National Aeronautics and Space Administration
NASA
NASA-JetBlue Airways Technical Interchange
DIP
DIGITAL INFORMATION PLATFORM
SERVICE PROVIDER
SWIM
Weather
January 11th, 2023

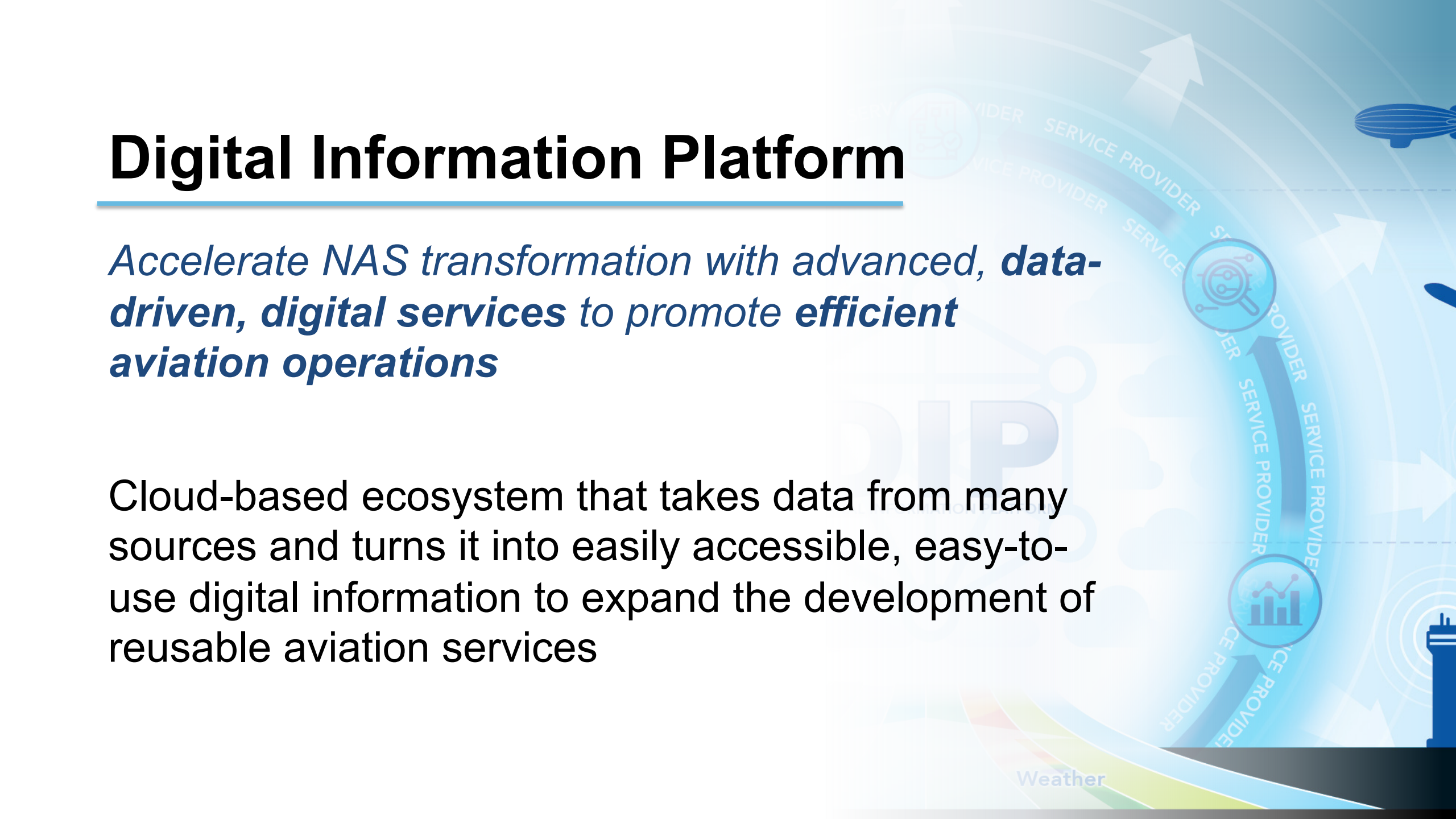
DIP Overview

Mirna Johnson

Digital Information Platform

Accelerate NAS transformation with advanced, ***data-driven, digital services*** *to promote* ***efficient aviation operations***

Cloud-based ecosystem that takes data from many sources and turns it into easily accessible, easy-to-use digital information to expand the development of reusable aviation services



Stakeholder Needs

Increase Access to NAS Information	Easy access to organized airspace data and information **Common, simplified API** to fused information
Improved Data Quality	**Trusted** and **reliable** data sources with safeguards Unified, aggregated, and **validated data** for consumption
High Reuse Solutions	Support **data-driven predictive** models **Scalable** and **adaptable** services
Commercialization Methodology	Architecture that **connects high reuse solutions** for exchange of services and information to create an ecosystem
Services for Efficiency and Sustainability	Advanced services to increase efficiency and predictability Digital Re-route, disruption management, trajectory optimization, etc

Sept – Nov 2019 - collected formulative input from **airline operators, airport operators, NBAA, FAA and vendor groups**.

March 2021 - DIP published a **Request for Information**; Received over 40 responses from flight operators, service providers, data integrators from traditional and emerging operations stakeholders

DIP Benefits

Data Integration
Faster Service development with fused data for simpler integration

Search & Discover
Ready to-use Services made available

Sustainability
Enable services for sustainable aviation operations

DIGITAL INFORMATION PLATFORM ECOSYSTEM
Larger airspace cohort to provide services with secure access

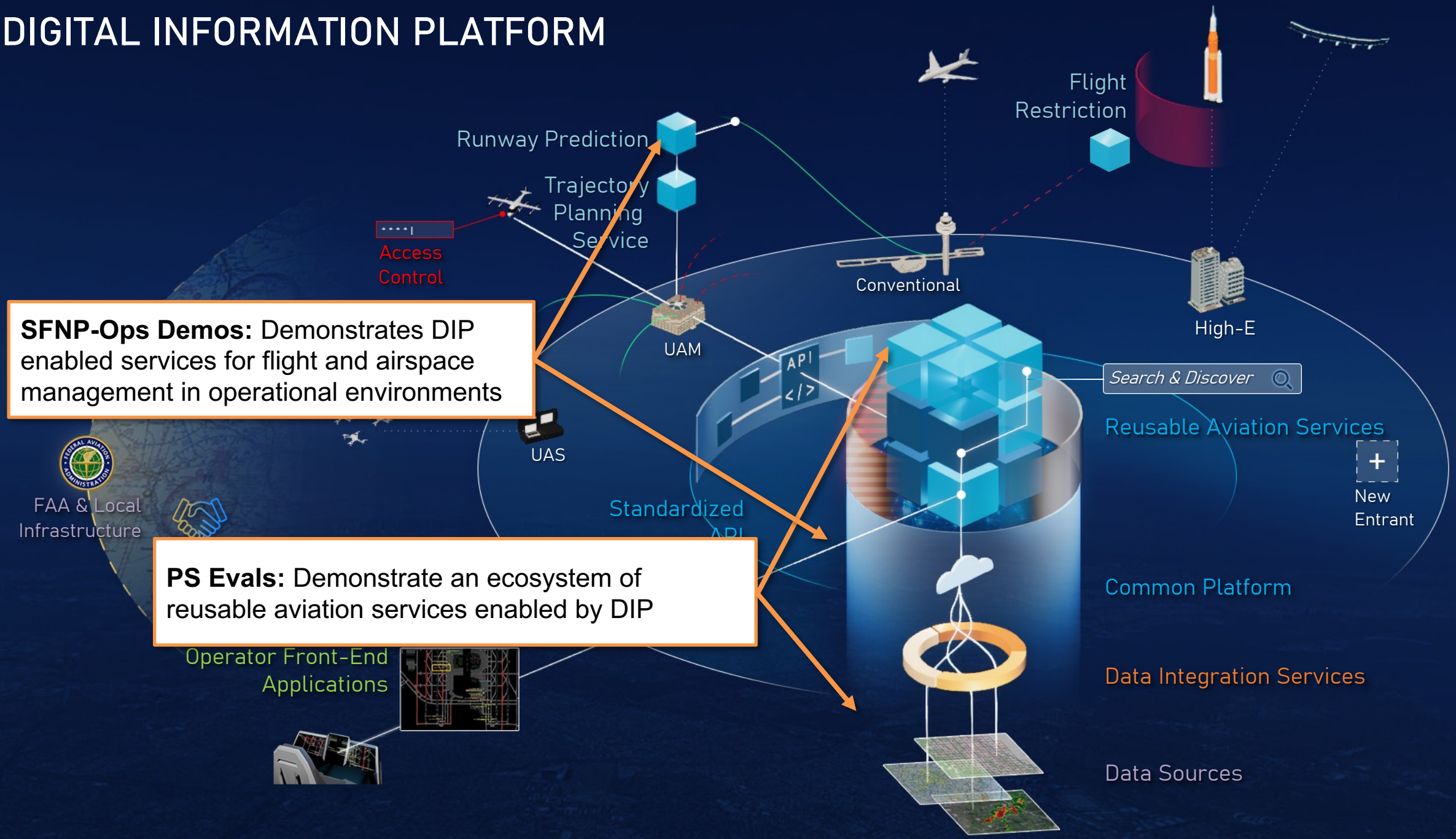
Advanced Technologies
Accelerate Innovation to improve adaptability and extensibility of services

Trusted Information
Reliable quality information with transparency and performance monitoring

Reusable Services
Building blocks for advanced services

Improve access and usability of NAS digital services for operator decision support tools

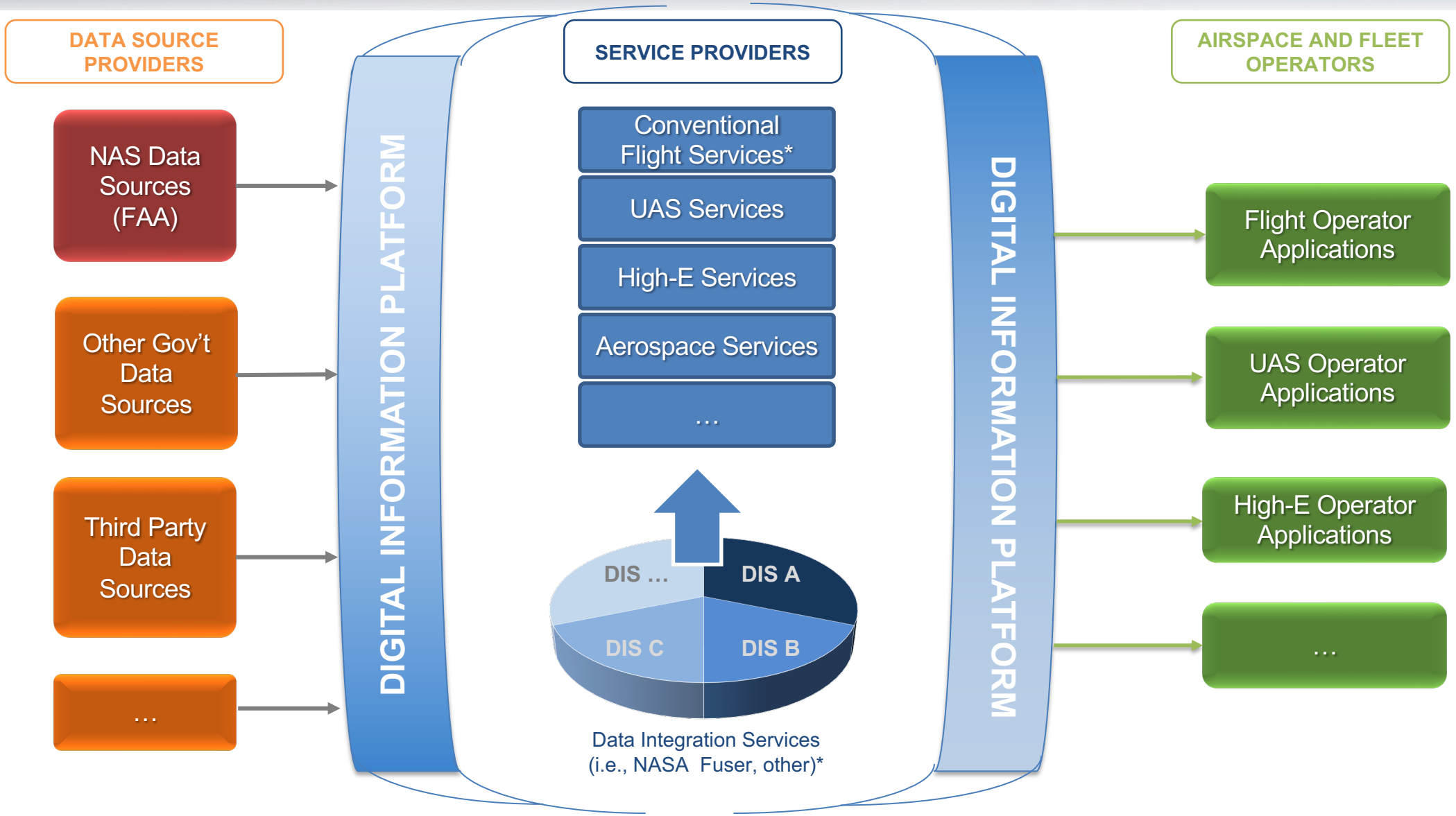
DIGITAL INFORMATION PLATFORM



SFNP-Ops Demos: Demonstrates DIP enabled services for flight and airspace management in operational environments

PS Evals: Demonstrate an ecosystem of reusable aviation services enabled by DIP

DIP Ecosystem



DIP Research Areas

NASA Led DIP-Enabled Services for Sustainability

Ground and flight deck services focused on improving the sustainability of aviation operations

“SFNP-Ops Demos”

Industry Led Partner Service Evaluations

Integration and demonstration of Partner services with DIP for validation of the platform

“PS Evals”

University Challenges

NTL NASA Tournament Lab

Development of innovative solutions and advanced algorithms for aviation services

Reference Digital Information Platform (DIP)

Development of a platform for advanced, data-driven, digital services for flight operators and service consumers

SFNP-Ops = Sustainable Flight National Partnerships - Operations

Opportunities for Demos

SFNP-Ops Demos

- Reach **Flight Operator** and **Consumer** stakeholders
- In a **High TRL** environment
- To demonstrate **airspace management** use cases
- With a **data-to-platform-to service-to-application** (E2E) system
- Achieve sustainability benefits using DIP

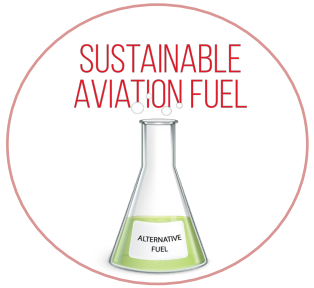
PS Evaluations

- Reach **service provider** and **platform host** stakeholders
- In a **Medium TRL** environment
- To demonstrate **service management** use cases
- With a **data-to-platform-to-services** system
- Achieve ecosystem of data and services

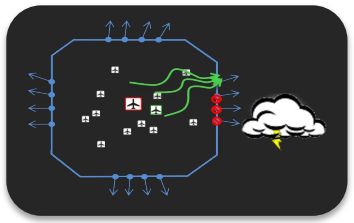
DIP-Enabled Services for Sustainability

Ground Services

Flight Deck Services



GLOBAL Aviation Industry's Goal:
50% reduction in carbon emissions by 2050 relative to 2005 and possible net zero emissions by 2060 through these three means



Collaborative Digital Departure Reroute (SFNP-Ops-1, FY22-25)

Sustainable Oceanic Airborne Re-Routing (SFNP-Ops-2, FY26)

Irregular Ops Recovery/ Disruption Management (SFNP-Ops-3, FY27)

4D Trajectory Optimization (SFNP-Ops-4, FY28)

SFNP-Ops = Sustainable Flight National Partnerships - Operations

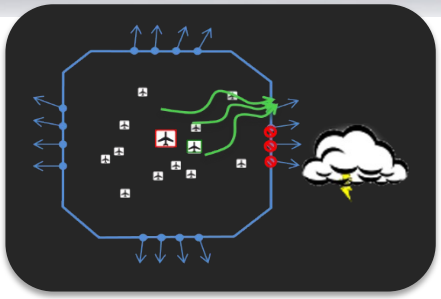
DIP Supports Sustainability Goals: Deliver reduction in emissions and optimize air operations through digital services

Image Credits: NASA

Collaborative Digital Departure Re-Routing (CDDR) for SFNP-Ops-1

Jeremy Coupe

SFNP-Ops- 1 | *CDDR Demonstration Updates*



SFNP-Ops-1: Collaborative Digital Departure Re-Route (FY22 - 25)

Demonstrate CDDR via Trajectory Option Set (TOS) by rerouting flights and departures starting at NTX towards a high-density operational area

Benefits: *Reduced fuel burn and emissions through reduced surface departure delay. Benefits rerouted flight as well as all departures*

SFNP-Ops 1 system-wide aggregated savings (individually re-routed + other flights)

at **D10 North Texas Metroplex** (01 Jan 2022 – 16 Sep 2022)

Fuel Savings

Over **24K** lbs.

Emissions Savings

Over **76.6K** lbs. **CO^2**

Over **569** urban trees

Delay Savings

OFF delay	**IN** delay
3.9+ hrs	**4.7+** hrs

Cost Savings

Passenger	**$31.7K**
Flight Crew	**$6.9K**

1038 CANDIDATE flights ➡ 102 Airline Re-Route Requests ➡ 41 ATC-approved re-routes

DIP can scale these savings across the NAS; additional validation in FY24 in more complex airspace

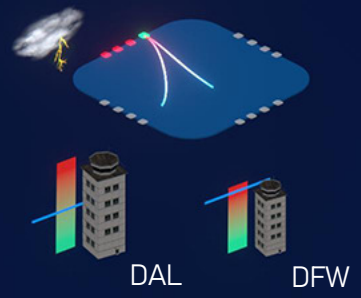
Collaborative Digital Departure Re-Routing

1 Preconfigure
TOS Parameters

Alternate Routes

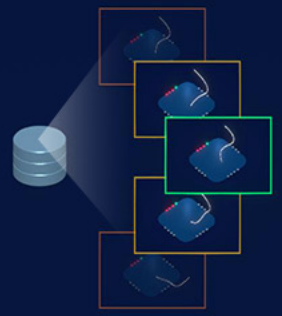
TOS database

2 Monitor
Demand & Capacity



System continuously assesses imbalance

3 Present
Candidate TOS



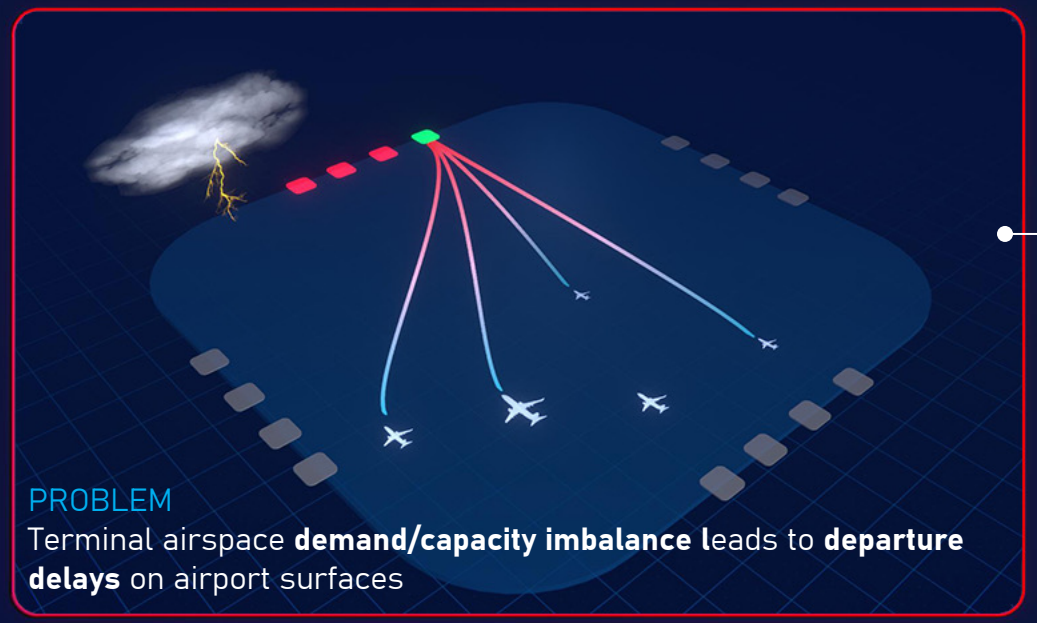
Delay savings > Relative trajectory cost

4 Submit
TOS to ATC

all users notified

5 Evaluate
Post Operation

Benefits
Refinements
Lessons
Analyses
Reports



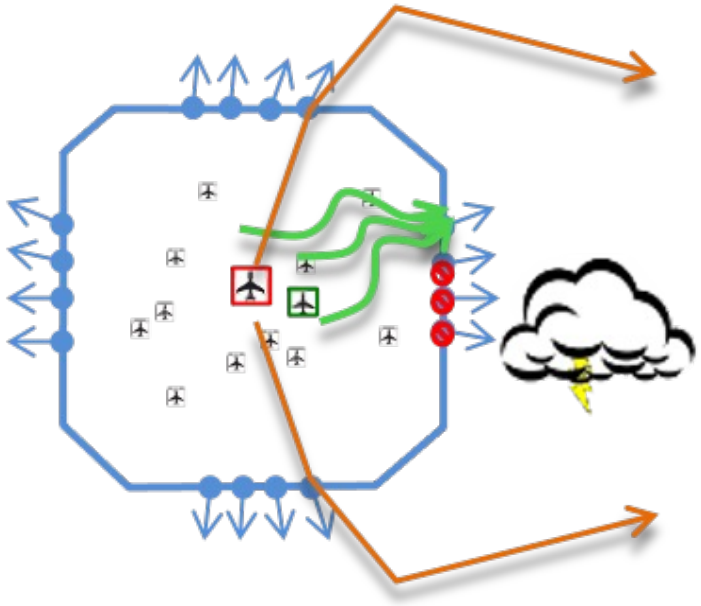
PROBLEM
Terminal airspace **demand/capacity imbalance** leads to **departure delays** on airport surfaces

Metroplex airports with departure fixes

4

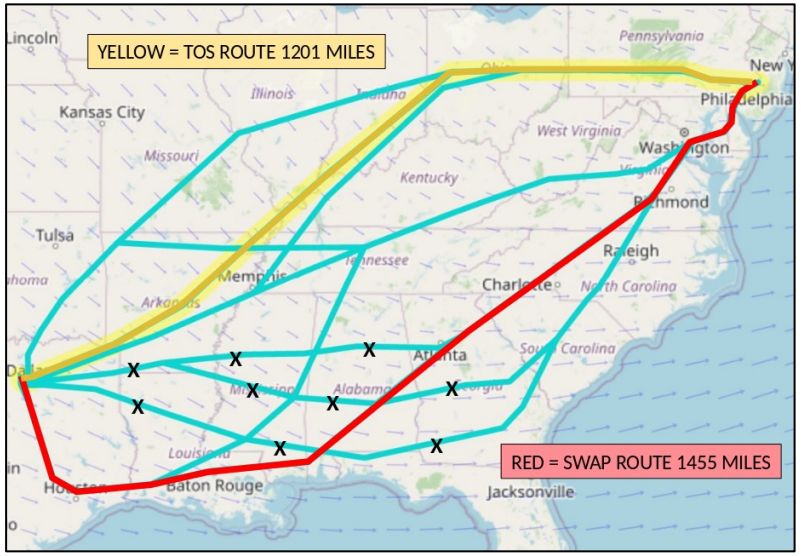
SOLUTION
CDDR system enables flight operators to **intelligently request reroutes** from the Air Traffic Control for **departure fix load balancing**

CDDR Use Cases and Benefit Mechanisms



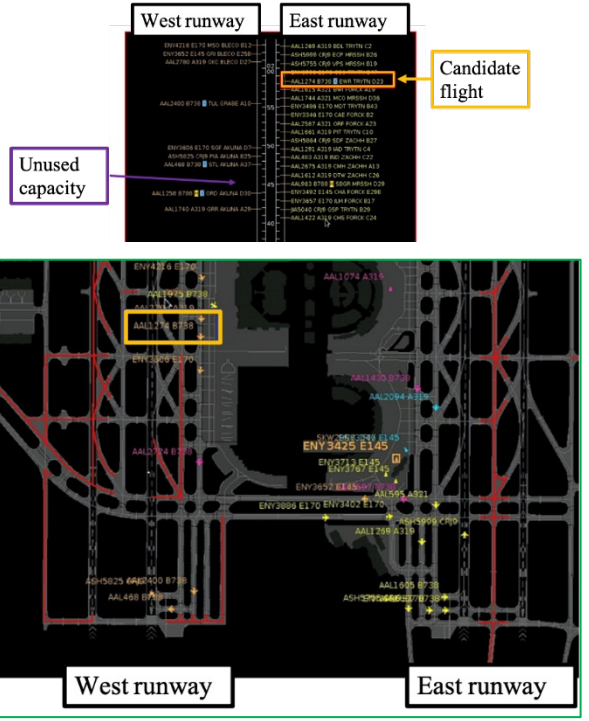
Traffic Management Initiative (TMI)

- Filed route is most direct route but subject to TMI
- Filed route remains through the original departure gate
- TOS route through adjacent departure gate and requires additional flight time
- TOS reroute reduces surface delay in exchange for increased flight time



Recovery from SWAP

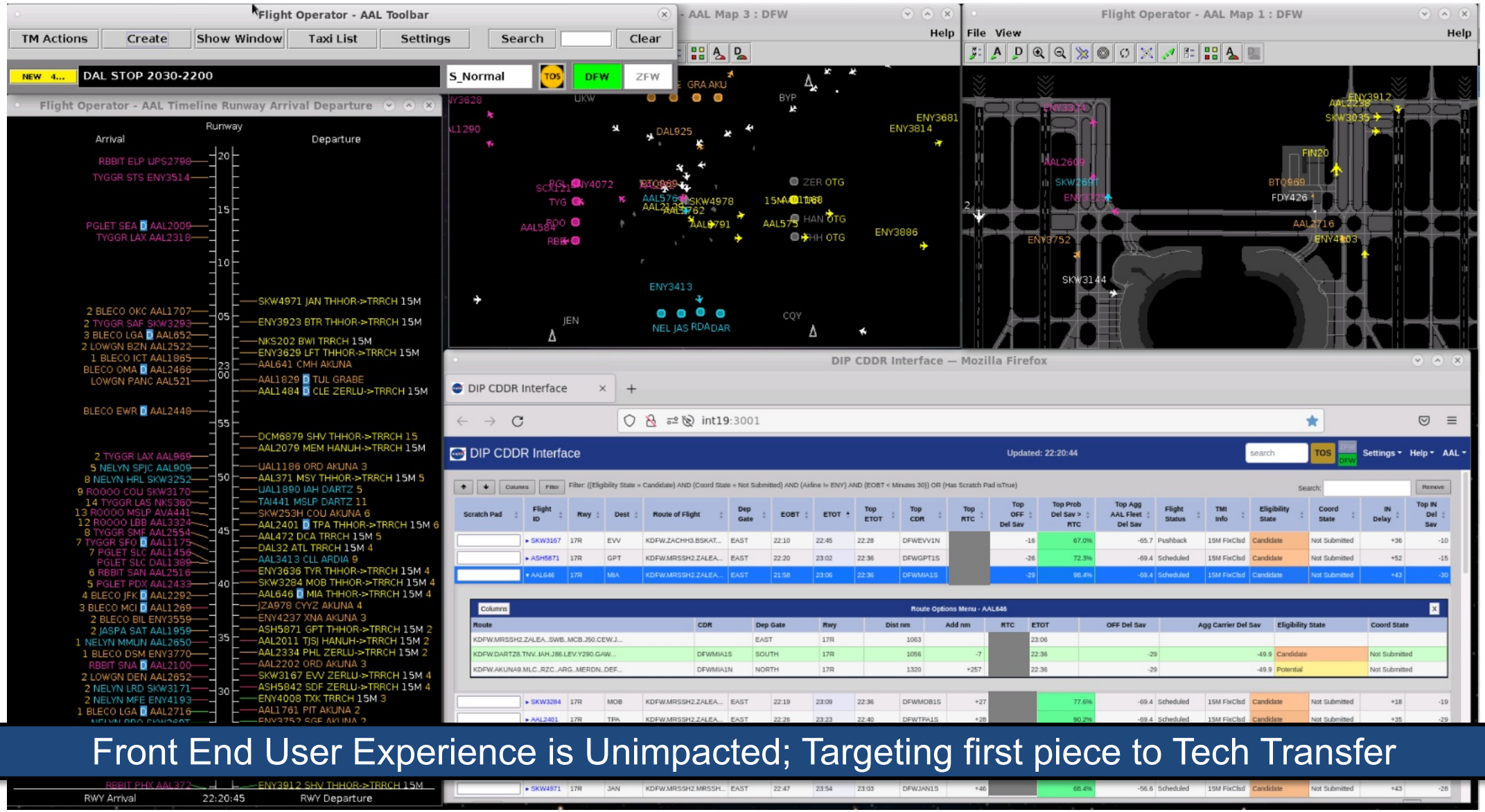
- Filed route is amended by ATC through an adjacent departure gate during a SWAP event
- SWAP event ends and TOS routes through the original Filed departure gate much shorter than SWAP route
- TOS reroute reduces surface delay and also has shorter flight time compared to SWAP route



Non-TMI Tactical Reroutes

- Often occurs when the parking gate is physically closer to the TOS runway than the Filed route runway
- Provides tactical opportunities to load balance runway demand to take advantage of unused capacity

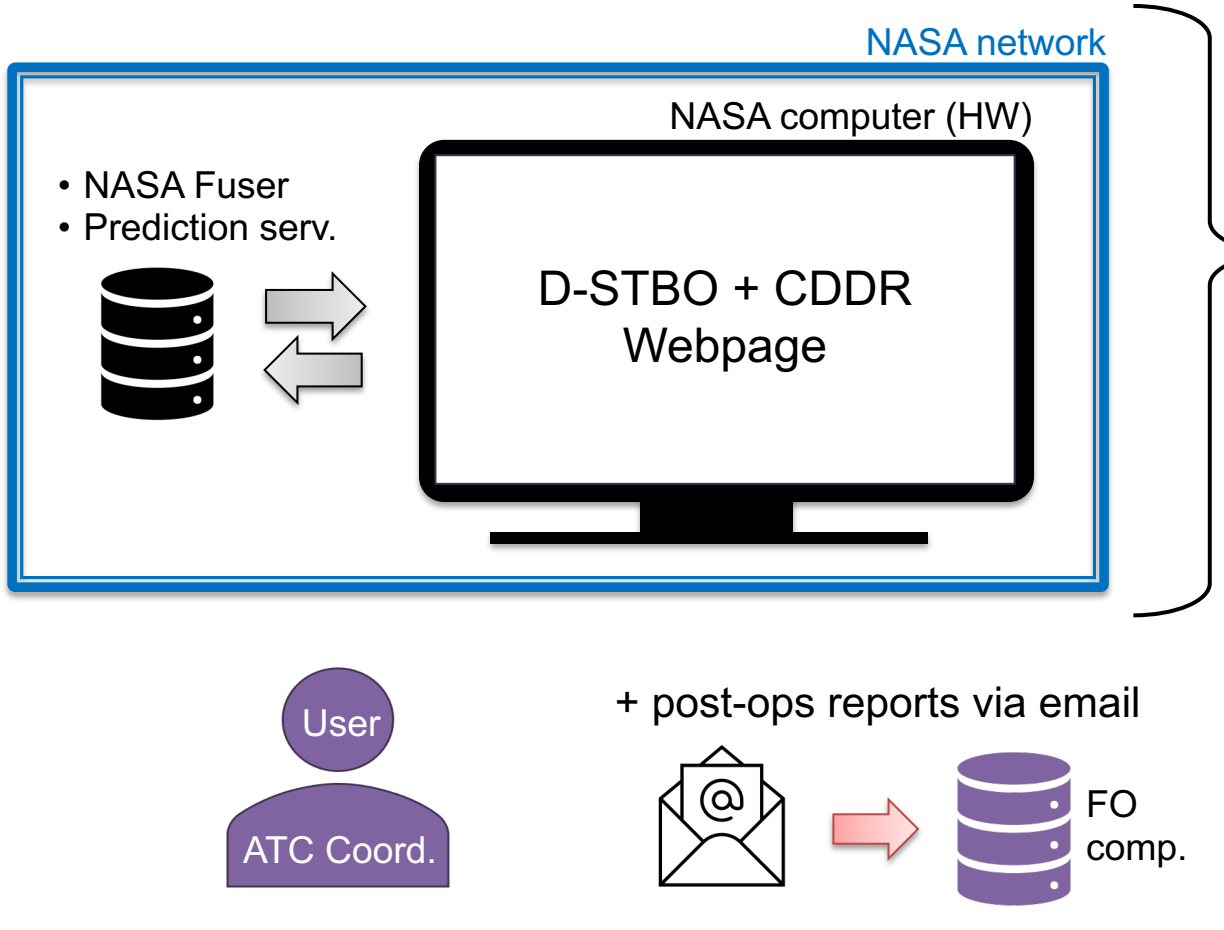
CDDR User Interface in North TX (SFNP-Ops-1a)



Front End User Experience is Unimpacted; Targeting first piece to Tech Transfer

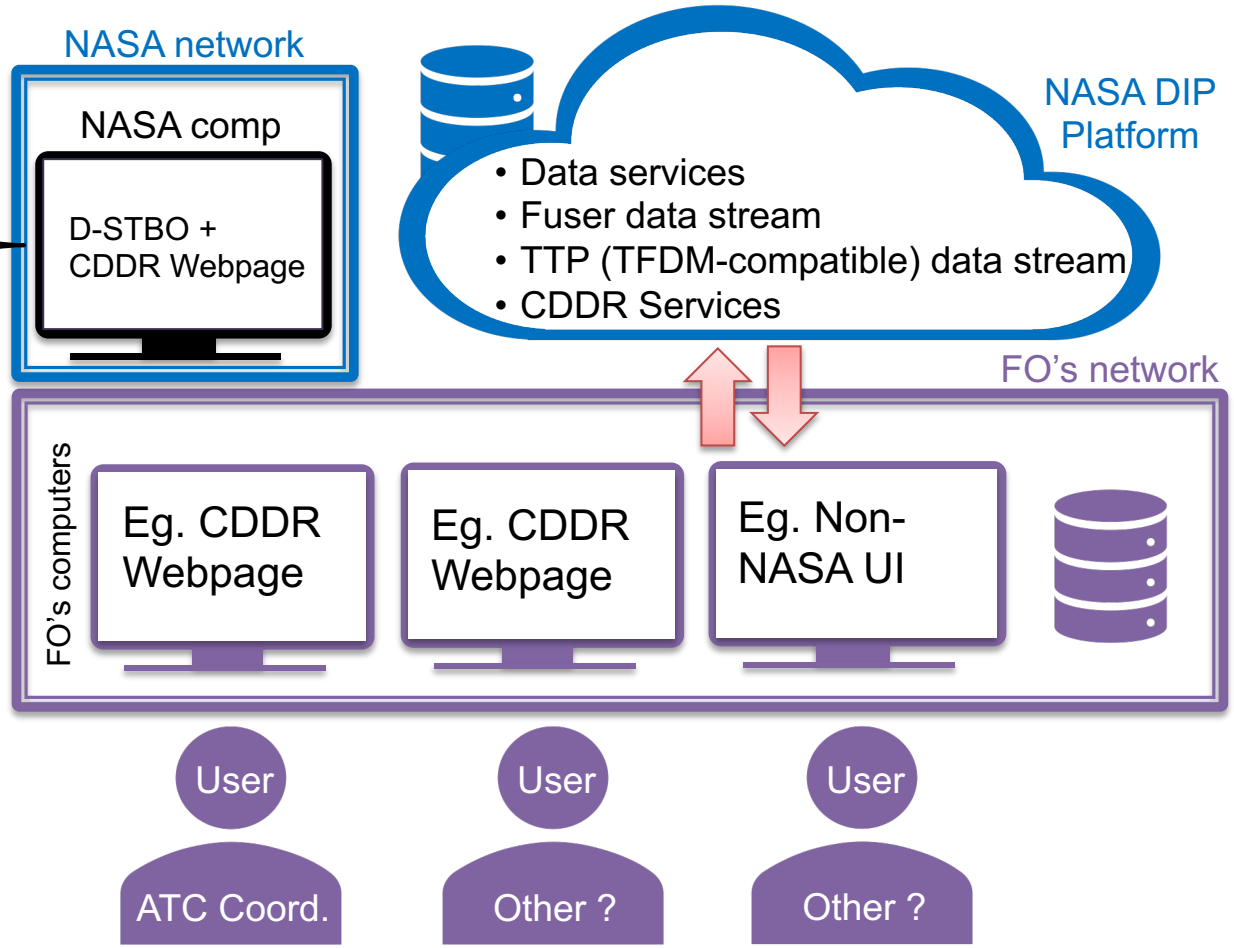
Transition to SFNP-Ops-1b with CDDR in the Cloud

In FY22



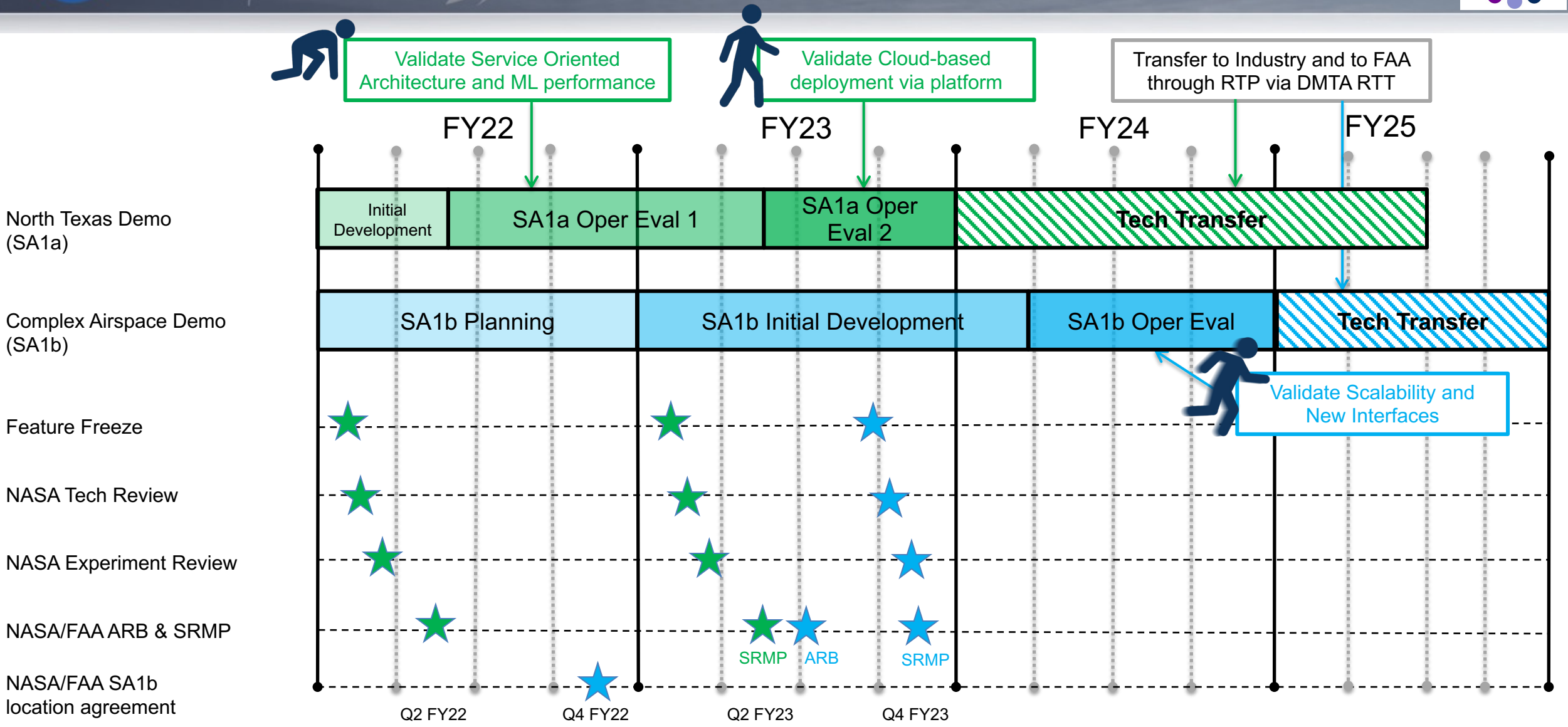
Access to data, services and interface *is limited to* a NASA computer behind a firewall

Starting in FY23 and beyond



Access to data, services and interface *is available* from the cloud

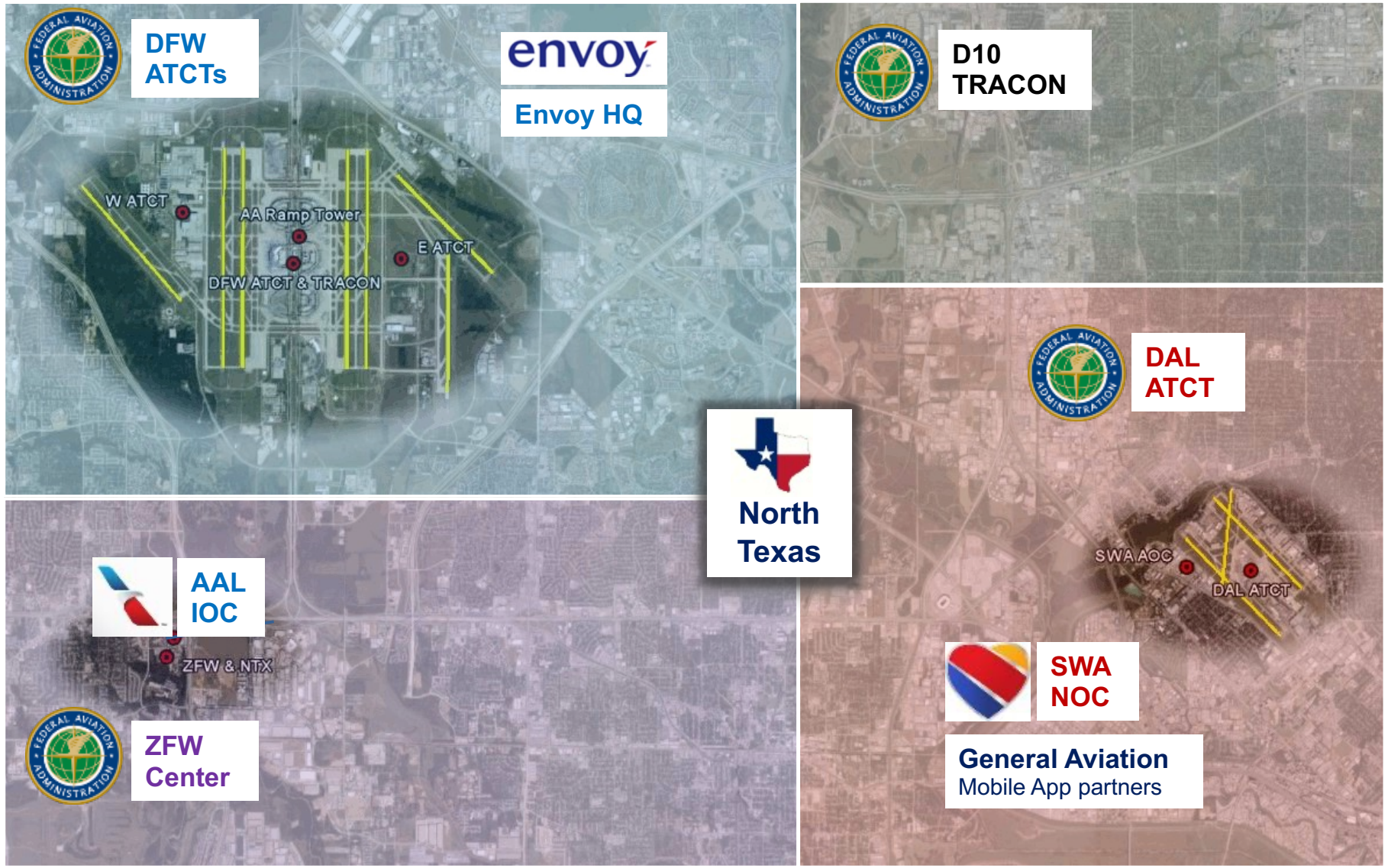
SNFP-Ops-1 Progress and Milestones



SNFP-Ops-1a North Texas Milestones in Green

SNFP-Ops-1b Complex Airspace Milestones in Blue

SNFP-Ops-1a Field Demo Partners and Locations



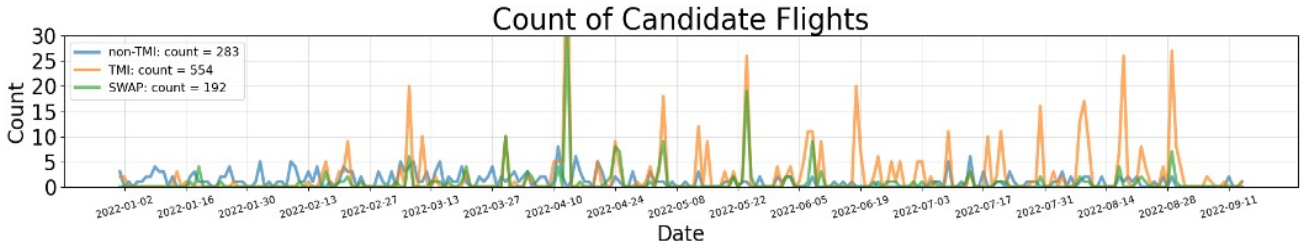
- 1a Field Demo partners leverage the existing relationships from ATD-2 Phase 3 Field Evaluation
- 1a plans to use the existing NTX NASA network installed at FAA and Flight Operator facilities
- 1a Field Demo partners already familiar with the CDDR concept, technologies, and workflow
- Provides an experienced field demo partner cadre to evaluate the 1a digital services that could be deployed to other locations

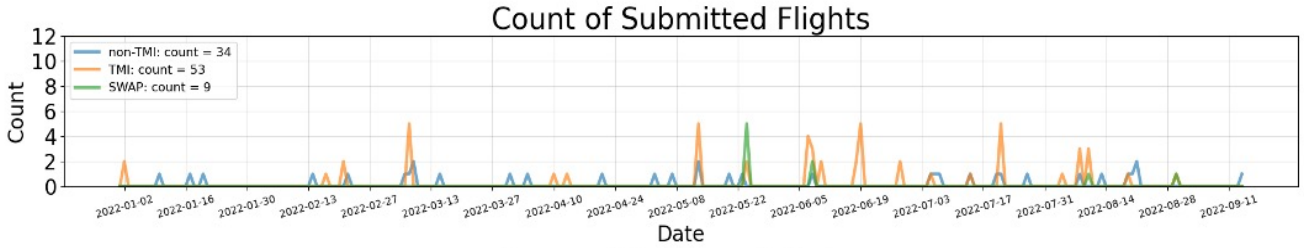
Meeting Performance Operational Goals

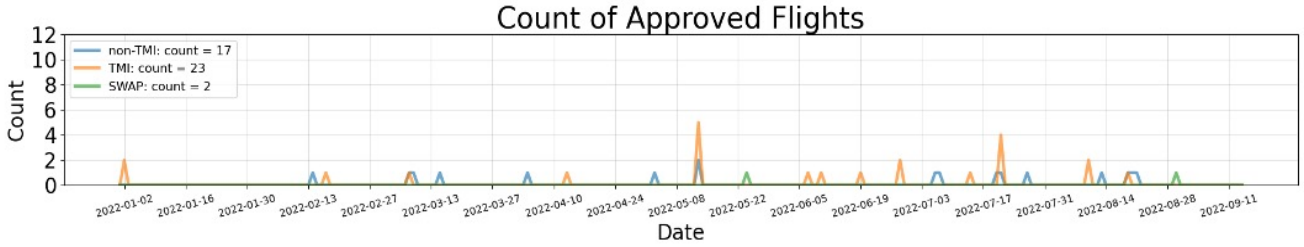
2022 CDDR Environmental Benefits

Between **January 1st, 2022 and Sep 16th**, 2022

- 24.8K pounds of **fuel** saved
- 76.6K pounds of **CO_2 emission** reduced
- 569 **urban trees** saved
- Average reroute saves 15.4 urban trees **+3.5% YoY**



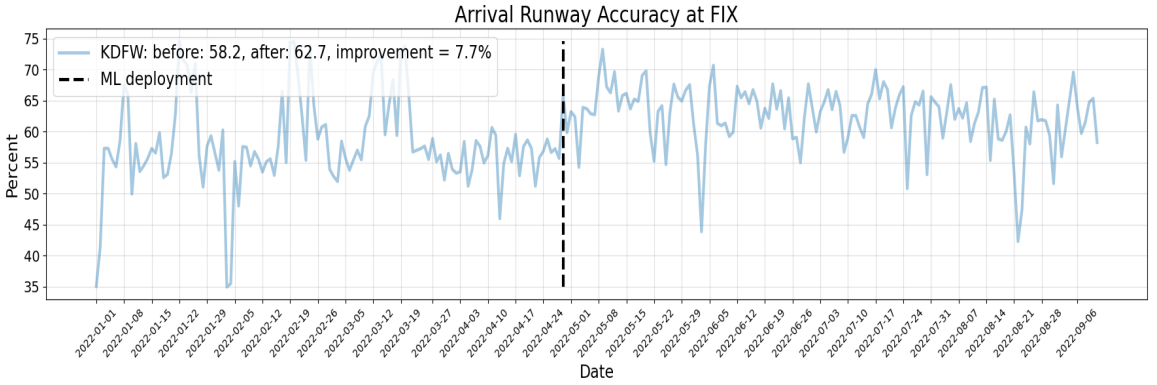




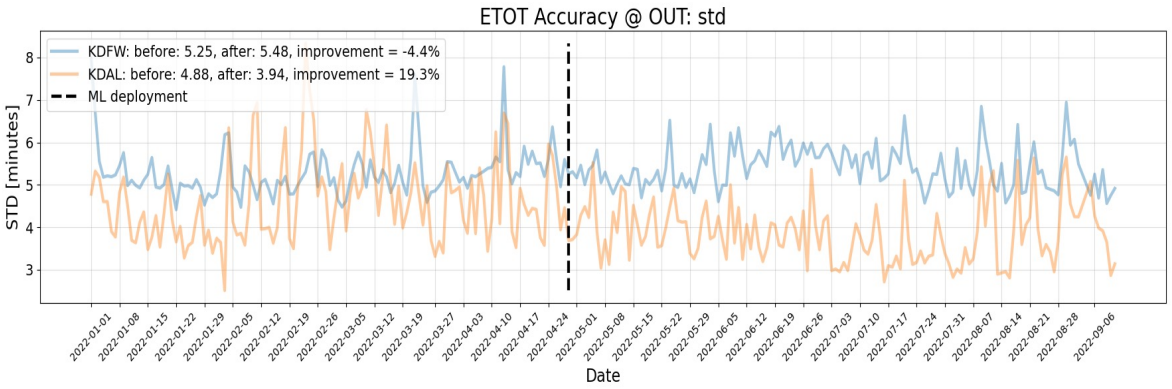
DIP Machine Learning vs Legacy ATD-2

- Arrival Runway Prediction: ML slightly outperforming
- ETOT: ML on par with ATD-2, outperforming TFMS

Arrival Runway Prediction

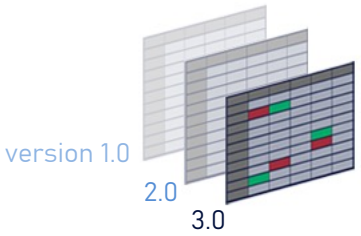


Estimated Take OFF Time (ETOT) Prediction

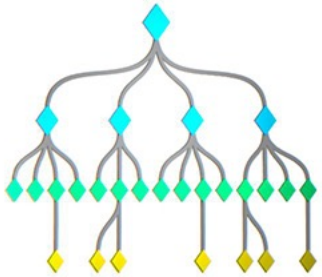


Legacy

ATD-2 Airport Surface Model



Requires **continuous** maintenance



Mental models encoded into **complex decision trees**

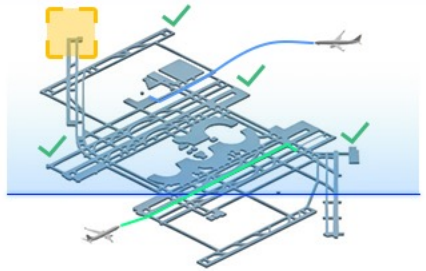
Similar to:
Skilled worker

Good at **specific** tasks
Requires detail knowledge

Current

Scalable DIP Machine Learning Airport Surface Model

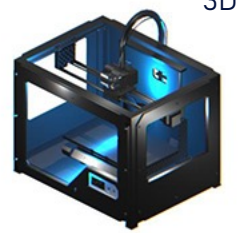
Updating...



Semi-automated maintenance

Absorbs information from multiple existing data sources

Similar to:
3D printer

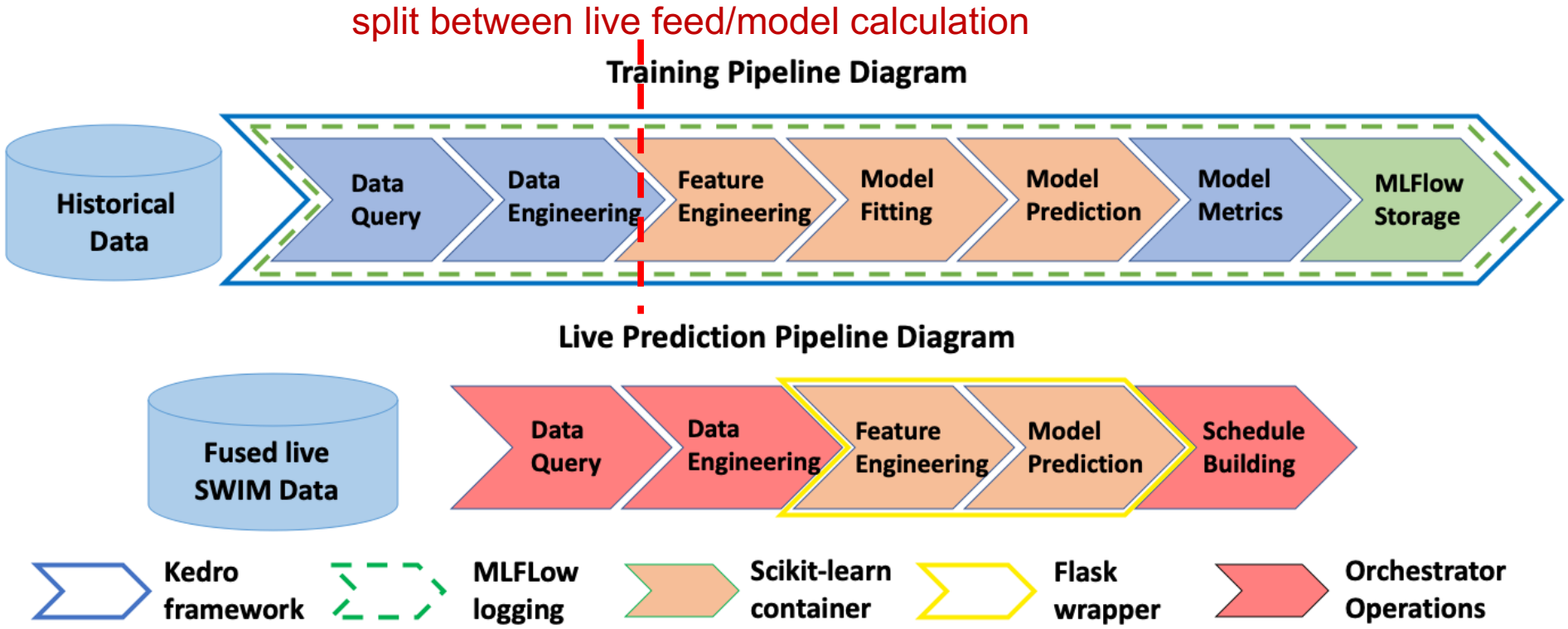


Flexible to new tasks
Learns detailed knowledge

ML Pipelines Enable Scalable Solution

We developed our training pipelines in Python around mainly three Python libraries :

- Kedro : pipeline structures defined by DAGs, help to abstract inputs and to define a common design for the team
- Scikit-learn: used for the Pipeline class that allows to store some feature engineering into the model
- MLflow : keeps track of the models, their artifacts, performances, tags the latest models

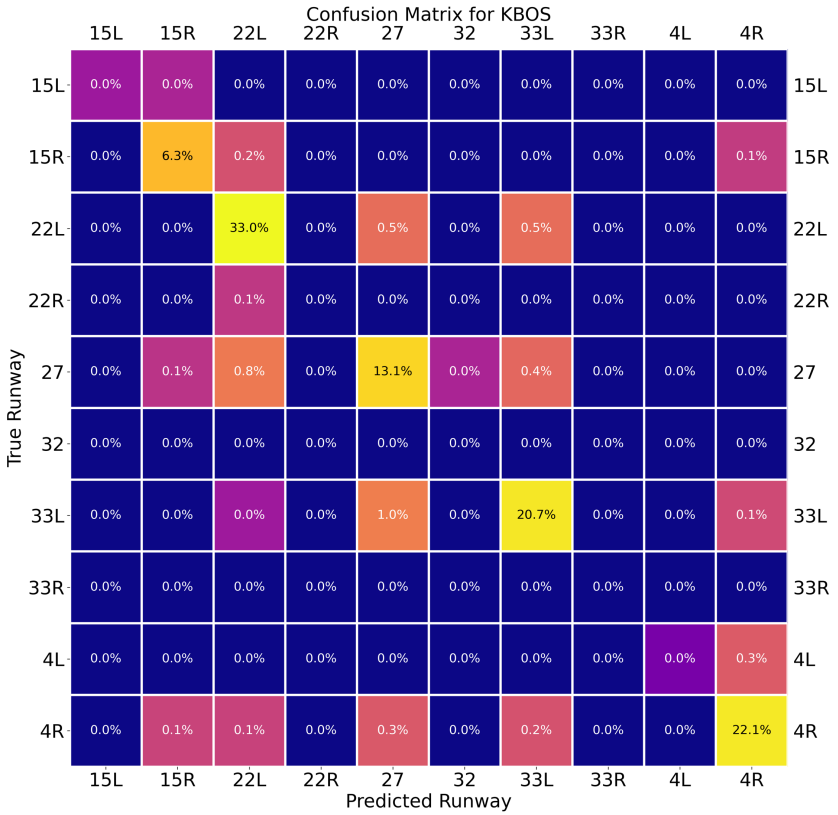


ML service code available on GitHub : https://github.com/nasa/ML-airport-configuration

Arrival Runway Prediction at Other Locations

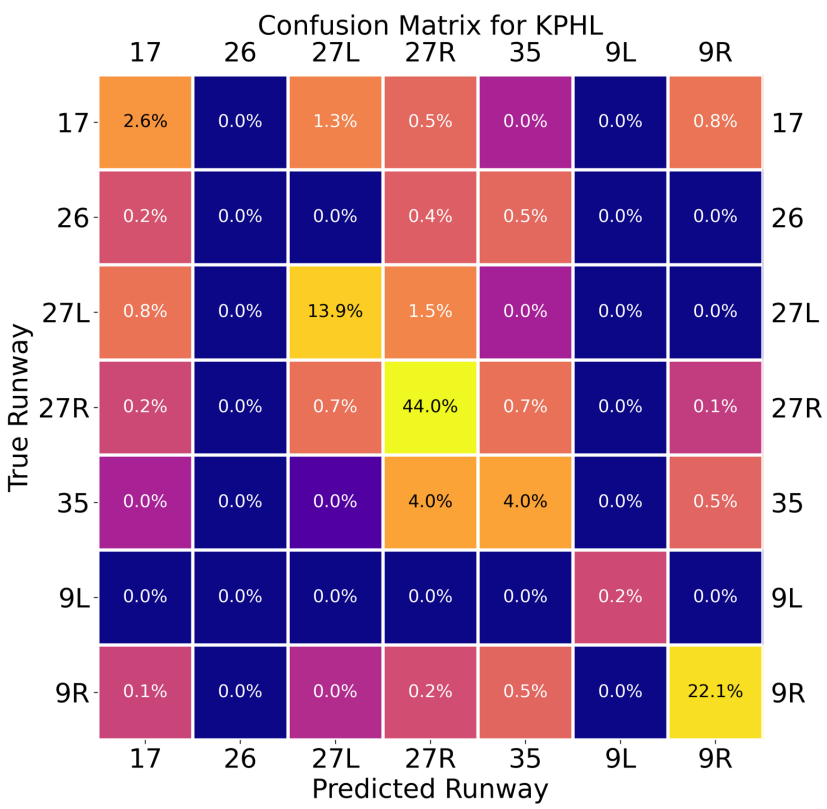
KBOS Arrival Runway

accuracy = 95.1%



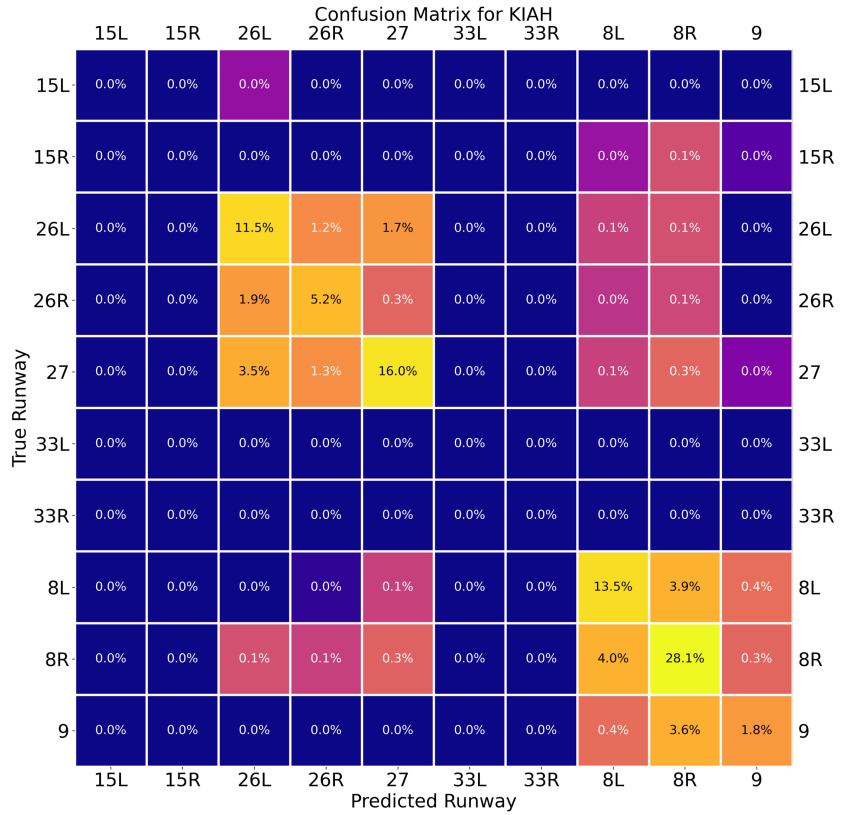
KPHL Arrival Runway

accuracy = 87.1%



KIAH Arrival Runway

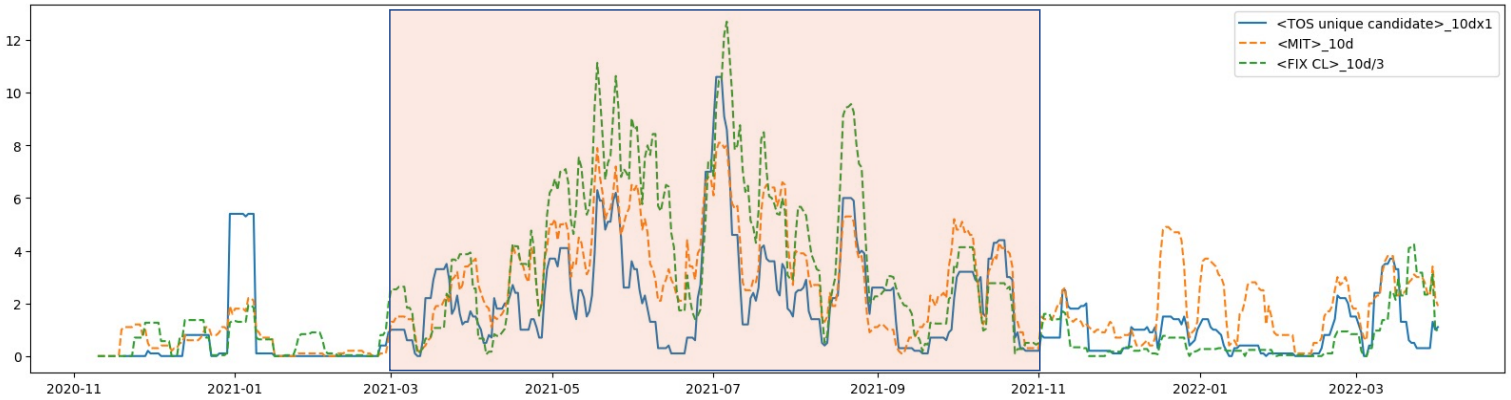
accuracy = 76.1%

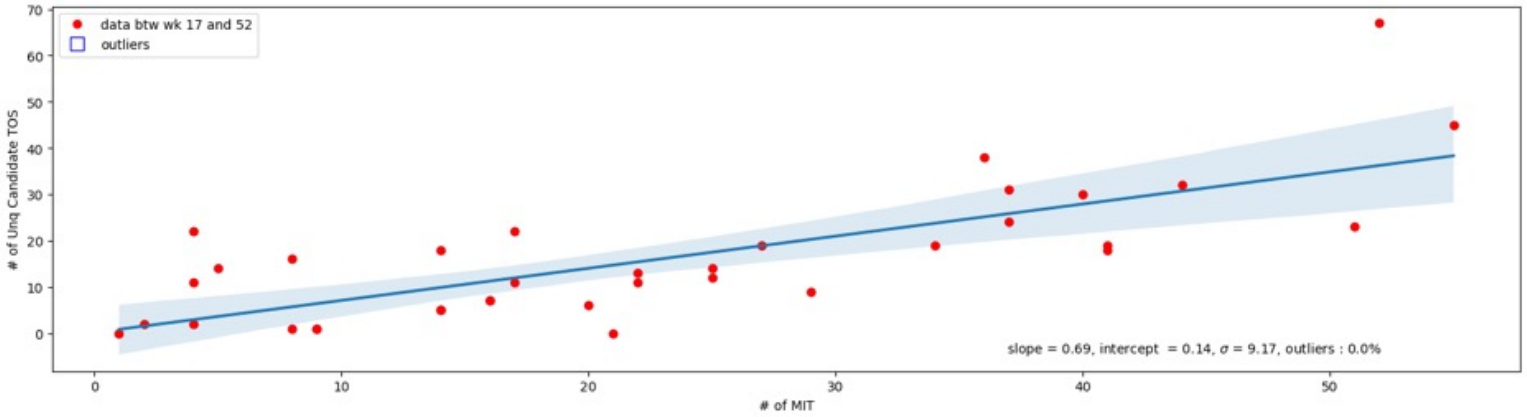


ML pipelines enable new models to be trained by simply changing configuration file

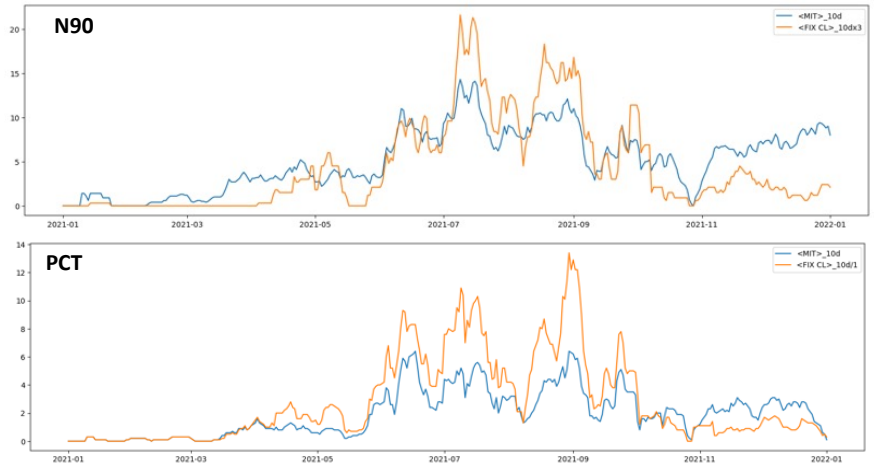
Extrapolating NTX Benefits to Other Airspaces

North Texas: Model Candidates as a Function of TMI





Model Applied to Other Airspaces



TRACON	Model with # of MIT (min)	Model with # of MIT (hour)
D10	675+-299	11.3+-5.0
N90	997+-443	16.6+-7.4
PCT	380+166	6.3+-2.8

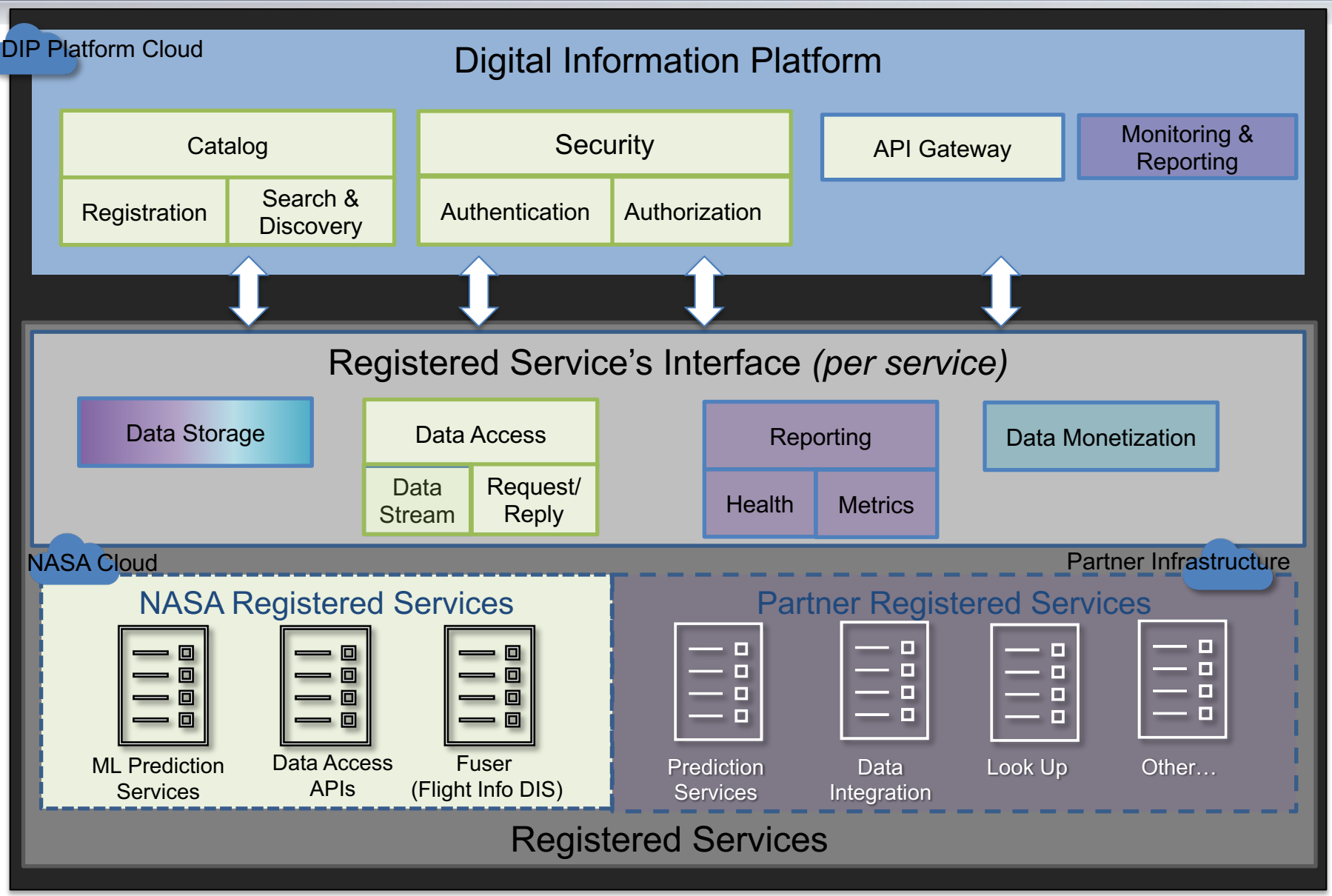
Benefits vary Depending on Operations & TMIs; EX: N90 ~1.5x; PCT ~.5x of North Tx

Platform Technology & Partner Services

Pallavi Hegde

Eric Chevalley

Current Platform Development



Current Features

- Secure access
- Service Registration support
- Catalog service
- Access to NASA services

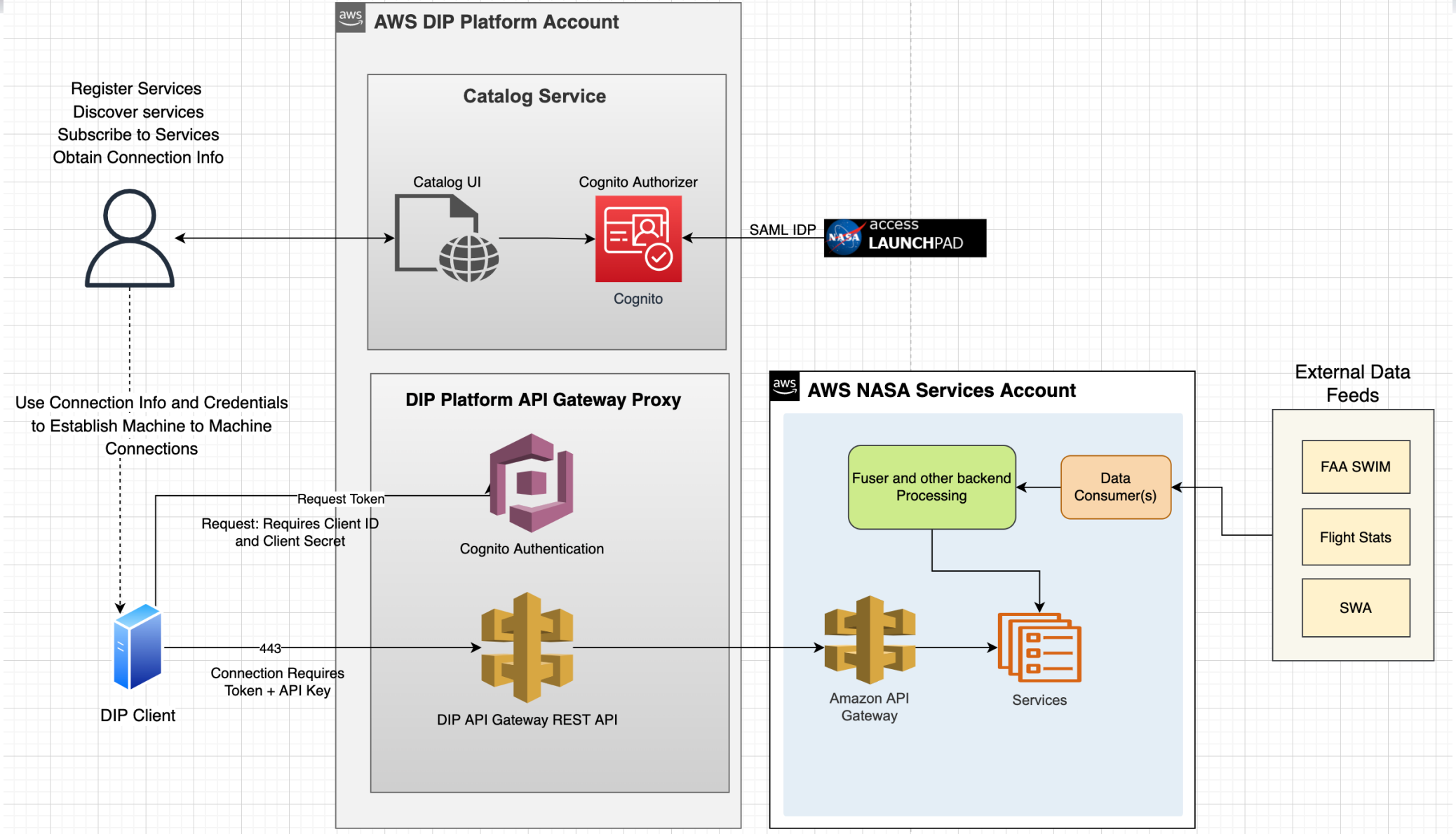
Features for FY23

- Key Performance Indicator
- Health monitoring
- Data Storage of NASA Services

Stretch Goal Features for FY23

- Peer-to-peer Communication with Payment gateway

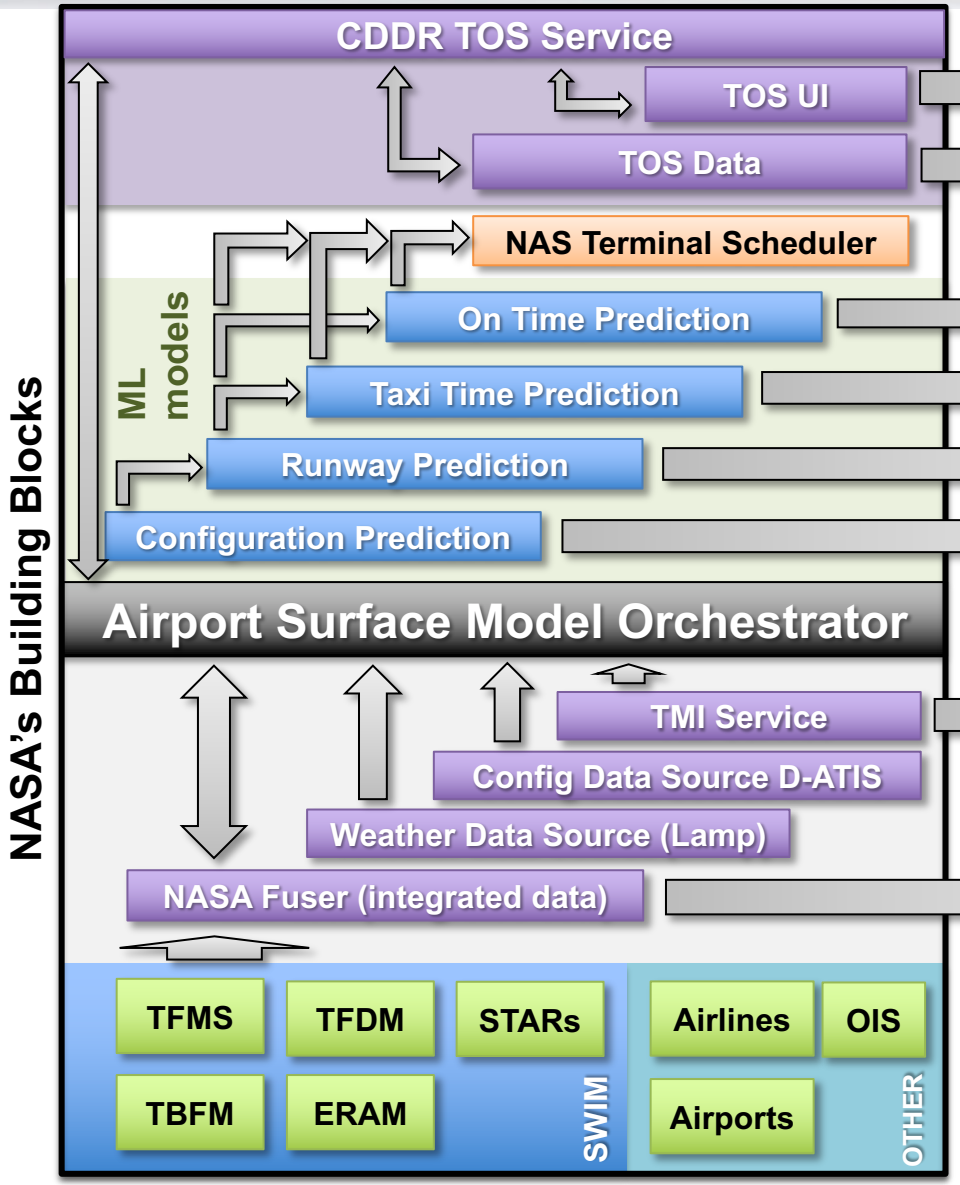
Platform & NASA Services



Platform Features

Features	Description	Scope
DIP Catalog	The DIP Catalog is a repository of information about services provided and available to the aviation community. The catalog allows users to register, browse, search, try, subscribe, and connect to services.	FY2022
Reporting and Monitoring	The platform facilitates Reporting and Monitoring Dashboard to visualize metrics at various levels	FY2023
Data Storage and Data Archival Service	Platform provides historical data archival and Data Archival service to access stored data	FY2023
Streaming Data API Solutions	Abstract implementation for Streaming and pub-sub solution using Distributed Application Runtime (DAPR)	FY2023
Data Governance - Identity	The DIP Identity Management Service (DIMS) provides the necessary APIs for entities to query, manage and verify identities within the DIP ecosystem	FY2023
P2P Communication & Payment Delegation	DIP enables P2P interaction between the DIP Platform and Partner infrastructure, facilitating the subscribers with URLs provided by service owners to pay for services using a payment gateway	FY2023-24
Distributed Architecture	The long-term vision for the platform is to move towards a distributed architecture approach where the network traffic is distributed using P2P-enabled interactions	FY2024

NASA Services via the Platform



TOS Web Table

TOS Data

Real-time flight TOS reroute data
Coordination of reroute submissions
Available on any machine for operational use

Planned

Predicted ON Time

Predicted Taxi Time

Predicted Runway

Predicted Config

Machine Learning Models for What-if applications

What services would YOU be interested in?

NAS-Wide TMI Service — *Parsed TMIs*

TMI Flight Service
TTP (TFDM) feed

TMIs by flight in selected airspaces
TFDM-like streaming feed

Planned

NAS-Wide Fuser — *Pub/sub streaming service*

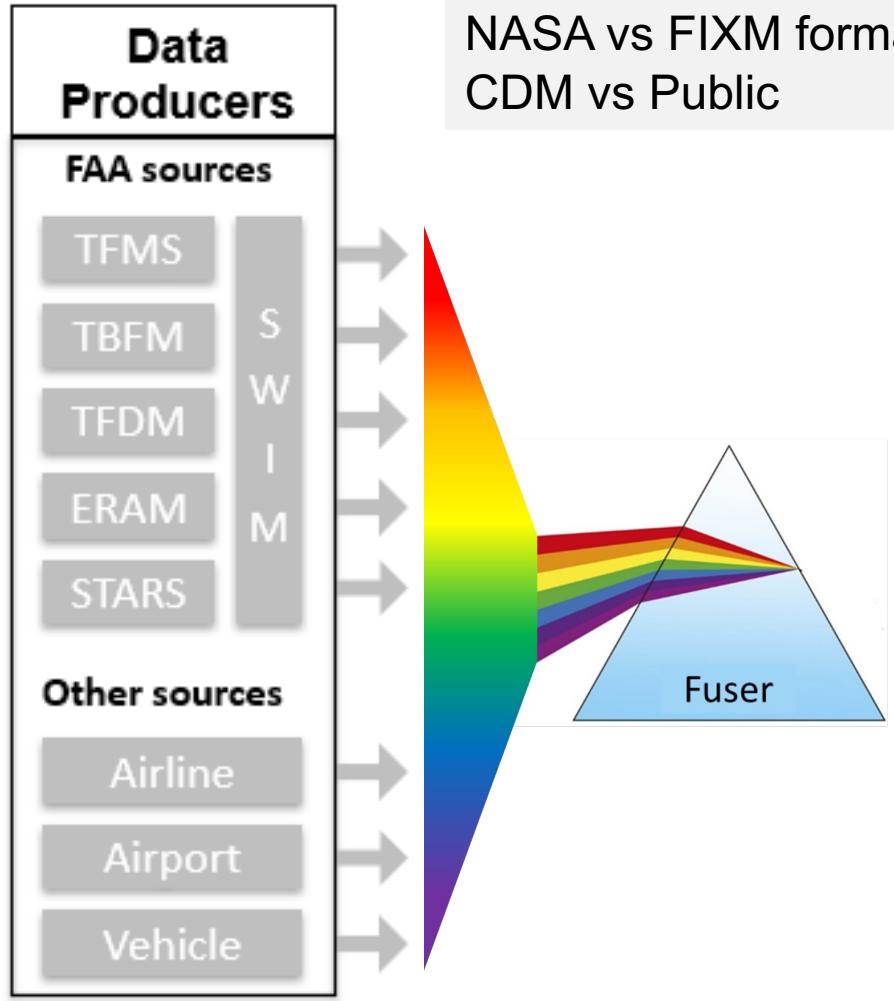
Flight Data
Arrival Runway
Departure Runway
Taxi IN/OUT

Data access services provide near real-time data from Fuser (NTX only)
REST API returns an actual or predicted values

Fuser Streaming Service

- System that can mediate between disparate sources of data, pulling in *the right data at the right time*
- Composed of multiple components providing
  - Parsers for various data sources
  - Matching Services providing a global unique identifier (GUFI)
  - Fusion Services
    - Transformation
    - Filtering
    - Updating
    - Mediation
  - Common well-defined schema

Versions available:
NASA vs FIXM format
CDM vs Public



Flight Data Service

- Source of data: Subset of archived Fuser data stored in databases
- Domain of Applicability: 30 days and data available for DFW and DAL
- Type of Data: Predictions and resources for a set of flights within +/- 3 hours based on a user defined timestamp (can be set to current up to 30 days in the past)
- Configurable list of fields set in the API call
  - ACID, departure and arrival airports, IGTD,
  - Runways: departure and arrival runway configuration, actual and predicted departure and arrival runways (+source), actual and estimated runway on and off times, departure runway detection model confidence,
  - Taxi times: ramp and AMA arrival and departure undelayed and estimated taxi times,
  - Terminal resources time: departure fix transit, estimated and actual departure fix times,
  - Timestamp

Traffic Management Initiative Service

- Source of data: parsed data available in SWIM TFM data and ATCSCC's webpages
- Domain of Applicability: 30 days and data available for DFW and DAL
- Type of Data: Active restrictions based on a user defined timestamp (can be set to current restrictions up to 30 days in the past)
- Restrictions (combinations of a single or all TMI type)
  - Airspace Flow Programs (manage excess demand in constrained airspace, impacted flights will get an EDCT)
  - Approval Requests – APREQ (wheels-up time to control the timing of flights at constraint point in the airspace)
  - Flow Constrained Areas (restricted piece of airspace that is usually associated with an AFP or reroute advisory)
  - Ground Delay Programs (manage excess demand at destination airports, impacted flights will get an EDCT)
  - Ground Stops (stop departures to specified destinations for a given period of time)
  - Miles/Minutes In Trail (requested in-trail spacing between flights at specified resources (e.g. runway, fix, route)
  - Reroute Advisories (impose flight routes to specified destinations based on specified origins)
  - Resource Closures (runway, fix, route)

- Each restriction provides fields, such as: start/end time, requesting/providing facility, type, reason, constrained resource, value, TMI id, associated TMI, TMI action (add/ remove/modify)…

Identified High-Value Services From RFI Responses

• **NAS-wide Fuser Service**	NASA's ATD-2 service expanded to the NAS
• **NAS-wide TMI Service**	NASA's TMI service expanded to the NAS
• **TOS related Services**	NASA's CDDR service expanded to new airspaces
• **Landing runway prediction service**	NASA's EON prediction service
• **IROP Disruption Management**	Potential multi-partners solution
• **NAS-wide Wind Miles Prediction**	Potential service
• **Weather Data Integration Service**	Potential service
• **NAS simulation and Playback**	Potential solution
• **Earliest Off Block Time (EOBT) generation**	Potential service for traditional aviation
• **Surface congestion prediction (Bank overlap)**	Potential prediction service
• **Surveillance Data Integration Service**	Potential service for traditional and new entrants
• **Noise Prediction for New Entrants**	Potential service for new entrants
• **…**	

→ Services and Solutions as identified by the Community who responded to the DIP Request For Information (RFI)
→ Via next ACO, DIP will seek Service Providers who can support the development of innovative solutions
→ DIP will continue to contribute to identified needs, however,
→ DIP ecosystem will enable the development of collaborative solutions across Partners

Agile Development and Partner Evaluation

Goals

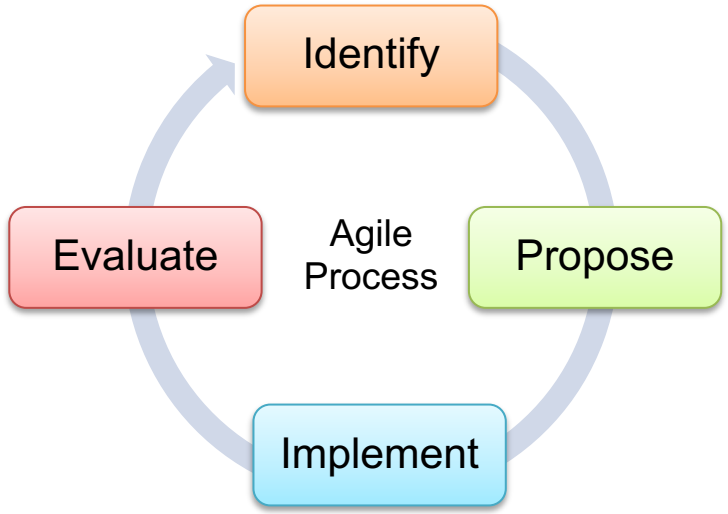
- Establish a cohort of partners of Service Consumers and Service Providers
- Complete PS-1 and conduct PS-2 evaluations
- Support partners to develop their use cases and facilitate high-value solutions that leverage DIP services

Approach

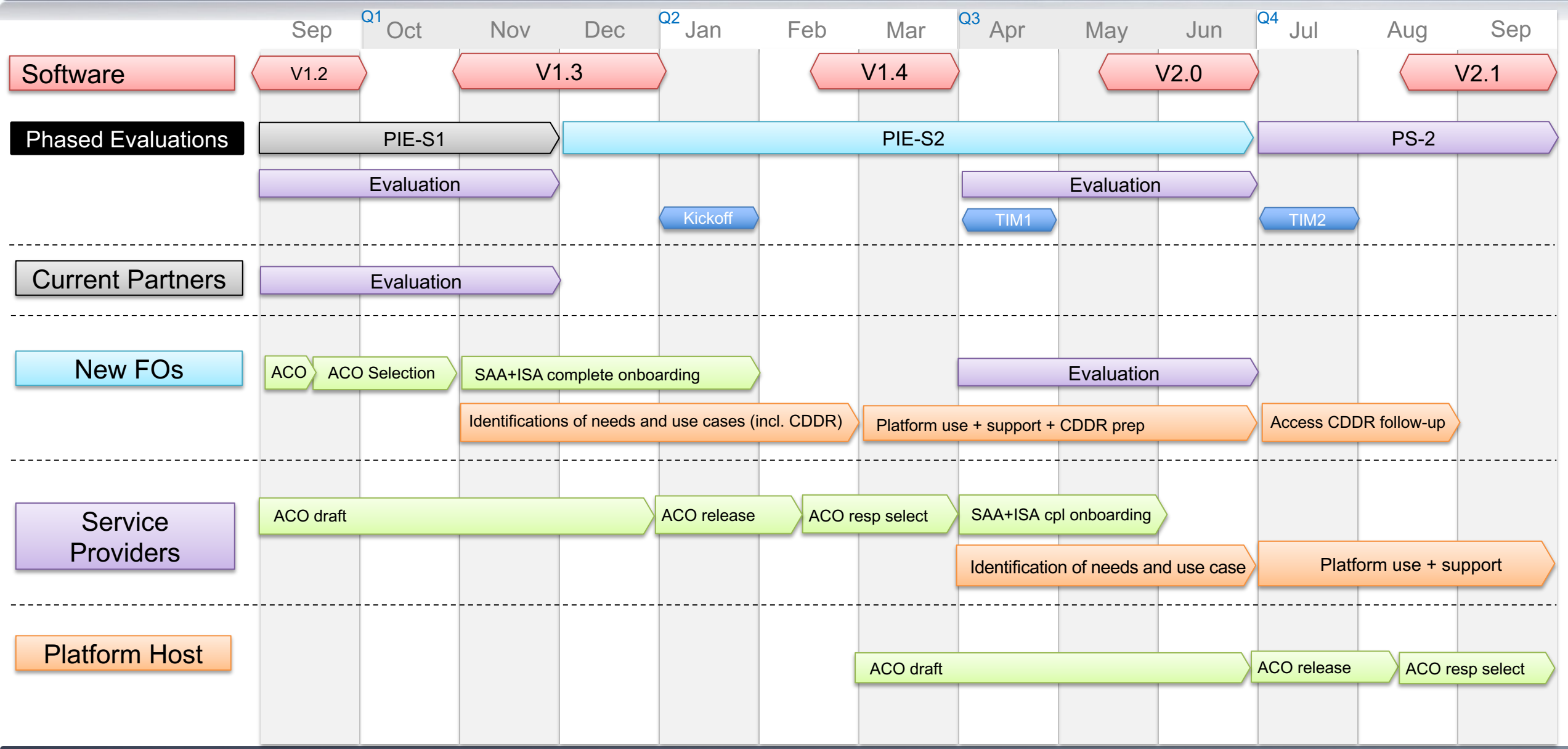
- Onboarding process and familiarization with Platform
- Individual Meetings (identify needs and use cases, provide support, get feedback on proposal and use)
- Group Meetings (provide updates, discuss topics, get feedback, eco-system events)
- Data Collection (usability + actual platform and services use)

Outcome

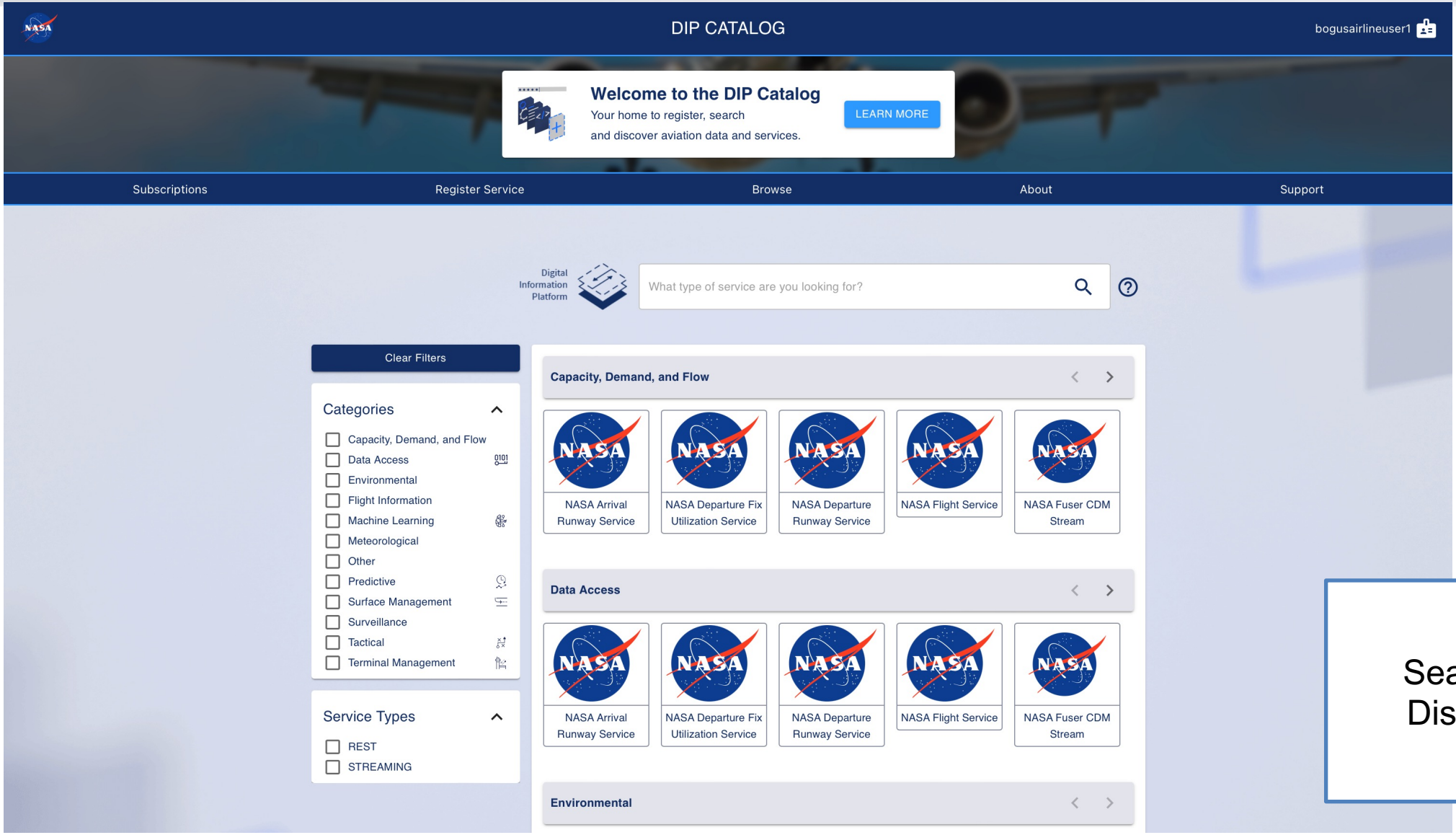
- Recommendations of Platform and Service development
- Lessons Learned and Benefits Analyses



Timeline With Partners

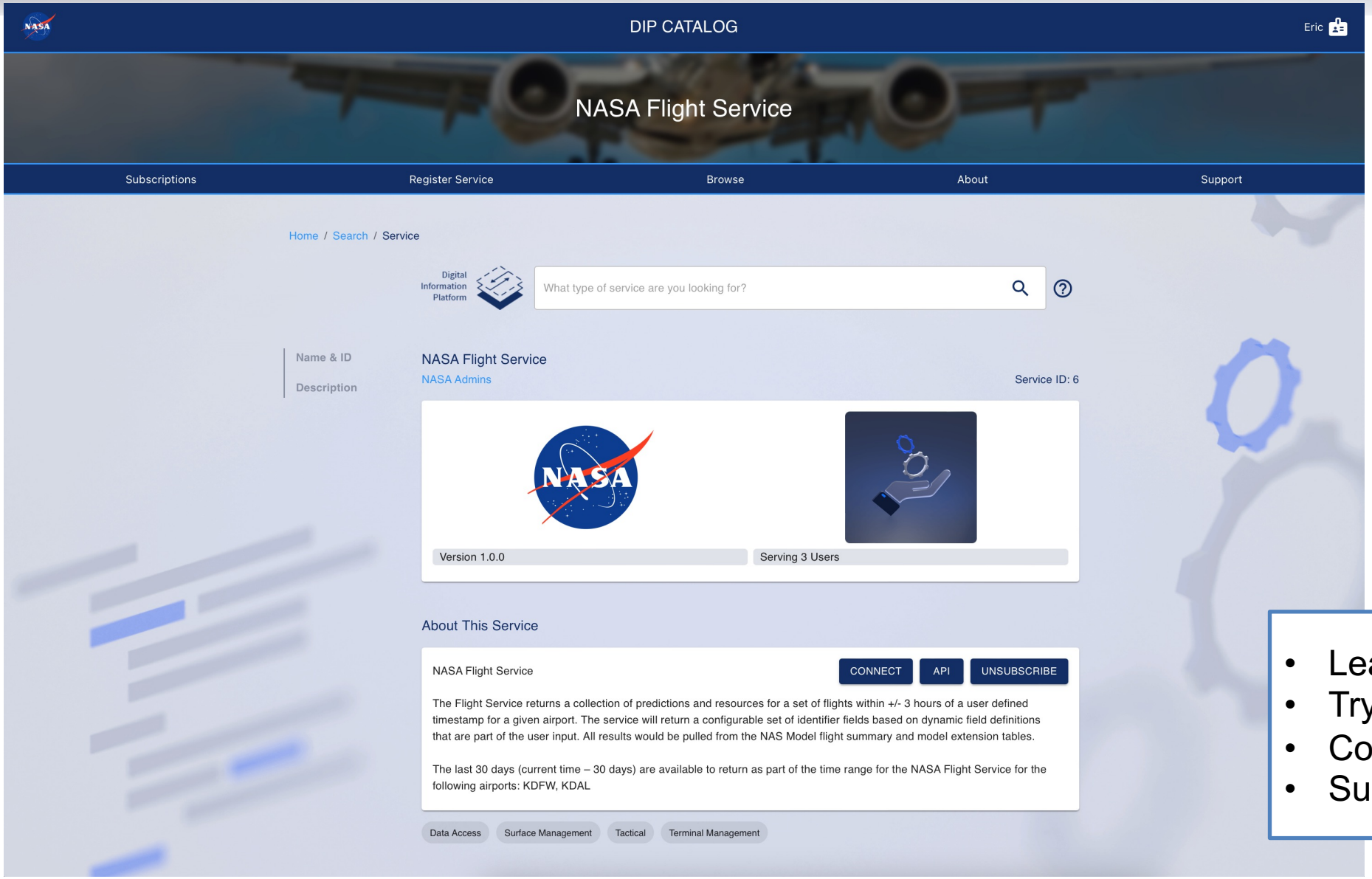


DIP Catalog



Search & Discover

Service Information Web Page



- Learn More
- Try It Out
- Connect
- Subscribe

Questions?

- Please email to ARC-DIP-EXT@mail.nasa.gov for questions or comments
- Visit https://nari.arc.nasa.gov/atmx-dip for more information regarding DIP sub-project and future events

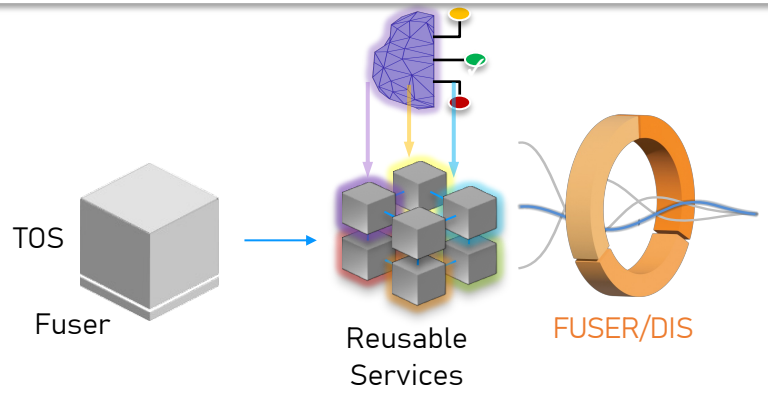
Acronyms (Selected)

Acronyms	Phrases
ACO	Announcement for Collaborative Opportunity
CDDR	Collaborative Digital Departure Rerouting
D-ATIS	Digital Automatic Terminal Information Service
DMTA-RTT	Digital Mesh Technology and Application-Research Transition Team
ISA	Interconnection Security Agreement
LAMP	Localized Aviation MOS Program
NTX	North Texas
PIE	Platform Integration and Evaluation
PS	Partner Services
RFI	Request for Information
SA	Sustainable Aviation
SAA	Space Act Agreement
SFNP	Sustainable Flight National Partnership
STBO	Surface Trajectory Based Operation

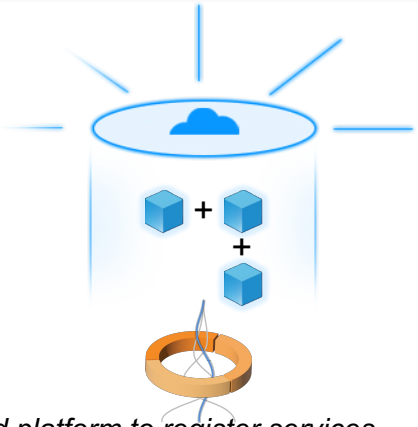
Back up Slides

DIP FY22-FY25 Progression with SFNP-Ops 1

TODAY – SFNP-Ops 1a CDDR w/ML @ NorTx



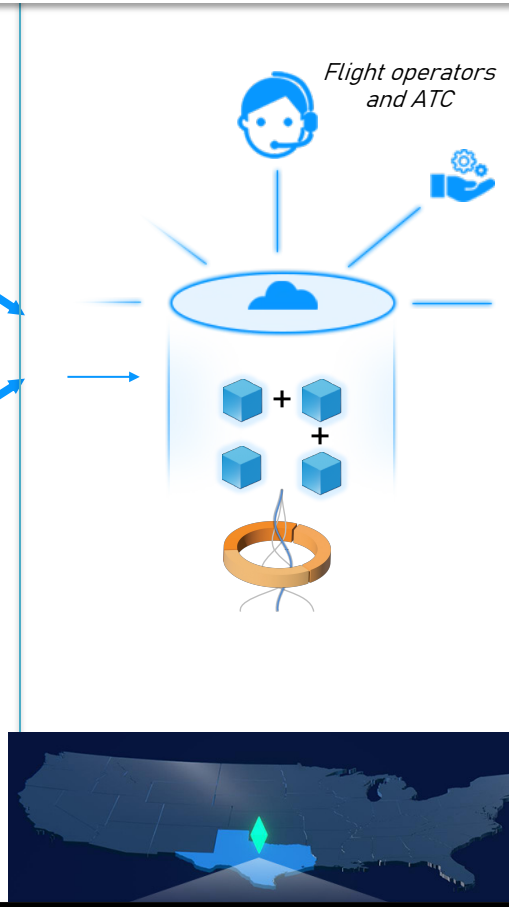
Applied machine learning to digital prediction services
Transformed to service oriented architecture



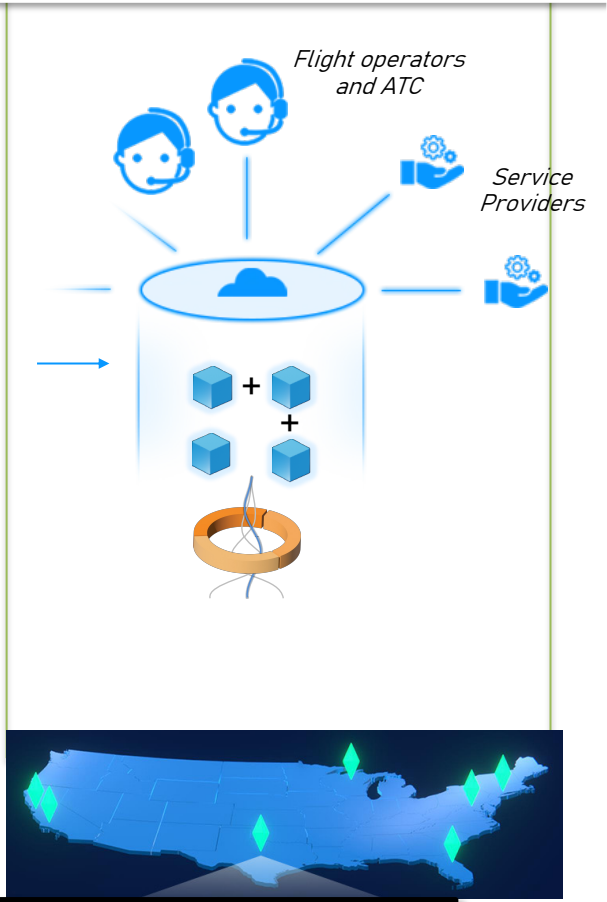
Build up cloud-based platform to register services

TODAY – Platform Build Up

FY23 @North TX – SFNP-Ops1a Integration of CDDR w/Platform



FY24/25 @ TBD– SFNP-Op1b Scale and Adapt to New Airspace



Immediate impact to RW Operations; Agile build up

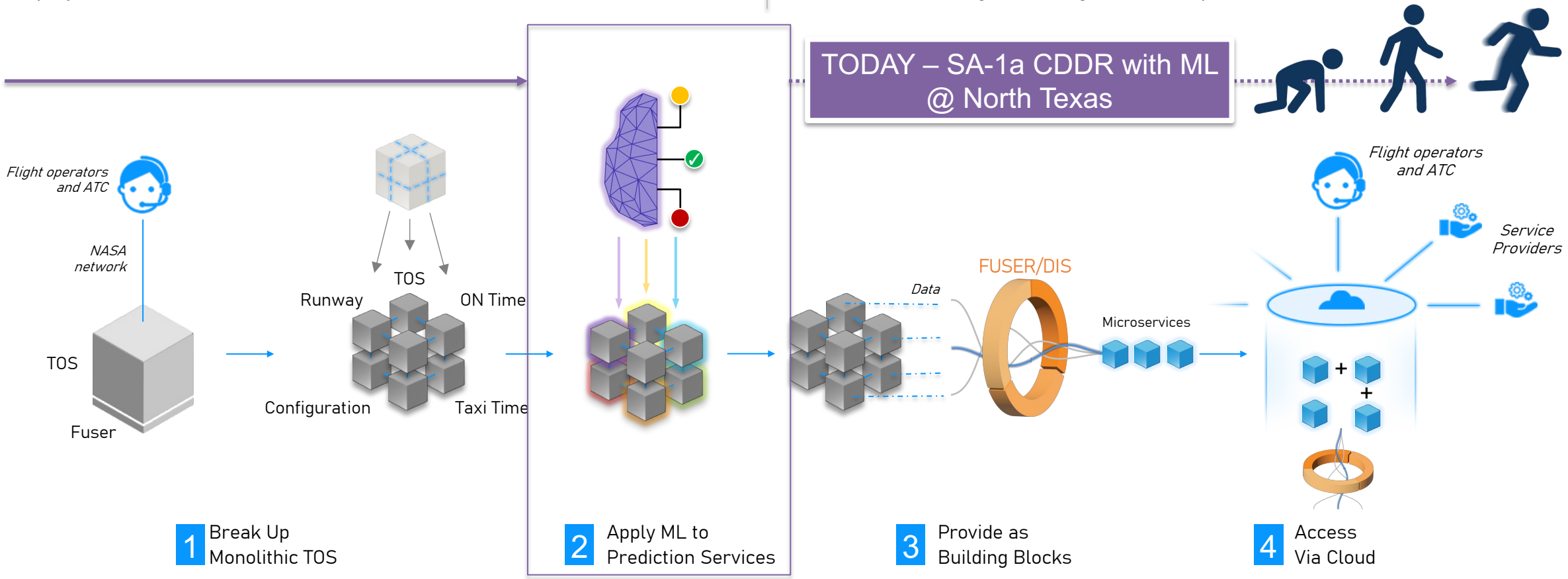
Leveraging ATD-2 to Build-Up Initial Ecosystem

BEFORE: ATD-2

Monolithic service for single application, using adaptation-based algorithms to generate trajectory predictions as input to terminal scheduler; requiring site-to-site deployment

FUTURE: DIP

Transformed into service-oriented architecture of highly reusable digital services accessible on the platform to support many advanced applications; upgraded to machine learning-based algorithms for predictions to enable NAS-wide scalability



Advancing Technology to scale and adapt for reusability in the NAS

Partner Engagement – Technical Approach – Platform Use Scope

Onboarding | **Evaluation and Validation**

PS-1 PIE-S1&S2

1

Authorization Access

- Set-up account
- Log in

2

Search for Service

- Discover services
- Try service

3

Consume from Service

- Request/Reply API
- Streaming API
- CDDR w/UI end-point
- Last-mile type of UI end-point (TL)

PS-2

4

Register Service

- Registration Wizard
- Automated process

5

Provide/Monitor QoS metrics

- Dashboard w/QoS metrics
- API to provide QoS data
- API to obtain QoS data

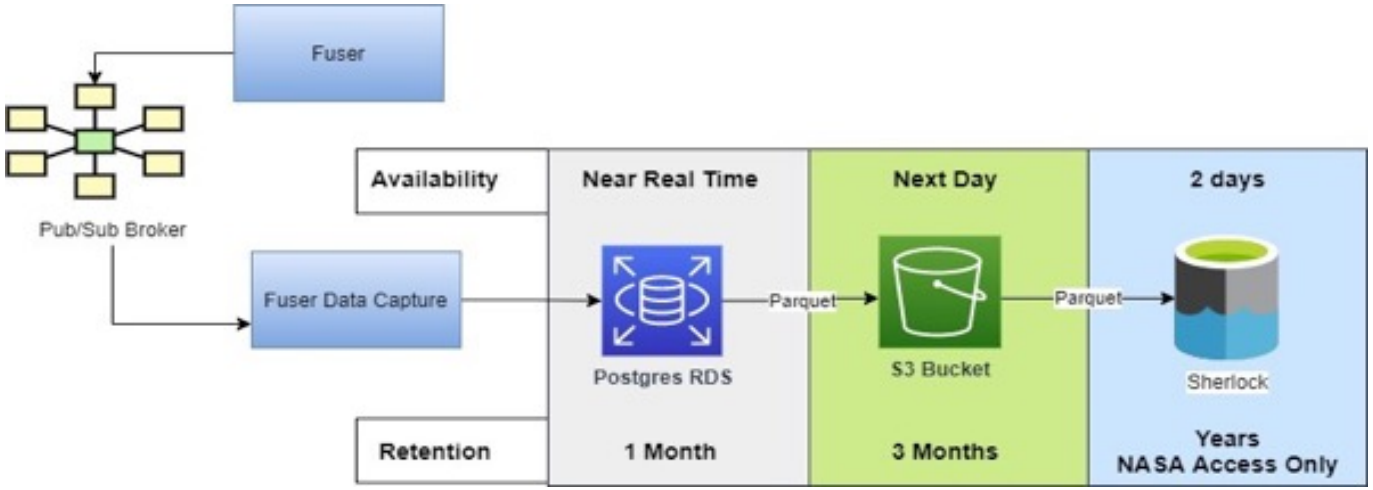
6

Test and Update Service

Stretch

NASA Data Storage

- **Data Storage**
  - RDS Database
    - Loaded continuously
    - Data will roll off after 1 month
  - S3 Buckets
    - Nightly process to export from Postgres, convert to parquet, load to S3
    - Data will roll off after 3 months
  - Sherlock
    - Process to copy from S3 buckets and store in Sherlock



Ways to Access NASA services and Data

- **Query data access API**: prediction services write results to data archive which can be queried for near real-time or historical results
- **Query model API:** machine learning models can be queried in what-if mode where user provides required input and model returns the prediction
- **Consume real-time Fuser data**: prediction services write results to the real-time Fuser data feed which can be consumed as pub/sub service
- **CDDR cloud-based TOS table**: prediction services write results to the backend system which show real-time data in cloud-based User Interface