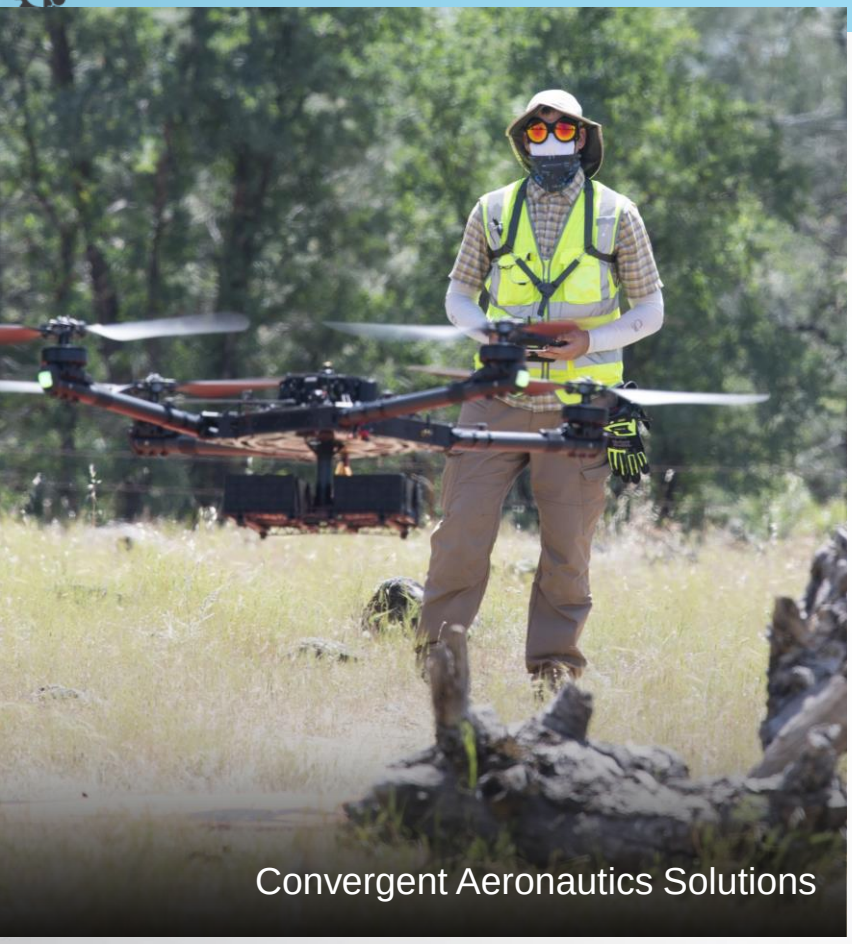
CONVERGENT AERONAUTICS SOLUTIONS PROJECT

Four Transformations for Sustainability, Greater Mobility, and Economic Growth

NASA Aeronautics agile innovation ecosystem



Transformational Tools and Technologies

NASA Leadership for the Aviation Community –
Exploration, Invention, and Innovation

Thinking differently to revolutionize aviation

Explores the unknown – Converges disciplines & industries – Advances disruptive concepts

Societal Needs

Policy Topics

Emerging Trends

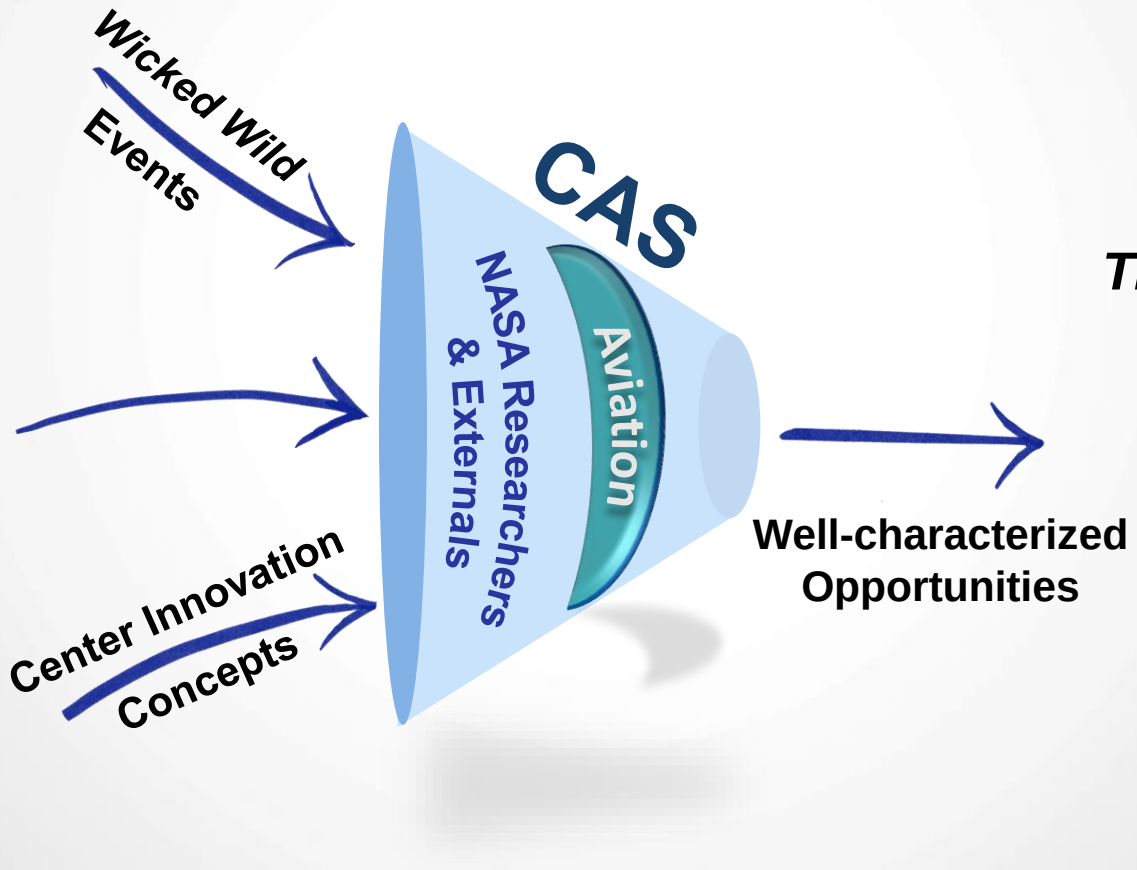
NASA Expertise

New Capabilities

Threats & Weaknesses

Market Movements

Scientific Discoveries



Swing for the ***Transformative*** fences… from and for aviation

Execute early-stage experiments with ***Transition*** potential

Many people, many ideas

For all humanity

….

with all humanity

Wildfire mitigation through advanced autonomy

Vision: help emergency responders know more, do more, safely

- CAS enhanced safety for wildland firefighters
- Fighting wildfires through deployable self-contained drones
- Delivered five operator “kits” for traffic managment to wildland firefighting partners for use in 2022 and beyond
- Supported the formulation planning of a new NASA project within called ACERO

STEReO

AOSP / ACERO
- Major contribution to new Project

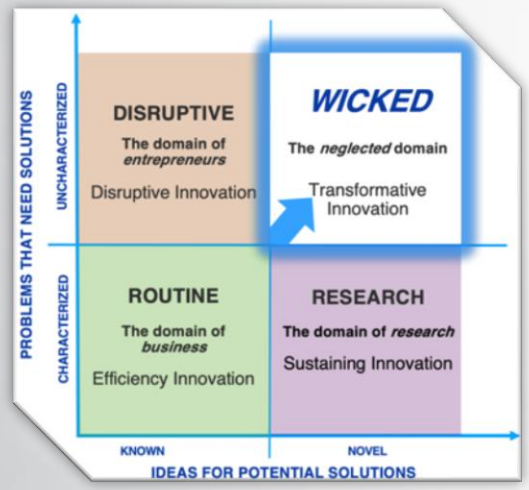
U.S. Forest Service & CAL FIRE
- Active engagement

But how?

Pillars of CAS innovation

Discovering systems-level, transformational impact for aviation

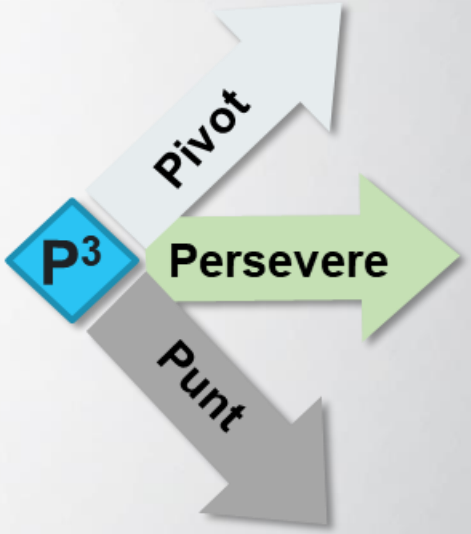
Wicked Problems



D-V-F Intersection

Barrier-Breaking Experiments

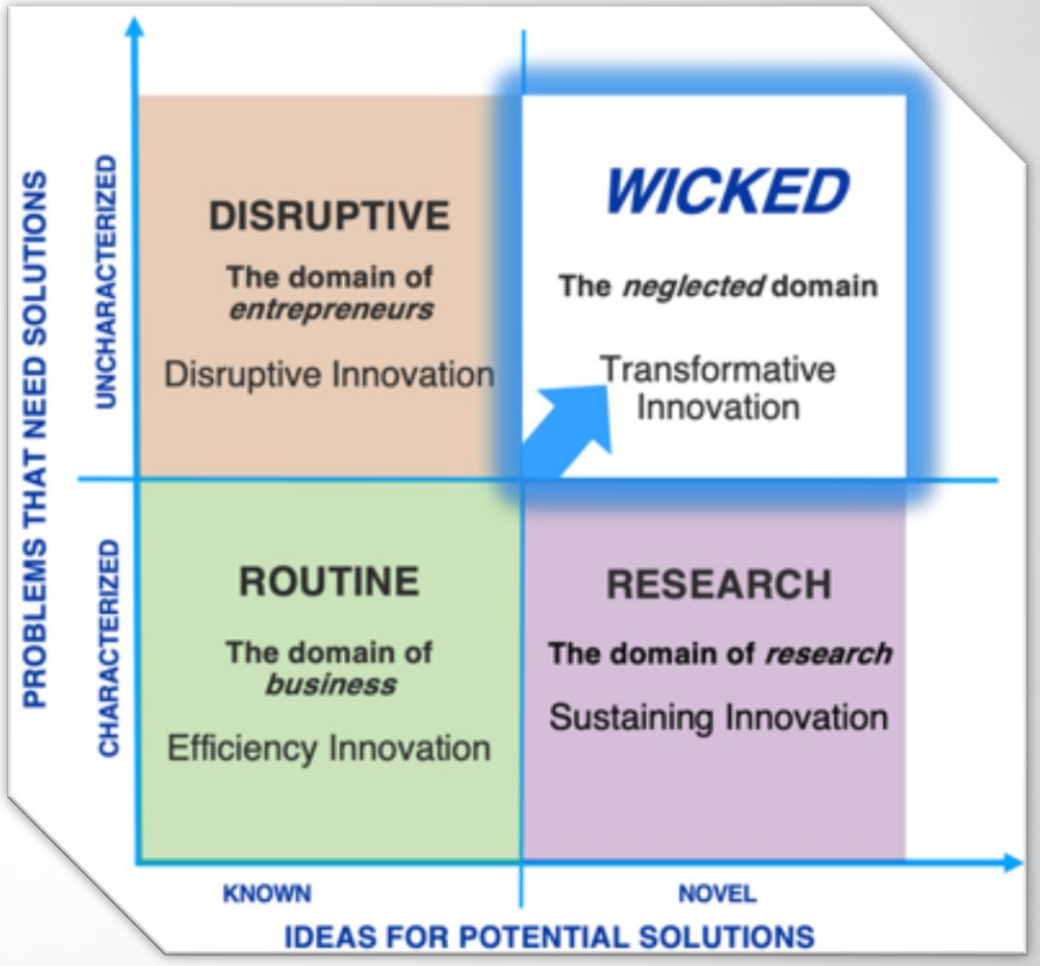
Aggressive Agility



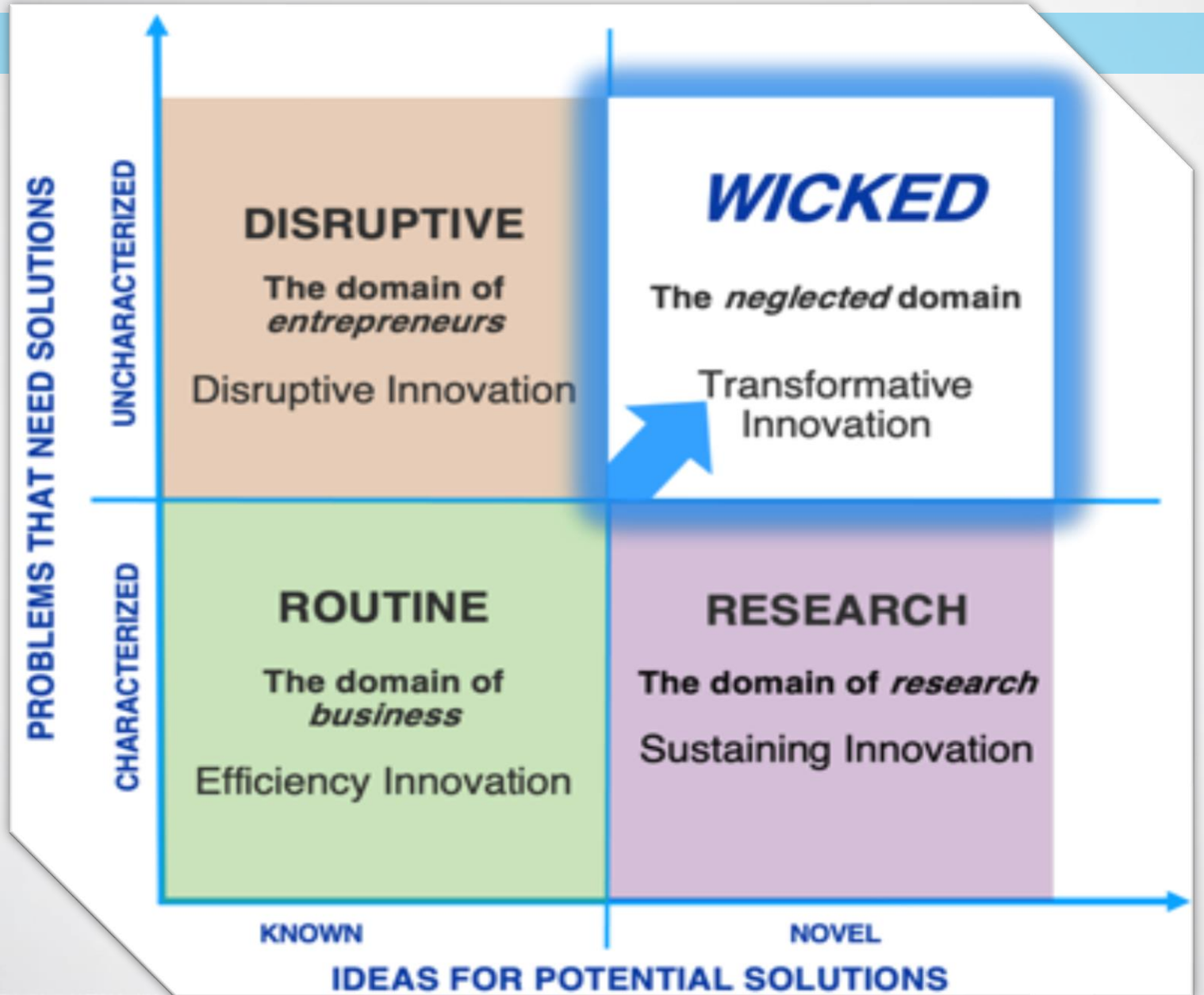
What is *Wicked*?

Wicked problems are…

- Changing constantly…
- Contradictory typically…
- Complex always…
- Interdependent amongst societal, economic, technical aspects…
- Solutions best assessed in terms of progress…
- **Key learnings by exploring the problem space**



Exploring the Wicked Quadrant… *and the Dragon of Chaos*




Departures
Arrivals

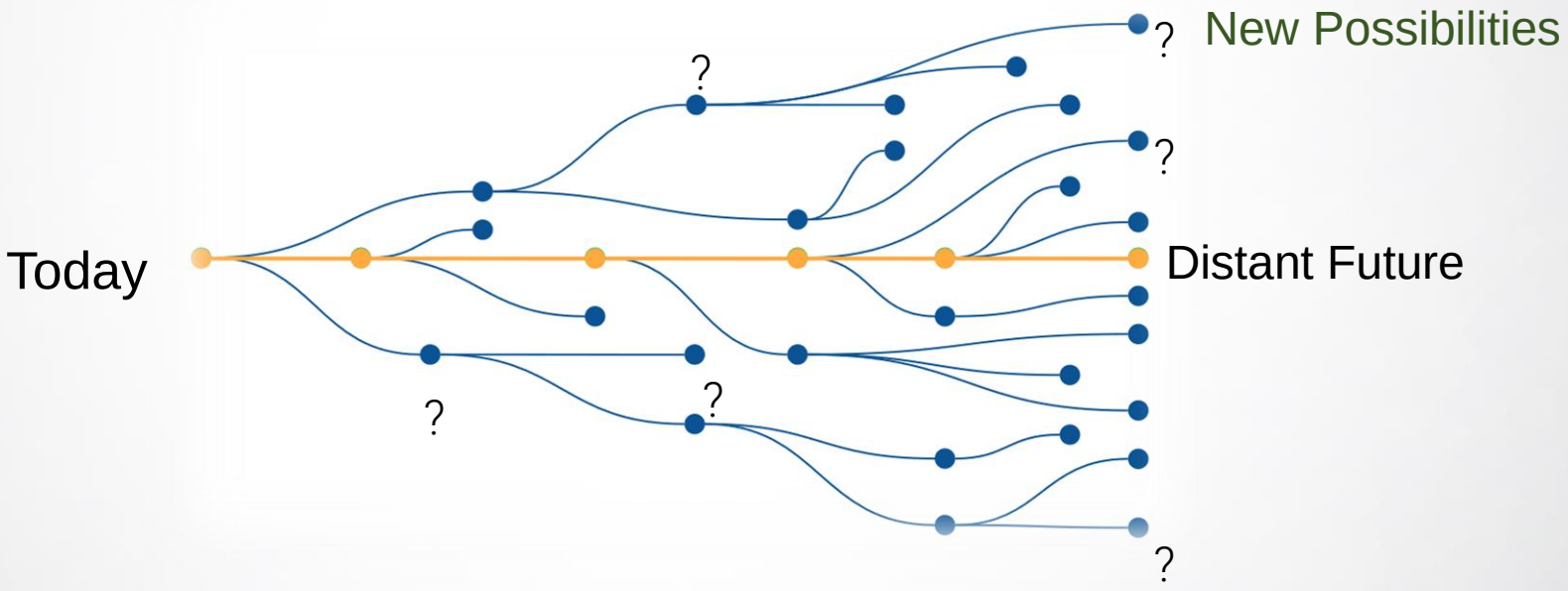

DIGITAL
transformation


BATTERY

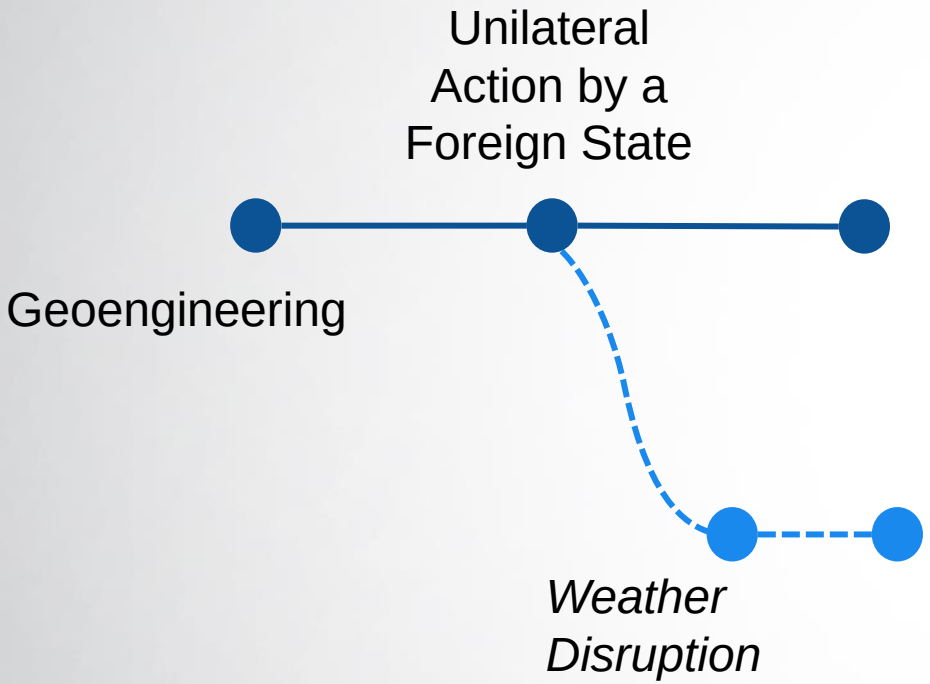
Discovery Process

1. Observations
   What raw data is out there?
2. Categorization
   What categories emerge from that data?
3. How & Why Laddering
   If X happens, then what? Why?
4. Theming & Scenario Development
   Imagine a future where… what are the problems?
5. Problem Exploration
   Keep digging until we understand the root cause and a solution opportunity.

Discovery Foresight

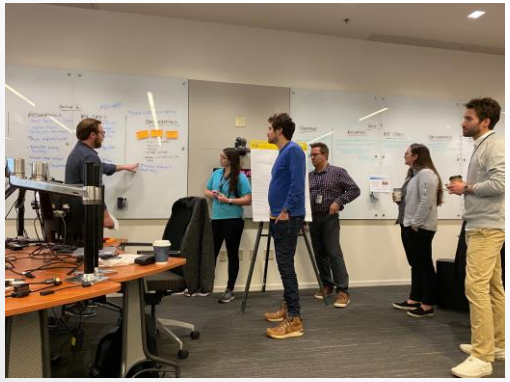


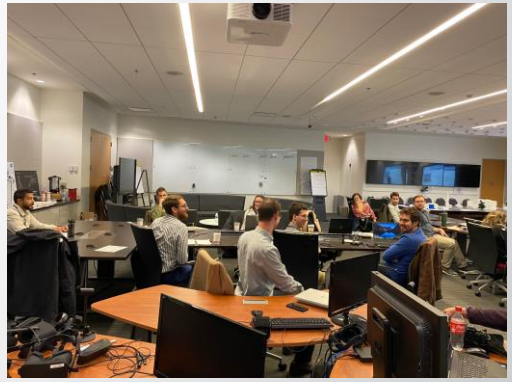
Discovery Foresight Example



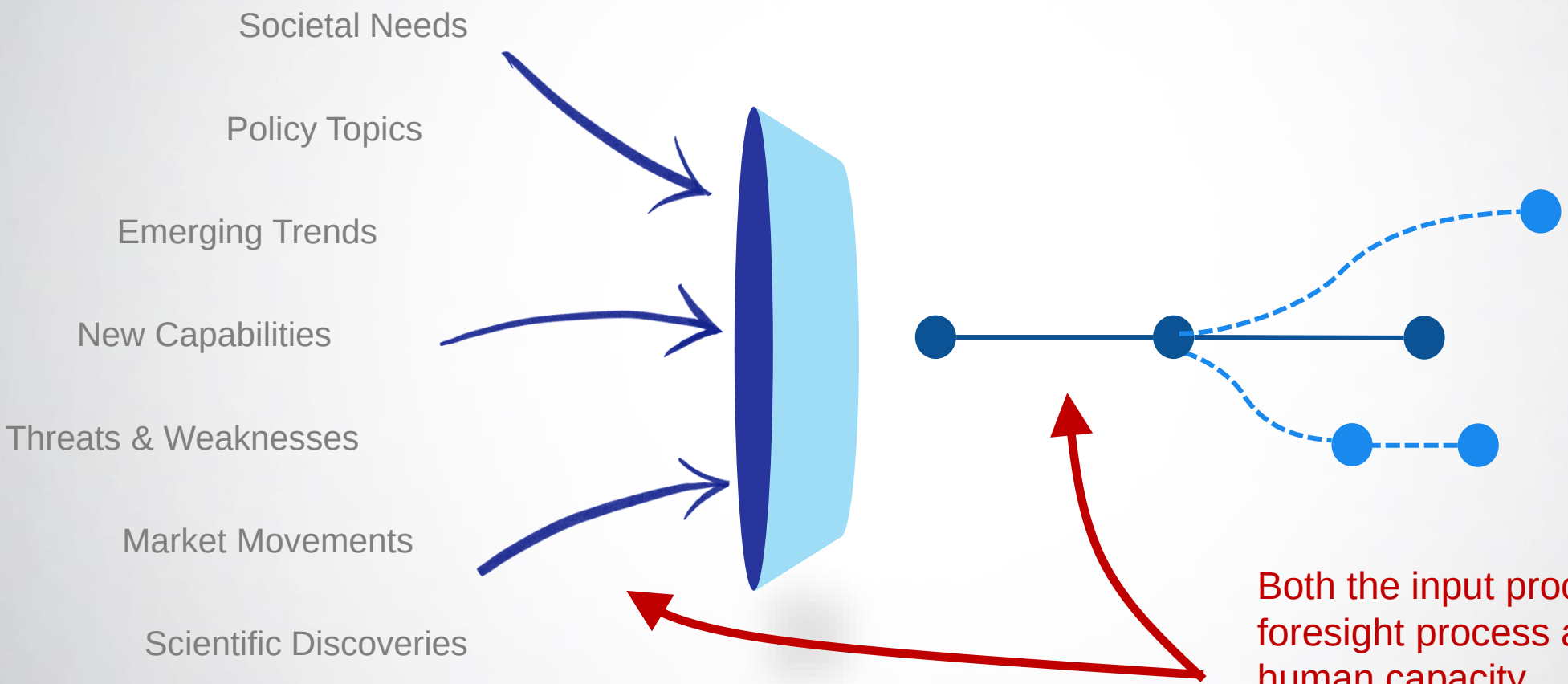
Discovery Problem Formulation

- We have identified a potential hotspot in the foresight phase and now we move into problem formulation
- This works a lot like think tanks or focus groups you see in many modern companies
- We converge thoughts, expertise, and geographical locations into one room to begin ideating on solution vectors





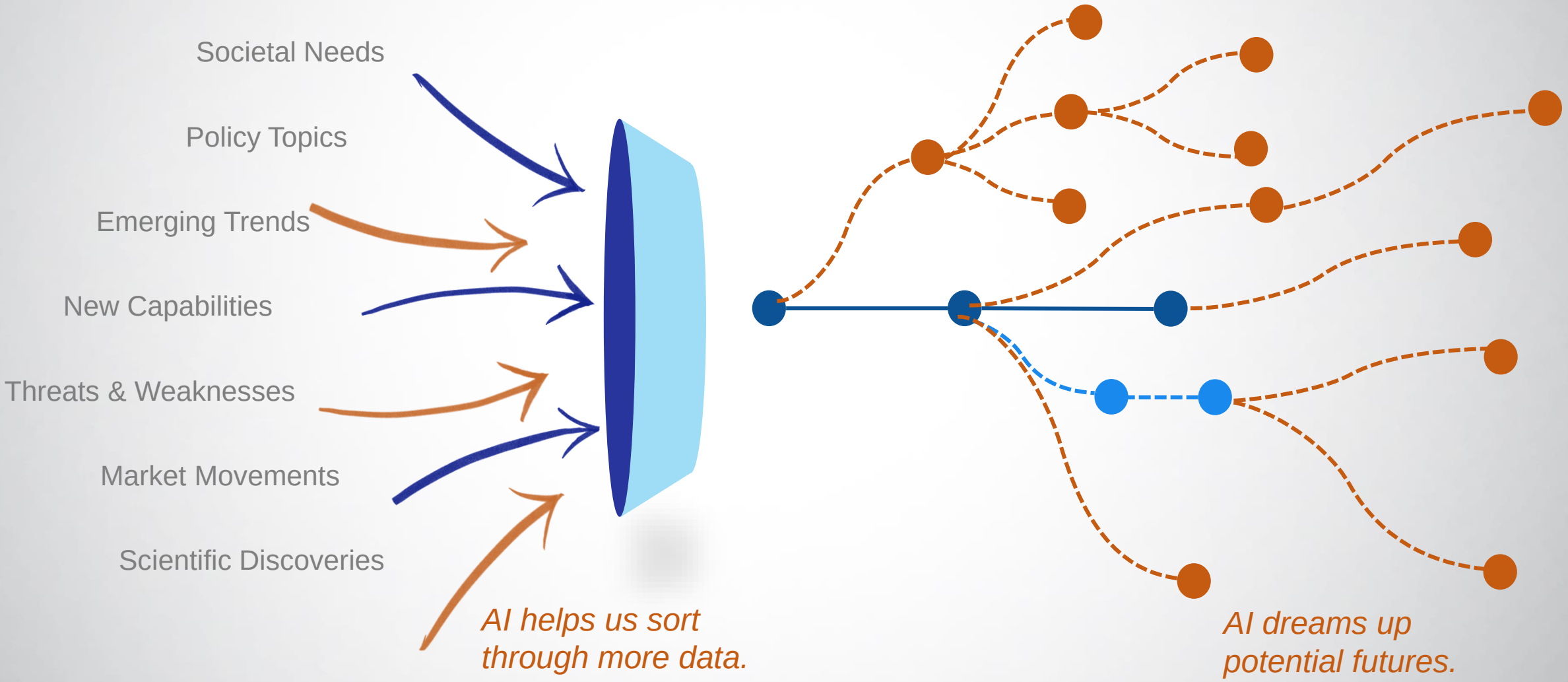
Using AI in Discovery



Both the input process and the foresight process are limited by human capacity.

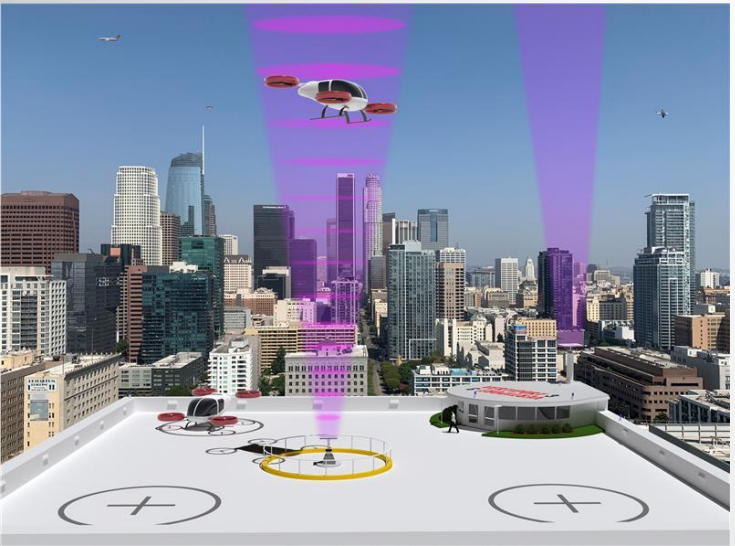
It's too much information.

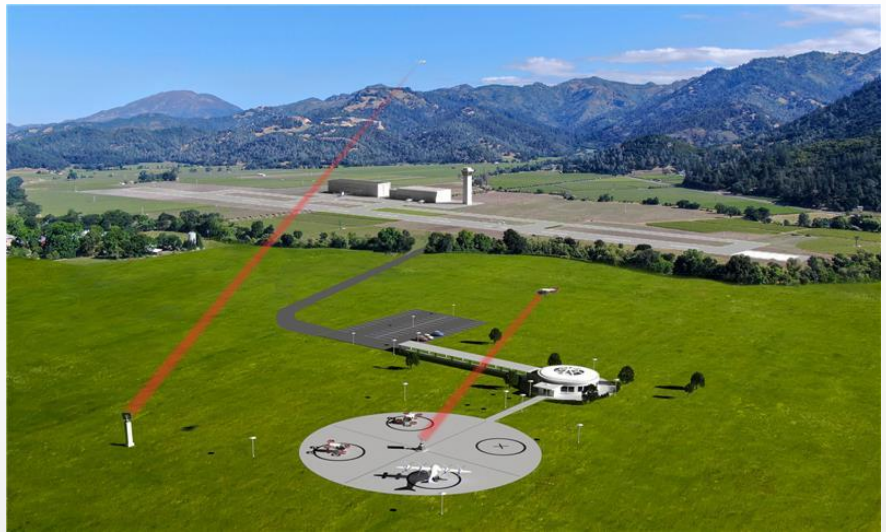
Using AI in Discovery



Beaming Energy for Air Mobility (BEAM)

- **Our goal**: safely beam direct energy to charge advanced air mobility vehicles in situations including but not limited to landing-descent, holding-hover, In-flight charging, and emergencies.
- What we asked:
  - How can we enable energy on demand?
  - Can we provide a power alternative in harsh or remote areas during natural disasters?





Urban canyon, micro-weather prediction and moderation

- How can we measure, predict and possibly control winds and weather near earth's surface and especially for urban aviation

- Effects on Advanced Air Mobility:
  - Safety
  - Operational efficiency
  - Ride quality
  - Passenger comfort
  - Vehicle wear and tear

Capabilities, Communities, & Connectivity

Collaborative, problem-focused research to vitalize rural communities through aviation technologies

How might we illuminate ways for rural communities to thrive and become resilient outside of single industry infrastructure?

So far, we've worked to…

- Discover
  - Partnering with rural communities to understand needs
- Analyze
  - Co-develop ideas with rural communities to address highest needs
  - Archetypes -Distinctive community archetypes emerged from the data according to similarities within community needs, motivations, and barriers
- Test
  - Types of solutions that could be explored when seeking to meet community needs

National Aeronautics and
Space Administration

Airports as Energy Nodes (ÆNodes)

Brandon Sells, Ph.D.
Aeronautics Systems Analysis Branch
NASA Langley Research Center
July 26, 2024

NASA Contacts: Dr. Nick Borer (ÆNodes Principal Investigator) and Dr. Nat Blaesser (Deputy Lead ACI)

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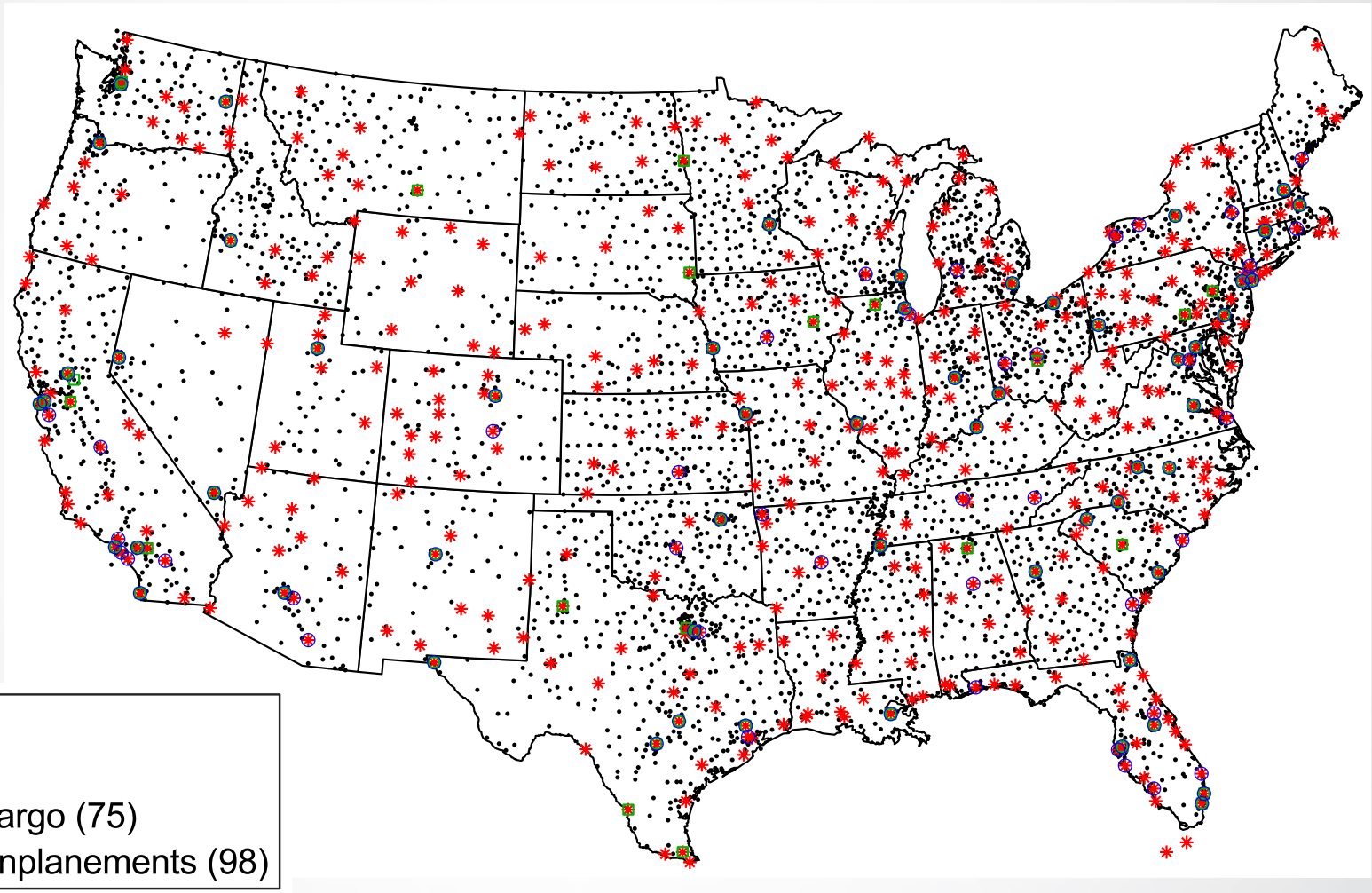
Advanced Air Mobility (AAM)

Safe, sustainable, affordable, and accessible aviation for transformational local and intraregional missions

Local Airports Enable AAM

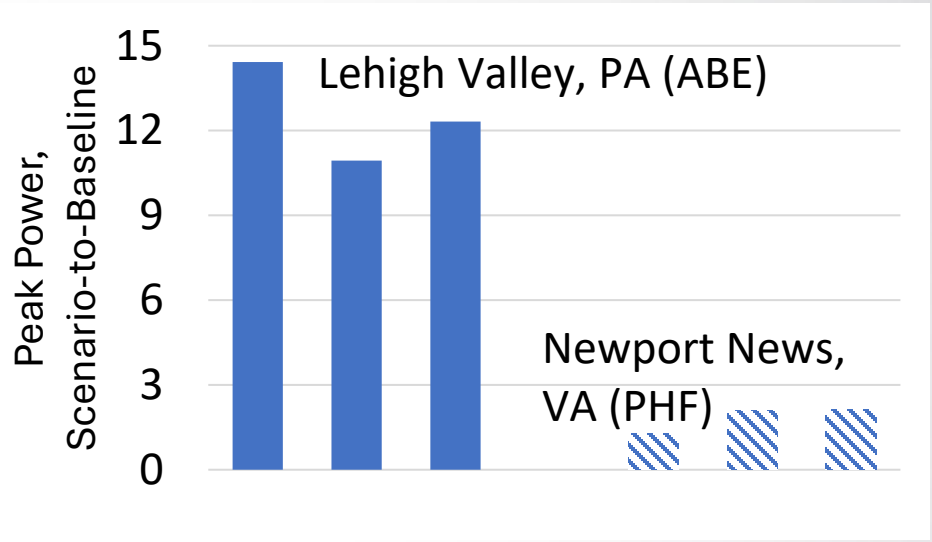
- Commercial service
- 95th percentile
- Part 139
- Public use

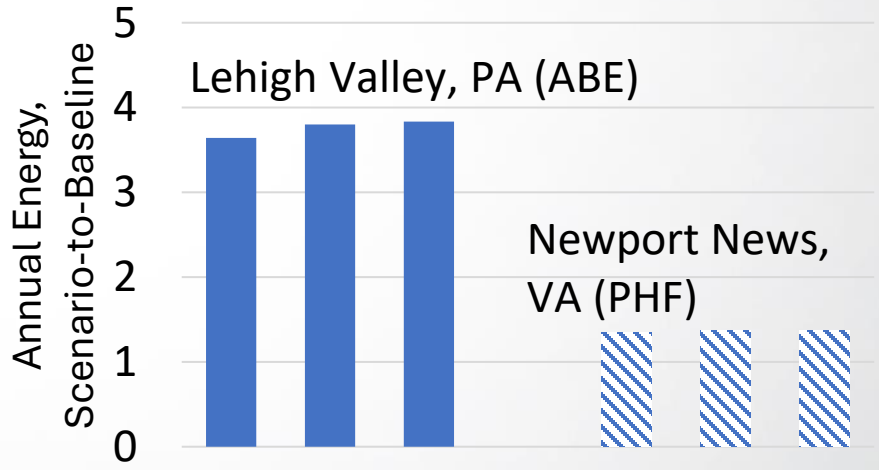


Opportunity for airports that do not currently serve the majority of commercial enplanements

RAM Impact on Airport Electricity Use

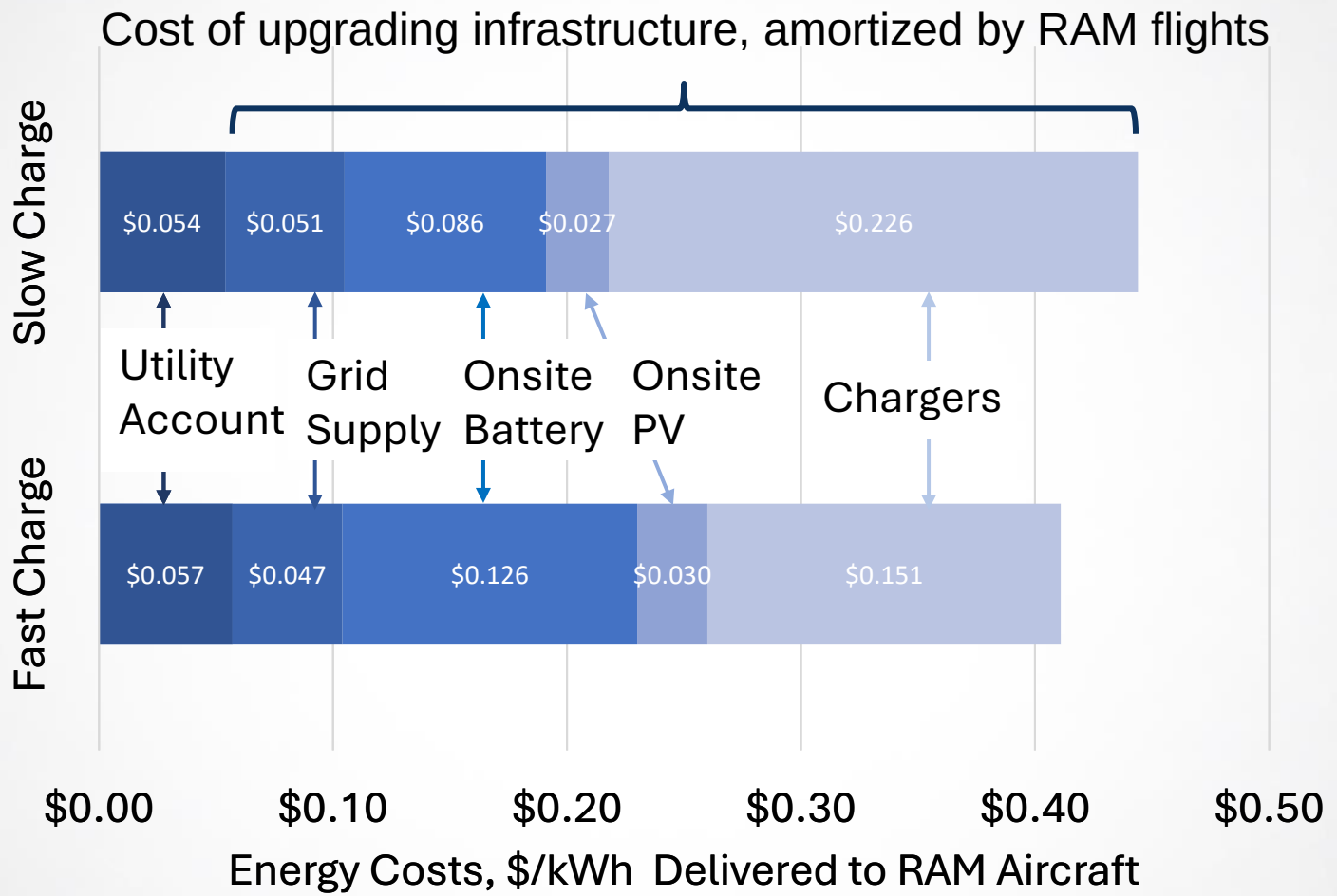
- NASA has been working with Georgia Tech and the National Renewable Energy Laboratory (NREL) to model the impact of RAM operations across the Mid-Atlantic region under three different energy build-out scenarios
- RAM operations can increase an airports peak power from 2x – 14x and increase annual energy usage from 1.3x – 4x
  - ABE: RAM "hub," ~52 MWh demand daily (276 flights, mix of battery-electric 9 pax and plug-in hybrid 19- and 48-pax)
  - PHF: RAM "spoke," ~3.3 MWh demand daily (20 flights, mostly battery-electric 9-pax)





Data from Cox et al., Impacts of Regional Air Mobility and Electrified Aircraft on Airport Electricity Infrastructure and Demand, NREL, February 2023.

It Takes More Than a Runway



Derived from Cox et al, "Impacts of Regional Air Mobility and Electrified Aircraft on Airport Electricity Infrastructure and Demand," NREL, February 2023.

AAM energy costs will be highly dependent on who pays for energy infrastructure burden

Airports as Energy Nodes (ÆNodes)

- ÆNodes is an activity within NASA's Aeronautics Research Mission Directorate (ARMD) in collaboration with the Department of Energy's National Renewable Energy Laboratory
- Big Question: *Can airports provide the right form and quantity of energy needed for future aviation operations in a scalable, affordable, and sustainable way that provides persistent value to aviation and community stakeholders?*
- Approach
  - **Engage aviation and community stakeholders** to define future airport, aircraft, and non-aviation scenarios and events of interest
  - **Identify robust solutions for aviation and community energy needs** for high-value scenarios
  - **Develop an energy virtual twin of selected airport sites** to evaluate detailed scenarios of interest and reduce areas of risk identified through stakeholder engagement
  - **Establish aircraft energy needs** for current and possible future scenarios
  - Leverage **aircraft component hardware testing** to establish detailed data on advanced aircraft energy needs, responses, and solutions

Flip the Script for Aviation Emissions


DoD


FAA

NPS


NREL

DoE

Opportunity for airports to become renewable, resilient energy partners for the local community

aero concepts incubator

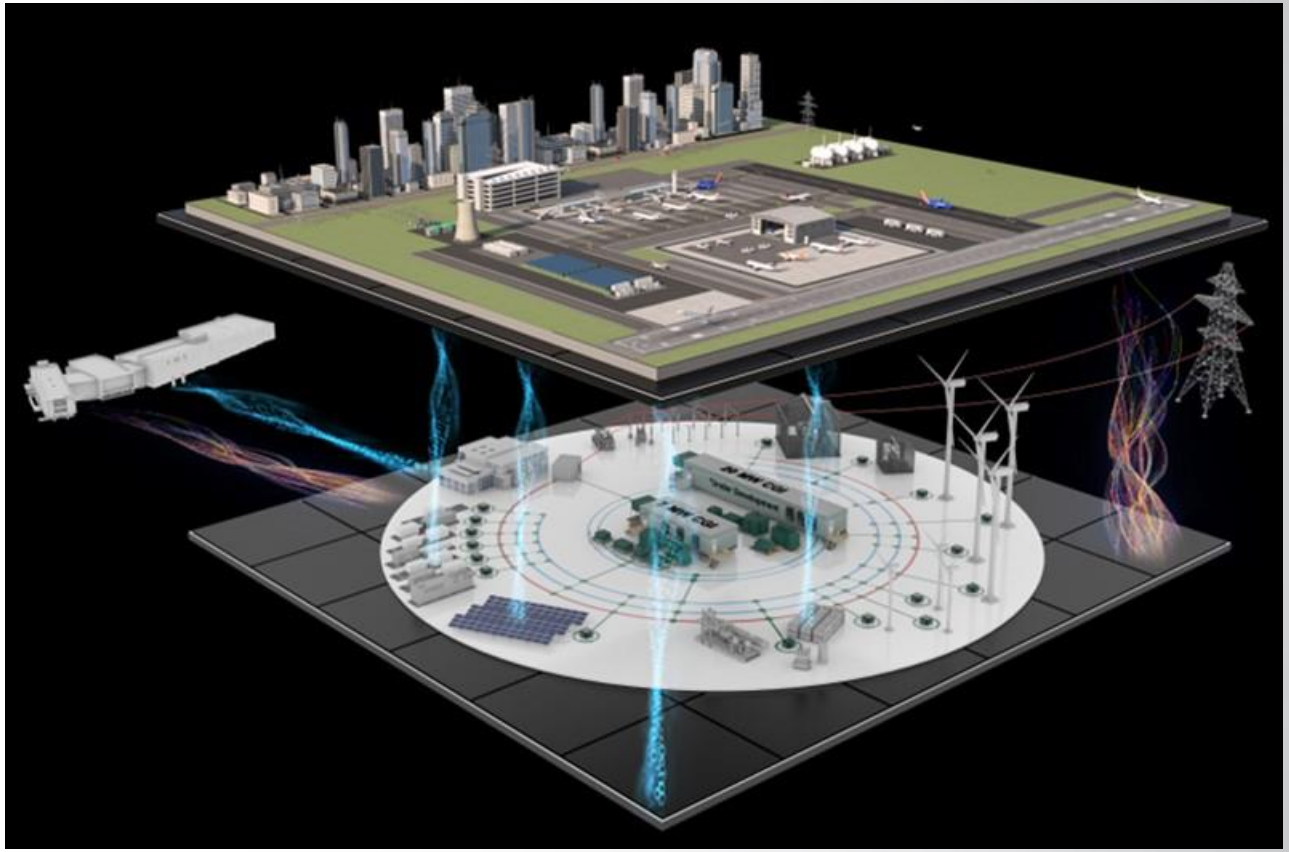
Why ÆNodes?

- *Need* to **enable airports to accommodate advanced air transportation** that may require alternative forms of energy while establishing the airport as a **desirable component of the community energy solution**
- *Goal* is to develop solutions that are robust to an uncertain future mix of vehicles/energy needs and types, provide lasting community value, and **enable investment pathways that accelerate adoption**
- *Objective* is to generate data, reports, and/or designs of future airport energy architectures suitable to **achieve buy-in from key stakeholders** (FAA, utility, airport, community) for full-scale development and demonstration

Let's make aviation a part of the energy solution, not a part of the energy problem!

ÆNodes Approach

- Airport Modeling
  - Model two partner airports to estimate cost-optimal build out vs. various energy load futures and community energy integration strategies
  - Develop “energy virtual twin” of one airport site using NREL’s Advanced Research on Integrated Energy Systems (ARIES) facilities
- Airspace Modeling
  - Model existing air traffic at selected partner airports
  - Anticipate future airspace operations for AAM vehicles
- Aircraft Modeling
  - Develop reference aircraft designs to determine energy needs for future aircraft needs including SAF, electric, and hydrogen
- Hardware Testing and Integration
  - Leverage X-57 hardware (batteries, inverters, etc.) to move beyond theoretical studies
  - Investigate/test flight-weight materials for LH2 storage



DECO: Digitally Enabled Cooperative Operations

Exploring a New Digitally Enabled Operating Mode to Complement VFR and IFR

EAA AirVenture
July 26, 2024

Graphic by R. Neale

What is an Operating Mode, Anyway?

Regulatory, procedural, and technical means for aircraft to *operate safely* within the airspace

aka "*flight rules*" as defined in regulations, policies, procedures, training materials, …

Routine Operating Modes	Specialized Operating Modes
Widespread use in most airspace classes *Routine for pilots & controllers*	*Limited to certain operations and/or airspace incompatible with VFR & IFR* *Routine for pilots who use them; Nonroutine for controllers and other pilots*
• Visual Flight Rules (VFR) • Instrument Flight Rules (IFR)	• State/Military Aircraft • Moored Balloons / Kites / Amateur Rockets / Unmanned Free Balloons • Ultralight Vehicles • Parachute Operations • Small Unmanned Aircraft Systems

Key Points:

An operating mode is a "must have" for all flights (safety requirement)

Our existing operating modes depend on human situation awareness and procedures

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A Look Back: 20th Century Evolution of Operating Modes

Origins of Visual Flight Rules (VFR)

See and Avoid

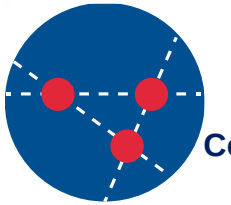
Visual Separation

Flexibility ✓
Access ✗

Radio Navigation

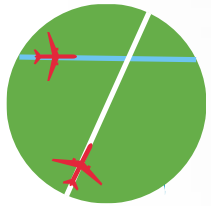
Origins of Instrument Flight Rules (IFR)

"Airways"



Increased Collision Risk

Flexibility ✗
Access ✓



"Airway" Traffic Control (ATC)

Procedural Separation

Radar Separation

Radar Surveillance

Voice Communications

Global Precision Navigation

Advanced Avionics

Traffic Management Automation

Data Communications

Initial Trajectory-Based Operations

Capacity ↑
Flexibility ✗
Access ✓

But Wait! Continued Aviation Growth Requires All of These:

Capacity ✓
Flexibility ✓
Access ✓

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Coming Soon to an Airspace Near You

What Innovations are Coming?

- New Types of Propulsion
- New Missions and Business Models
- Flight Operations in New Locations
- Remotely Piloted Aircraft
- Increasingly Automated
- Unknown Future Innovations

What Operating Modes Can Be Used?

Existing Operating Modes

Existing Operating Modes w/ waivers & special procedures at low operational tempos

Increasing Ops Tempos, Volume, Density, Complexity →

Existing Operating Modes May Be Insufficient

Community Awareness:

*"**New and adapted flight rules and procedures will be required** to efficiently manage these increasingly dynamic operations of differing priority and types."* Airbus and Boeing

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A Look Forward: Operating Mode Options for 21st Century Aviation

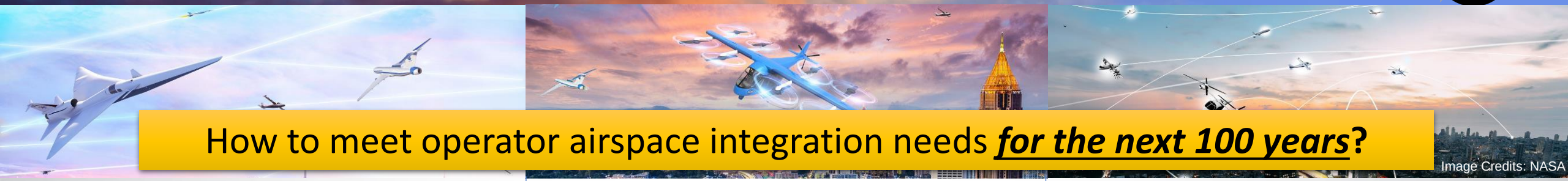

Image Credits: NASA

How to meet operator airspace integration needs *for the next 100 years*?

Do Nothing

Operating Modes of the 20th Century are

- Not adaptable to increasing flight diversity
- Not scalable to high tempos and density
- Not suited to self-piloted aircraft
- Not sufficiently predictable
- Not conducive to regional growth

Cannot be solved by Traffic Management alone

Not really an option

Add to Specialized Modes

Specialized Operating Modes

- State/Military Aircraft
- Moored Balloons etc. (Part 101)
- Ultralight Vehicles (Part 103)
- Parachute Operations (Part 105)
- sUAS (within visual) (Part 107)
- sUAS (beyond visual) (Part 108?)
- Another (Part 109?)
- And another
- And yet another

Proliferation of Solutions

- Divergent?
- Incompatible?
- Segregated?

Starting to happen

Converge to One New Routine Mode

Routine Operating Modes

- **Visual Flight Rules (VFR)**
- **Instrument Flight Rules (IFR)**
- **New Routine Operating Mode (digitally native & cooperative)**

Convergent Aeronautics Solution

- Unifying
- Compatible
- Integrated
- Flexible
- Adaptable

Needs to happen!

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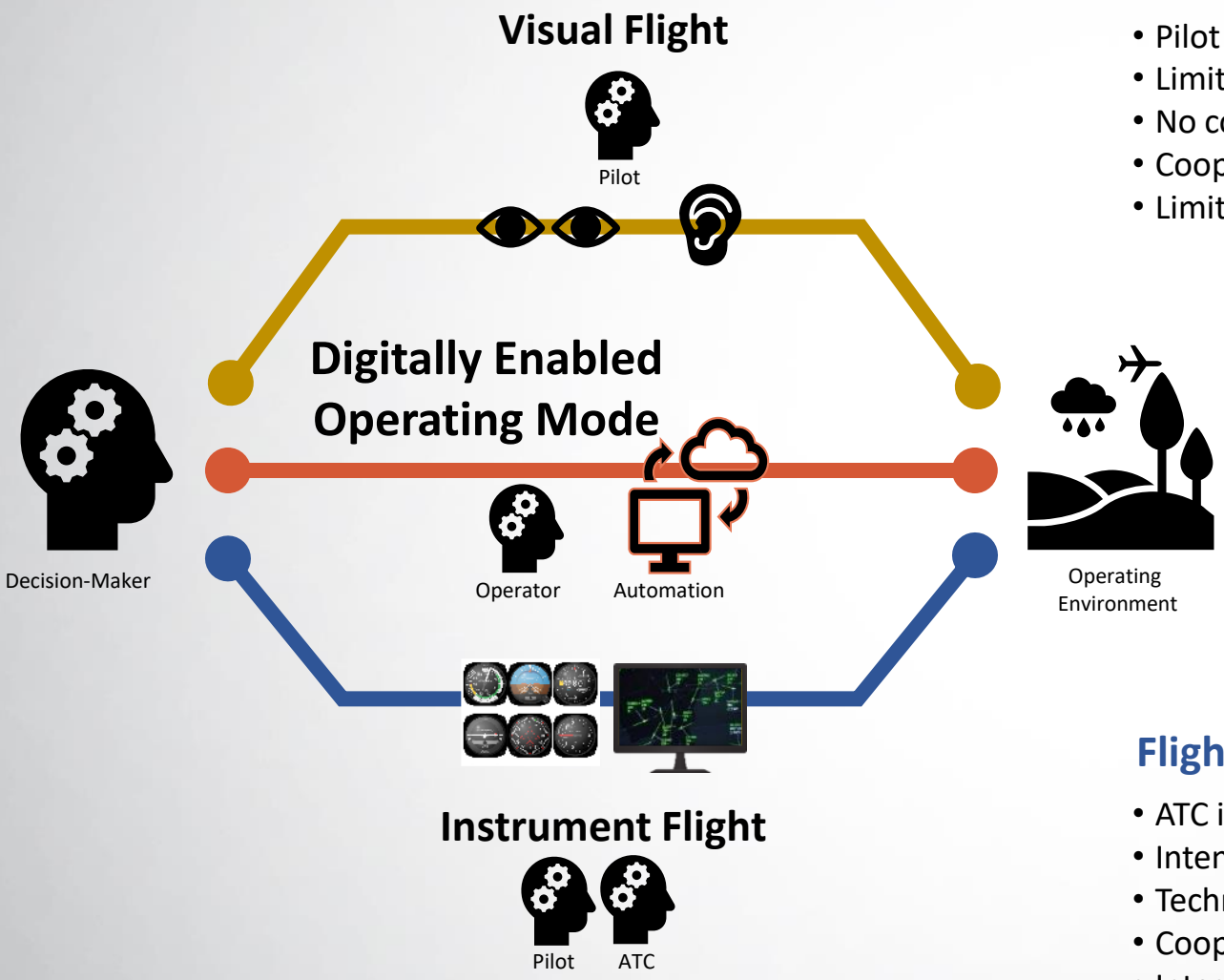
We're Exploring a *Routine Digital* Operating Mode



Flight by Reference to Visual Cues

- Pilot is the separator (see and avoid)
- Limited to no intent sharing
- No conflict management technology required
- Cooperative through human interpretation & judgment
- Limited to no dependence on traffic management

Flight by Reference to Digital Capabilities

- **Operator is the separator**
- **Required intent sharing**
- **Technology-dependent separation function**
- **Encoded cooperative practices**
- **Collaborative with traffic management**

Flight by Reference to Instruments and ATC Services

- ATC is the separator
- Intent sharing with ATC, not with other IFRs
- Technology dependence (communications, navigation, surveillance)
- Cooperation through centralized control
- Integrated with traffic management

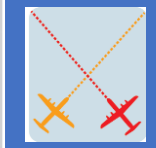
Detailed Framework for a Digitally Enabled Operating Mode

Info Services & Connectivity

Integrated Information Environment

Maintains a digital model of the operating environment for use by decision-making automation systems

Cooperative Practices



Governs the behavior of digital operations to ensure harmonized use of the airspace

Essential Elements

- Information Services & Connectivity
- Shared Traffic & Intent Awareness
- Cooperative Practices
- Automated Conflict Management Capabilities

Shared Traffic & Intent Awareness

Sharing of relevant traffic & intent information for use by automation in conflict management

Automated Capabilities

Automates the critical functions in tactical separation and strategic conflict management

Design Attributes

Safety

- Safety Benefits
- Embedded Risk Mitigations

Integration

- All Airspace Classes
- Non-Disruptive to Incumbents

Performance

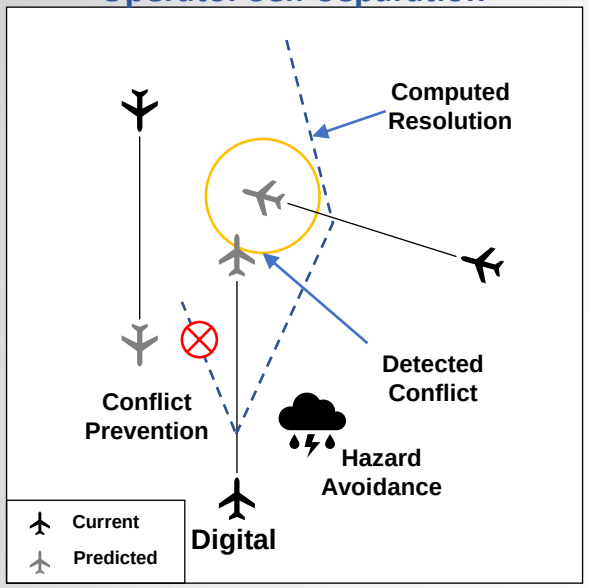
- Tailorable Separation
- Aircraft Diversity

Value

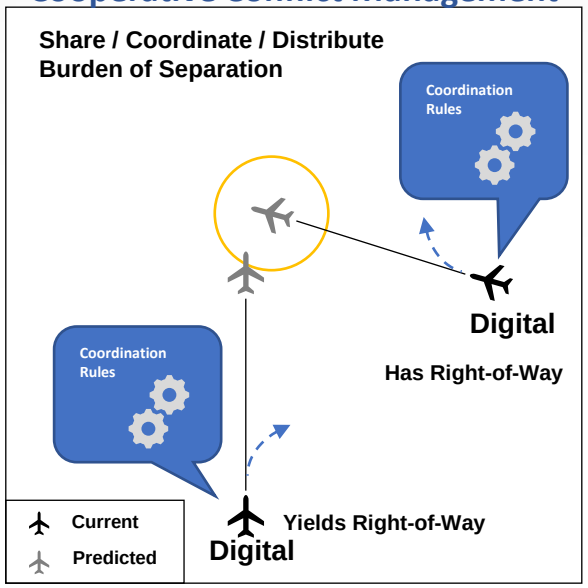
- User Community
- Individual Stakeholders

Candidate Digital Automated Capabilities

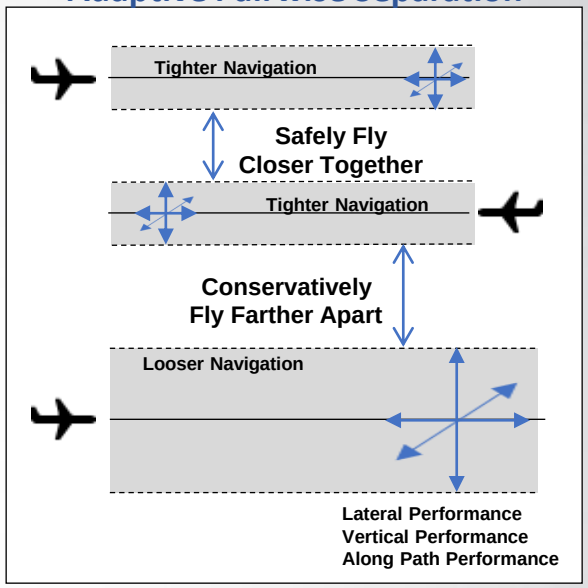
Operator Self-Separation



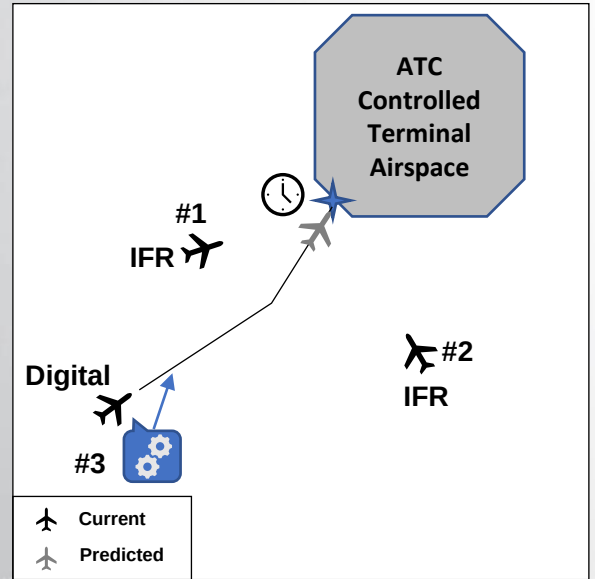
Cooperative Conflict Management



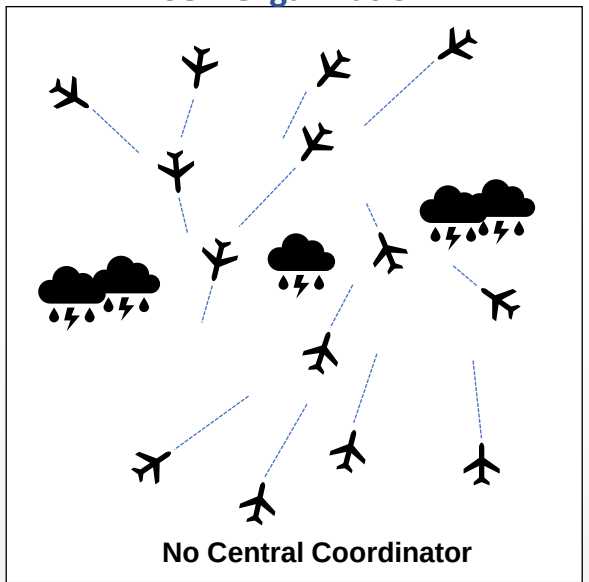
Adaptive Pairwise Separation



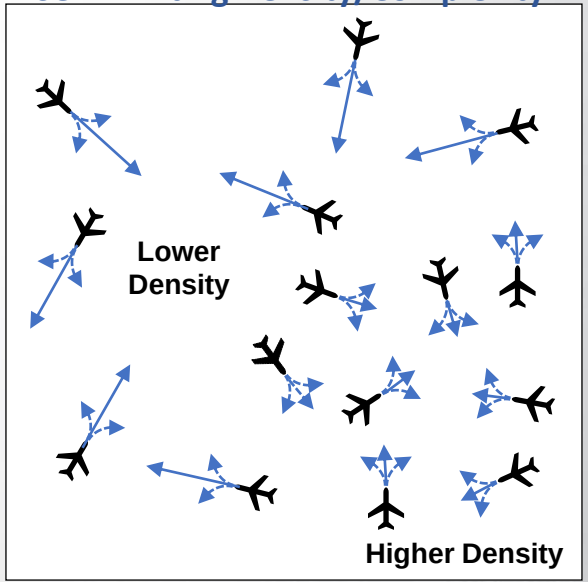
Constrained Resource Collaboration



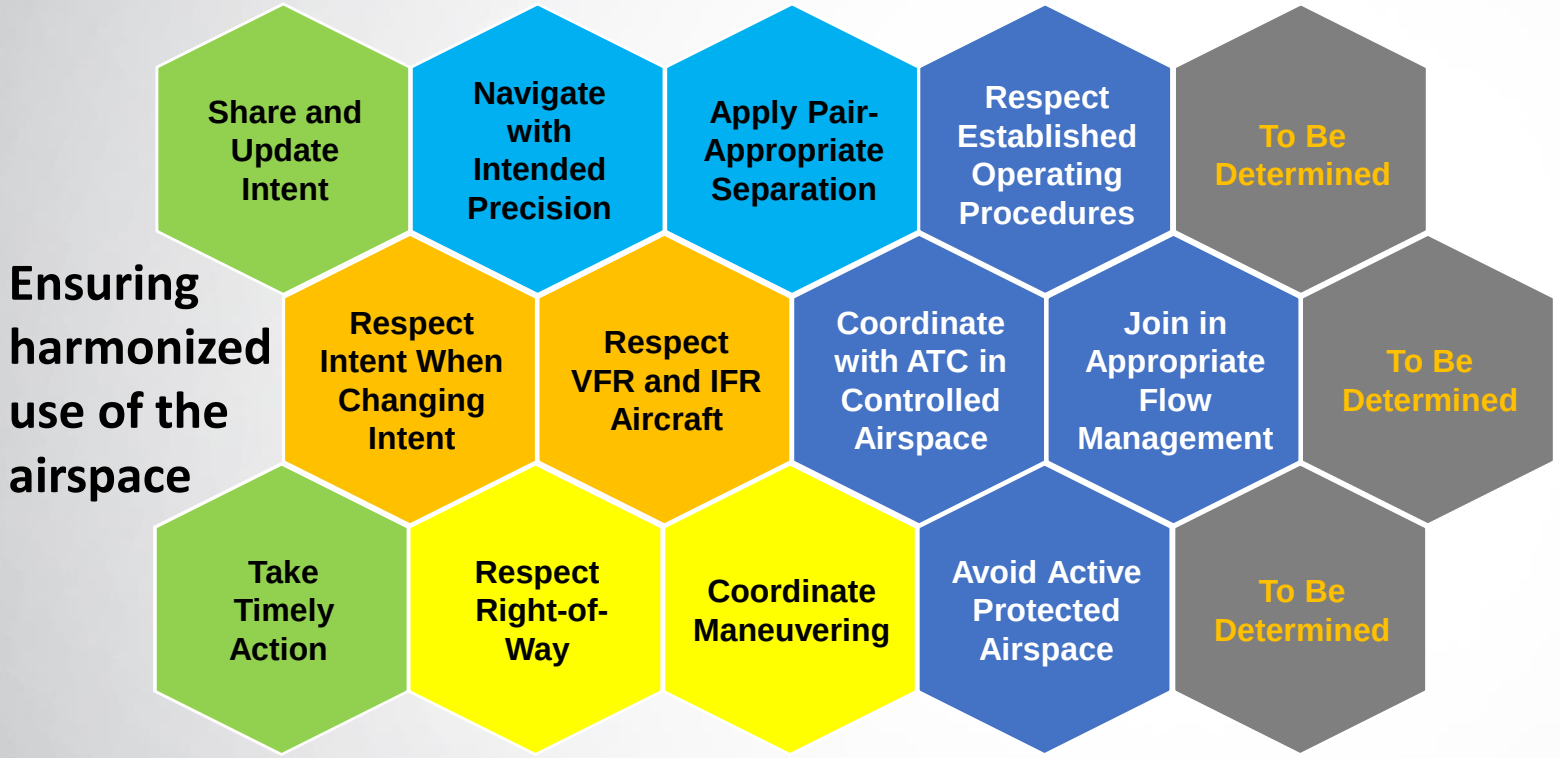
Self-Organization



Self-Limiting Density/Complexity



Candidate Digital Cooperative Practices



Intended Effect
Increase predictability, efficiency, stability, and safety
Minimize disruption to existing operations
Increase airspace capacity Reduce actionable conflicts
Distribute separation burden Increase safety
Facilitate airspace integration Minimize controller workload Minimize disruptions

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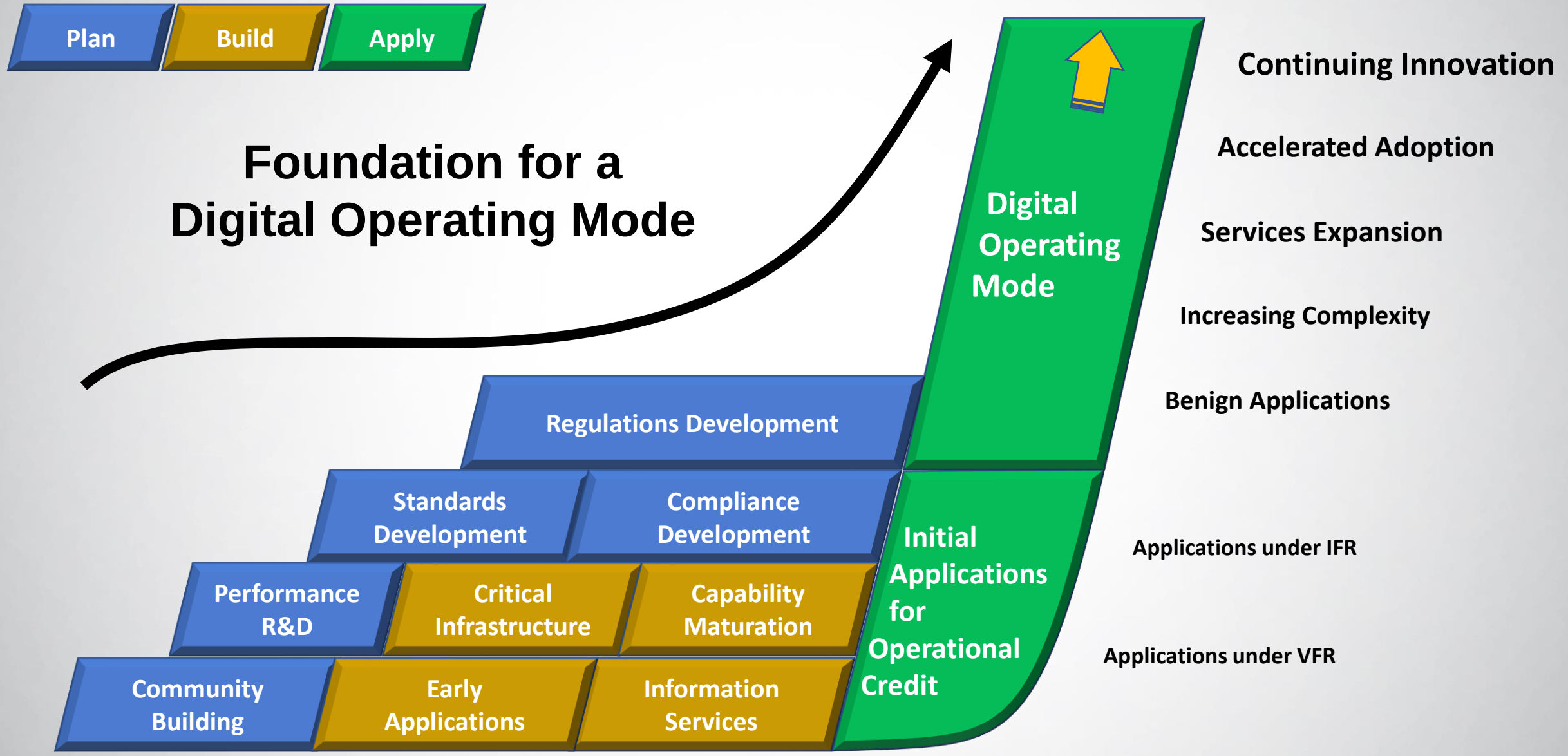
A Path Forward



DECO: Digitally Enabled Cooperative Operations

Exploring a New Digitally Enabled Operating Mode to Complement VFR and IFR

Thank You!

David.Wing@nasa.gov

Use this QR code to access a 2022 NASA publication describing the concept framework in greater detail.

Many people, many ideas

For all humanity

….

with all humanity