AIRSPACE TECHNOLOGY DEMONSTRATIONS
TECHNICAL INTERCHANGE MEETING

ATD-3 Dynamic Routes for Arrivals in Weather (DRAW) and Multi-Flight Common Route (MFCR)

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FAA ATD-3 Project Lead

September 22, 2021

Session Agenda & Topics

ATD-3

- **Airspace Technology Demonstration 3**
  - Tool Suite Overview
  - Recap: ATD-3 Tool Suite's Transfer to the FAA

MFCR

- **Multi-Flight Common Routes**
  - Capability Overview & Current Status ♦ Guest Speaker: Karl Bilimoria (NASA)
  - Program Accomplishments

DRAW

- **Dynamic Routes for Arrivals in Weather**
  - Capability Overview & Current Status ♦ Guest Speaker: Douglas Isaacson (NASA)
  - Human-in-the-Loop (HITL) Study Overview ♦ Guest Speaker: Philip Bassett (Cavan Solutions)

The Typical Problem: Weather

- Adverse weather accounts for ~70% of Total National Airspace System (NAS) Delay in U.S. Operations
  - Convective Weather is the most difficult to deal with as a result of its unpredictability

- Traffic Flow Management (TFM) Decision Support Tools are available to traffic managers & airspace users to help identify & apply strategic mitigations, e.g., Severe Weather Avoidance Plans (SWAPs)

- Automation is not sufficient today to adequately notify traffic managers & airspace users when weather constraints have changed & avoidance routes (or segments of them) may no longer be necessary

- Strategic Weather Avoidance Routes often result in large deviations from user preferred trajectories, therefore, leading to unnecessary:
  - Delays
  - Fuel
  - Airline Operating Cost
  - Environment Impact

The Solution: ATD-3

- ATD-3 was a subproject sponsored by NASA ATD Project as part of NASA's Airspace Operations & Safety Program (AOSP)

- **Addressing AOSP Technical Challenge #3:**
  - To reduce weather-induced delays through the integration of weather information to better manage aircraft, traffic flow, airspace, & schedule constraints by delivering air/ground procedure & user-tool technologies, assuming current-day data sharing & automation infrastructure limitations

- **ATD-3 Objectives:** To develop integrated air/ground automation tools that:
  - Reduce impacts of uncertainty in weather
  - Enable continuous analysis & identification of more efficient routes for either individual flights or for groups of flights
  - Efficiently share route correction or implementation options between traffic managers, pilots, dispatchers, & controllers

ATD-3 Potential Benefits

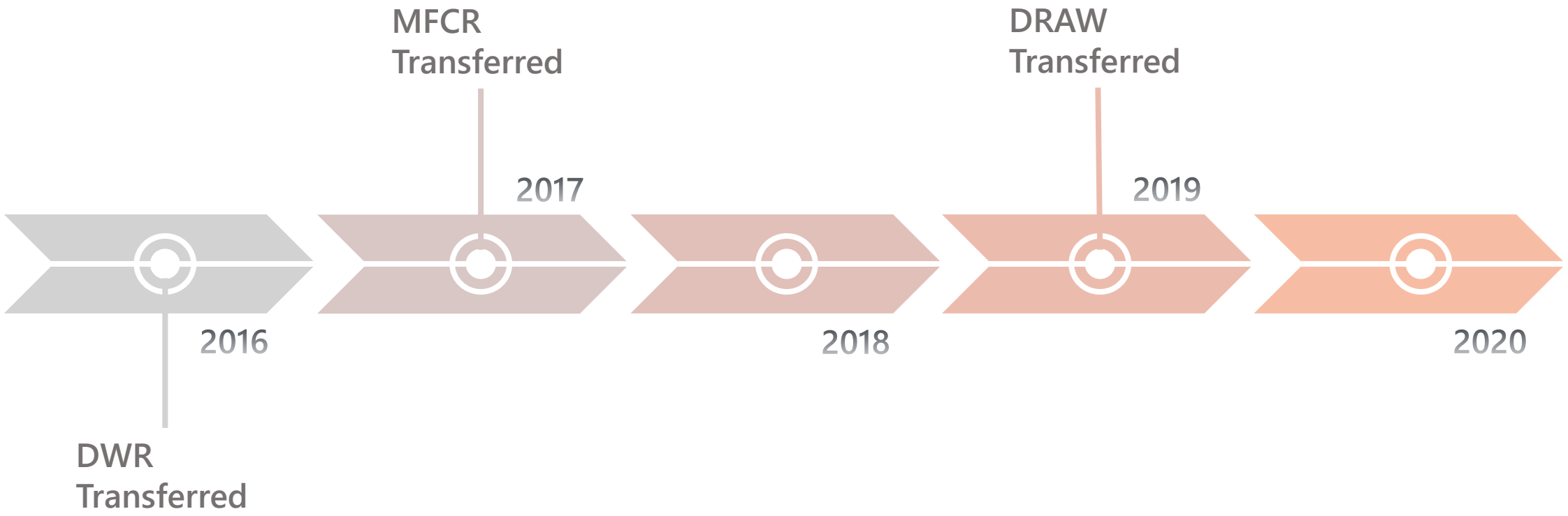
- Integrating ATD-3 Technologies into the NAS could:
  - Improve trajectory efficiency in the en route & arrival phases of flight
  - Improve TFM coordination & productivity
  - Improve responses to changes & uncertainty in demand & constraint predictions
  - Accelerate the recovery from outdated Traffic Management Initiatives (TMIs)
  - Revise long duration TMIs expeditiously

ATD-3 Tool Suite

ATD-3

- Dynamic Weather Reroutes (DWR)
- Multi-Flight Common Routes (MFCR)
- Traffic Aware Strategic Aircrew Requests (TASAR)
- Dynamic Routes for Arrivals in Weather (DRAW)

ATD-3's Technology Transfer Timeline



MFCR Functionality

Multi-Flight Common Routes (MFCR) identifies opportunities for delay recovery by refreshing outdated routes

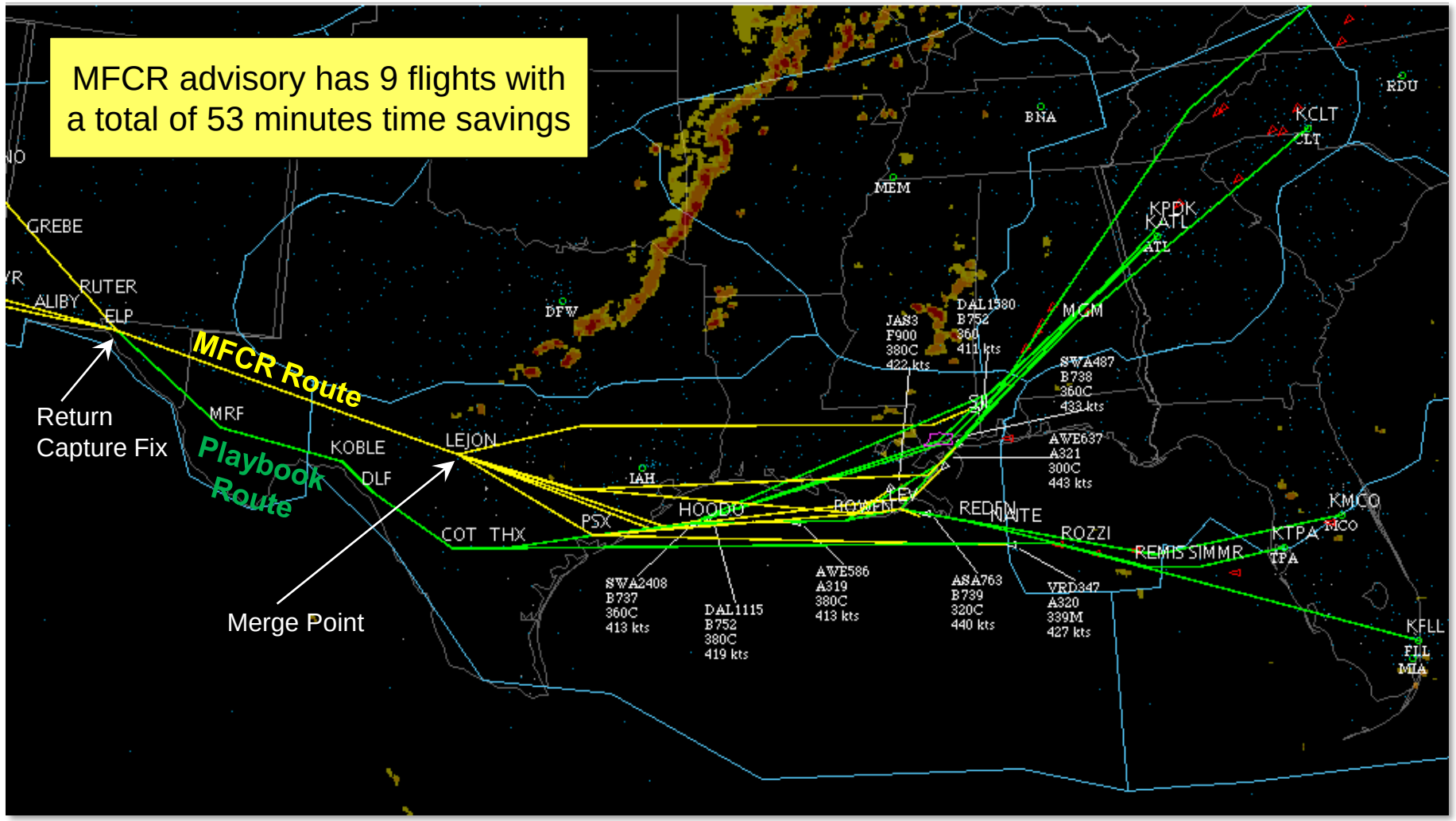
MFCR Usage

- MFCR is designed for use by Traffic Flow Managers, for possible implementation as a module of TFMS
  - NAS-wide coverage, looking for time-saving advisories in all Centers
  - Each advisory covers a group of flights currently in the same Center
  - May be used as an exit strategy from Playbook routes, but it also identifies opportunities to refresh outdated routes in other situations
- Possibly gain the benefits of large delay recovery, at the “cost” of evaluating & coordinating a small number of re-route advisories
- Establish new flows for groups of flights having a common route segment, for enhanced operational acceptability
- Present re-route advisory to Traffic Manager, with graphical functionality for review/modification prior to implementation

MFCR Advisory Features

- MFCR merges multiple flights to a common route, creating a new flow for increased operational acceptability
- Each route segment is clear of weather
- Each flight has time savings of at least 3 minutes (user selected)
- Total flight time savings for group is at least 10 minutes (user selected)
- MFCR provides graphical functionality for review & modification prior to implementation of advisory

Example MFCR Advisory



Technology Transfer

- NASA completed technology transfer to FAA in December 2017

- Key deliverables include:
  - Concept of Operations
  - Functional Requirements
  - Benefits & Cost Assessment
  - HITL Evaluation Summary
  - Software; Version Description Document; User Guide
  - Technical Publications

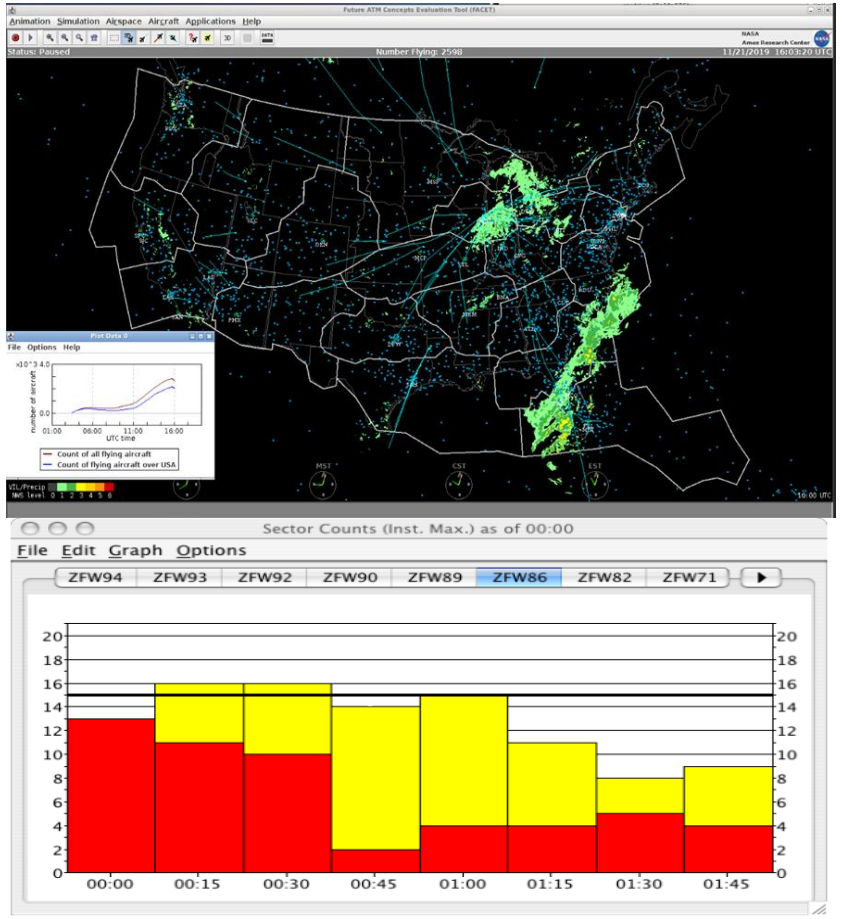
ATD-3 MFCR Current Status

- MFCR was tech transferred to the FAA's Mission Support Services Organization for incorporation into their Advanced Flight Specific Technologies (AFST) program
  - AFST was a candidate for inclusion in TFMS Enhancements 5
    - TFMS Enhancements 5 is currently on hold pending technology refresh of TFMS

- NASA developed the Future ATM Concepts Evaluation Tool (FACET) to evaluate Traffic Flow Management (TFM) capabilities
  - The NAS Constraint Evaluation & Notification Tool (NASCENT) is an application within FACET that was utilized to demonstrate the MFCR concept
  - FACET/NASCENT were software transferred to the FAA's NextGen Organization for use in evaluating future TFM concepts

FACET & NASCENT Capability Overview

- FACET provides Fast-time/Real-time simulation or playback of air traffic, weather, & airspace constraints & restrictions.
  - Can receive all this data from an external source in live mode.
- Provides variety of metrics in graphical & text format
  - Delays: minimum, maximum, average, per airline, per time bucket
  - Fuel burn, Distance flown, Time flown
  - Duration of exposure to weather
  - Number of aircraft in CONUS, ARTCCs, Sectors, Airports, geographical grid cells at each time bucket
- NASCENT provides alternative routes that can be modified & validated to be replaced with the active flight plan.
  - Proposes routes to save time or fuel, avoid airspace constraints, or avoid weather.
  - Can operate in live mode & on the fly proposed route for live traffic around live constraints or weather (can be integrated with an external lab data feed)



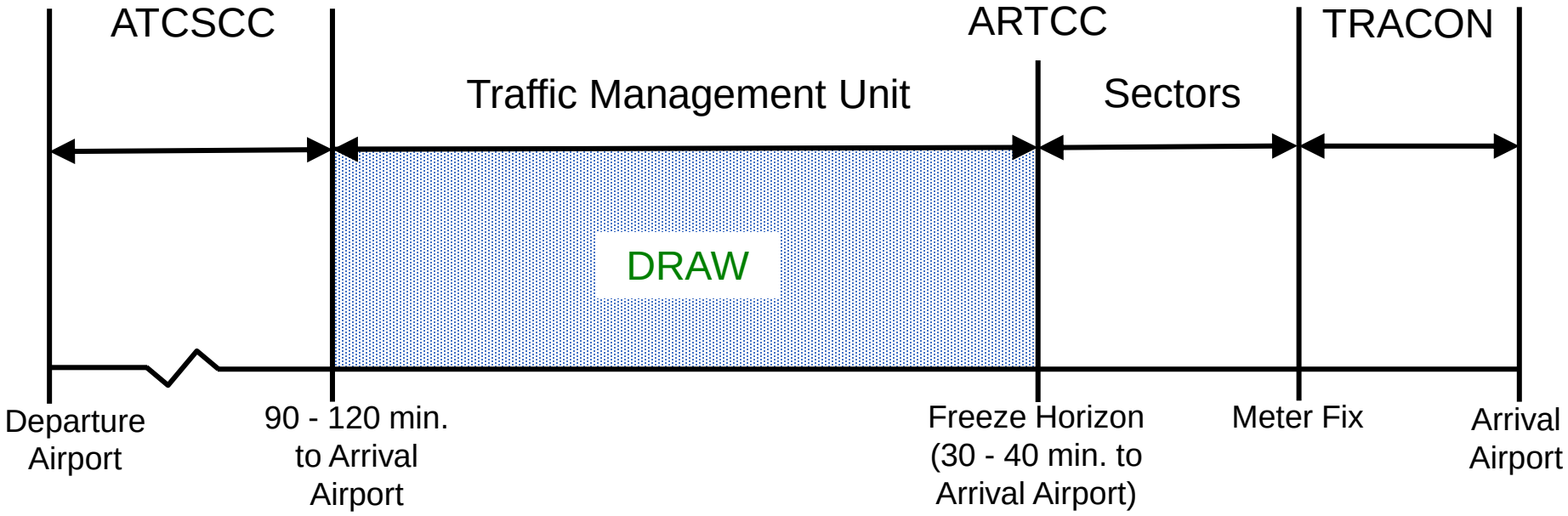
Dynamic Routes for Arrivals in Weather (DRAW) – Today's Arrival Operations

- **Weather is one of the primary reasons for time-based metering to be discontinued.**
- **Current operational system cannot adjust its scheduled times of arrival (STA) for aircraft that need to deviate around weather.**
- **Traffic Management Coordinators (TMCs) & Controllers revert to less efficient methods of managing arrival traffic flow in weather**
  - Implement conservative alternate routes hours in advance
  - Miles-in-trail (MIT)

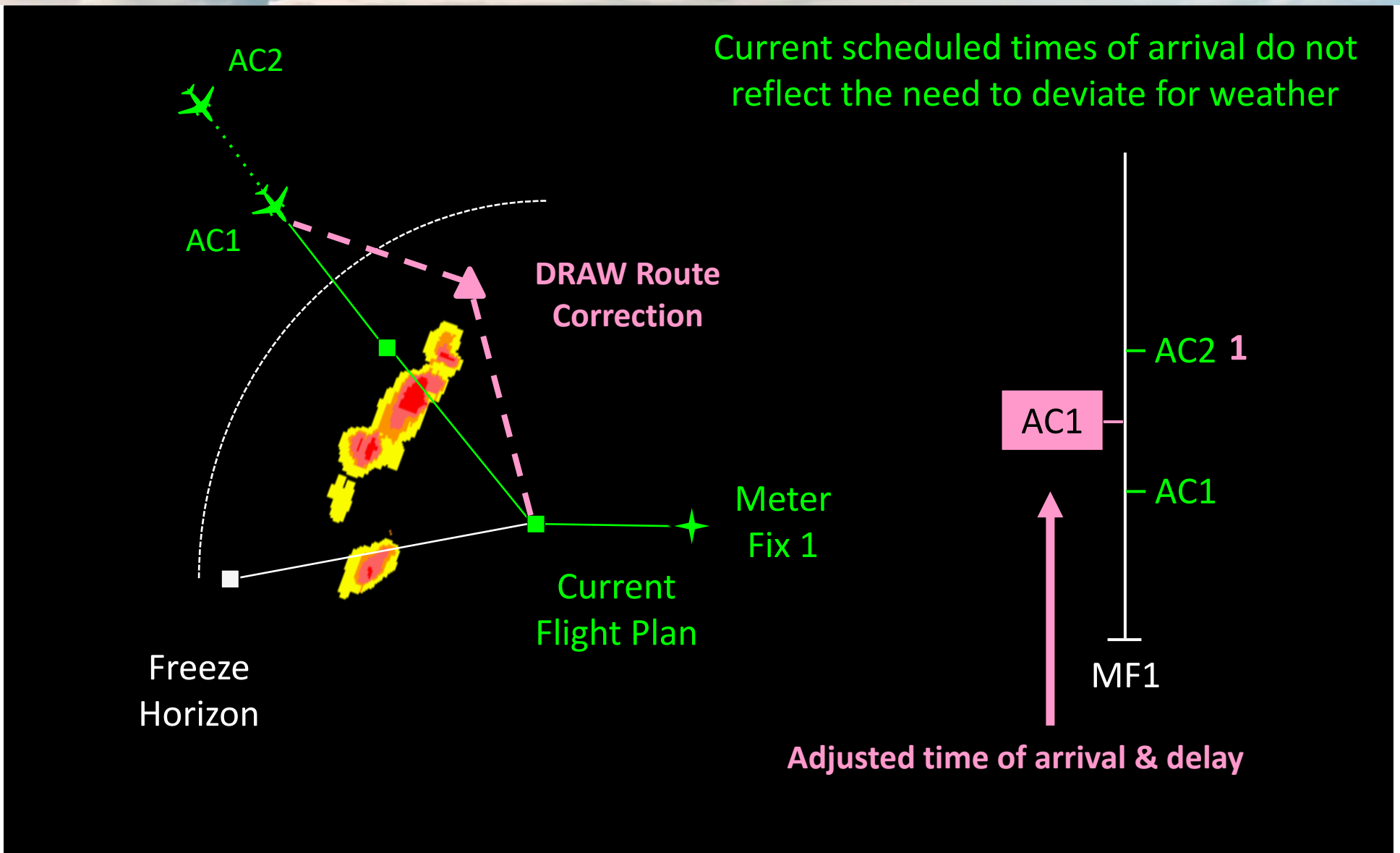
What is DRAW?

Traffic management decision support tool that proposes reroutes to improve arrival traffic flow

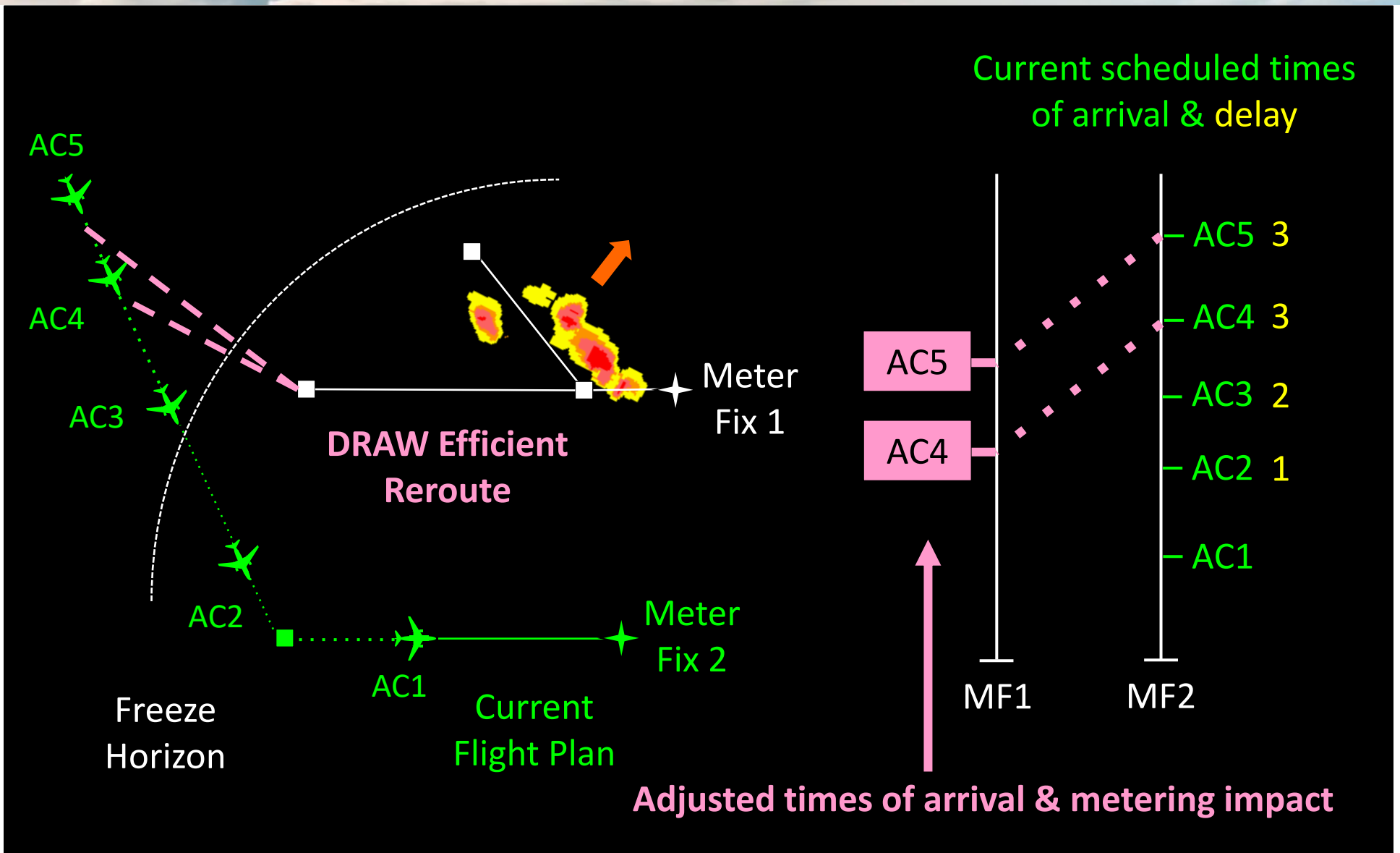
- Sustain metering operations in the presence of weather
- Find efficient arrival routes
- Balance meter fix demand



1) Weather-Avoidance Route Advisory



2) Alternate-Route Advisory

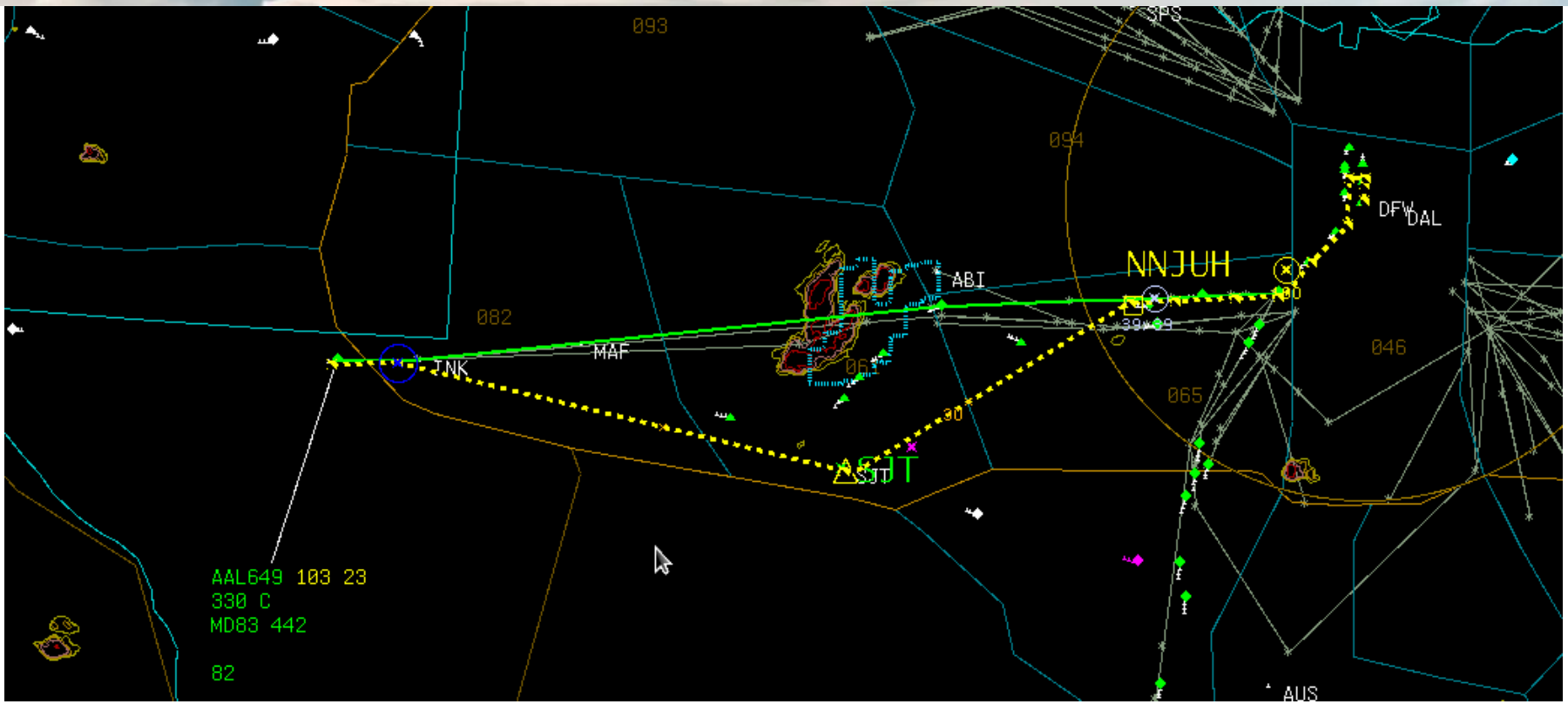


DRAW Advisory List

DRAW Advisories

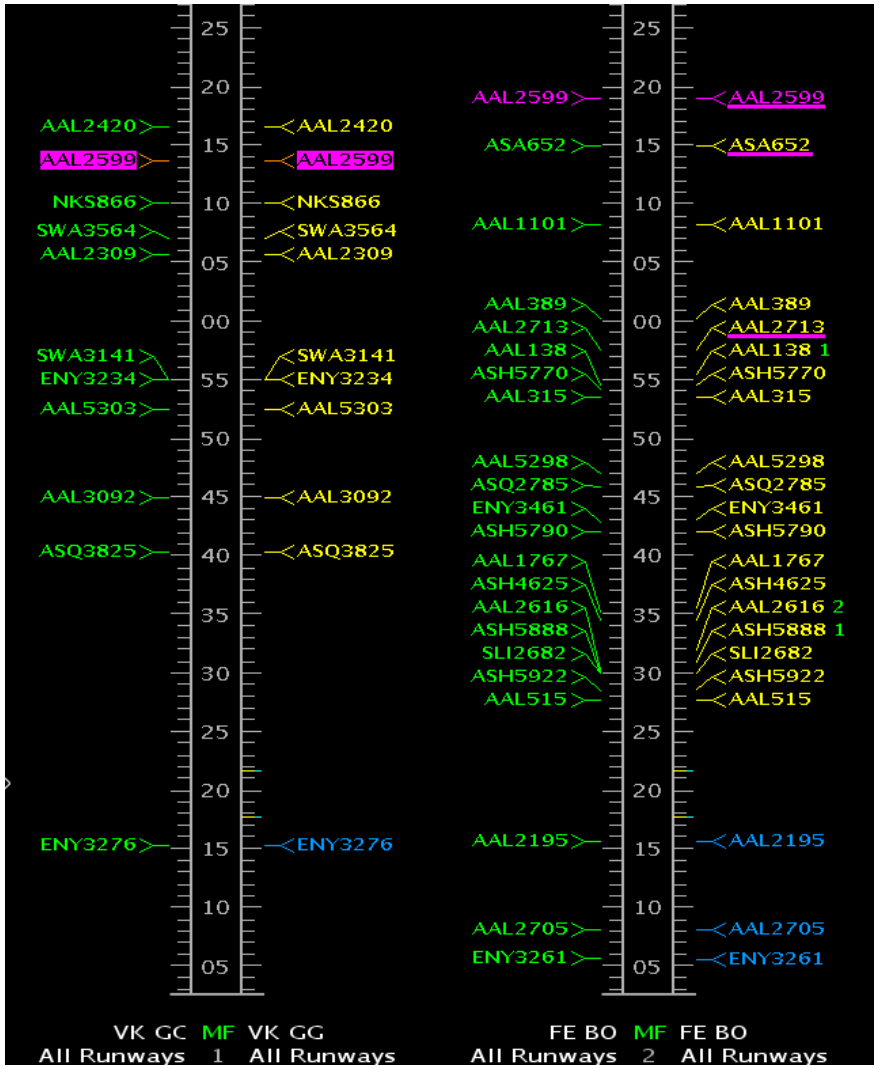
TL	TP	GP	ACID/DEP/ARR	SAV	TRANS.STAR/AUX	STATUS	HIDE
■		VKTRY |	GREGS |				
■		FEVER |	KNEAD | BOOVE |				
	☐		AAL2289/KSAN/KDFW	1.2	BOOVE.BOOVE4/1	OK	☐
	☐		AAL1117/KLAS/KDFW	2.8	BOOVE.BOOVE4/1	OK	☐
	☐	☐	AAL1243/KLAX/KDFW	1.1	BOOVE.BOOVE4/1	OK	☐
	☐	☐	AAL767/KSNA/KDFW	1.3	BOOVE.BOOVE4/1	OK	☐
	☐		AAL2705/KSJC/KDFW	0.3	JEN.JEN1/1	OK	☐
	☐	☐	AAL6731/KSNA/KDFW	-0.2	BOOVE.BOOVE4/1	OK	☐
	☐	☐	AAL4421/KPHX/KDFW	0.2	BOOVE.BOOVE4/1	OK	☐
■		KARLA |	SASIE | FINGR | BRDJE |				
■		HOWDY |	DODJE | ORVLL | YEAGR |				

DRAW Reroute Trial Planning (TP)



- Clicking on a flight in DRAW List displays the advisory route on the map.
- User can modify the route by clicking & dragging, & then press “Accept” button to amend.
- If the route conflicts with a Convective Weather Avoidance Model (CWAM) polygon, the conflicting polygon is presented.

Timeline



- **Flights that have DRAW advisory show magenta underline.**
- **When the user modifies flight routes via TP, the flight's ETA & STA on Timeline are updated in real-time (magenta box) to visualize the effect of the modification.**

DRAW HITLs #1-5

	HITL #1	HITL #2	HITL #3	HITL #4	HITL #5
Month	May 2017	Oct. 2017	Apr.-May 2018	Oct.-Nov. 2018	Jul.-Aug. 2019
System	CTAS	CTAS	CTAS	CTAS	TBFM
ARTCC (Arrival Gates)	ZFW (SW → DFW)	ZFW (NW, SW → DFW)	ZTL (SW, SE → ATL)	ZTL & ZJX (SE → ATL)	ZFW (All 4 corners → DFW)
DRAW vs. No-DRAW	Y	Y	---	Y	Y
# of Weather Scenarios	4	2	4	2	4
# of TMC	4	4	4	4	4
# of Sector Staffed	5	7	7	5	0
Notes	1 Baseline run (clear weather), 6 Storyboard runs	TMC & Controller sessions on separate days, 16 TMC-Only runs	1 Baseline run (clear weather)	2 Freeze Horizon distances 2 Baseline runs (clear weather)	TBFM demo TMCs only

Why Is the DRAW Capability Important?

- Current operational TBFM system cannot adjust Scheduled Times of Arrival (STAs) for aircraft that deviate around weather
  - Causes uncertainty in downstream arrival schedules
- Presence of severe weather is the primary reason for traffic flow managers to discontinue TBFM operations & revert to less efficient methods of managing arrival flows, e.g.,
  - Conservative Alternate Routes
  - Mile-in -Trail Restrictions
- As the use of TBFM expands, the need for decision support capability to manage arrival aircraft through & around weather is evident

DRAW's Value to Traffic Flow Managers

- Traffic Management Decision Support Tool that:
  - Proposes reroutes to improve arrival traffic flow
  - Sustain metering operations in the presence of weather
  - Proposes efficient arrival routes reducing fuel burn
  - Enables balancing of meter fix demand
  - Provides convective forecast updates every 5 minutes
  - Utilizes ERAM traffic feed from home & adjacent ARTCCs

Where is DRAW Now In The FAA?

- **<u>Current Goal:</u>**
  - To assess the DRAW capability in multi-scheduler configuration environments within the TBFM System (i.e., Extended Metering [XM] / Coupled Scheduling [CS]) via a HITL experiment

- **<u>Goal Justification:</u>**
  - The XM & CS multi-scheduler environments are used to extend the operational range of the TBFM System, along with any speed advisories used to achieve the desired schedules at metering reference points
  - These multi-scheduler environments allow for greater flexibility & efficient options in managing schedule deconfliction & delay absorption
  - **It is unknown how DRAW will function within the XM & CS environments; therefore, FAA is currently investigating the operational effects of the DRAW capability operating within these extended TBFM environments utilizing a HITL experiment**

DRAW HITL Project Timeline

2020

DRAW Capability Installation & Recommendations

2021

DRAW Tech Transfer Analysis
DRAW HITL XM & CS Test Plan

2022

DRAW HITL XM & CS Scenarios
DRAW HITL XM & CS HITL & Documentation
DRAW Preliminary Program Requirements

DRAW HITL Team Overview

FAA William J. Hughes Technical Center

- HITL Study Environment Configuration, Scenario Development, & Experimental Design

Cavan Solutions

- HITL Site Selection, HITL Scenario Development, & Traffic Flow Management Subject-Matter- Experts (SMEs)

Massachusetts Institute of Technology Lincoln Laboratory (MIT LL)

- DRAW Software Porting & Weather Scenarios

DRAW HITL Components

HITL Study Site Selection

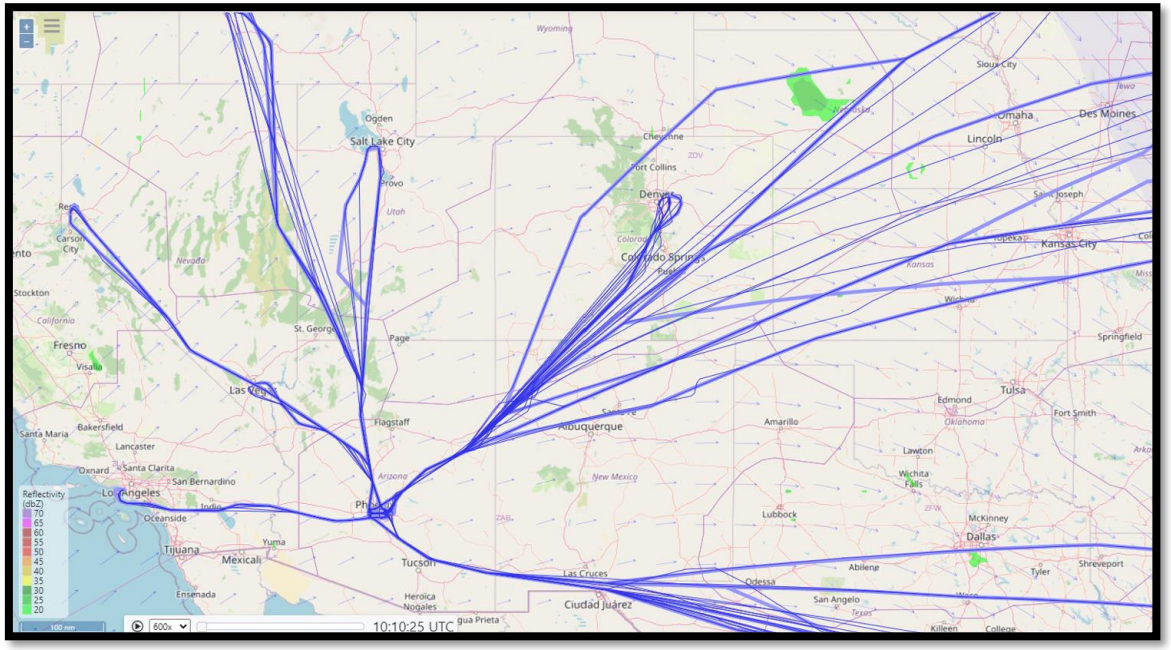
HITL Study Environment

DRAW Software Porting & HITL Weather Scenarios

Site Selection Criteria

- Operational site must utilize TBFM XM/CS on a regular basis
- Available TBFM adaptation must be compatible with DRAW prototype software (TBFM 4.7)
- Airspace should be conducive to DRAW HITL scenario development
  - Traffic flows/meter fix locations suitable for a variety of DRAW reroutes
  - General enough to be used to extrapolate DRAW performance to other airspaces

Site 1: Albuquerque Center (ZAB)

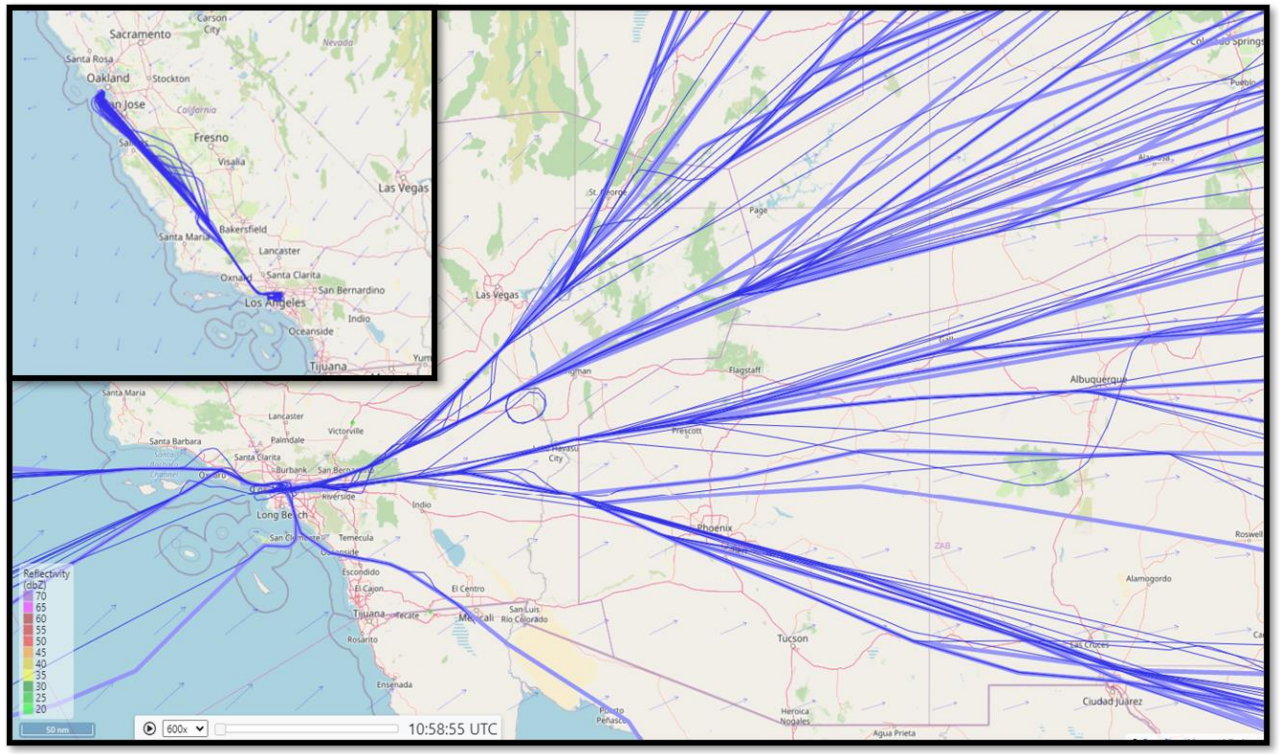


Click on picture to zoom-in

- Operates with both TBFM XM & CS
- ZAB operates in the XM environment with:
  - Extended Metering Points (XMPs) for Phoenix International Airport (KPHX) arrivals
  - Coupled Scheduling Metering Points (CMPs) for Los Angeles International Airport (KLAX) arrivals
- KPHX is a major airline hub
- KPHX/ZAB has multiple busy arrival streams (i.e., multiple arrival routes/meter fix options)
- ZAB operational expertise encompasses both ZLA & ZAB TBFM-XM configurations

Site 2: Los Angeles Center (ZLA)

- ZLA has operated with TBFM XM, since it's inception
- Geographic constraints (i.e., oceanic & international airspace)
- The FAA has identified KLAX/ZLA as one of the four initial "TBO operating areas"
- KLAX has consistent traffic volume from the east with the TBFM-XM configuration extending into ZAB airspace



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Site Selection Summary

- ZAB/KPHX & ZLA/KLAX selected to give research team flexibility
  - Compatible TBFM adaptations
  - Wide range of airspace characteristics
  - Options for scenario development (e.g., XM & CS operations, Multiple & varied freeze horizons/meter fixes, etc.)

- By analyzing both ZLA & ZAB configurations, we can demonstrate the best use of DRAW in the XM/CS environment, point out benefit mechanisms & identify limitations/development needs

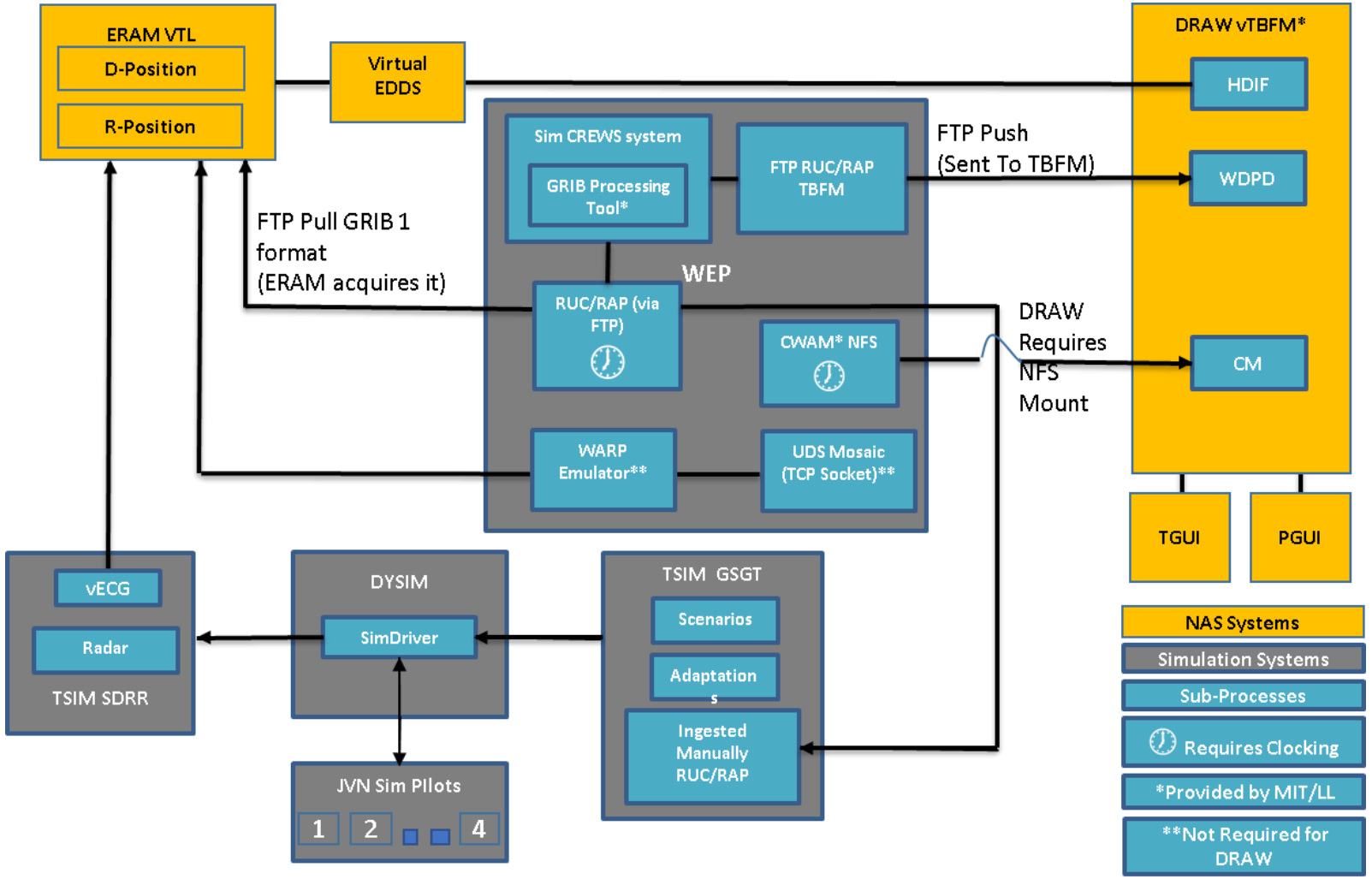
- Conducting the simulation using unique scenarios across multiple Air Route Traffic Control Centers (ARTCCs) will provide excellent examples of DRAW-TBFM-XM & CS interaction for analysis of operational suitability & software/systems compatibility

- Utilization of ZLA & ZAB configurations provide excellent opportunities for operational TFM analysis including coordination with multiple facilities including Denver Center (ZDV), another fully deployed TBFM-XM adaptation

William J. Hughes Technical Center (WJHTC)

- Located 10 miles northwest of Atlantic City, New Jersey
- **Mission:** To provide the safest, most efficient & responsive aerospace system in the world
- Accomplishing the mission by:
  - 500,000+ square feet of lab space adapted for research, development, test & evaluation activities
  - Laboratory facilities proficient at simulating the capabilities that are operational in the NAS
    - Known as having the “NAS under one roof”

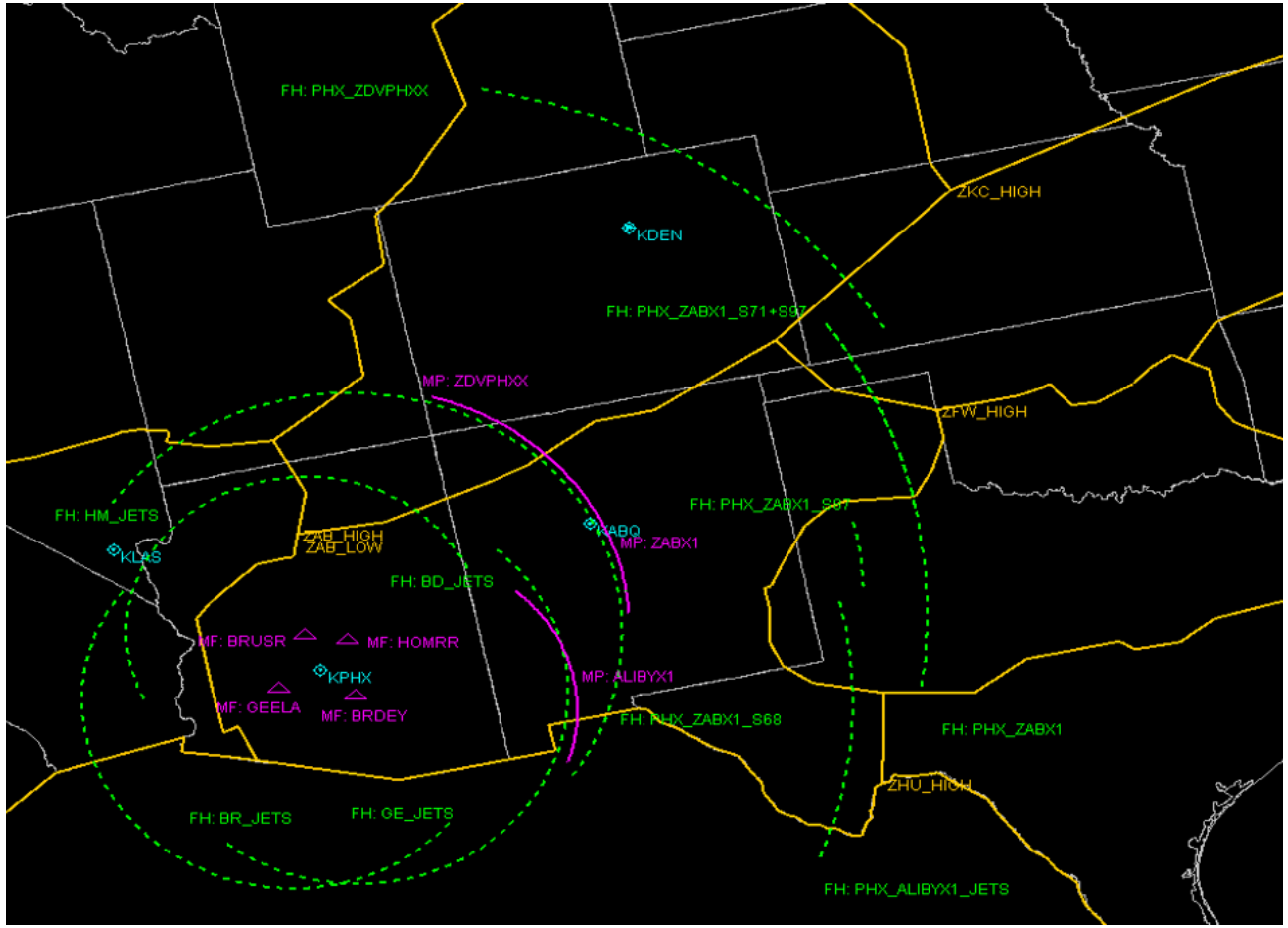
WJHTC DRAW HITL Architecture



CWAM: Convective Weather Avoidance Model
CIWS: Corridor Integrated Weather System
CM: Communication Manager
CREWS: CTAS Remote Weather System
CTAS: Center TRACON Automation System
D-Position: Data Position
DYSIM: Dynamic Simulation
EDDS: En Route Data Distribution System
ERAM: En Route Automation Modernization
FTP: File Transfer Protocal
GRIB: Gridded Binary
GSGT: Graphic Simulation Generation Tool
HADDS: Host ATM Data Distribution System
HDIF: HADDS Data Interface
PGUI: Planview GUI
RAP: Rapid Refresh
R-Position: Radar Position
RUC: Rapid Update Cycle
SDRR: Simulation Driver Radar Recorder
TCP: Transmission Control Protocol
TGUI: Timeline GUI
TSIM: TBFM Simulation
VTL: Virtual Test Lab
WARP: Weather And Radar Processor
WDPD: Weather Data Processor Daemon
WEP: Weather Enterprise Playback
UDS: User Display Systems
vTBFM: virtual Time Based Flow Management

ZAB Airspace Diagram & Lab Configuration

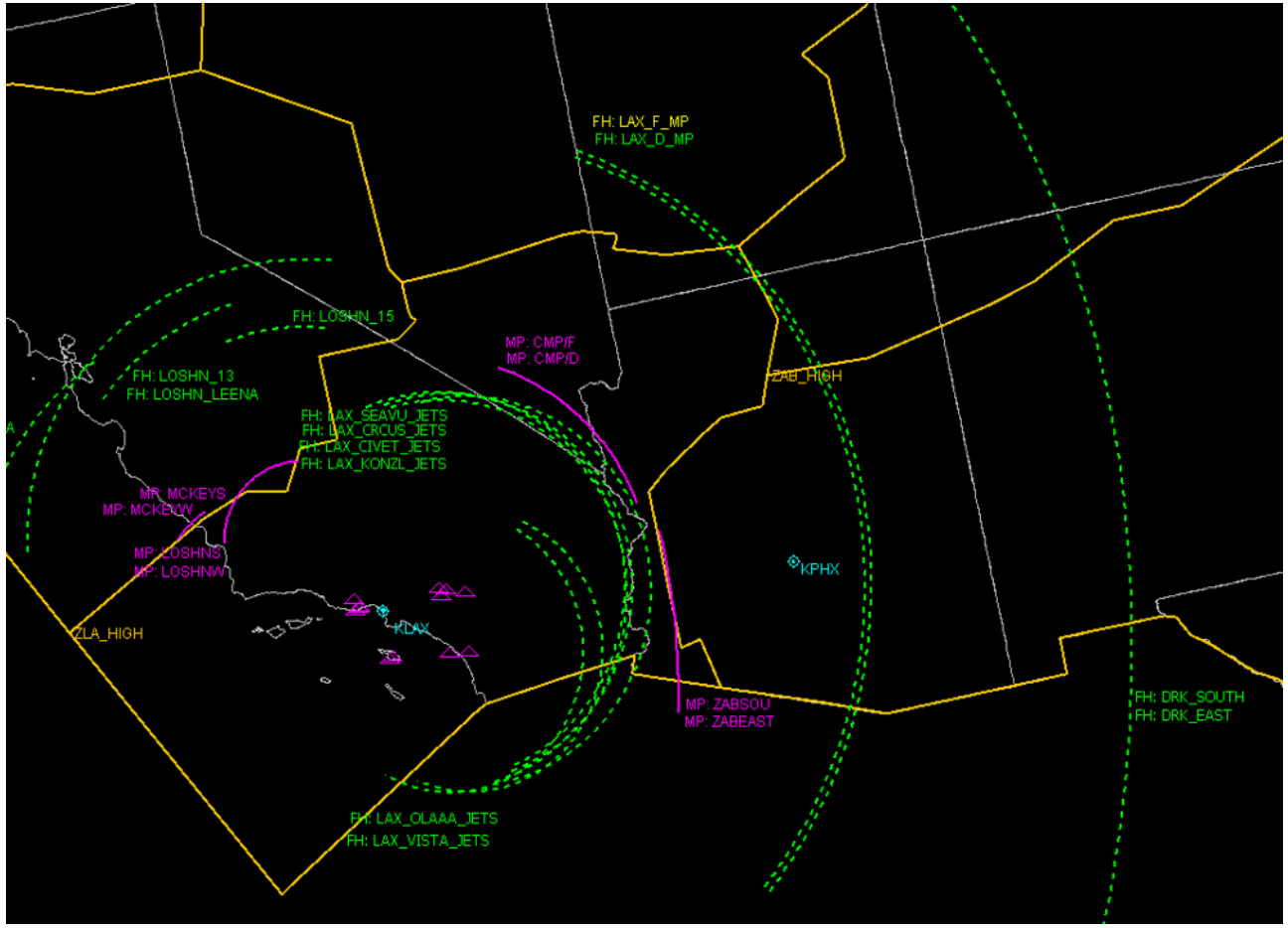
- KPHX Arrivals
- ZAB arrival TBFM system
  - vTBFM provided by MIT/LL
  - TBFM 4.7 with DRAW Prototype Software
  - TBFM Adaptation
    - ZAB_T4.7.1_6.2
    - Chart Cycle: 10/11/2018
  - ZDV & ZLA receive Metering Times
- VTL ERAM
  - ZAB, ZLA, ZHU, ZFW, ZDV, ZKC
    - Chart Cycle: 9/13/18
    - National: eae4102a
- Weather & Aircraft Scenario
  - SDRR, DYSIM, GSGT (TSIM)
  - WEP Version: TBD
  - Traffic Date: TBD



Magenta = KPHX Meter Points & Arrival Fixes	**Green** = XMPs Paired with KPHX Meter Points & Arrival Fixes, Respectively

ZLA Airspace Diagram & Lab Configuration

- KLAX Arrivals
- ZLA arrival TBFM system
  - vTBFM provided by MIT/LL
  - TBFM 4.7 with DRAW Prototype Software
  - TBFM Adaptation
    - ZLA_T4.7.1_9.1
    - Chart Cycle: 10/11/2018
  - ZAB only receives Metering Times
- VTL ERAM
  - ZLA, ZAB, ZOA, ZLC, ZDV
    - Chart Cycle: 9/13/18
    - National eae4102a
- Weather & Aircraft Scenario
  - SDRR, DYSIM, GSGT (TSIM)
  - WEP Version: TBD
  - Traffic Date: TBD



Magenta = KLAX Meter Points & Arrival Fixes	**Green** = CMPs Paired with KLAX Meter Points & Arrival Fixes, Respectively

TBFM Adaptation Settings

- All tests will be run with both CS or XM, i.e.,
  - CS will be tested in the ZLA configuration
    - Only operational site in NAS that runs CS metering operation
    - Will allow for a realistic CS operational checkout of DRAW functionality
    - Neighboring ZAB is one of a few NAS sites to utilize Ground Interval Management-Spacing (GIM-s) allowing team to realistically test the interaction of GIM-s speed advisories in conjunction with DRAW reroutes
  - XM will be tested in the ZAB configuration
    - XM is utilized at ZAB in the NAS operationally
    - Allows the team to evaluate XM DRAW functionality realistically
    - ZAB is one of a few NAS sites to utilize GIM-s allowing team to realistically test the interaction of GIM-s speed advisories in conjunction with DRAW reroutes

DRAW Software Porting: Operating System Upgrade

- The DRAW software that was tech-transferred from NASA to MIT LL was running on Linux CentOS 6
  - Incompatible with MIT LL & FAA security standards & is at its end of life

- With NASA support, MIT LL upgraded DRAW to CentOS 7 with all working functionalities:
  - DRAW reroutes shown on Planview Graphical User Interface (PGUI) & downstream arrival schedule impacts on Timeline Graphical User Interface (TGUI)
  - PGUI displays CWAM polygons
  - Trial Planner presents reroute options around weather & downstream arrival schedule impact highlighted on TGUI

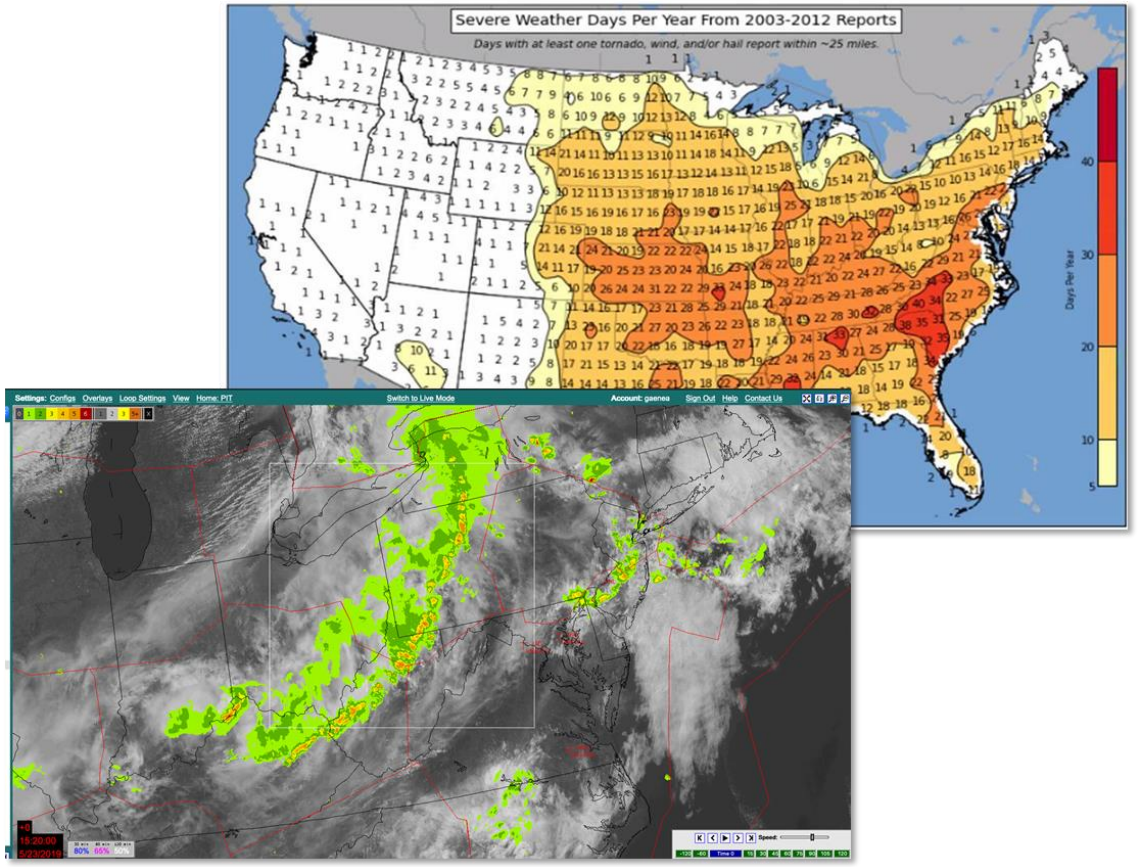
DRAW Software Porting: Current Status

- DRAW is now running on a dedicated workstation at the WJHTC in preparation for the HITL

- Integration & TBFM Adaptation Testing On-going
  - To test basic integration issues, the Initial DRAW package is adapted to ZFW the original site received from NASA
  - MIT LL is testing different DRAW adaptations in preparation for the HITL sites of ZAB & ZLA

- A number of software functionality issues have been identified as part of the porting process & by general testing of the system
  - Some of these issues are being resolved in preparation for the HITL

DRAW HITL: Weather Scenarios



- MIT LL weather archive data will be used to identify how often certain locations are impacted by convective weather & identify scenarios
- Select weather events or extreme weather useful for system evaluation may not have occurred or have been identified in the region of analysis (e.g., ZLA or ZAB)
  - If necessary, weather taken from different regions, (e.g., the southeast) may be translated to the HITL region of interest
- Coupled weather required for HITL include:
  - “Truth” wind & temperature data for simulated aircraft, e.g., High Resolution Rapid Refresh (HRRR) 0-hour
  - Forecasted winds/temps from Rapid Update Cycle (RUC) for TBFM trajectory estimators
  - CWAM forecasts from NextGen Weather Processor (NWP)

DRAW's Future In The FAA

- At the conclusion of the DRAW HITL, the FAA's NextGen Organization will package results, findings, & lessons learned for tech transfer to appropriate FAA stakeholders

- DRAW will be a candidate capability for consideration in future TBFM Enhancements

Thank You For Your Time!

Contact Information:

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NextGen Organization

Technology Development & Prototyping Division

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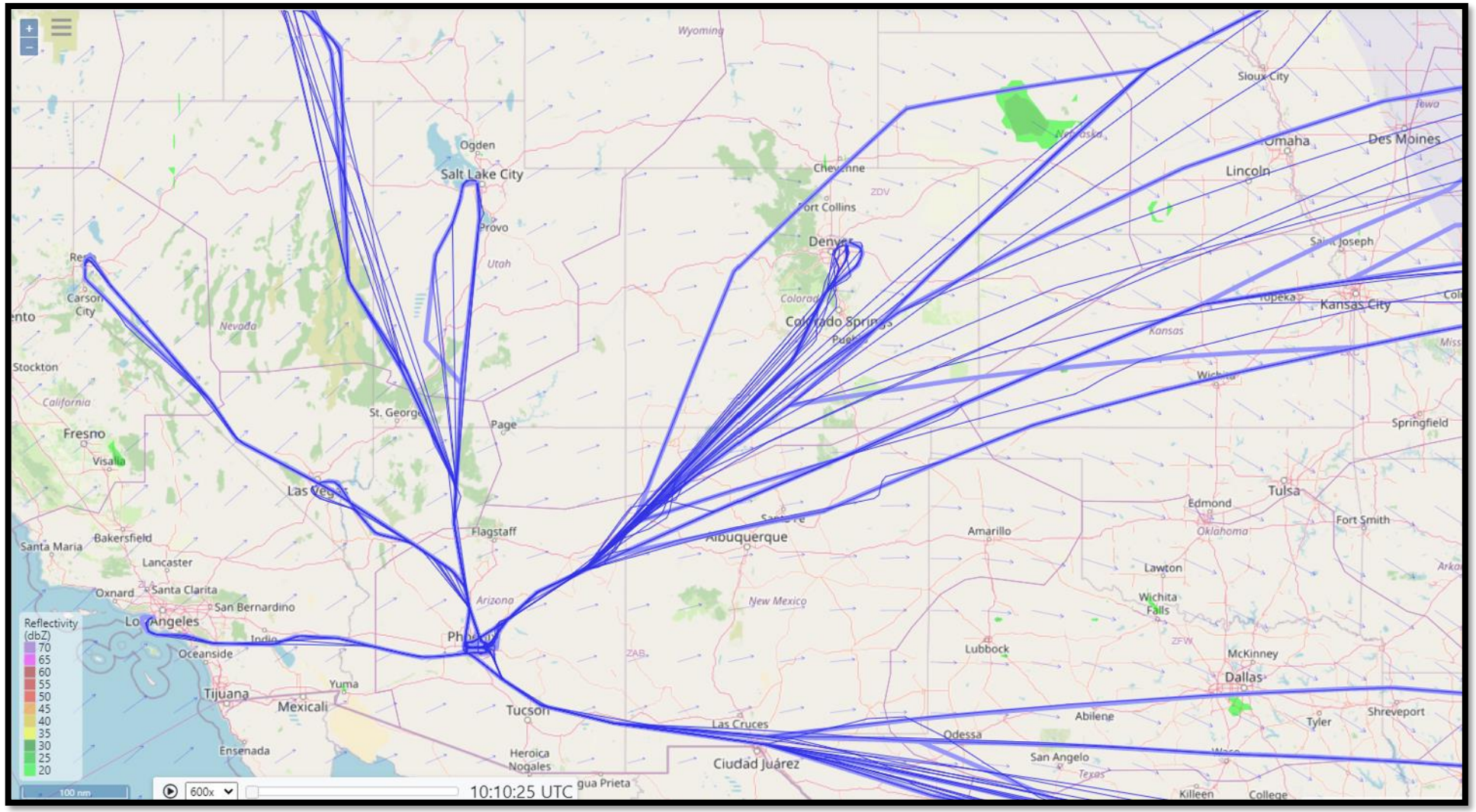
Zoom-In: Albuquerque Center (ZAB)



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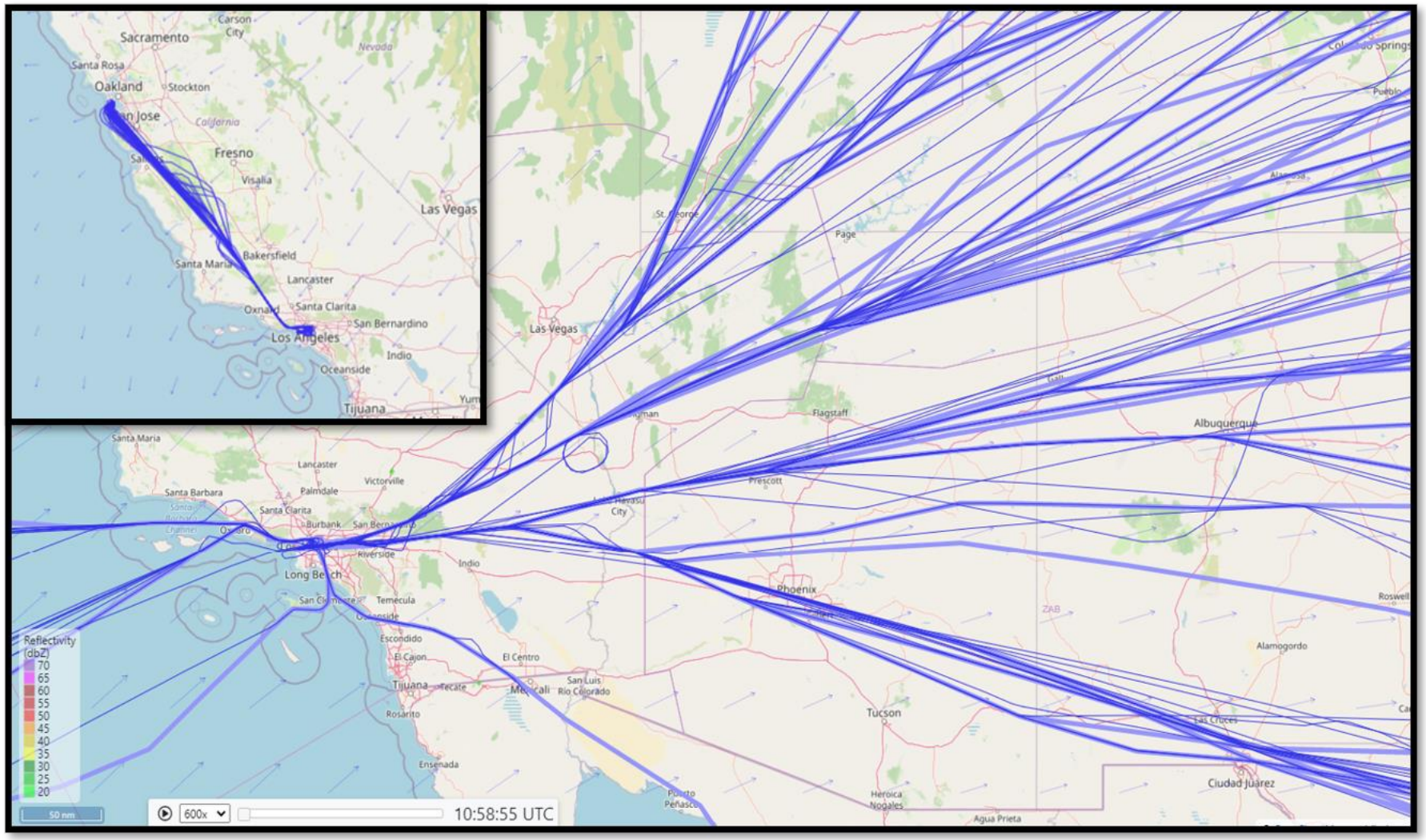
Zoom-In: Los Angeles Center (ZLA)



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