

An aerial view of New York City, featuring the Empire State Building and other skyscrapers. The sky is filled with various aircraft, including a large white fighter jet, a smaller white jet, a blue and white commercial jet, a red and white propeller plane, a black and white drone, and a black and white helicopter. White lines crisscross the sky, suggesting flight paths or data connections.

EXPLORE FLIGHT

WE'RE WITH YOU WHEN YOU FLY

Data and Reasoning Fabric (DRF) Close-out
October 2023

Transformative Aeronautics Concepts Program (TACP)
Convergent Aeronautics Solutions (CAS) Project
Data and Reasoning Fabric Team



Agenda

- Air Mobility Challenges
- Critical Barriers
- DRF – Original Proposed Solution
- Mission Statement and Approach
- Execution Plan
- DRF Core Implementation
- CAP Field Test # 1
- GPMA Field Test
- CAP Field Test # 2
- Lessons Learned
- Transitions
- Publications & Knowledge Disseminations

- Transportation shapes society, enabling economic and social interactions
- The quality of life is impacted by ever growing commute time
- Transportation is increasingly driven by door-to-door challenges



Air Mobility can convert our 2D mobility system to a 3D mobility system, increasing mobility options for both people and goods

Air Mobility Data and Reasoning Challenges



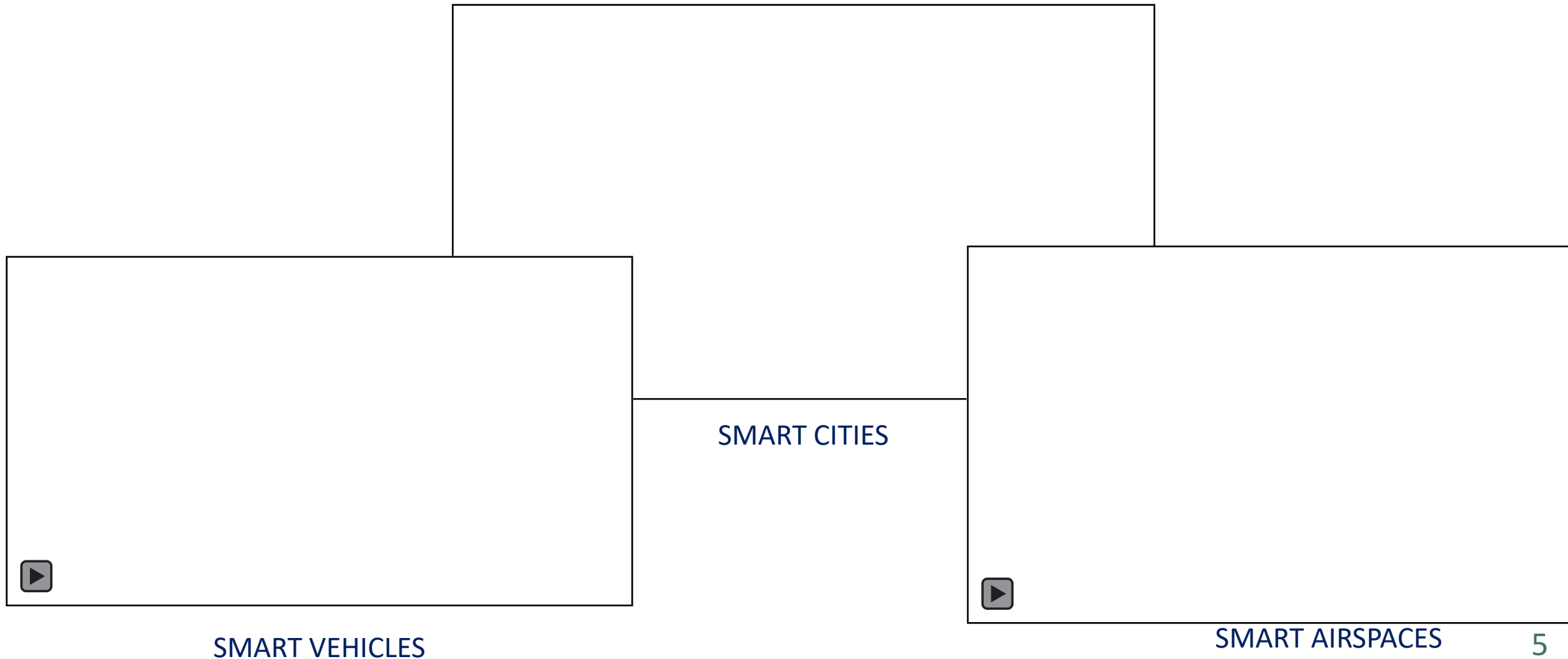
- Urban air operations require decisions based on diverse and dynamic data, including vehicle, airspace, weather, infrastructure, payload, and customer data
- Decisions need to be made where the data exist and, increasingly, data may be too large or dynamic to centralize
- The envisioned density of operations will only be achieved if decision processes continue to move from purely human decisions, to machine-intelligence based decisions with human oversight
- Machine-intelligence generally requires greater volumes of digital data of explicitly known applicability, quality, and many other “ilities”



Advanced Air Mobility Data Sources



Data will arise from Smart Vehicles operating in Smart Airspaces, within Smart Cities:



Air Mobility Planning, Operations, and Performance

- Current Trajectory -



Aerospace Service Users

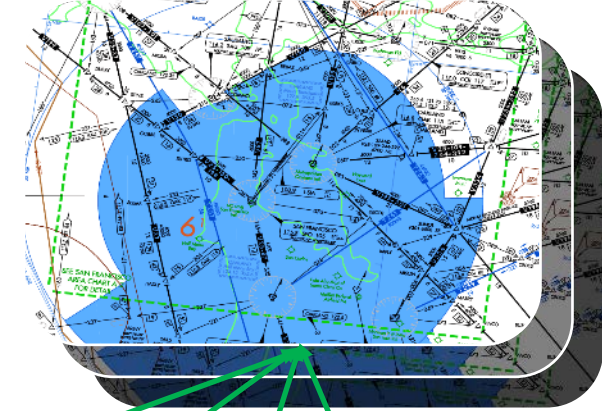
PLANNING



OPERATIONS



PERFORMANCE



CASE-BY-CASE DATA

- DISCOVERY
- AGGREGATION
- VETTING
- DATA/\$ TRANSACTIONS

City "A"
Planner

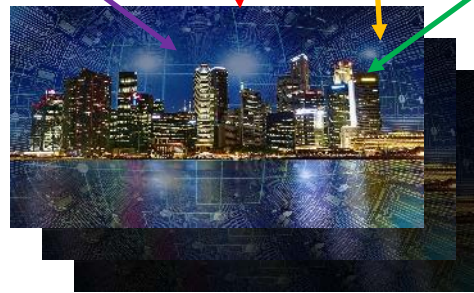
Package As-Service
Provider "A"

City "L"
Planner

Mobility-As-Service
Provider "U"



SMART AIRSPACES



SMART CITIES



REGULATORY



MICRO-WEATHER

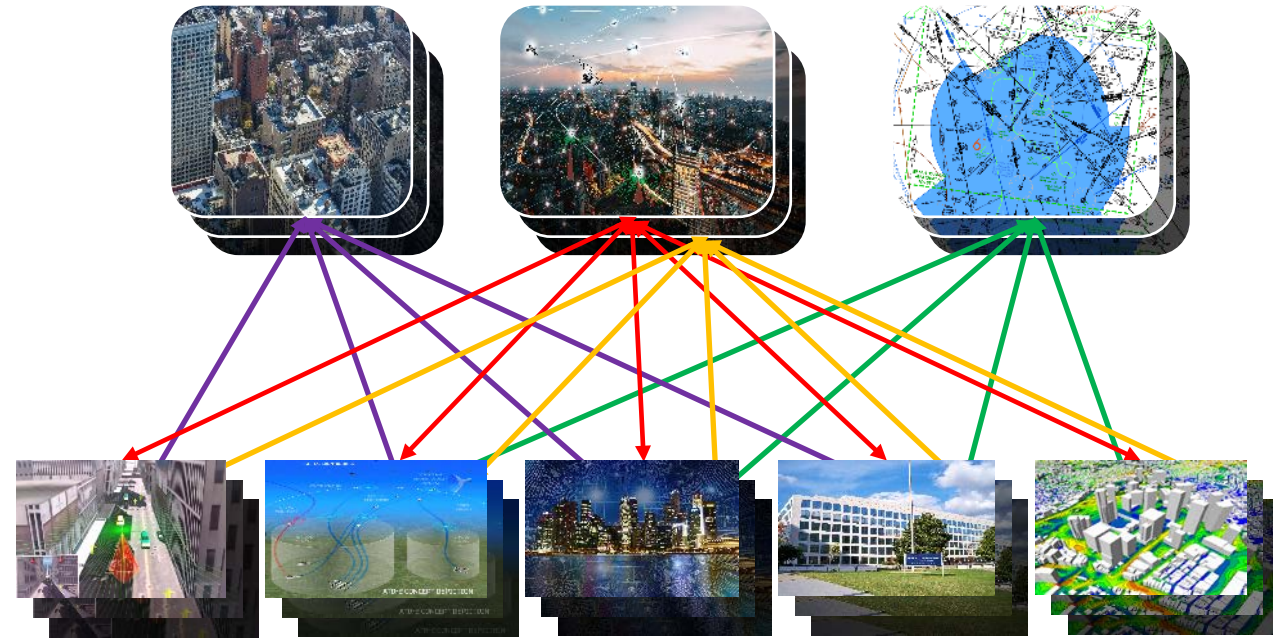


Data & Reasoning Services

Air Mobility Data & Reasoning Current Trajectory - Concerns



- Many "stovepipe" connections
 - o Labor intensive
 - o Lack agility
 - o Fractured community
- Inconsistent implementation and quality
 - o Security vulnerabilities
 - o Varying performance
- Lack of standards
 - o Inconsistent interpretation and exchange of data
 - o Ongoing interoperability headaches
- Lack of common foundation
 - o Difficult to define and revise systemwide policies
 - o Difficult to measure systemwide performance, health
 - o Difficult to support consistent, robust safety standards
 - o Difficult to extend system to new missions, technologies over time



Critical Barriers



The DRF Opportunity addressed seven critical barriers that must be overcome before a widespread data and reasoning fabric can be adopted in mid-term and far-term advanced air mobility environments

Barrier	Desirability	Viability	Feasibility
Limited Interoperability	X	X	X
Insufficient Current and Accurate Data Where it is Needed to Make Airspace Operations & Management Decisions	X		X
Adverse Impact to Safety Related Decisions without High-Reliability and Low-Latency Data Interconnect to Edge Computing Devices	X		X
Reusable Reasoning Services are not Easily Accessible	X		X
Limited Data Standardization			X
Clear Economic Incentives		X	
Inability to Switch Between Different Service Providers		X	X

Critical Barriers & Minimum Success Criteria



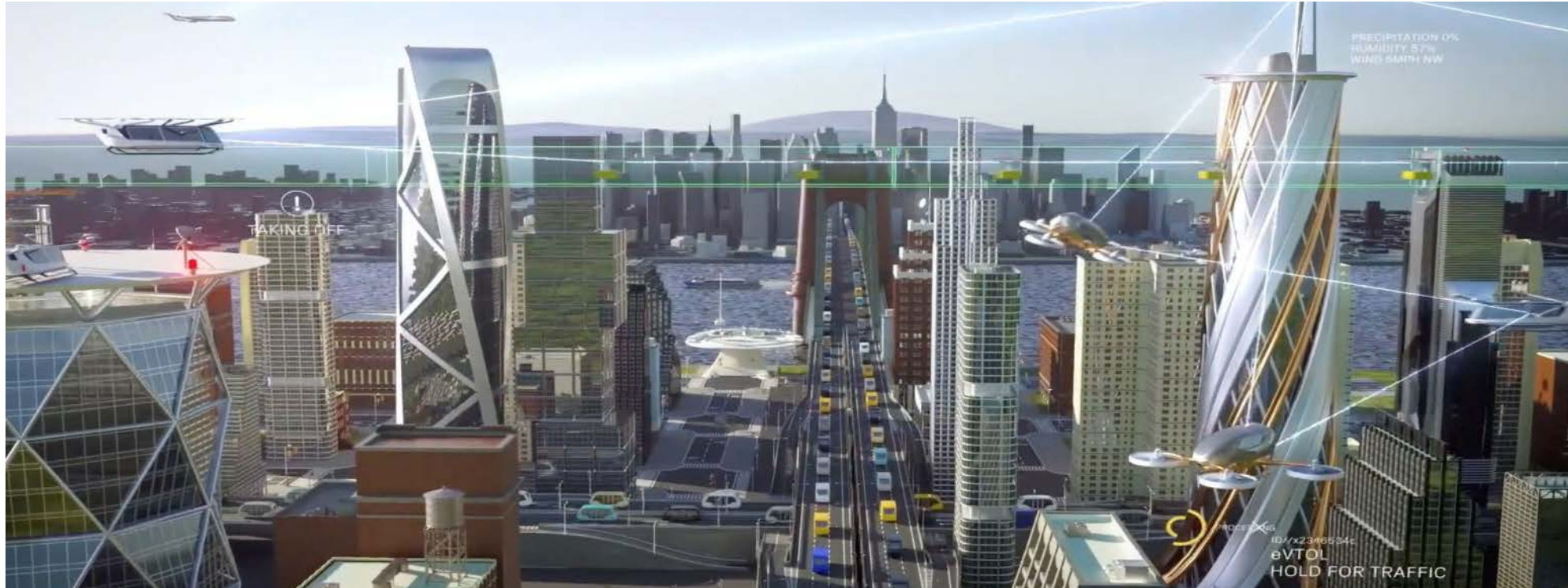
Critical Barrier	Minimum Success Criteria
Limited Interoperability	Demonstrate successful data exchange and interpretation between three participants (a consumer, data provider and a reasoning provider)
Limited data standardization	Create and use standard metadata schema and format for two datasets
Clear Economic Incentives	Demonstrate one monetary transaction for data exchange
Insufficient Current and Accurate Data Where it is Needed to Make Airspace Operations & Management Decisions	Demonstrate integration between two data and two reasoning services with 100 data and reasoning simulated consumers

Critical Barriers & Minimum Success Criteria



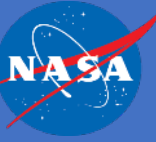
Critical Barrier	Minimum Success Criteria
Inability to Switch Between Different Service Providers	Demonstrate swapping one data provider and adding another one at run time
Lack of Economic Incentives	Integrate 1 external data service and one external reasoning service.
Reusable Reasoning Services are not Easily Accessible	Demonstrate integration with two reasoning services to support real time decisions.
Adverse Impact to Safety Related Decisions without High-Reliability and Low-Latency Data Interconnect to Edge Computing Devices	Demonstrate one service deployed at a physical or simulated Edge node with latency less than 20ms for safety related data less than 1KB in size

Data & Reasoning Fabric (DRF)



Trusted Service Discovery and Exchange Backbone
for the Future Airspace Ecosystem

Data & Reasoning Fabric – Original Proposed Solution



Data & Reasoning Fabric – Original Proposed Solution



Service Providers

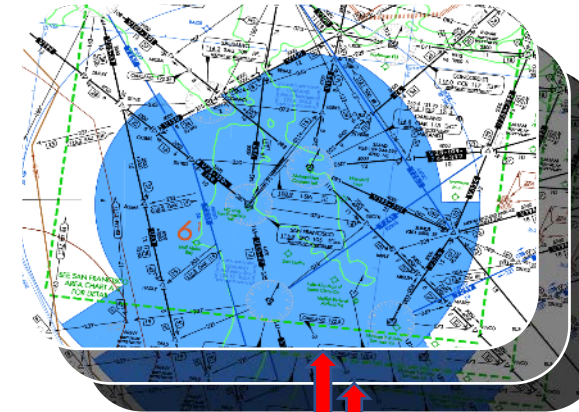
PLANNING



OPERATIONS

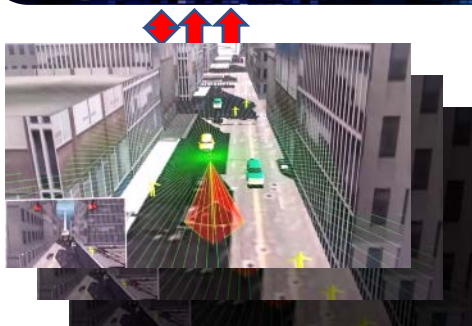


PERFORMANCE

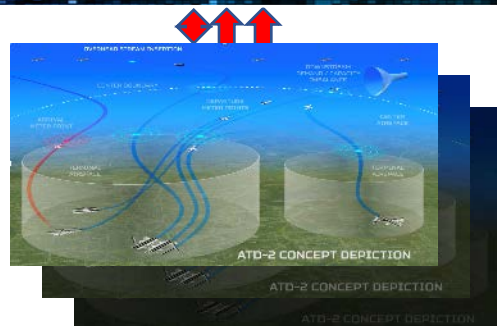


DATA & REASONING FABRIC

ENABLE EFFICIENT AND PERVASIVE DATA DISCOVERY, AGGREGATION, AND DATA/\$ TRANSACTIONS,
IN ORDER TO ENABLE A DATA AND REASONING SERVICE EXCHANGE FOR AAM ENVIRONMENTS



SMART VEHICLES



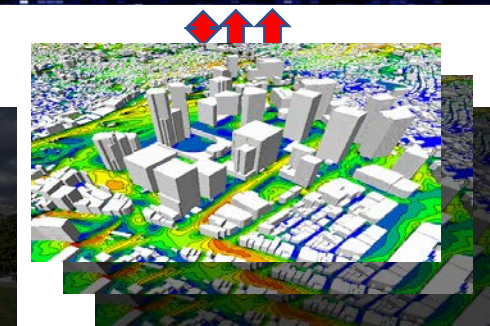
SMART AIRSPACES



SMART CITIES



REGULATORY



MICRO-WEATHER

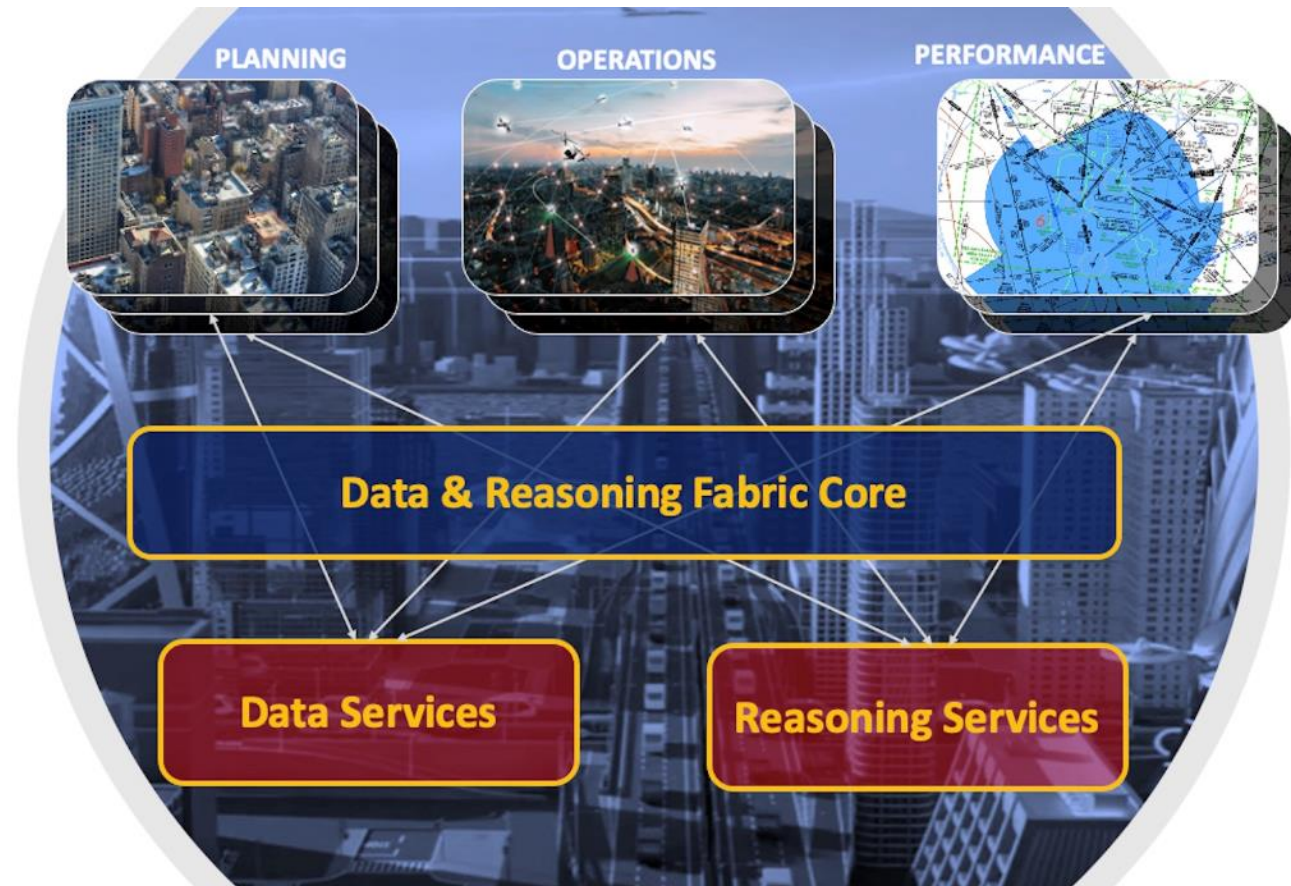
Data & Reasoning Services

Data & Reasoning Fabric – Original Proposed Solution



DRF is envisioned to provide access to data and AI-driven decision support tools to:

- Provide transportation for people and cargo to places previously not served or underserved by aviation.
- Enable increased flights in congested urban areas
- Support the growth of AAM operations that depend on accurate, reliable, and current data



By completion of the DRF CAS Project, provide the information required by ARMD management to make an informed decision whether and how to continue investing in DRF

- [Develop a DRF Accelerator](#) which includes prototype instantiations of key DRF features, including data and reasoning services, a DRF marketplace software architecture sufficient to engage end-user representatives
- [Exercise the DRF Accelerator](#) with representatives of key service providers and end user stakeholder communities in order to demonstrate that the DRF Accelerator provides key data and reasoning functions
- [Assess the DRF Accelerator](#) to determine if the minimum viable system concept (MVSC) can overcome the identified critical barriers across the desirability, viability and feasibility perspectives

Execution (X2) Approach



Community Engagement

Work with the community through workshops, working groups and interviews, in order to refine representative use cases that can be used to validate DRF concepts



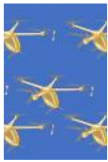
DRF Core

Develop a prototype implementation of the DRF framework and services, in order to enable the rapid deployment of candidate data and reasoning capabilities



Data Services

Develop and functionalize data services and metadata models for DRF data life cycle



Reasoning Services

Leverage DRF Core and data services to develop AI/ML reasoning service demonstration cases



Simulations

Develop, test and evaluate the DRF through simulations

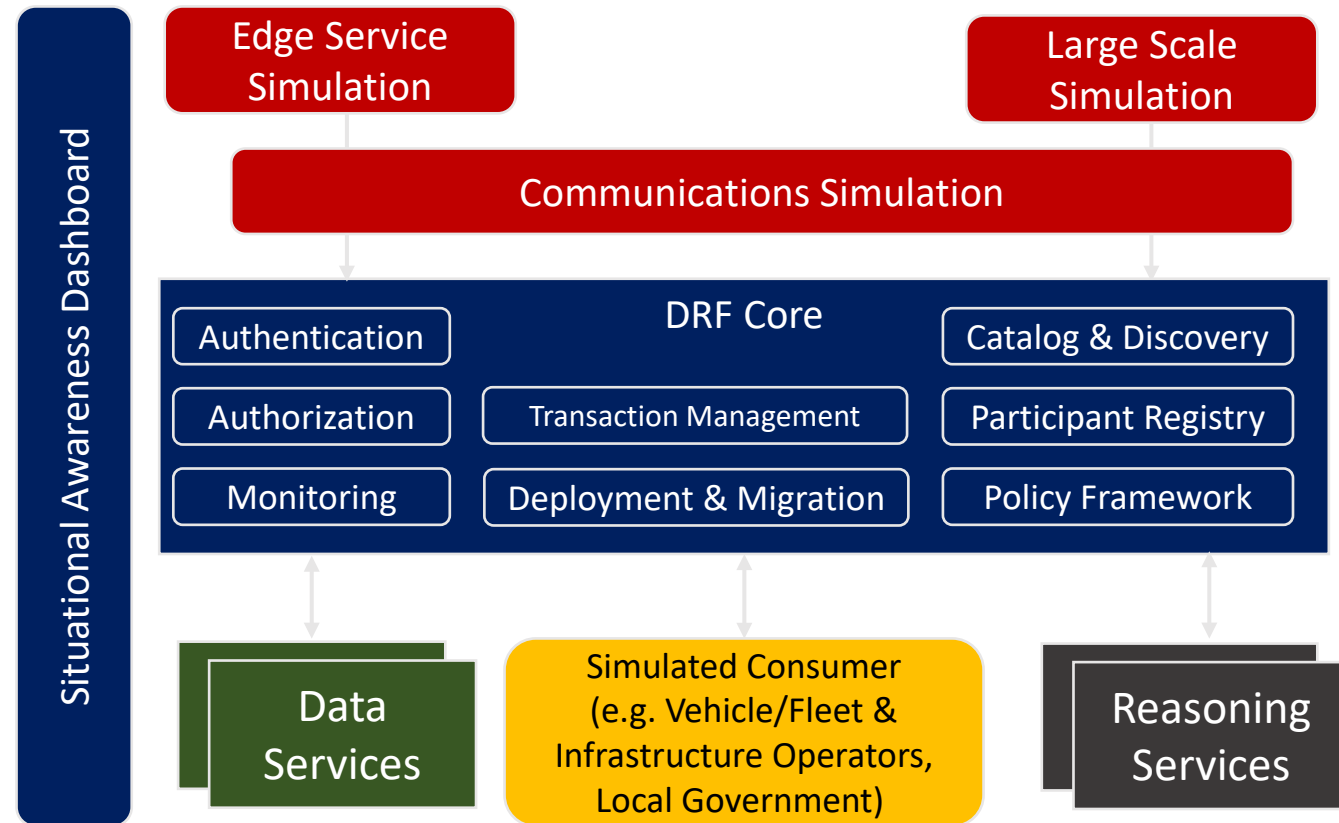


Refinement and Demonstrations

Refine and demonstrate elements of the DRF Core and services to test and evaluate core system functionality

- Work with community stakeholders to refine the use cases that are used to evaluate the DRF and understand requirements needed to support advanced mobility
- Deliver DRF Accelerator
 - DRF Framework
 - DRF Core
 - DRF metadata models and ontology
 - Reference data services
 - Reference reasoning services
 - Simulator
- Deliver a set of community best practices required to make the DRF successful

The DRF framework, data services and reasoning services will guide software development kits (SDK), with associated application program interfaces (API)



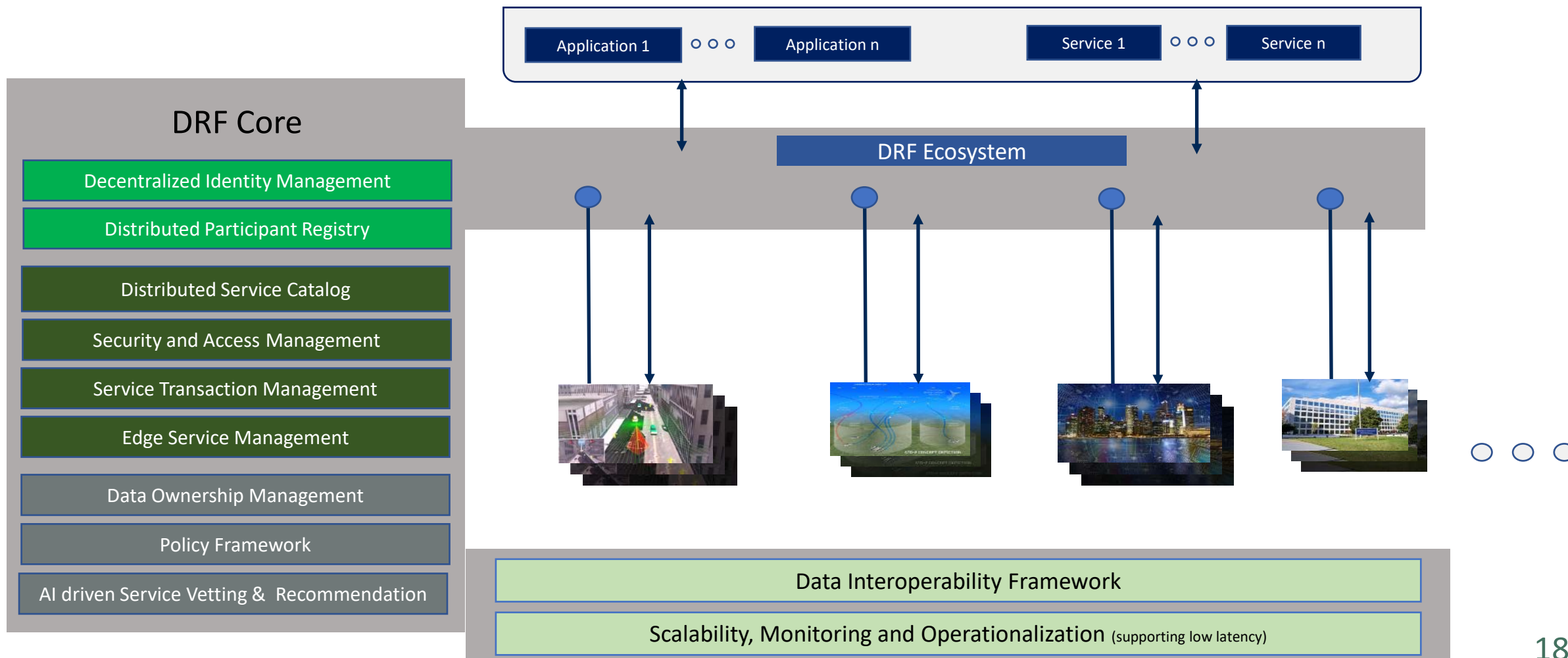
Develop, test and evaluate the DRF through simulations

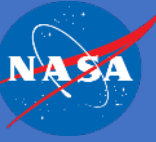
Execution Plan - DRF Core Architecture



DRF – A better way to share data and reasoning

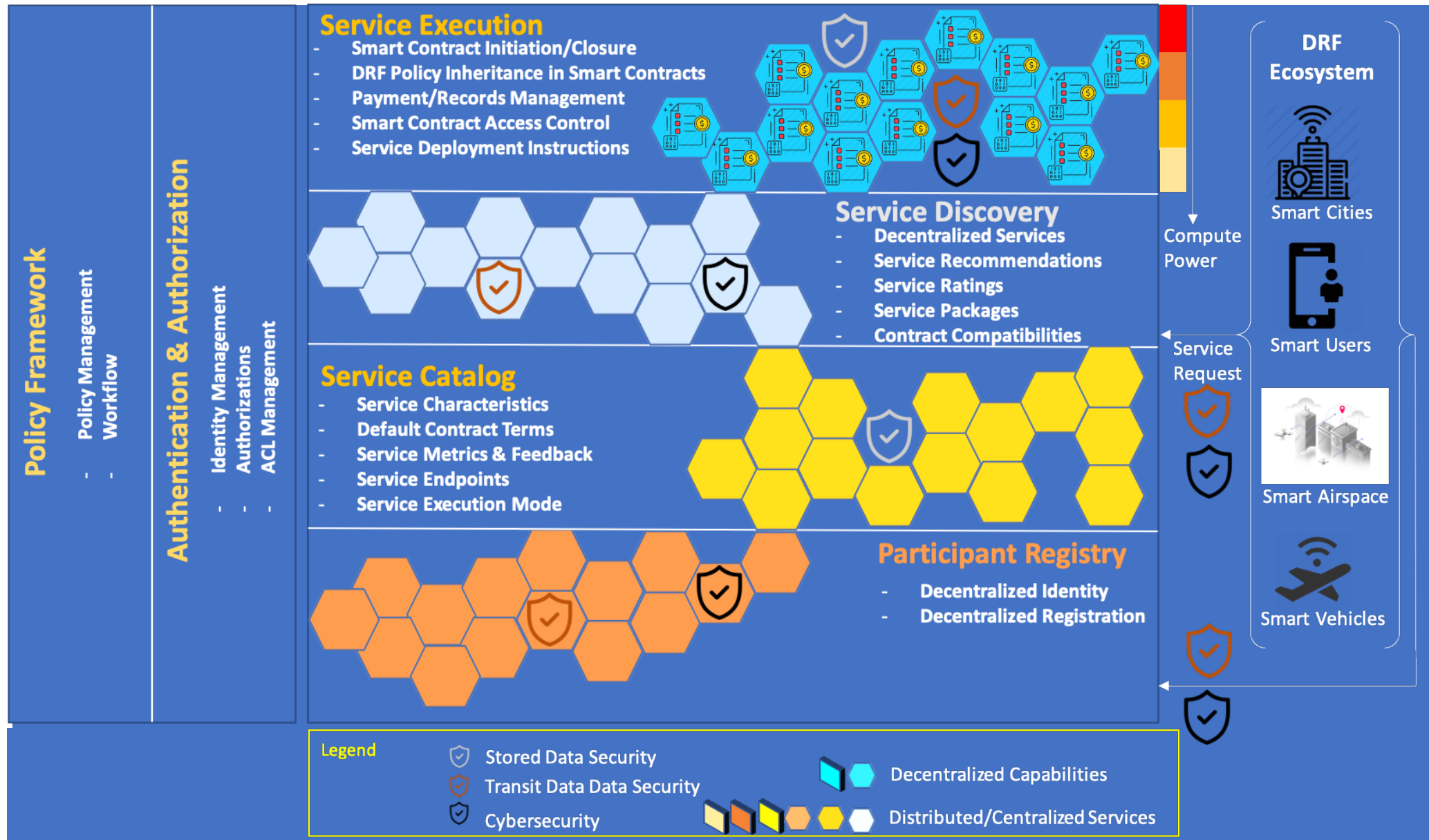
Find, understand, trust and access data and reasoning





- The DRF Opportunity team will engage with internal partners and partners external to NASA to support the completion of its objectives and assess the barriers of the DRF Accelerator.
- The DRF Opportunity team will leverage partnerships with four types of organizations:
 - o Technology providers (Feasibility)
 - o End user organizations (Desirability & Feasibility)
 - o Data service providers (Viability & Feasibility)
 - o Reasoning services providers (Viability & Feasibility)

DRF Core Implementation



- To test the robustness and accuracy of the DRF Accelerator, three field tests were carried out between March 2022 to August 2023:

Field Test	Partner	Episodes
Emergency Response to Wildfires (simulated)	Civil Air Patrol – California Wing	Episode 1: April 26, 2022 Episode 2: May 2, 2022 Episode 3: May 12, 2022 Closeout: May 16, 2022
Drone Medical Delivery (simulated)	Autonomy Association International	Episode 1: February 16, 2023 Episode 2A-B: March 14, 2023
Emergency Response to Wildfires (crewed and UAS flight)	Civil Air Patrol – California Wing	Episode 1: August 16, 2023 Episode 2: August 18-20, 2023 Closeout: September 15, 2023



Civil Air Patrol (CAP) – California Wing (CAWG) operates in coordination with CalFire and other government entities of California in wildfire emergency response.

CAP-CAWG collects aerial imagery data of regions impacted by recent lightning strikes where wildfires are likely to have started.

Wildfire Detection Field Test



The DRF team in collaboration with the California Civil Air Patrol (CAP), executed a field test that identified a preliminary set of data and reasoning service areas that can be enabled and enhanced by DRF to potentially bring forth improved accuracy and reduced latency to CAP's mission critical decision making, in wildfire detection.

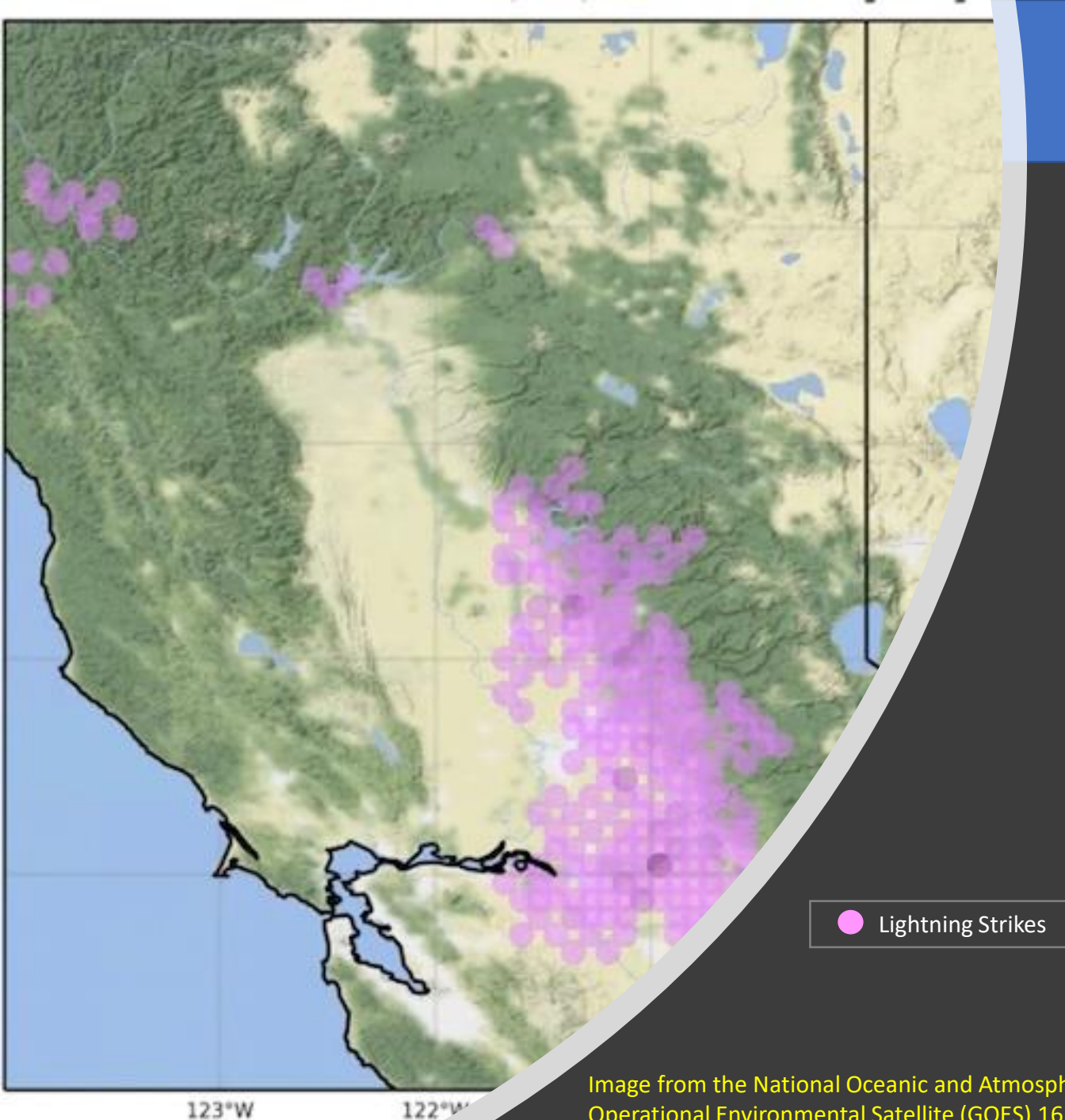
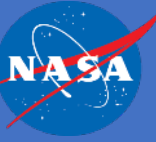


Image from the National Oceanic and Atmospheric Administration (NOAA) Geostationary Operational Environmental Satellite (GOES) 16, a geostationary spacecraft

Enabling Data & Reasoning Service Discovery



Leverage DRF to discover the data or reasoning (AI-driven decision support) services to select region for wildfire detection.

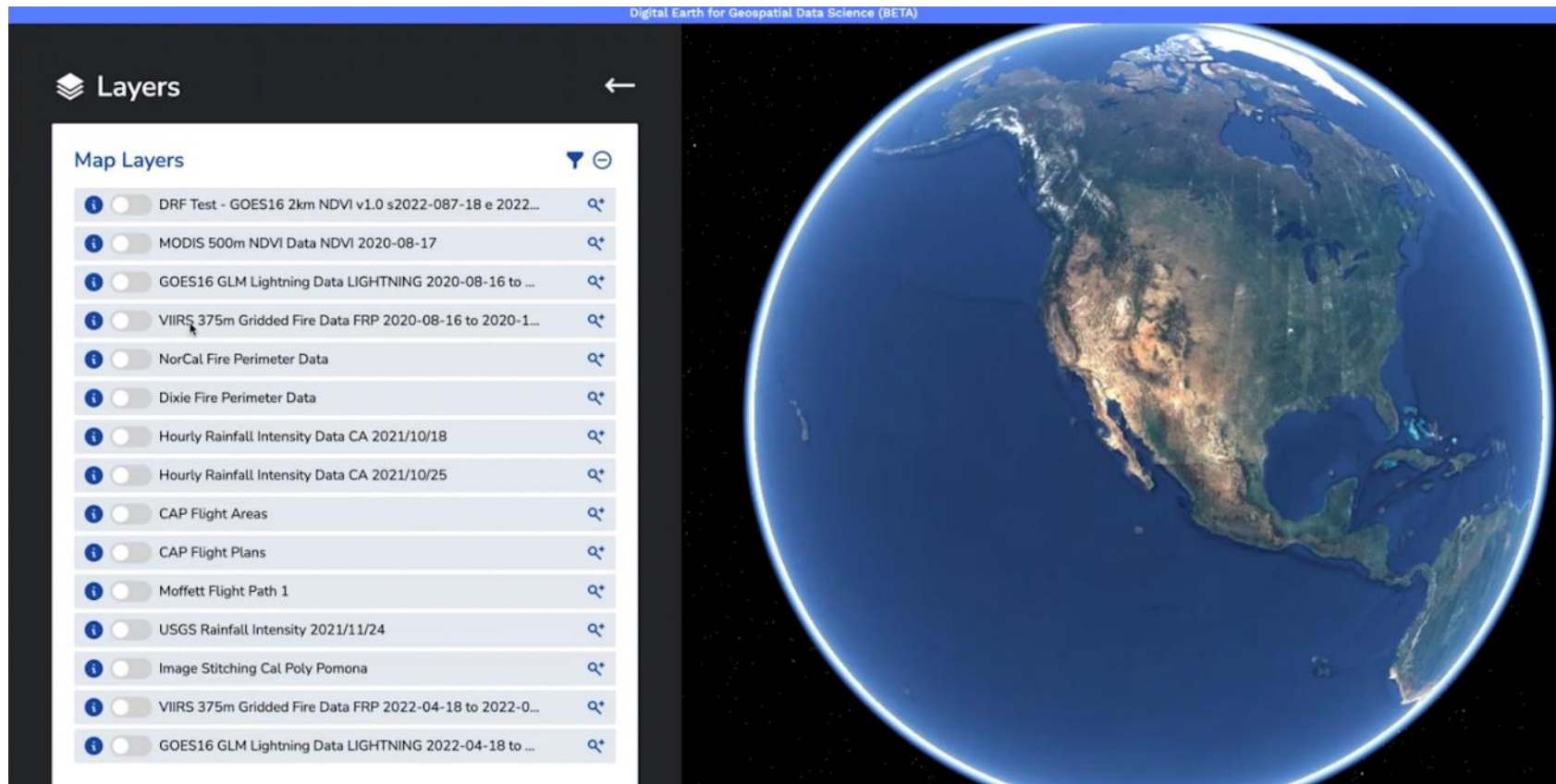


Image from from the National Oceanic and Atmospheric Administration (NOAA) Geostationary Operational Environmental Satellite (GOES) 16, a geostationary spacecraft and Universities Space Research Association (USRA)

Leverage DRF to access weather services, such as lightning strike and terrain data, to select target areas for wildfire detection

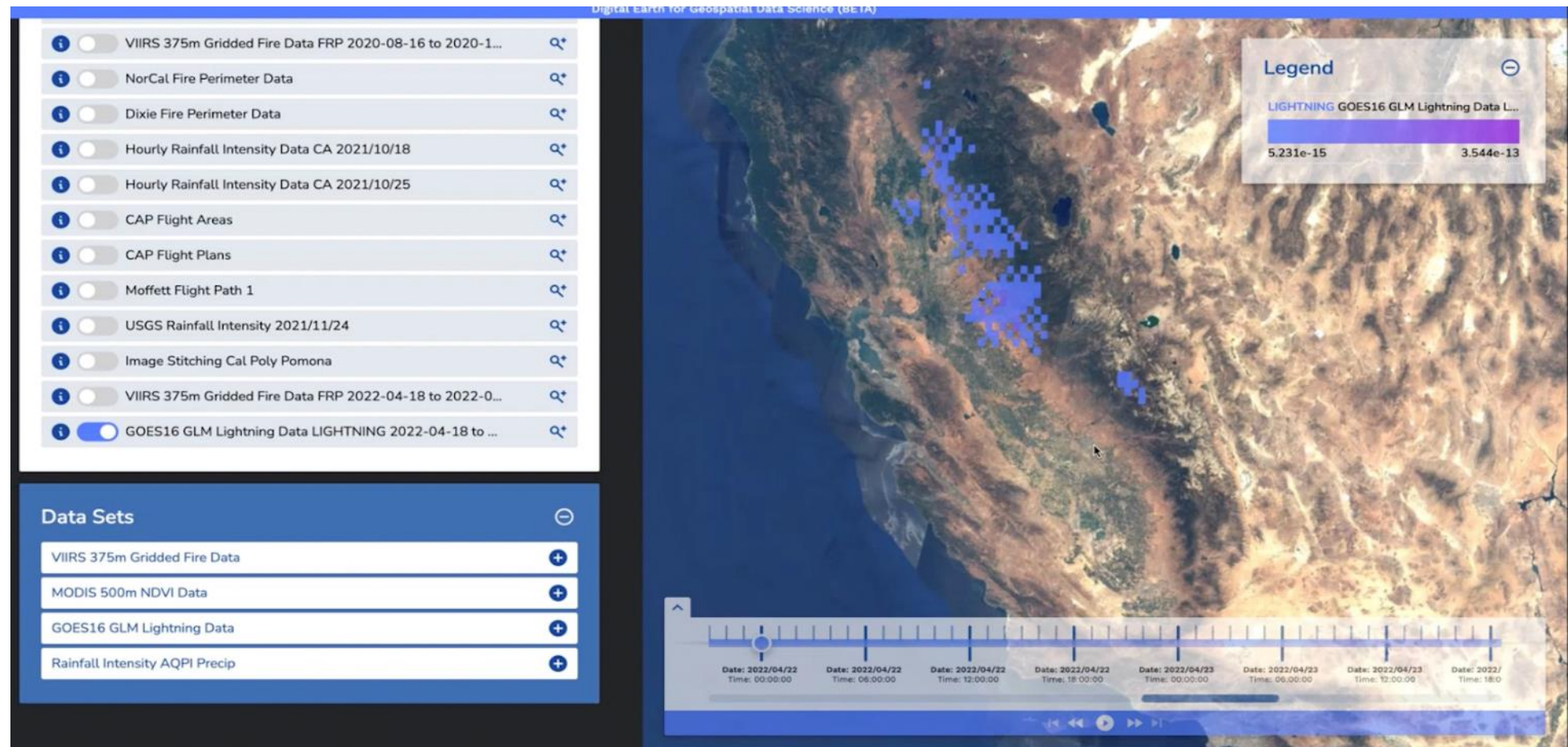


Image from from the National Oceanic and Atmospheric Administration (NOAA) Geostationary Operational Environmental Satellite (GOES) 16, a geostationary spacecraft and Universities Space Research Association (USRA)

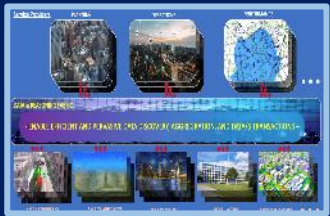
Data & Reasoning Fabric (DRF) – CAP Use Case

Fire Detection Route Planning Field Test with the California Civil Air Patrol

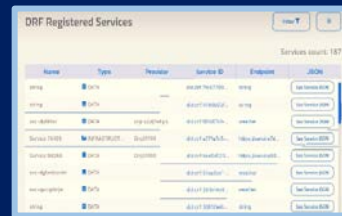


The DRF team in collaboration with the California Civil Air Patrol (CAP), executed a field test that will identify a preliminary set of data and reasoning service areas that can be enabled and enhanced by DRF to potentially bring forth improved accuracy and reduced latency to CAP's mission critical decision making, in wildfire detection.

Registration of Data & Reasoning Services



Registration of Users & Service Discovery



Simulated Lightning Strike



Identification of Fly Target Areas



Identification of Flight Trajectories



Leveraging weather and environmental data and decision support reasoning services to plan wildfire detection missions

Onboarding data & reasoning services

Enabling data & reasoning service discovery

Access weather data services

Interoperable access to diverse data to support reasoning service

Leveraging multiple reasoning services for decision support

Identification of Fly Target Areas

Interoperable access to
diverse data to support target
selection reasoning service



LAUNCH LOCATION (LAT/LON)

MISSION TIME (MINS)

SELECT LOCATION	LOCATION ID	SET PRIORITY	SERVICE TIME (SECS)	REMAINING BATTERY (%)
☒	1	1	40	0
☒	2	1	40	0
☒	3	1	40	0
☒	4	1	40	0
☒	5	1	40	0
☒	6	1	40	0
☒	7	1	40	0
☒	8	1	40	0
☒	9	1	40	0
☒	10	1	40	0

Identification of Flight Trajectories

Leveraging multiple reasoning services for decision support to select flight path for wildfire detection

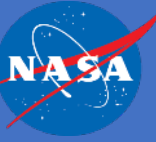


Barrier Progress After CAP Field Test

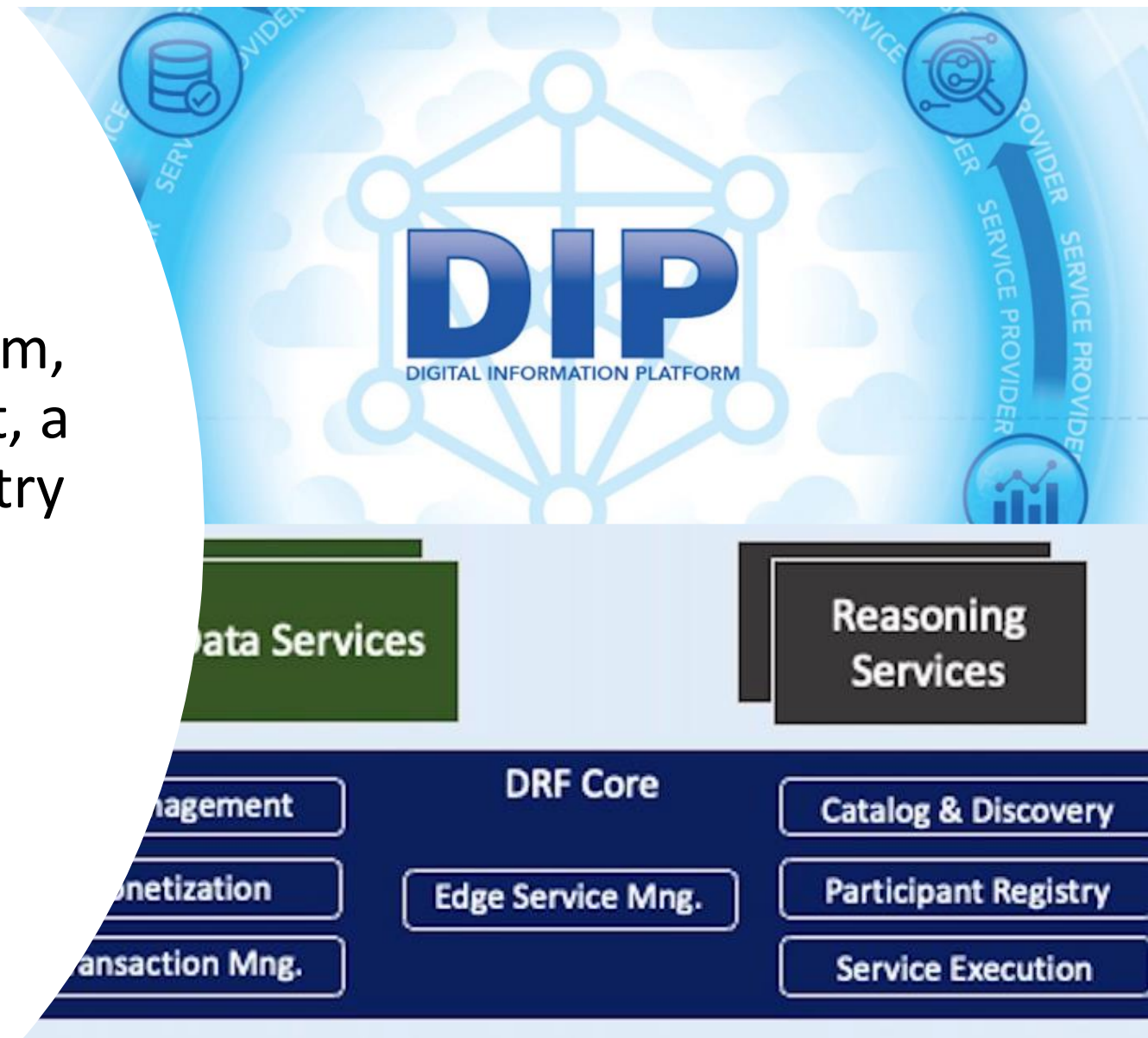


Barrier	Progress
Limited Interoperability	In-Progress
Insufficient Current and Accurate Data Where it is Needed to Make Airspace Operations & Management Decisions	Complete
Adverse Impact to Safety Related Decisions without High-Reliability and Low-Latency Data Interconnect to Edge Computing Devices	Not Started
Reusable Reasoning Services are not Easily Accessible	Complete
Limited Data Standardization	In-Progress
Clear Economic Incentives	In-Progress
Inability to Switch Between Different Service Providers	Not Started

Transition –Digital Information Platform (DIP)



DIP is leveraging multiple DRF concepts as part of its core platform, including the marketplace concept, a service catalog, a participant registry and monetization



Phoenix

DRF ran a Field Test with the Greater Phoenix Metropolitan Area (GPMA) that will help to advance AAM research, based on local community requirements



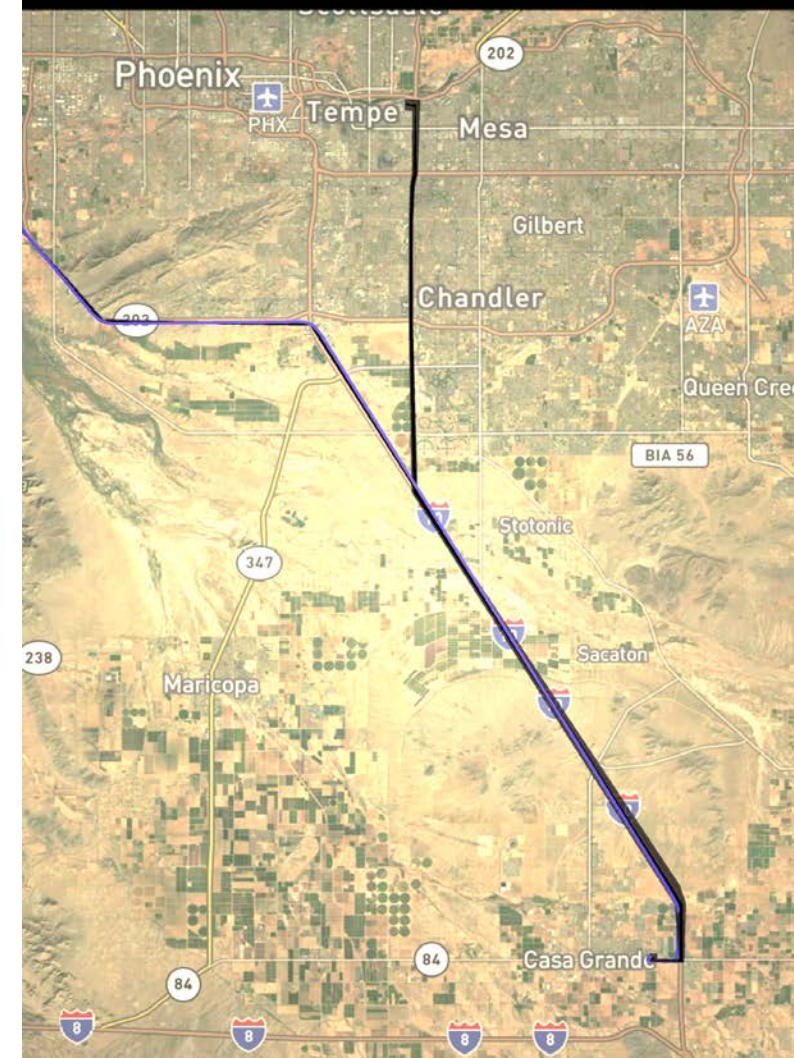
Data & Reasoning Fabric - Greater Phoenix Metropolitan Area



DRF ran a Field Test with the Greater Phoenix Metropolitan Area (GPMA) that will help advance AAM research, based on local community requirements



MISSION VIEW

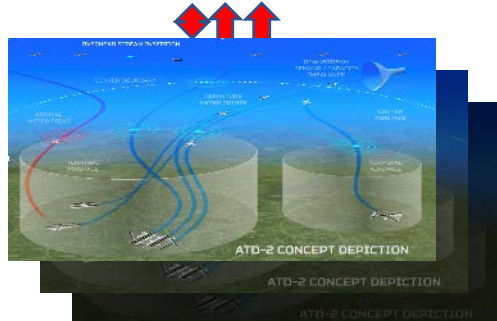


Data & Reasoning Fabric - Greater Phoenix Metropolitan Area



Operator

DATA & REASONING FABRIC



SMART AIRSPACES



SMART CITIES



MICRO-WEATHER

MISSION VIEW

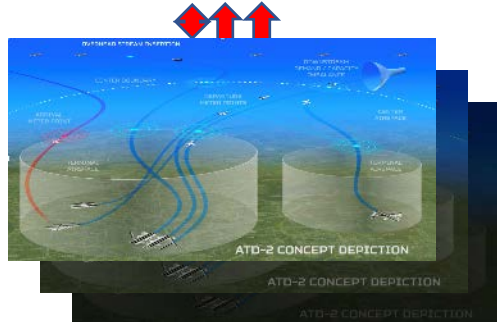


Data & Reasoning Fabric - Greater Phoenix Metropolitan Area



Operator

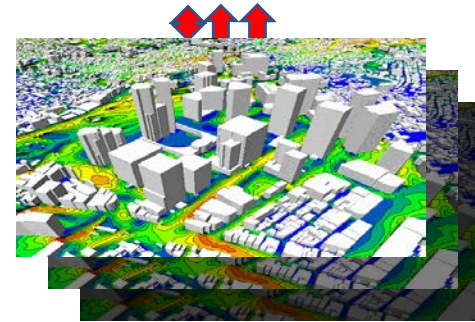
DATA & REASONING FABRIC



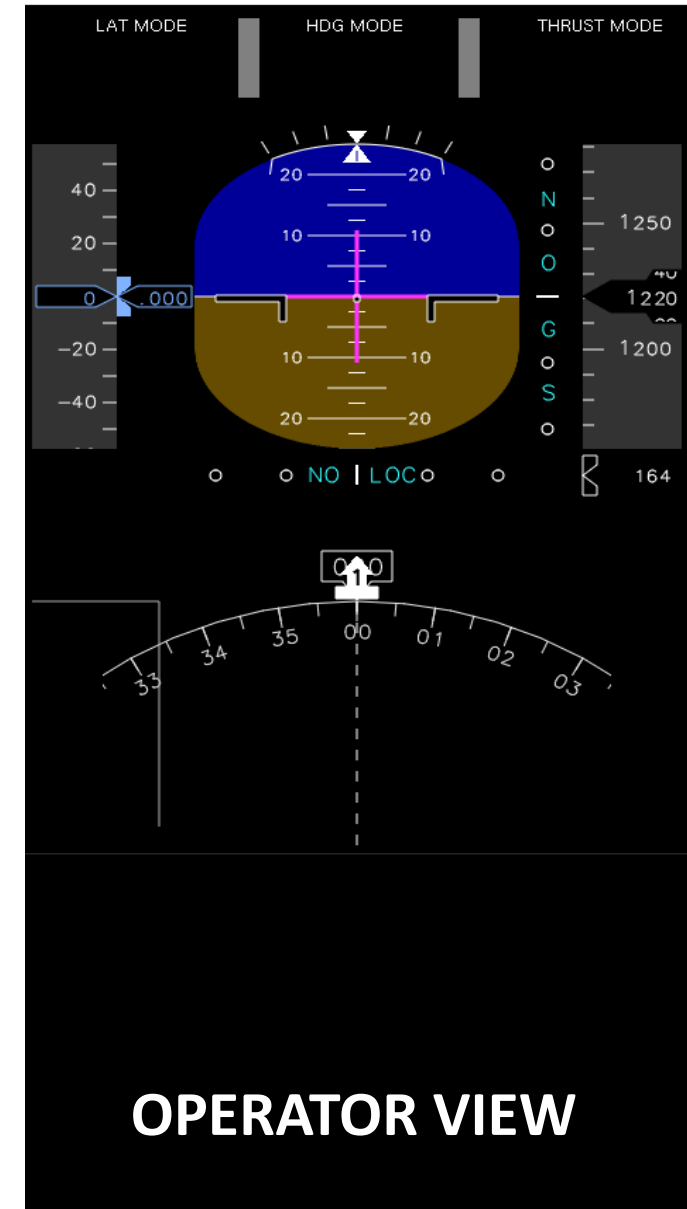
SMART AIRSPACES



SMART CITIES



MICRO-WEATHER



Data & Reasoning Fabric - Greater Phoenix Metropolitan Area



Operator

DATA & REASONING FABRIC

Airspace
Volume
Service

Airspace
Services

Vehicle
Trajectory
Service

(Battery)
Health
Service

Weather
Service

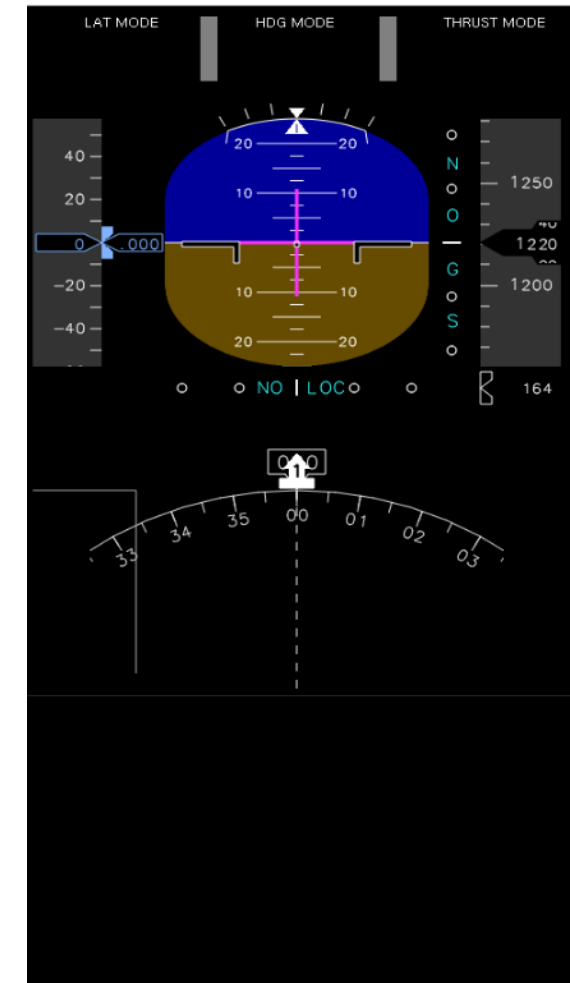
MISSION VIEW



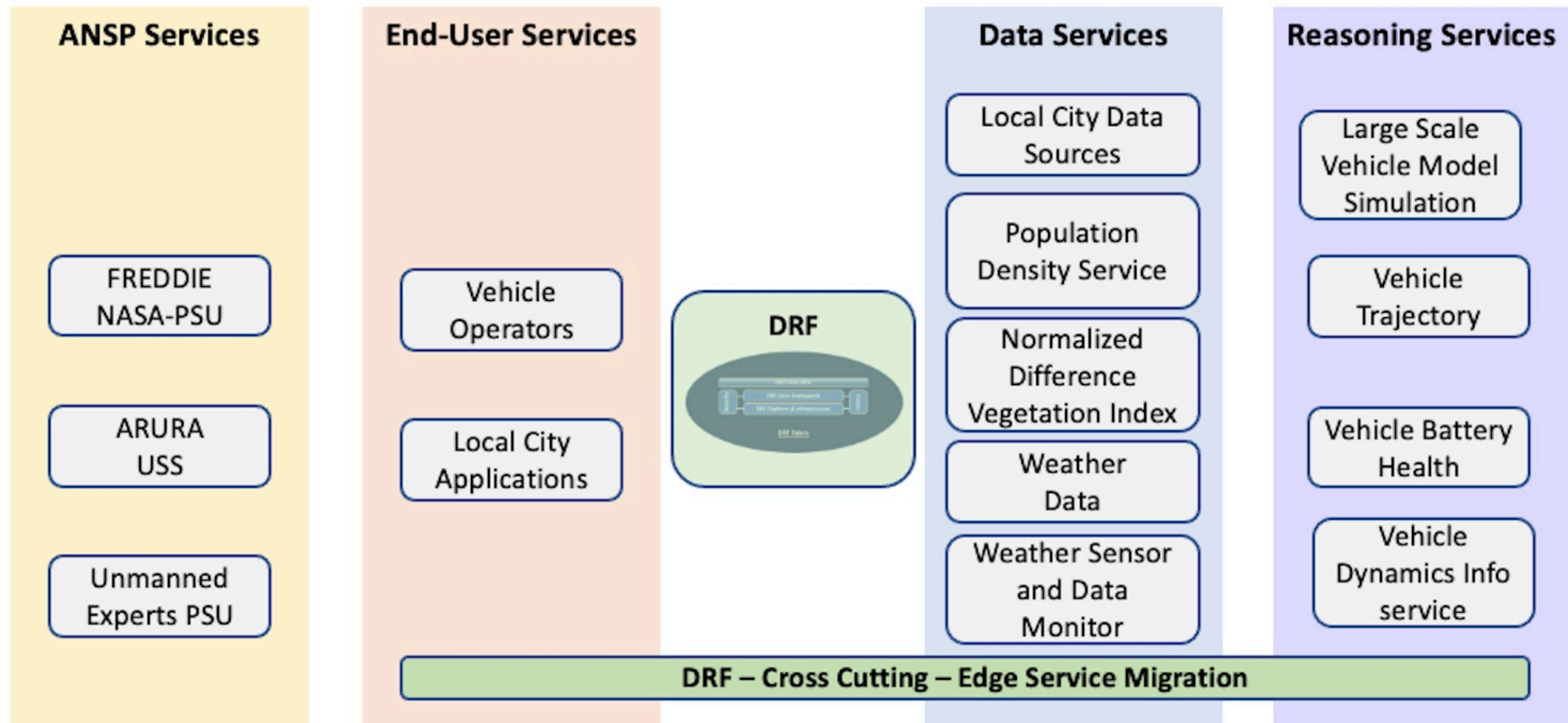
Data & Reasoning Fabric - Greater Phoenix Metropolitan Area



OPERATOR VIEW

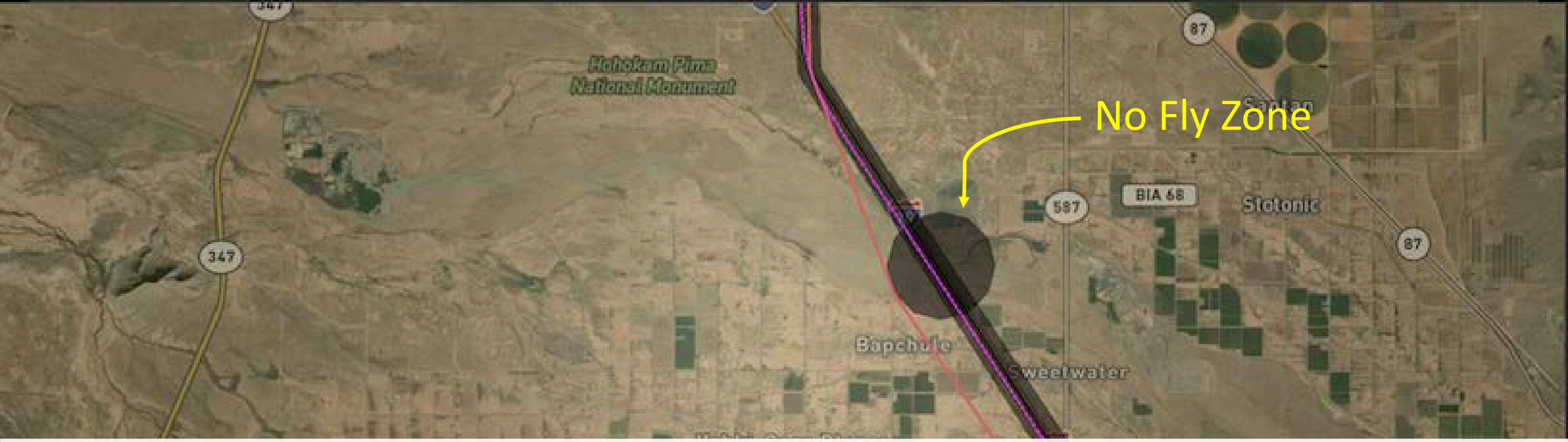


Data & Reasoning Fabric - Greater Phoenix Metropolitan Area

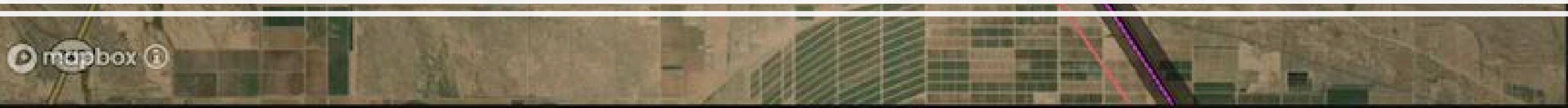


ANSP = Air Navigation Service Provider

AIRCRAFT ID	DEPARTURE LOCATION	DEPARTURE TIME	ARRIVAL LOCATION	ARRIVAL TIME	VEHICLE TYPE	TRAJECTORY	% BATTERY LEFT	EXECUTE TRAJECTORY
NCC1701	111.90W 33.43N	13:40:38	111.71W 32.88N	14:17:50			59%	

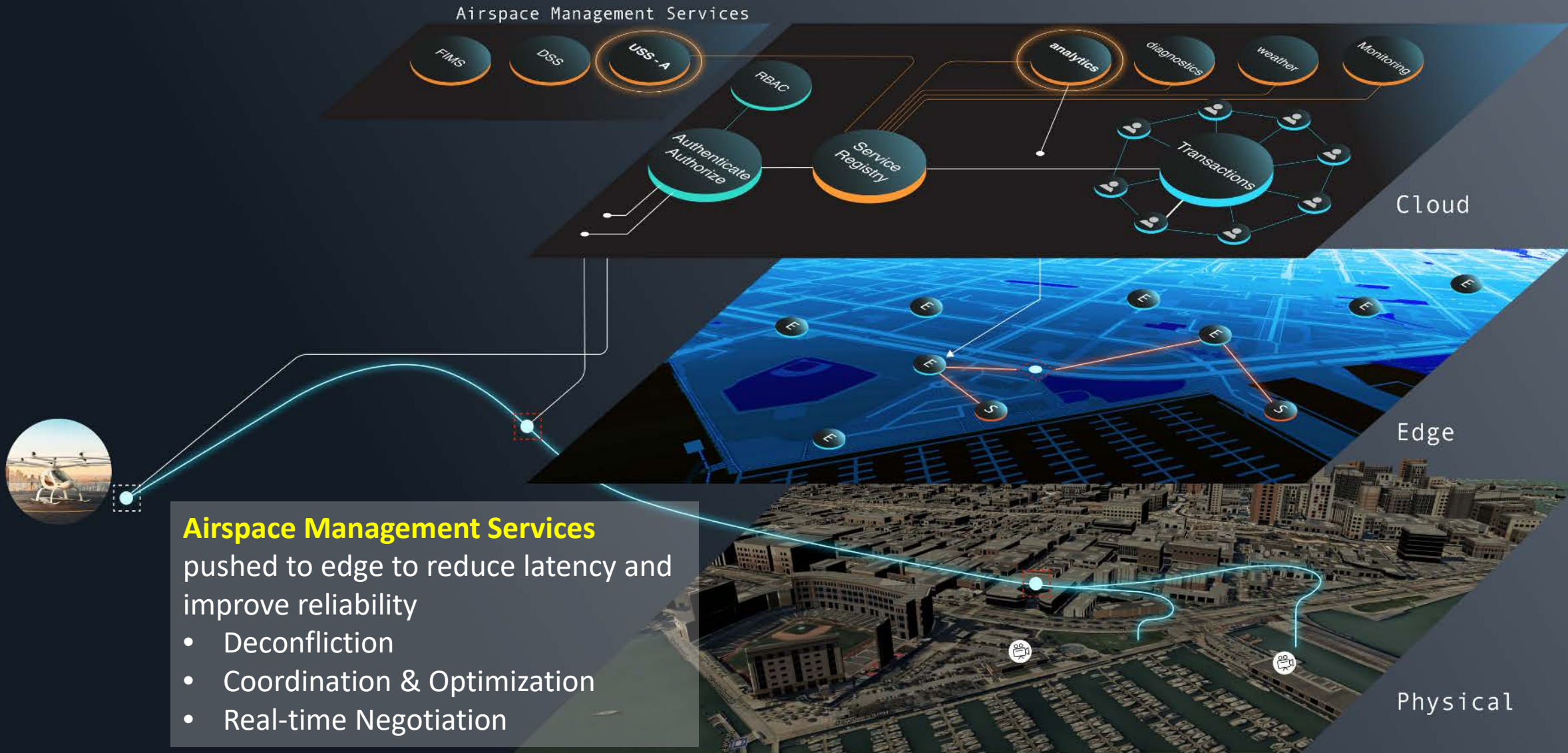


Three use cases selected that require vehicle re-route, while in flight



DRF Architecture

Computing at the Edge



Barrier Progress After GPMA Field Test



Barrier	Progress
Limited Interoperability	Complete
Insufficient Current and Accurate Data Where it is Needed to Make Airspace Operations & Management Decisions	Complete
Adverse Impact to Safety Related Decisions without High-Reliability and Low-Latency Data Interconnect to Edge Computing Devices	Complete
Reusable Reasoning Services are not Easily Accessible	Complete
Limited Data Standardization	In-Progress
Clear Economic Incentives	Complete
Inability to Switch Between Different Service Providers	Complete

Host	IP	Port	Service	Version	OS	Service status
10.10.10.10	10.10.10.10	22	SSH	OpenSSH 7.6p1 Ubuntu	Linux 4.15.0-47-generic	Running
10.10.10.11	10.10.10.11	22	SSH	OpenSSH 7.6p1 Ubuntu	Linux 4.15.0-47-generic	Running
10.10.10.12	10.10.10.12	22	SSH	OpenSSH 7.6p1 Ubuntu	Linux 4.15.0-47-generic	Running
10.10.10.13	10.10.10.13	22	SSH	OpenSSH 7.6p1 Ubuntu	Linux 4.15.0-47-generic	Running
10.10.10.14	10.10.10.14	22	SSH	OpenSSH 7.6p1 Ubuntu	Linux 4.15.0-47-generic	Running
10.10.10.15	10.10.10.15	22	SSH	OpenSSH 7.6p1 Ubuntu	Linux 4.15.0-47-generic	Running
10.10.10.16	10.10.10.16	22	SSH	OpenSSH 7.6p1 Ubuntu	Linux 4.15.0-47-generic	Running
10.10.10.17	10.10.10.17	22	SSH	OpenSSH 7.6p1 Ubuntu	Linux 4.15.0-47-generic	Running
10.10.10.18	10.10.10.18	22	SSH	OpenSSH 7.6p1 Ubuntu	Linux 4.15.0-47-generic	Running
10.10.10.19	10.10.10.19	22	SSH	OpenSSH 7.6p1 Ubuntu	Linux 4.15.0-47-generic	Running
10.10.10.20	10.10.10.20	22	SSH	OpenSSH 7.6p1 Ubuntu	Linux 4.15.0-47-generic	Running



Onboarding data & reasoning services

Enabling data & reasoning service discovery

Access weather data services

Interoperable
access to diverse
data to support
reasoning service

Leveraging multiple reasoning services for decision support



Civil Air Patrol (CAP)

- CAP's Air Mobility Missions:
 - o CAP operates manned and unmanned flights, in coordination with CalFire and other government entities in the state of California, to collect aerial imagery data of regions sustaining recent lightning strikes and, therefore, are more likely to have a fire started there.
 - o Additionally, CAP provides mission support in search and rescue operations, and cadet training programs.





CAP – NASA DRF Partnership

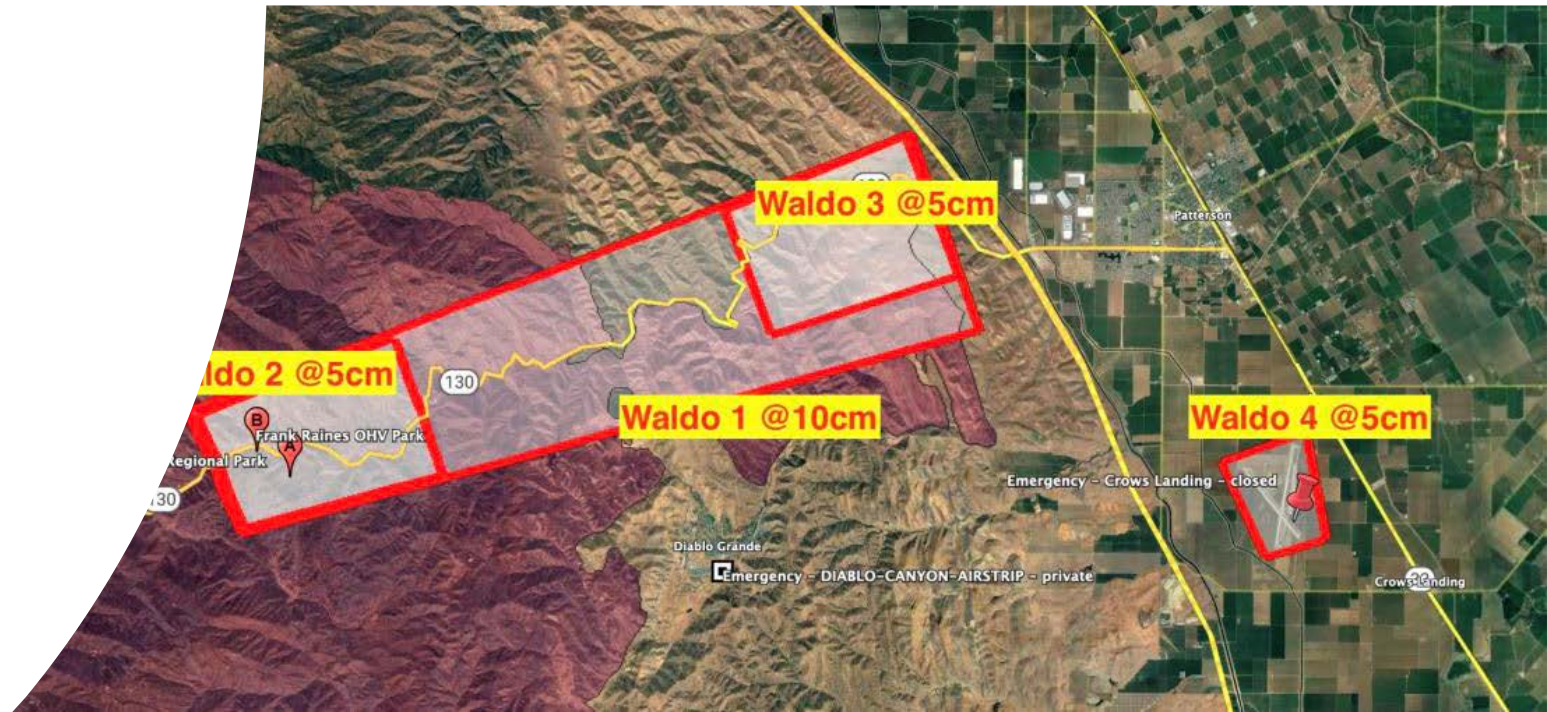
Data-Driven Decision Making for Emergency Response and Training Missions

- Technology Fit for NASA DRF:
 - o DRF is based on an open foundational ecosystem of data and reasoning exchange between systems that must seamlessly interplay to manage complex and/or dense airspace operations.
- Current Pain Points and Bottlenecks in CAP Missions:
 - o Timely access to holistic data for mission-specific decision making
 - o Availability of ready-to-use data processing services for actionable information gathering
 - o Mission framework structuring and automation

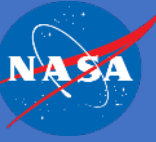


Selected Investigation Test Site: Santa Clara Unit (SCU) Lightning Fire

- SCU lightning complex fire burnt 393,624 acres during August September of 2020, making it the fourth largest overall wildfire recorded in California's modern history.
- 3 potential fire mockup sites are selected for investigation during the 18th, 19th and 20th of August 2023



DRF Support Scope for CAP Mission

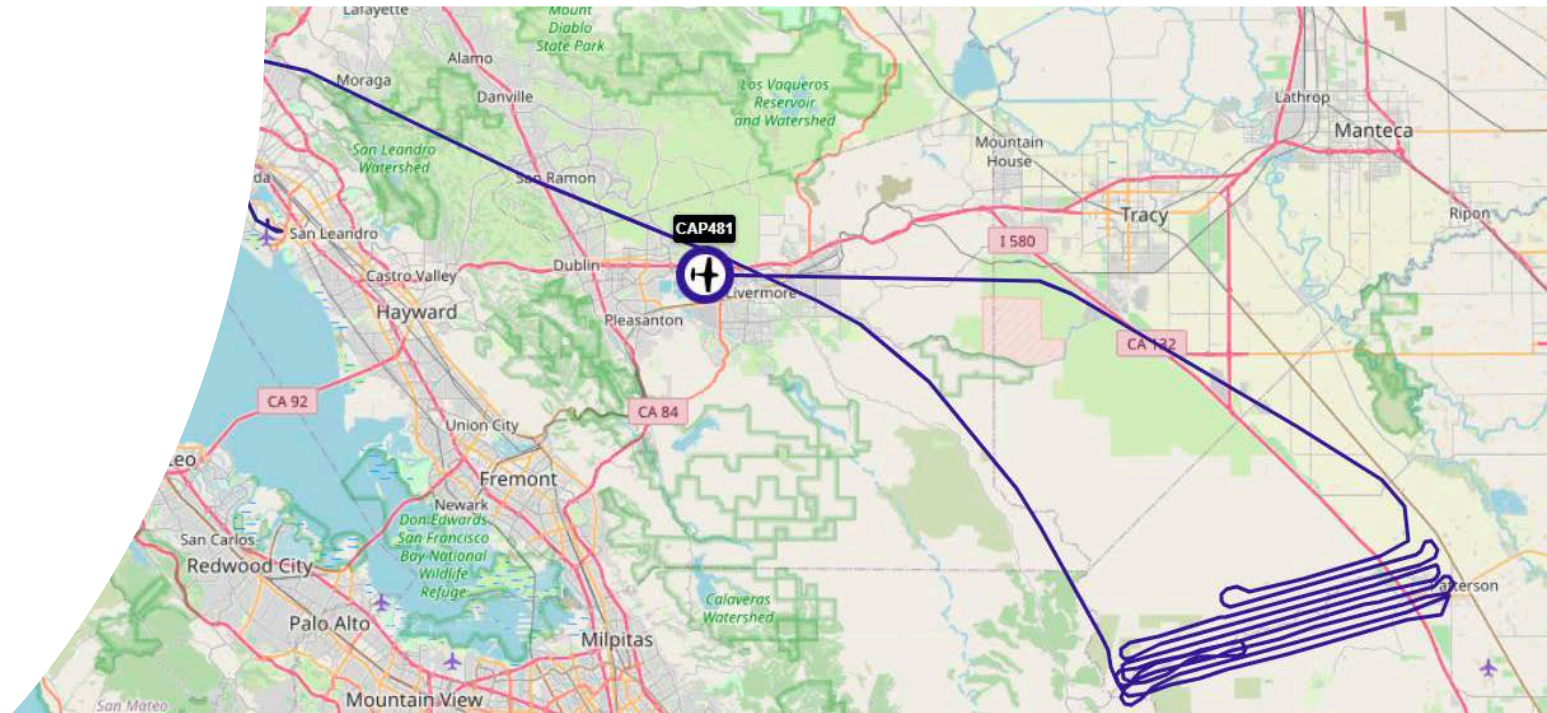


To support the lightning induced fire detection flight mission of CAP, the use of the DRF aims to facilitate:

- **PRE FLIGHT: Streamlined access to decision support data that includes:**
 1. Lightning strike data [sourced from the GOES 16 and GOES 17 satellites managed by NASA/NOAA]
 2. Normalized Difference Vegetation Index (NDVI) data [sourced from GOES satellite]
 3. Existing fire data [sourced from the VIIRS equipment onboard the Suomi NPP satellite]
 4. Weather data [sourced from openweathermap.org data]
 5. Wind data [sourced from openweathermap.org data]
 6. Population density data [sourced from US Census Bureau data]
 7. Route planning [internally developed by NASA DRF team]
- **IN FLIGHT: Coordinated information gathering and exchange among flight entities for:**
 1. Detection and processing of fire markers [internally developed by NASA DRF team]
 2. Notification of mission status and task assignments [internally developed by NASA DRF team]
- **POST FLIGHT: Information sharing for the fire response team that includes:**
 1. Publishing of actionable data [internally developed by NASA DRF team]



Crewed Aircraft Track



Crewed Flight Imagery Analysis



50 Mega Pixel High resolution (8688 x 5792) image captured by the XCAM Ultra50



Segmented image
(1086 pixels x 724 pixels) for processing



Detection of suspicious area

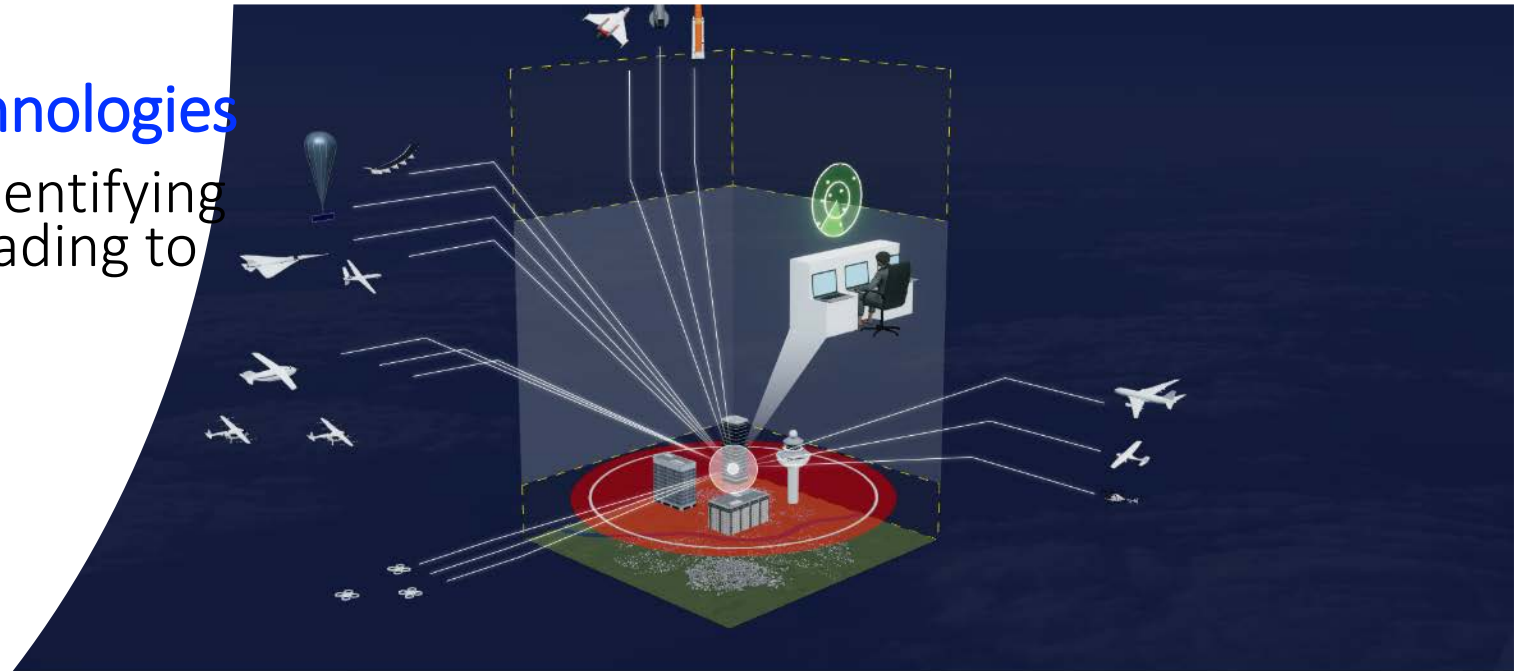


What's NExCT



NAS Exploratory Concepts and Technologies

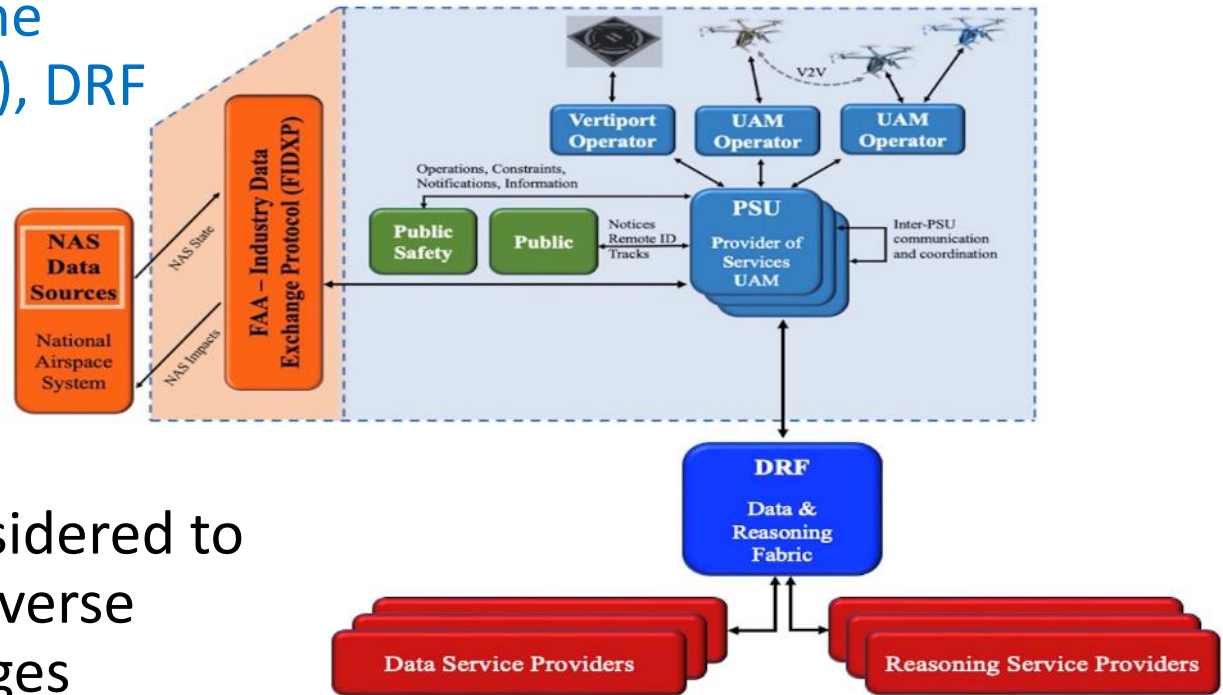
Leveraging digital technologies and identifying commonality across xTM domains, leading to an integrated Sky for All



Transition – ATM-X Extensible Traffic Management (xTM)



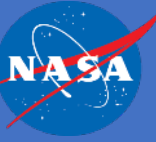
- Located in between the PSUs or USSs and the supplemental data service providers (SDSPs), DRF facilitates:
 - Discovery
 - Accessibility
 - Accountability
 - Interoperability
- Within ATM-X, DRF technology is being considered to support decentralized data exchanges for diverse extensible traffic management data exchanges



- **Discovery and Synchronization Service (DSS):**

- o The purpose of the DSS is to discover relevant operations and to ensure information that is shared and distributed in a federated network is synchronized to enable a Common Operating Picture
- o The current DSS represents a technical risk to future UAM efforts, DRF is considering proposing to expand DRF capabilities to meet UAM DSS requirements and find commonalities across xTM domains

Transition Status - External



- **Autonomy Association International (AAI) (Phoenix Partner)**

- Pending DRF open-source release, AAI plans to leverage DRF for community problems
- In the long term, AAI is interested building a community, based on DRF technology to solve customer problems, across multiple domains



- **Active Digital Twin Coalition**

- Active Digital Twins will be developed within Public-Private Partnership (P3) Data Exchange leveraging Open Standards and supporting commercial transactions.
- In North Texas, the Active Digital Twin Coalition is hoping to utilize DRF technologies to solve data exchange problems in support of improving citizen living and creating economic opportunity.



- **Resilienx**

- Resilienx has developed software that monitors the health and performance of complex systems and has been working with NASA ARMD projects on UTM and UAM initiatives.
- Pending DRF open-source release, Resilienx plans to leverage DRF to meet planned requirements, based on decentralized or diverse UTM data exchanges



Partner Opportunities - External



- NASA Aerosciences Evaluation and Test Capabilities (AETC)

- o AETC is providing funding to pilot DRF to to solve a distributed wind tunnel data integration issues

- Coral Gables

- o Coral Gables, FL possesses a considerable inventory of sensors and data sources around Smart City, Emergency Management.

- George Mason University

- o National Capital Region Project - Model drones as a First Responder system addressing major traffic incidents



Publications & Knowledge Disseminations



Year	Presentation/Paper Title	Author(s)	Report/Patent/ Document ID	Event(s) / Conference, etc.
2019	Air Mobility Data & Reasoning Fabric	Van Dalsem, W., Shetye, S., Das, A., Krishnakumar, K., Lozito, S., Freeman, K., Swank, A., Dorais, G. A.	NTRS: 20190033259	Series of presentations to various audiences
2020	A Data & Reasoning Fabric to Enable Advanced Air Mobility	Van Dalsem, W., Shetye, S., Das, A., Krishnakumar, K., Lozito, S., Freeman, K., Swank, A., Shannon, P., Tomljenovic, L.,	AIAA 2021-2033 Session: Data and Reasoning Fabric to Enable Advanced Air Mobility https://doi.org/10.2514/6.2021-2033	AIAA SciTech Forum, January 2020
2020	Data & Reasoning Fabric	Van Dalsem, W., Shetye, S., Das, A., Krishnakumar, K., Lozito, S., Freeman, K., Swank, A.,	NTRS: 20205005501	Outreach presentation for a meeting with Verizon
2020	Data & Reasoning Fabric Overview	Van Dalsem, W., Shetye, S., Freeman, K., Shannon, P.,	NTRS: 20205007964	Presentation for public meetings

Publications & Knowledge Disseminations (Continued)



Year	Presentation/Paper Title	Author(s)	Report/Patent/ Document ID	Event(s) / Conference, etc.
2020	Data and Reasoning Fabric (DRF) Phase I & Phase II Report	Van Dalsem, W., Shetye, S., Das, A., Krishnakumar, K., Lozito, S., Freeman, K., Swank, A., Shannon, P., Tomljenovic, L.,	NTRS: 20205011322	AIAA SciTech Forum
2020	Air Mobility Data & Reasoning Fabric	Van Dalsem, W., Shetye, S., Das, A., Krishnakumar, K., Lozito, S., Freeman, K., Swank, A., Dorais, G. A.	NTRS: 20205002456	Presentation for meeting with San Jose State University
2021	CAP – NASA DRF Wildfire Mitigation Partnership	Van Dalsem, W., Freeman, K., Das, A.,	NTRS: 20210015196	NASA ARMD Wildfire Management Workshop

Publications & Knowledge Disseminations (Continued)



Year	Presentation/Paper Title	Author(s)	Report/Patent/ Document ID	Event(s) / Conference, etc.
2021	"Data & Reasoning Fabric Minimum Viable Product,"	Van Dalsem, W., Freeman, K., Shetye, S., Das, A., Krishnakumar, K., Swank, A., Shannon, P., Tomljenovic, L., Lozito, S., Euler, H., Kaur, S., Wong, C., O'Brien, J.,	AIAA 2021-2386 Session: Machine Learning and Big Data Applications to Air Transportation I https://doi.org/10.2514/6.2021-2386	AIAA Aviation 2021 Forum, 2021.
2021	Data & Reasoning Fabric (DRF) Outreach	Van Dalsem, W., Freeman, K., Shetye, S., Das, C. A. N., Krishnakumar, K. S., Kaur, S., O'Brien, J., Wong, C., Carbajal, K.,	NTRS: 20210020090	NASA DRF Website

Publications & Knowledge Disseminations (Continued)



Year	Presentation/Paper Title	Author(s)	Report/Patent/ Document ID	Event(s) / Conference, etc.
2021	DRF: A Software Architecture for a Data Marketplace to Support Advanced Air Mobility	Abdelbaky, M., Chen, J., Fedin, A., Freeman, K., Gurram, M., Ishihara, A., Joe-Wong, C., Knight, C., Krishnakumar, K., Reyes, I., Robinson, C., Shannon, P., Shetye, S., Tomljenovic, L., Van Dalsem, W.	AIAA 2021-2387 Session: Machine Learning and Big Data Applications to Air Transportation I https://doi.org/10.2514/6.2021-2387	AIAA Aviation 2021 Forum, 2021.
2022	NASA Data & Reasoning Fabric e-brochure	Freeman, K., Shetye, S., Das, C. A. N., Krishnakumar, K. S., Kaur, S., Wong, C.	NTRS: 20220004936	NASA DRF Website
2022	NASA Data and reasoning Fabric	Freeman, K., Shetye, S., Das, C. A. N., Krishnakumar, K. S., Kaur, S., Wong, C.	NTRS: 20220010954	EAA Airventure Oshkosh 2022

Publications & Knowledge Disseminations (Continued)



Year	Presentation/Paper Title	Author(s)	Report/Patent/ Document ID	Event(s) / Conference, etc.
2022	An Approach to Reasoning Service Migration in Data and Reasoning Fabric (DRF) Implementation	Kalmanje S., K., Schuet, S., Stepanyan, V.	AIAA 2022-0787 Session: Autonomy I https://doi.org/10.2514/6.2022-0787	AIAA SCITECH 2022 Forum
2023	Reasoning Service Exemplars for NASA's Data and Reasoning Fabric	Baculi E., J., Hosagrahara, V., Jarvis, K., Kalmanje S., K., Schuet, S., Stepanyan, V.	AIAA 2023-1658 Session: Autonomy III https://doi.org/10.2514/6.2023-1658	AIAA SCITECH 2023 Forum
2023	"DRF - Meet the Team" "DRF - Additional Concepts" "Data & Reasoning Fabric (DRF)" "DRF Intern Highlights"	Freeman, K., Kaur, S., Sullivan, F.,	NTRS: 20230001870 20230001922 20230001871 20230001869	2nd Annual ImaginAviation Conference

Publications & Knowledge Disseminations (Continued)



Year	Presentation/Paper Title	Author(s)	Report/Patent/ Document ID	Event(s) / Conference, etc.
2023	"Data & Reasoning Fabric (DRF)" video – Supreet Kaur "Data & Reasoning Fabric (DRF)" video – Kalmanje Srinivas Krishnakumar "Data & Reasoning Fabric (DRF)" video – Kalmanje Srinivas Krishnakumar Data and Reasoning Fabric (DRF): Wildfire Detection Field Test with the California Civil Air Patrol (CAP) presentation	Freeman, K., Kaur, S., Kalmanje S., K.	NTRS: 20230000135 20230000136 20230000134 20230000132	One Giant Leap for Machine Kind Workshop (Phoenix, AZ)
2023	Data & Reasoning Fabric (DRF)	Freeman, K.,	NTRS: 20230010338	NASA Community College Aerospace Scholars



DRF

Data & Reasoning Fabric

enabling the full potential of future air mobility

<https://drf.nasa.gov>