout - Breakout Group 2 – Day 1 and 2



PNT Opportunities, Capabilities, Technology, Data, Metrics for Low Altitude Fixed-Wing Logistics Mission

Need For Specific Mission Element/Segment

Pre-Flight Planning	Takeoff & Landing	Enroute Flt Path Mgmt.	Conflict Avoidance	Mission Objective Delivery	Return Home	Contingency
Built In Test	Radio Nav	ADS -B				

Day 1

Need for All Mission Elements

Accuracy | Integrity | Govt Private Partnership | Tech Maturity

Day 1 & 2

Day 2

Opportunities

Barriers

Day 1 Activity

Capability/Function

Enabling Technology/Data Source

Metric/Performance Measure

Go To Breakouts

Break 0945 – 1000 am PDT

Regroup - Discussion from Breakouts – DAY 2

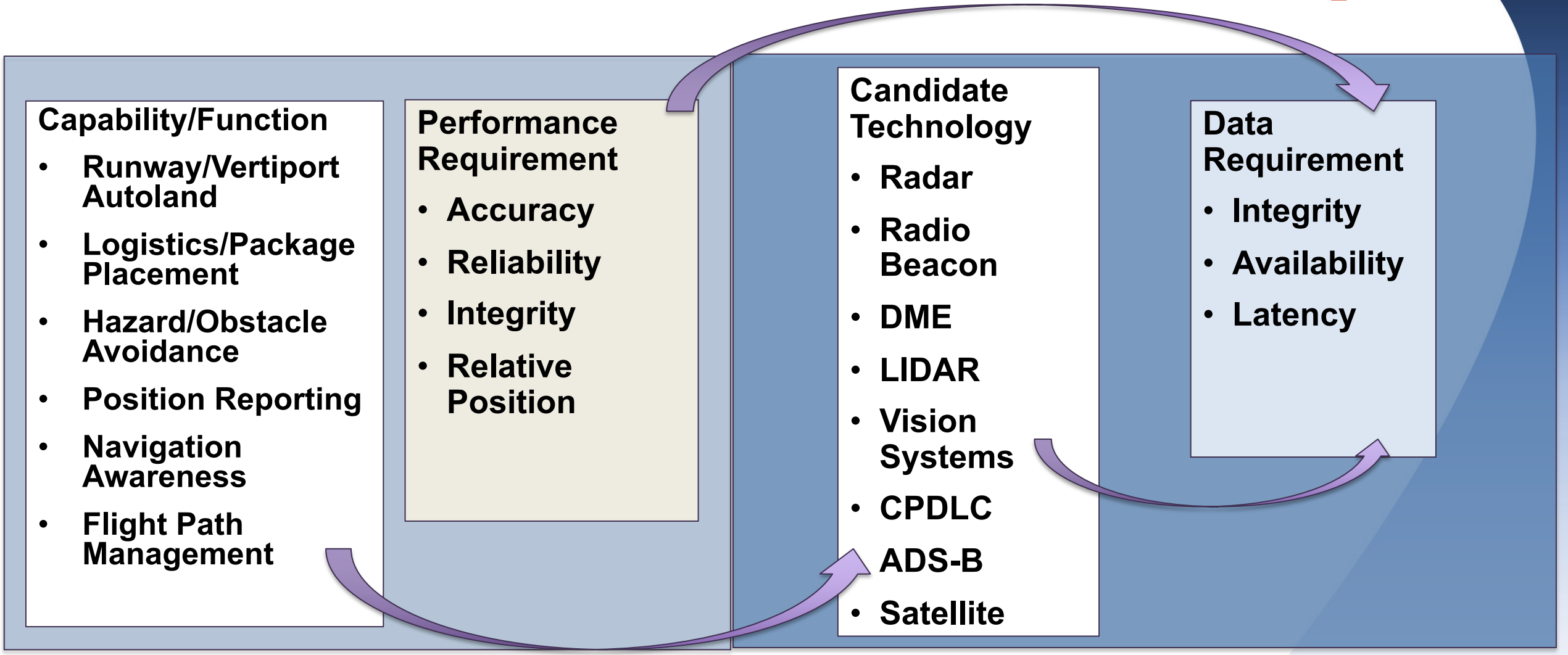
- Barriers/Opportunities for PNT for Use Case 2
- Summarize Findings from Mural Sessions
- Actions for Future Meetings
- Recap/Report out of what each breakout learned (Top 5)
- Identify actionable steps and areas for future work

Backup Slides

PNT Needs for Capabilities

- **Cooperative receiver on-board aircraft**
  - Can detect cooperative aircraft (e.g., ADS-B IN)
- **Non-cooperative sensors (e.g., Electro-optic) on-board for detecting potential collision threats**
  - E.g., Within 1000' feet laterally with 180^{o} lateral and -10/+50^{o} vertical field of view
  - Algorithms are capable of tracking multiple potential intruders simultaneously
- **Aircraft is equipped with automatic position reporting capability**
  - E.g., Low-power, 0.01W, ADS-B OUT (or something similar) capable of omni-directional transmission of ~2 NM
- **Aircraft and Ground Control Station capable of receiving traffic situation data from the ground**
  - Cooperative IFR and VFR traffic in the vicinity (e.g., TIS-B) and other UAS telemetry information
- **On-board automated conflict resolution algorithms**
  - Resolves conflicts by altering planned path to ensure well-clear or separation from other traffic, as appropriate
- **On-board automated collision avoidance capabilities**
  - Detect and resolve potential collision threats through avoidance maneuvers consistent with right of way rules
- **Contingency management**
  - In the event of the loss of critical systems (e.g., GNSS, extended C2 loss), on-board systems will be able to execute a safe precautionary landing on the right-of-way but not on the rail-bed

Mural Board
Sample Sticky Notes



Identify PNT Barriers & Opportunities for Each

Certification Process – How NASA Data Collection Fits

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*
- Certification Basis Established*
- 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

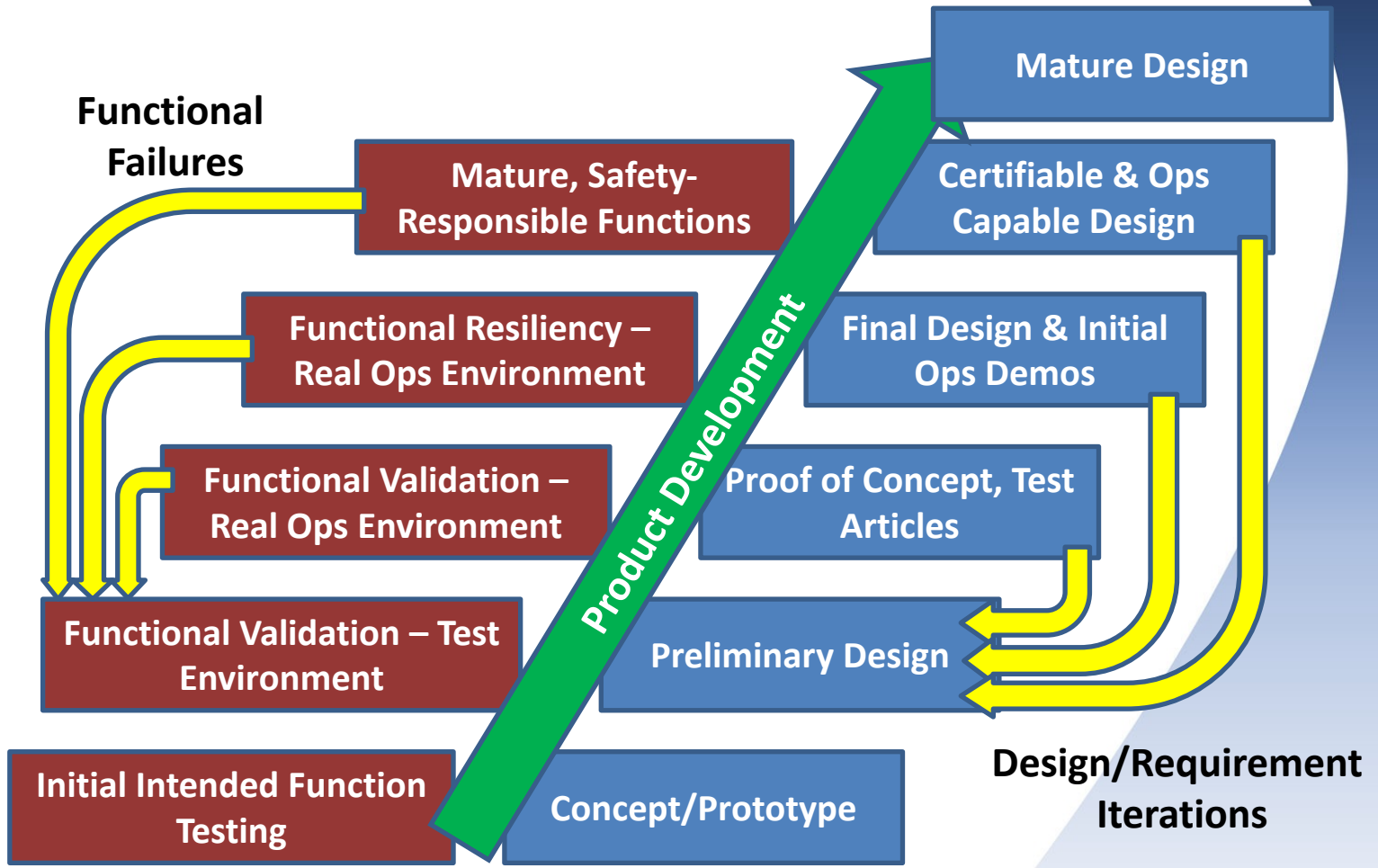
- Type Inspection Report
- Data Retention
- Required Documents at Delivery
- TC Holder Info
- Continued Airworthiness
- ICA Changes
- Post Certification Evaluation

Red Items = Examples of Where NASA Data May Prove Useful

*** Denotes items that are specific to PNT Certification**

Capability/Design Maturity Path

- **Methodical Progression from Prototype, to Initial Function with Human Monitoring/Backup, to Safety Responsible Function**
- **Define Technology, Requirements, & Data Sources to Enable Certifiable Design**



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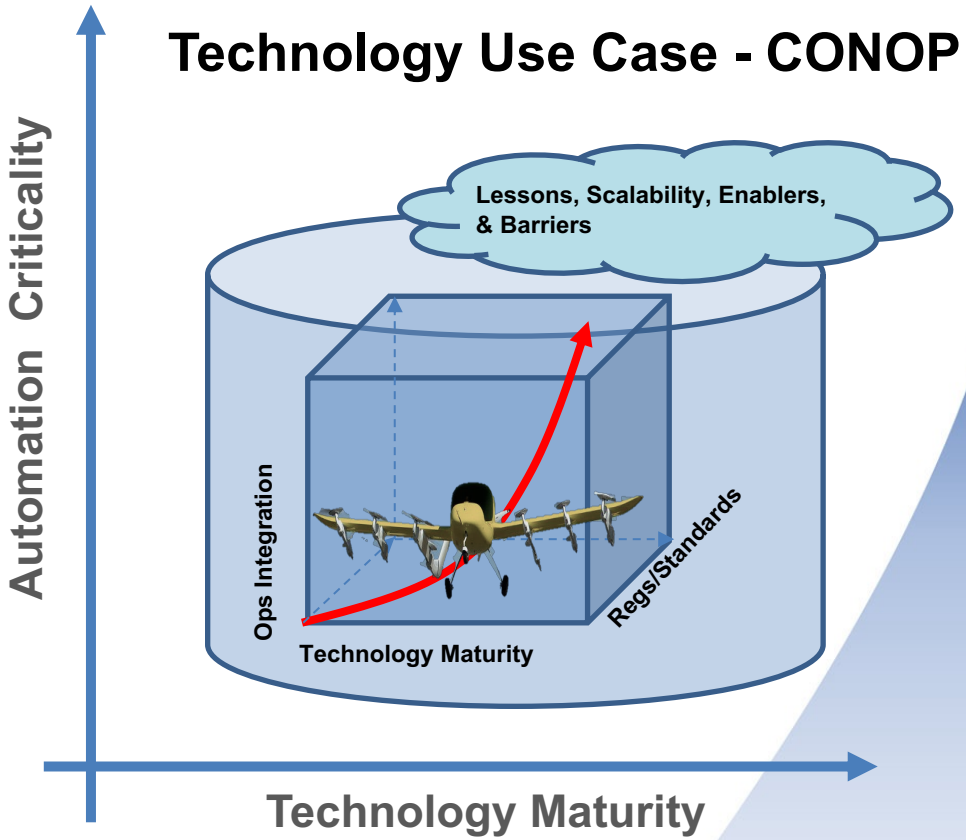
Capability Maturity Model – CONOP Focus

- 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



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Requirements - Sample

- PNT “on vehicle” or “distributed” must not be susceptible to single point failures of GPS or other GNSS
- Loss of PNT (jamming or spoofing) data must not cause immediate loss of flight or unsafe operations
- Degraded mission capability and residual operational risk from degradation must be mitigated (redundancy, procedures, etc.)
- PNT systems must be able to identify loss of integrity in function and in data regardless of the source.
- The vehicle must be able to communicate 4D intent, and if PNT confidence is degraded to communicate and not adversely impact flow management and separation functionality

PNT Ties to Other NASA Projects

Wildfire – Localized Services

TACP/T3 – Core Technology Testing

AOSP Airspace Modernization

UAS Test Range at Ames

National Campaign Tech Maturation Tests

Digital Flight

Sky for All

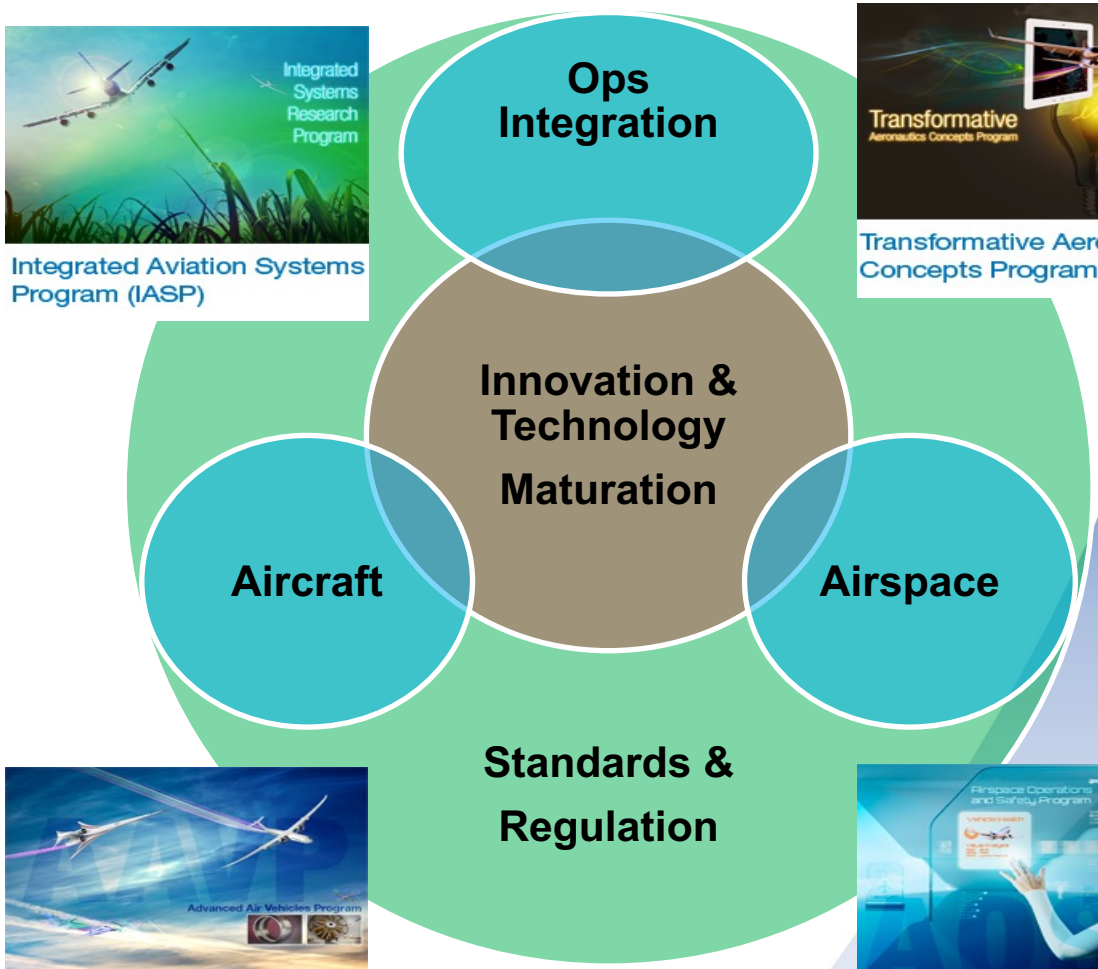
AAM & AEWG Automation Integration

M:N – One to Many UAS/AAM Ops

Others?

PNT Vision Must Include Whole Ecosystem

- Considerations for new PNT must Include evaluation of the Aircraft, Operational Procedures, and Airspace Management
- Moving Towards Automation/Autonomy
  - New Capabilities Require Evaluation of Technical Readiness, Regulatory Readiness, and Changing Role of the Human
  - Automation Integration and Maturation Strategy: Demonstrate New Capabilities in 1:1 Before M:N Ops Acceptance
  - Changing Roles Must be Based on Demonstrated Resilient, Proficient Technology Supported by Data
  - Changing Human Centric Airspace Management Must Be in R&D Planning and Evolution



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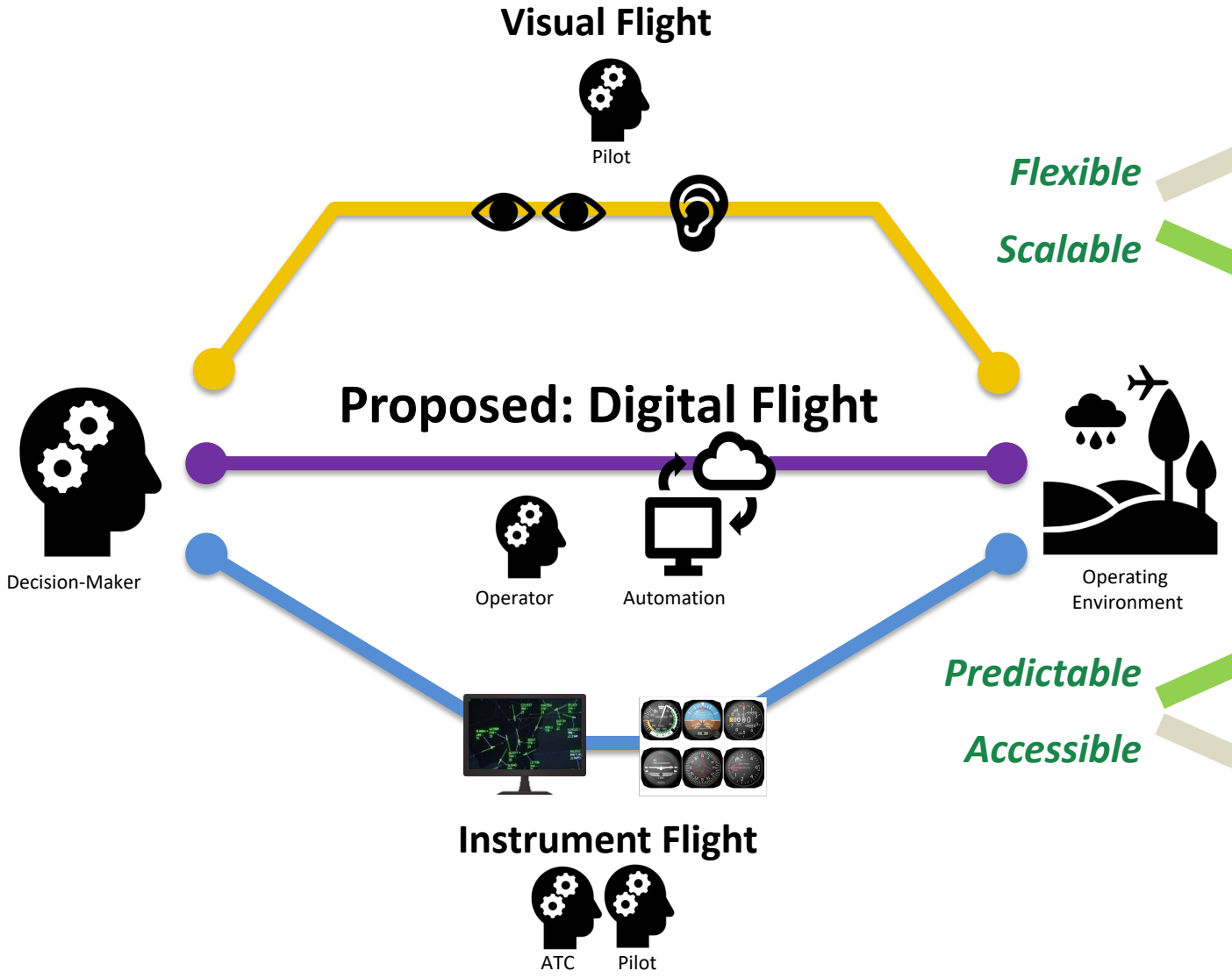
PNT Possible Enabler For New Modes of Operation



Flexible

Scalable

Pilot is the separator

- Self-managed by cooperative procedures and rules
- Distributed decision-making without centralized coordinator

Predictable

Accessible

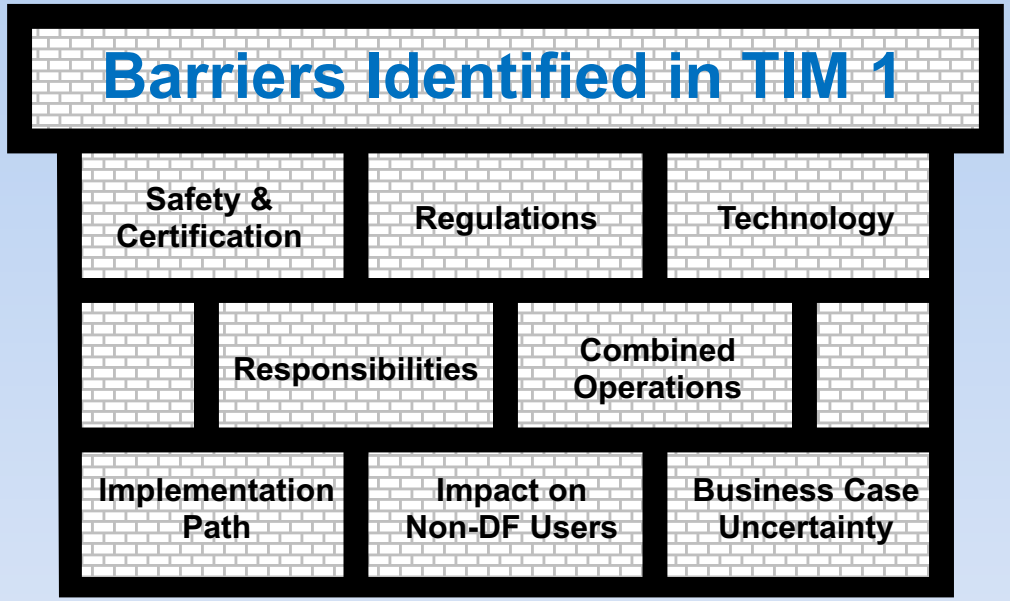
Operator is the separator
(relying upon automation services)

- Self-managed by cooperative operating practices
- Traffic awareness, including intent
- Connectivity to centralized information services for shared situation awareness
- Highly-automated separation through flight path management automation

ATC is the separator
(providing instructions to the pilot)

- Sharing of intent (i.e., flight plan)
- Centralized strategic and tactical conflict management

Digital Flight TIM 1&2: Outcome Summary



Safety and Certification
Difficulty of certifying safety-critical automation systems

Regulations
Lead time and complexity to implement rulemaking

Technology
Feasibility of enabling technologies and data links

Responsibilities
Uncertainty about operator and controller responsibilities

Combined Operations
Challenge of integrating with IFR and VFR

Implementation Path
Viable early operational capabilities

Impact on Non-DF Users
Both operations and cost

Business Case Uncertainty
Minimum viable products and return on investment

Chisels / Paths Forward

Concept Communication
Develop Concept of Use to describe capabilities and use-cases for DF and reduce uncertainties identified in TIM 2 deep dives

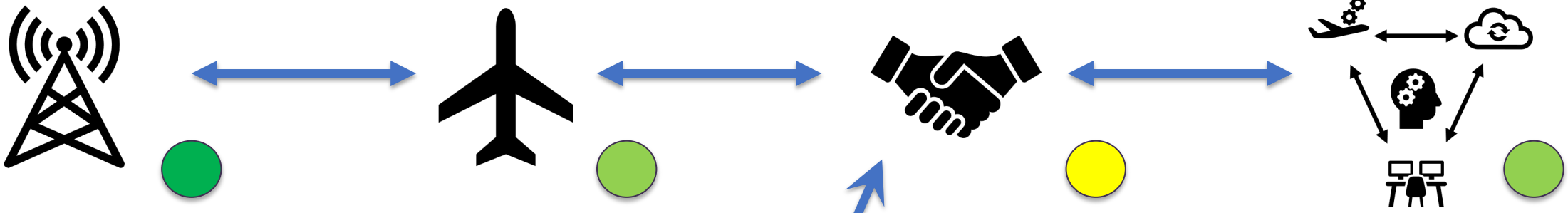
Stakeholder Engagement
Engage with key stakeholders to communicate concept and potential DF policy, especially FAA

Modelling and Simulation
Conduct detailed M&S to quantify improvements in safety, security, and efficiency resulting from DF

Technology Demonstration
Define and conduct real-world demonstrations of DF capabilities including vehicle-to-vehicle datalinks

DF Critical Elements / Building Blocks

ARMD Subproject Activity Alignment*



Communications and Services for Shared Situation Awareness

- CAS-DRF
- CAS-STEReO
- ATM-X UAM
- ATM-X DIP
- ATM-X PAAV
- Sky for All
- TTT
- SWS
- AAM Cyber
- AAM NC

Traffic Awareness

- CAS-STEReO
- ATM-X UAM
- ATM-X DIP
- Sky for All
- AAM HDV

Cooperative Operating Practices for Conflict Management

- ATM-X UAM
- Sky for All
- AAM NC
- AAM HDV

Flight Path Management Automation

- ATM-X PAAV
- ATM-X UAM
- ATM-X xTM
- Sky for All
- CAS-STEReO
- SWS
- AAM AFCM
- AAM HDV

Largest Research GAPs

- **Informing policy decisions** associated with changing flight rules, practices, and procedures
- **Identifying an integrated concept** which ties these pieces together across use cases

Under-addressed areas include:

- Drafting alternative rule and procedural changes
- Modeling of operations under uncertainty and stressing conditions
- Sensitivity analyses of various rule change specifics
- Benefit analysis and identification of key performance indicators
- Evaluation of operational impact on stakeholders
- Driving community consensus toward critical mass

Very good coverage

Good coverage

Potential gaps

ARMD Projects

- CAS
- ATM-X
- TTT
- SWS
- AAM

* Best guess and may not represent a comprehensive view of all subproject activities

Digital Flight Elevates All User Communities

Helping All User Communities *Exceed* Their Visions

Regional Air Mobility
"Community-friendly regional travel"

DF could increase scale of access to non-towered airports

Larger UAS
"Seamless integration in the NAS"

DF could reduce lost link contingency impacts and maximize NAS access

Small UAS
"Beyond visual line of sight"

DF could enable access above 400 ft and beyond visual line-of-sight

Harmonization

Urban Air Mobility
"Dense / complex urban operations"

DF could enable expansion beyond capacity-limited corridors

General Aviation
"Simplified Vehicle Operations"

DF could reduce pilot training costs while increasing safety and access

Convergence

Airline / Business Aviation
"Reduced operating costs"

DF could increase flexibility to optimize under dynamic conditions

High Altitude Operators
"Cooperative separation"

DF could optimize flexible operations in Upper Class E airspace

Common Mode

All Operators
"Advanced Air Mobility"

Digital Flight (DF) is an opportunity for convergence and operational harmonization by creating a common new operational mode across all airspace users