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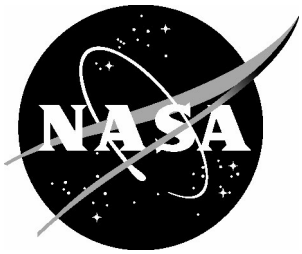

Airspace Technology Demonstration 2 (ATD-2) Technology Description Document (TDD)

Andrew Ging, Shawn Engelland, Al Capps, Michelle Eshow, Yoon Jung, Shivanjli Sharma
Ames Research Center, Moffett Field, California

Ehsan Talebi
Millenium Engineering & Integration Co.
Ames Research Center, Moffett Field, California

Michael Downs, Cynthia Freedman, Tyler Ngo, Hank Sielski, Easter Wang
Universities Space Research Assn.
Ames Research Center, Moffett Field, California

Jason Burke, Shawn Gorman, Brian Phipps
Mosaic ATM, Inc.
Ames Research Center, Moffett Field, California

Louise Morgan Ruszkowski
KBRWyle/Parallel Innovations
Ames Research Center, Moffett Field, California

March 2018

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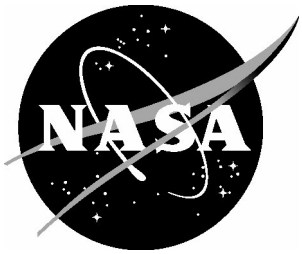

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KBRWyle/Parallel Innovations
Ames Research Center, Moffett Field, California

National Aeronautics and
Space Administration

Ames Research Center
Moffet Field, California 94035-1000

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1 Introduction

1.1 Identification

This Technology Description Document (TDD) provides an overview of the technology for the Phase 1 Baseline Integrated Arrival, Departure, and Surface (IADS) prototype system of the National Aeronautics and Space Administration's (NASA) Airspace Technology Demonstration 2 (ATD-2) sub-project, which began demonstration in 2017 at Charlotte Douglas International Airport (CLT). Development, integration, and field demonstration of relevant technologies of the IADS system directly address recommendations made by the Next Generation Air Transportation System (NextGen) Integration Working Group (NIWG) on Surface and Data Sharing and the Surface Collaborative Decision Making (Surface CDM) concept of operations developed jointly by the Federal Aviation Administration (FAA) and aviation industry partners. NASA is developing the IADS traffic management system under the ATD-2 sub-project in coordination with the FAA, flight operators, CLT airport, and the National Air Traffic Controllers Association (NATCA). The primary goal of ATD-2 is to improve the predictability and operational efficiency of the air traffic system in metroplex environments, through the enhancement, development, and integration of the nation's most advanced and sophisticated arrival, departure, and surface prediction, scheduling, and management systems.

The ATD-2 effort is a five-year research activity through 2020. The Phase 1 Baseline IADS capability resulting from the ATD-2 research is being demonstrated at the CLT airport beginning in 2017. Phase 1 will provide the initial demonstration of the integrated system with strategic and tactical scheduling, tactical departure scheduling to an en route meter point, and an early implementation prototype of a Terminal Flight Data Manager (TFDM) Electronic Flight Data (EFD) system. The strategic surface scheduling element of the capability is consistent with the Surface CDM Concept of Operations published in 2014 by the FAA Surface Operations Directorate.[1]

1.2 Background

This TDD is intended to be a companion document for the ATD-2 Concept of Use (ConUse) document.[2] The reader will be referred to the ConUse document for sections where the inclusion of that material in the TDD would be repetitive. Please consult Section 1.2 of the ConUse[2] for background on the ATD-2 sub-project.

1.3 Document Purpose and Scope

The primary purpose of the ATD-2 TDD is to support the ConUse by providing a moderate-level overview of the technology comprising the IADS traffic management system and the IADS system architecture and implementation strategy. Implementation details provided herein are generally outside the scope of the ConUse, but will likely provide helpful context to the readers of the ConUse.[2]

The reader should note that this TDD is not intended to be a formal system design document. Rather it is an overview of the technologies that contribute to the IADS system, and describes how they are being integrated to support the CLT field demonstration.

The ATD-2 field demonstration is divided into three phases, as described in Appendix B. At the end of each demonstration phase, NASA will transfer the ATD-2 technology to the FAA and industry partners.

System capability will increase from one phase to the next. The current ConUse document has been strictly limited to Phase 1 in order to clearly identify just those system capabilities required for Phase 1 success. The ConUse will be updated for Phase 2 and Phase 3 prior to the operational evaluation freeze point for each phase. The strict "Phase 1 only" constraint has been relaxed for this document. The Phase 1 system will form the foundation for Phase 2 and Phase 3. Consequently, the system design must look ahead to the future phases. That being said, this document will contain more detail for system components required for Phase 1 than for future Phases.

The intended audience for this document includes:

- The NASA ATD-2 team, who will use this document to coordinate research and development activity with NASA and its research partners, including the FAA, flight operators, the CLT airport operators, and the Surface CDM community.
- The NASA/FAA IADS Research Transition Team (RTT), which is facilitating the research transition process.
- The FAA NextGen implementers, who may use this TDD and other ATD-2 research products, to inform development of the IADS elements of the NextGen enterprise architecture.

1.4 Document Organization

This document is organized as follows:

Section 1 provides introductory and background material and describes the nature of this document.

Section 2 describes the various FAA and NASA technologies that contribute to the ATD-2 IADS system.

Section 3 presents an operational view of IADS, with reference to the technologies in use at each operational location.

Section 4 presents a system view of ATD-2 IADS via the logical architecture diagram and subsystem descriptions.

Section 5 presents an interface view of ATD-2 IADS, with reference to external data interfaces.

Section 6 contains the document summary.

Section 7 contains references cited and documents consulted.

Appendix A describes the operational environment for IADS.

Appendix B contains a high-level description of the three phases of ATD-2 technology demonstrations.

Appendix C describes the surface data elements.

Appendix D provides background information on security, NEXUS, and interfaces.

Appendix E contains acronyms in common use within the ATD-2 sub-project.

2 Technologies Contributing to ATD-2

The ATD-2 IADS traffic management system is being built on a rich legacy of NASA, FAA, and industry research and technology development. Figure 1 illustrates the relationships among the various contributing technologies. The timescale for this chart was chosen to capture key technology transfers (small yellow arrows) contributing to ATD-2, which is depicted by the blue arrow beginning in 2014. Many of the Research and Technology (R&T) activities began before 2010, and ATD-2 will continue through 2020 with technology transfers to the FAA, flight operators, airport operators, and suppliers beginning in 2018. The two yellow stars on the ATD-2 timeline highlight the ATD-2 initial deployment and the Phase 1 field demo "go-live" in CLT.

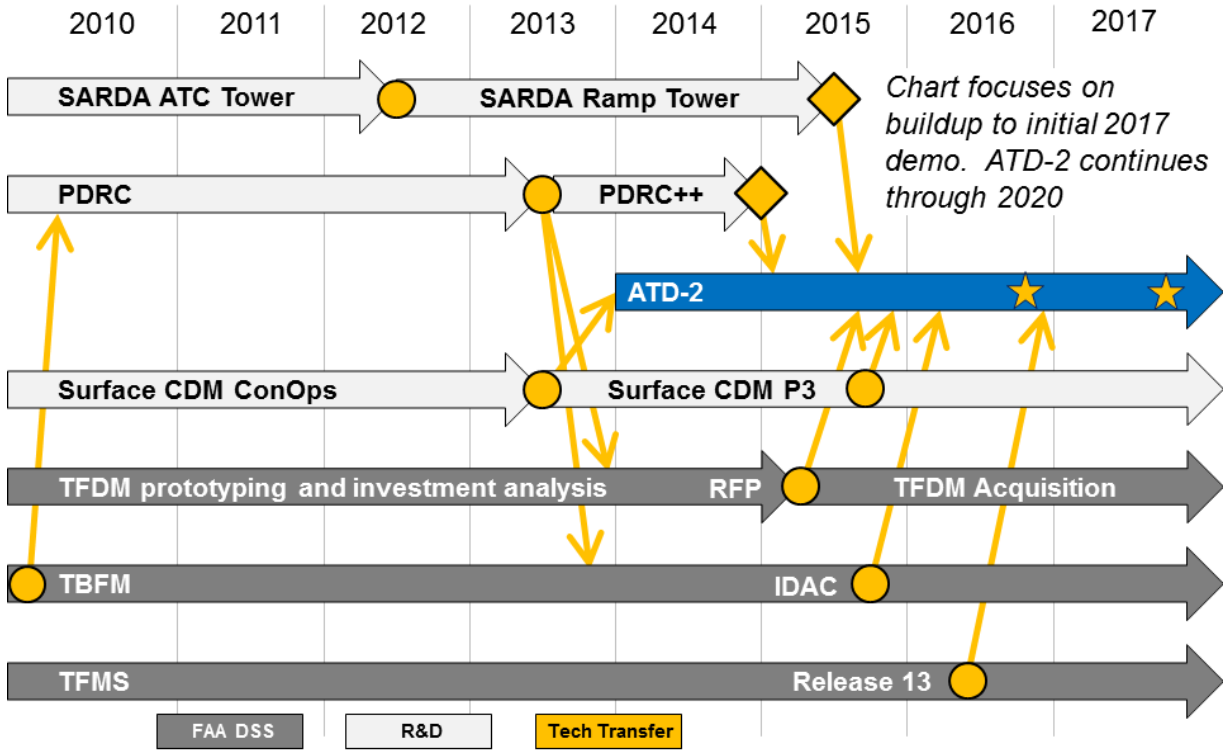

Figure 1 - NASA and FAA research and development activities have contributed significantly to ATD-2.

The remainder of this section will provide a brief overview of the various technologies depicted in Figure 1. The narrative will periodically reference Figure 1 to help connect each technology to its role in the IADS prototype system.

2.1 FAA Contributing Technologies

The three dark gray arrows at the bottom of Figure 1 represent the FAA's NextGen Air Traffic Management (ATM) Decision Support Systems (DSS)[3] that provide most of the IADS capabilities in the National Airspace System (NAS). The three DSS programs all begin with the letter "T" and are commonly called the "3Ts." As shown in Figure 2, the 3Ts are managed together within the FAA's Program Management Organization.

The following is an excerpt from the FAA's NextGen DSS website:[3]

> Decision Support Systems (DSS) provide air traffic controllers with the tools they need to optimize traffic flow across the National Airspace System (NAS). DSSs integrate multiple technologies and enable faster, more effective responses to evolving conditions. They share data among controllers, traffic managers, and other stakeholders who collaborate to solve traffic flow constraints...
>
> Three "Ts" comprise DSS:
>
> - Traffic Flow Management System (TFMS)
> - Time Based Flow Management (TBFM)
> - Terminal Flight Data Manager (TFDM)
>
> Each component has a specific role, but together they provide integrated, responsive, and collaborative traffic flow management solutions that maximize efficiency to reduce delays through each phase of flight.

This section gives a top-level description of the FAA suite of decision support Traffic Flow Management (TFM) tools – the 3T systems of TFMS, TBFM, and TFDM. These tools are designed to enhance the NAS by ensuring an efficient flow of traffic and maintaining throughput while improving situational awareness through real-time information sharing and improving the quality of service to NAS users by accommodating user preferences.

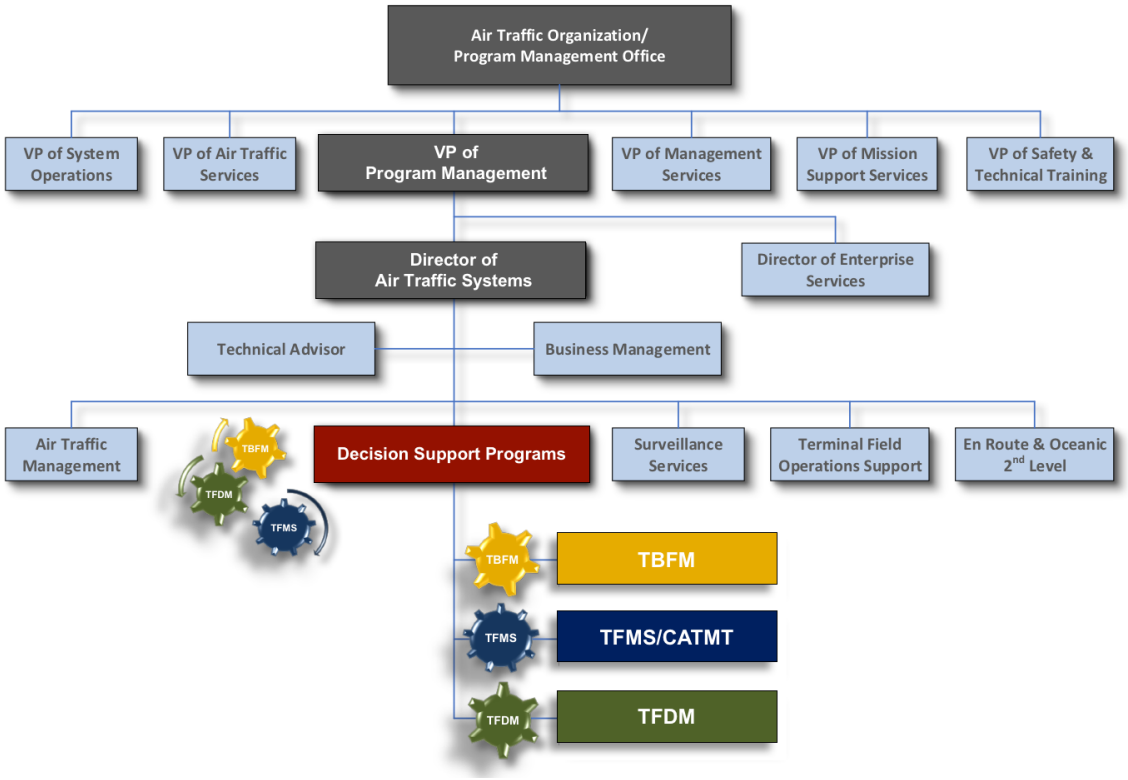

Figure 2 - The Decision Support Systems (DSS) programs are managed within the FAA Program Management Organization.

The goal of these tools is to provide integrated, responsive, and collaborative air traffic control solutions that maximize efficiency and reduce delay. Integration is achieved by modeling and

implementing strategic and tactical Air Traffic Control (ATC) strategies as a single cohesive strategy. An emphasis on responsiveness promotes more effective responses to evolving conditions in the NAS. By facilitating solutions that impose minimal controls on flights, data sharing among stakeholders enhances collaboration and thus allows flight operators to fly their preferred routes at preferred times.

Figure 3 shows the conceptual view of TFM as it is applied across the various stages of flight, implemented for both strategic and tactical operations, and used by the various air traffic control facilities.

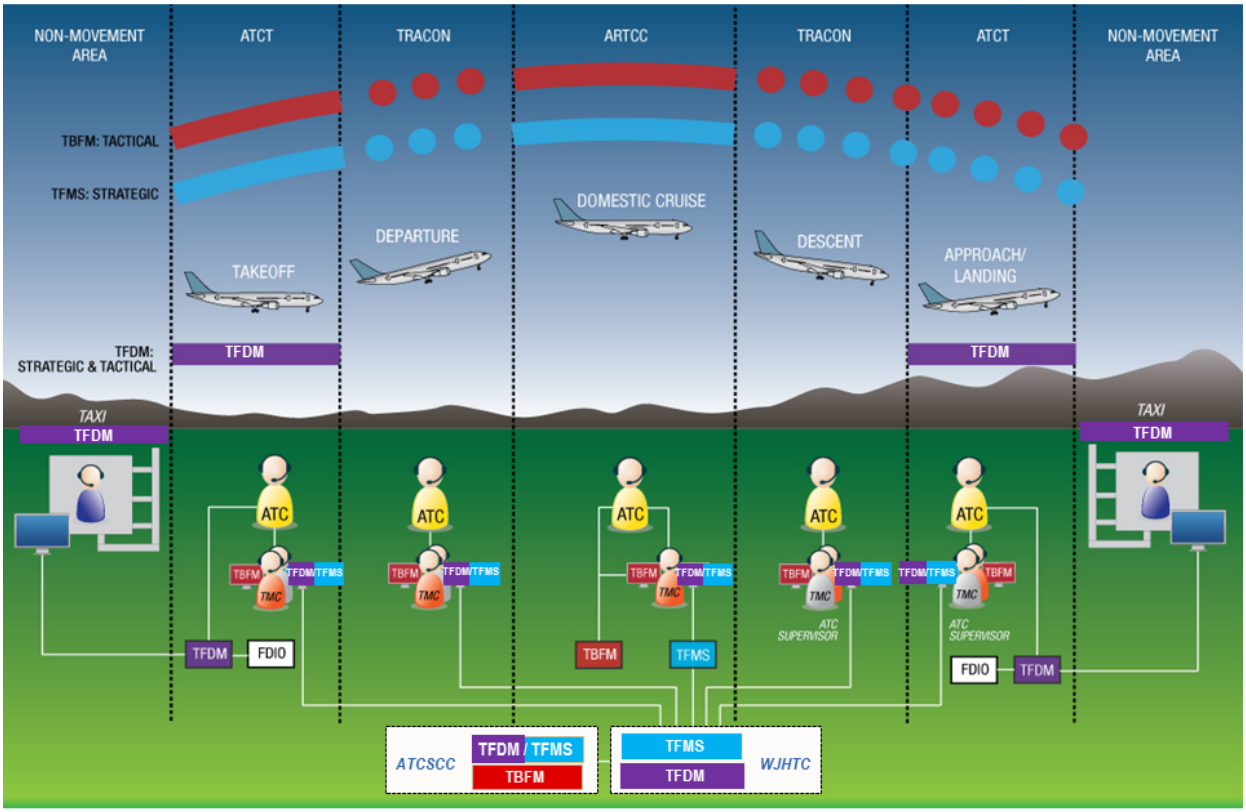

Figure 3 - Integrated Traffic Flow Management (TFM) systems work together to enhance the NAS [as briefed at April 2016 CDM meeting].

Integration of the 3T systems is a major emphasis for the FAA, and it is central to the ATD-2 concept and field demonstration effort.

2.1.1 Traffic Flow Management System (TFMS)

The following is an excerpt from the FAA's NextGen DSS website:[3]

> TFMS is a suite of automation tools that serves as the FAA's primary system for planning and implementing traffic management initiatives (TMI) to mitigate demand and capacity imbalances throughout the NAS. TFMS is tactical when applied locally and strategic when used to balance capacity throughout the whole system.
>
> TFMS monitors demand and capacity information, assesses the impact of system constraints, provides alerts, and helps determine appropriate adjustments. Benefits

> include increased predictability, flexibility, efficiency, and capacity that lead to decreased delays, safety risks, and costs.

The TFMS is a decision support system for planning and mitigating demand-capacity imbalances in the NAS. Its main objective is to efficiently improve the overall NAS by monitoring the NAS, predicting demand/capacity imbalances, and balancing demand with capacity, as shown in Figure 4. TFMS is relevant in scope for both the national and regional areas of the NAS.

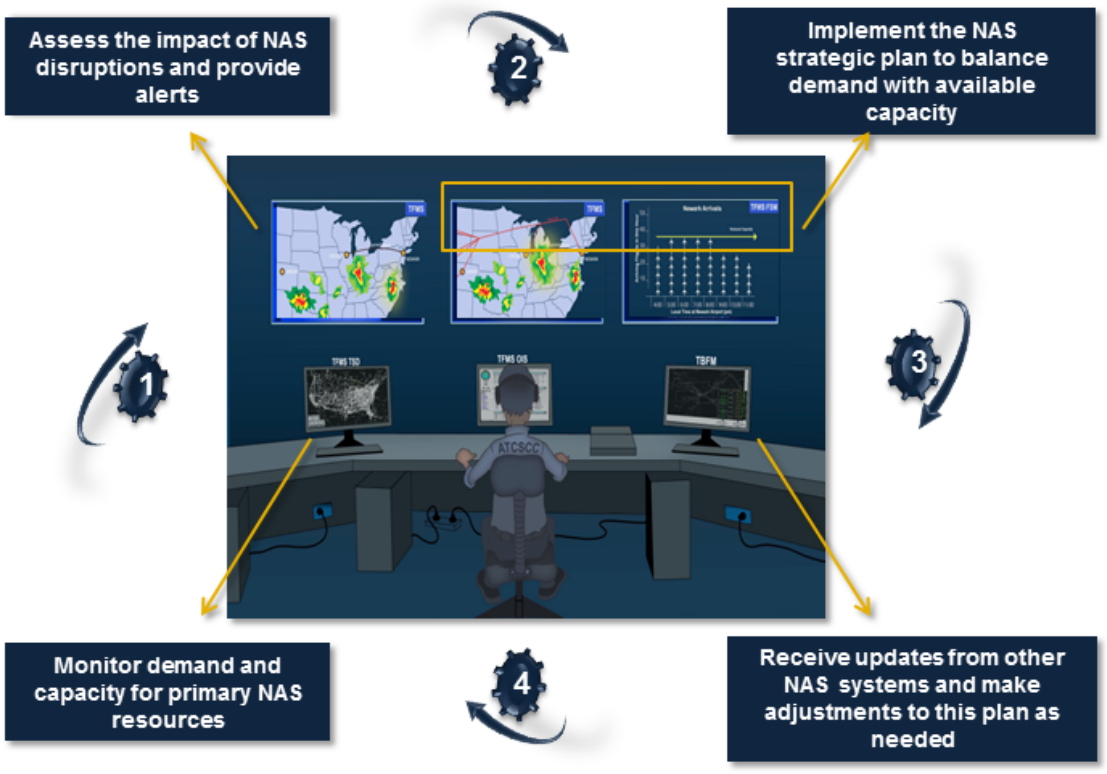

Figure 4 - This general overview of the Traffic Flow Management System (TFMS) shows the primary functions of the system [as briefed at April 2016 CDM meeting].

TFMS has a strategic planning horizon of up to 12 hours, and a tactical planning horizon of up to 90 min. The main operational users of TFMS are the Command Center's TFMs, the Air Route Traffic Control Center (ARTCC, or Center) Traffic Management Unit (TMU) Traffic Management Coordinators (TMCs), the airport TMU TMC/Supervisor, and non-FAA NAS users. The TMI control mechanisms that this system uses are to delay flights on the ground and to reroute airborne flights to less congested areas.

As illustrated by the yellow technology transfer arrow in Figure 1, the ATD-2 IADS system depends on TFMS Release 13 (R13), which was deployed on 30 April 2016. R13 provides the mechanism for flight operators and the FAA to exchange the surface data elements specified in the Surface CDM Concept of Operations (ConOps).[1] The FAA's NextGen DSS website[3] provides the following background on R13 data sharing:

> The FAA is committed to ensuring its Decision Support Systems can access the most current and accurate information. As part of a data sharing agreement brokered through the NextGen Advisory Committee (NAC), a federal advisory group composed

> of aviation stakeholders, air carriers have committed to provide the FAA with additional operational information. The information is entered into TFMS and disseminated to other systems through System Wide Information Management (SWIM).
>
> This information will mark the times of aircraft events on the ground, including the earliest time an aircraft can leave the gate, when it enters the taxiway, and when it reaches the runway ready for takeoff. The FAA, in turn, will use this data to improve NAS efficiency.

The NAC-brokered agreement mentioned in the preceding excerpt includes a commitment by the FAA to use the surface data elements provided by flight operators to implement departure queue management consistent with the Surface CDM ConOps.[1] This was one of the primary motivators for FAA/NASA collaboration on the ATD-2 field demonstration, which will reduce the risk for the TFDM implementation of the Surface CDM departure queue management.

Basic surface data elements in R13 include: Actual Off-Block Time (AOBT), Actual Takeoff Time (ATOT), Actual Landing Time (ALDT), Actual In-Block Time (AIBT), aircraft tail/registration number, Earliest Off-Block Time (EOBT), flight cancellation message, flight intent (e.g., whether the flight operator plans to pushback early during a Departure Metering Program (DMP) and hold in the movement area), gate assignment, Initial Off-Block Time (IOBT), and Earliest Runway Time of Departure (ERTD). More information on these data elements is provided in Appendix C.

2.1.2 Time Based Flow Management (TBFM)

The following is an excerpt from the FAA's NextGen DSS website:[3]

> TBFM uses time instead of distance to help controllers sequence air traffic. Compared to the traditional miles-in-trail process to separate aircraft, TBFM provides a more efficient traffic flow that reduces fuel burn, lowers exhaust emissions, and increases traffic capacity.
>
> TBFM uses the capabilities of the legacy Traffic Management Advisor (TMA), a tool for planning efficient flight trajectories from cruise altitude to the runway threshold. It has the ability to sequence and schedule aircraft, taking into account aircraft types and flight characteristics. It is used to maximize capacity at select airports and terminal radar approach control (TRACON) facilities without compromising safety. It is operational at all 20 domestic en route centers, the facilities that control air traffic between the end of an aircraft's departure procedure and the beginning of its arrival procedure.
>
> Improvements in TMA's trajectory modeler and time-based metering, which help air traffic controllers regulate traffic flow by directing aircraft to be at a specific location at a specific time, optimize arrival flow. TBFM enables en route controllers to deliver aircraft that are more evenly spaced to TRACON controllers…
>
> TBFM metering creates a time slot for fixed points along an aircraft's route. Controllers use speed advisories or vectors to direct an aircraft to cross points at allotted times.
>
> Extended Metering creates additional metering points over longer distances for the arrival stream. Meter points can be coupled to other meter points. Longer distances between meter points reduce timing accuracy, so multiple shorter distances between meter points improve predictions of aircraft arrival times.

TBFM is a decision support system for metering based on time to optimize the flow of aircraft. Its main objectives are the sequencing and spacing of airborne flights, merging of departures into the overhead stream, and maximizing the use of flow capacity, as shown in Figure 5.

TBFM is relevant in scope for 300 NM from a metering location. It has a tactical planning horizon of up to 90 minutes. The main operational users of TBFM are the Command Center's TFMs and the TMCs, residing in each Center, TRACON, and airport facility's TMU. The TMI control mechanisms that this system uses are time based metering and delaying flights on the ground.

After TFMS implements a NAS strategy, TBFM meters and sequences the flow of aircraft through congested areas to provide a smooth and orderly flow. TBFM metering lists assist Air Traffic Controllers by displaying the required delay for each aircraft in the list, and are generated using complex algorithms, which take into account many factors (e.g., aircraft type, wind predictions) to maximize use of the available capacity. Metering lists are updated dynamically as conditions change.

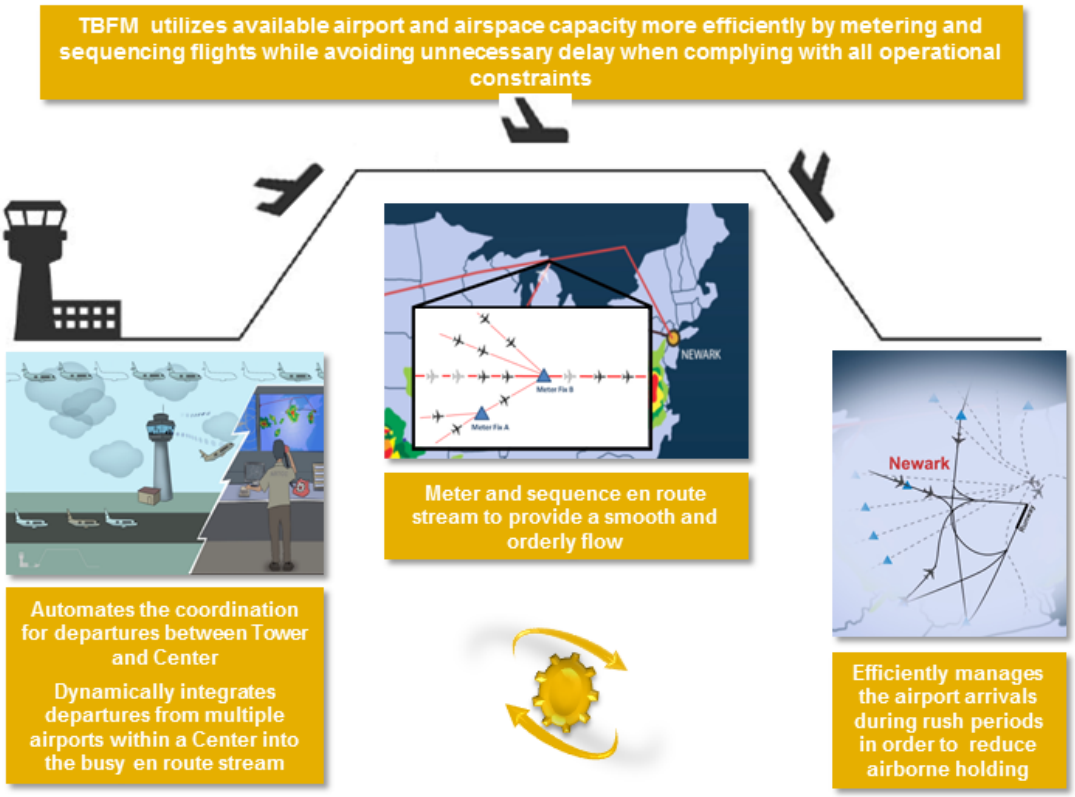

Figure 5 - Metering and sequencing with Time Based Flow Management (TBFM) provides significant advantages to stakeholders [as briefed at April 2016 CDM meeting].

Figure 1 shows three yellow technology transfer arrows associated with TBFM. The first arrow on the far left denotes the fact that the en route portion of NASA's Precision Departure Release Capability (PDRC)[4] was created from the operational TBFM software. At the conclusion of PDRC, a technology transfer package was delivered to the TBFM and TFDM programs to serve as a guide for en route/surface integration. The arrow on the far right denotes the fact that ATD-2

will leverage one of the latest FAA investments in TBFM. The new Integrated Departure Arrival Capability (IDAC) is described on the DSS website[3] as follows:

> Integrated Departure Arrival Capability (IDAC) automates the process of monitoring departure demand, identifying departure slots, and assigning them to aircraft. IDAC coordinates the departure times between airports and provides situational awareness to air traffic control towers so they can select from available departure times and plan their operations to meet these times.
>
> IDAC streamlines departure scheduling in automatic and semi-automatic modes. It improves situational awareness of current and future congestion in constrained areas, as well as automates notification of new constraints and approval request statuses. This enables more efficient traffic flow.

TBFM/IDAC provides a solid foundation for the tactical departure scheduling functions of the IADS system.

2.1.3 Terminal Flight Data Manager (TFDM)

The following is an excerpt from the FAA's NextGen DSS website:[3]

> Some of the best opportunities for improving air traffic efficiency are on the airport surface and in terminal airspace, so the FAA is developing the Terminal Flight Data Manager (TFDM) to take advantage of them. TFDM operates through four core functions:
> - Improved electronic flight data distribution and electronic flight strips in the tower
> - Traffic flow management integration between TBFM, TFMS, and TFDM
> - Collaborative decision-making on the airport surface
> - Systems consolidation
>
> In June 2016, the FAA awarded Lockheed Martin a $344 million contract to develop and deploy the TFDM system. This key NextGen system will provide electronic flight strips as well as improved surface management tools that will allow streamlined operations in the air traffic control towers for busy airports… TFDM's initial operating capability for Phoenix is planned for January 2020, with 88 more sites to follow.

TFDM is a decision support system for airport surface management and Airport Traffic Control Towers (ATCT, or Tower) functions. Its main objectives are to improve Tower controller efficiency for Tower operations, to manage flights on the airport surface, and to improve the efficiency of surface operations. TFDM is relevant in scope for the airport surface (i.e., gate/ramp, taxiway, and runway).

TFDM has a strategic planning horizon of up to 4 hours, and a tactical planning horizon of up to 60 minutes.[5] The main operational users of TFDM are the airport Tower controllers, the airport TMU TMCs/Supervisor, and non-FAA NAS users. The TMI control mechanism that this system uses is holding of flights at the gate.

TFDM is an acquisition program with four envisioned components that include Electronic Flight Data (EFD), Surface CDM, Surface TFM, and System Consolidation, shown in Figure 6. The Surface CDM component includes flight data exchange and departure queue management capabilities. The System Consolidation component will replace or incorporate several system pieces, including the Advanced Electronic Flight Strip (AEFS) prototype system, the Departure Sequencing Program (DSP), the Electronic Flight Strip Transfer System (EFSTS), the Surface Movement Advisor (SMA), and the Airport Resource Management Tool (ARMT). The ARMT is

a tool used by Front Line Managers (FLM) and/or TMCs to provide the ability to monitor and analyze arrival and departure demand, based on flight plan and event data received from the TRACON and flight event data received from the Tower. This tool is being transitioned out as TFDM comes into play.

The TFDM program successfully passed the Final Investment Decision (FID) milestone on 15 June 2016, and the TFDM acquisition contract award was publicly announced on 7 July 2016.

The yellow technology transfer arrow connecting TFDM to ATD-2 in Figure 1 denotes the central role that TFDM system requirements have played in the development of ATD-2 IADS. The ATD-2 team carefully studied the TFDM Screening Information Request (SIR)[6] package to ensure that the ATD-2 IADS system architecture and requirements were well aligned with the FAA plans. The motivation for doing so was to maximize the benefit to the FAA and industry partners, and to minimize the barriers to technology transfer.

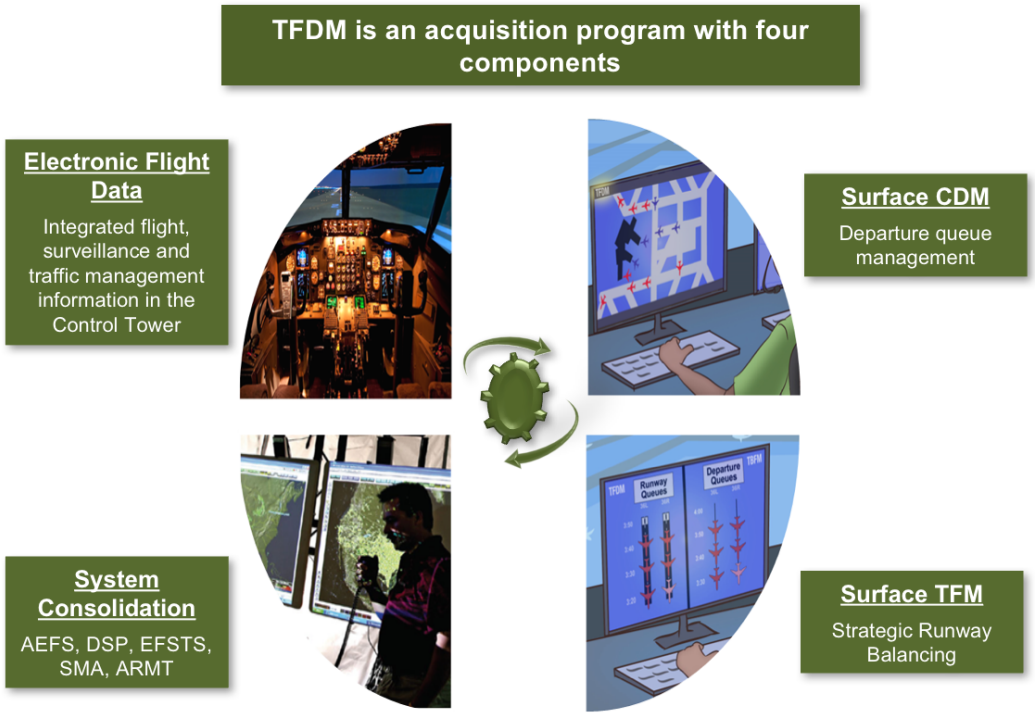

Figure 6 - The four components of Terminal Flight Data Manager (TFDM) include Electronic Flight Data, Surface CDM, Surface TFM and System Consolidation.

The EFD and Surface CDM components of the TFDM program are particularly relevant to ATD-2, and are further described in the following subsections.

2.1.3.1 Electronic Flight Data (EFD)

The following is an excerpt from the FAA's TFDM Capabilities website:[7]

> TFDM provides air traffic controllers with a view of available surface and terminal area surveillance information when integrated with electronic flight data information. The EFD exchange replaces paper flight strips with electronic processing and distribution of Instrument Flight Rules and Visual Flight Rules data. Automated manual flight data processes enable enhanced data sharing between air traffic, traffic management, and

> Flight/Airline Operators, and other aviation stakeholders. The TFDM system will replace the Electronic Flight Strip Transfer System (EFSTS) in the tower and Terminal Radar Approach Control Facilities (TRACON), and the Advanced Electronic Flight Strip (AEFS) Prototype System in the towers.

Figure 7 includes a typical screenshot of the AEFS ground controller user interface. The FAA plans call for the AEFS prototype system to be deployed to a number of Airport Traffic Control Towers (ATCTs) as part of the TFDM early implementation effort designed to address immediate needs for EFD capability.

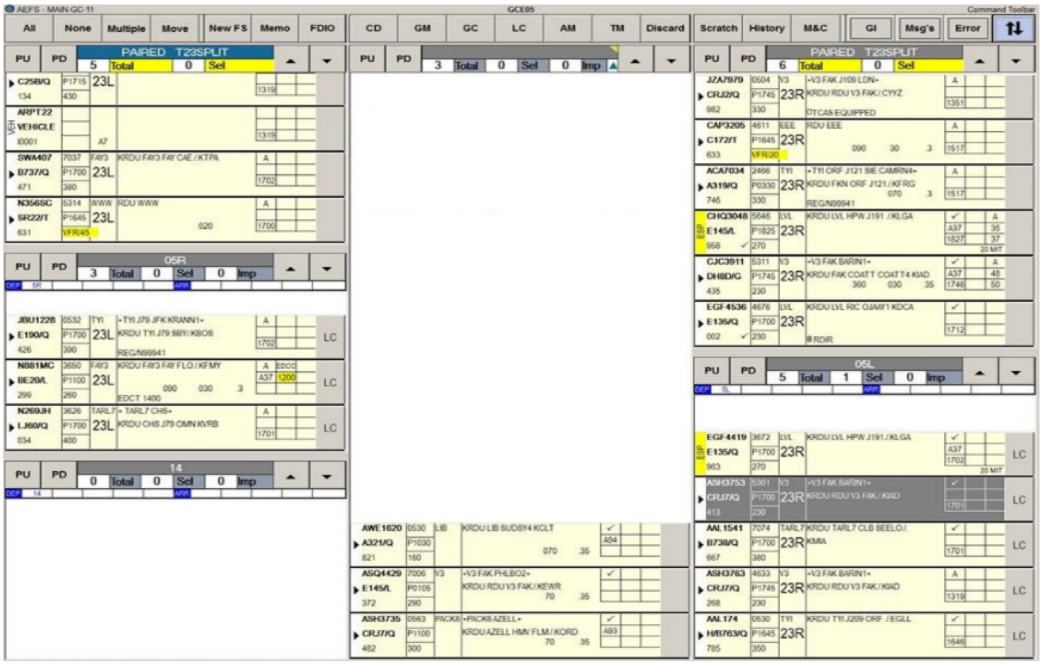

Figure 7 - The Electronic Flight Data (EFD) component of TFDM will replace paper strips in the Airport Traffic Control Towers, enabling data sharing with other NAS systems.

To support ATD-2, the FAA committed to deploy a TFDM EFD solution to CLT ATCT prior to the beginning of the Phase 1 field demonstration. The FAA determined that AEFS would be the EFD for the ATD-2 Phase 1 demo. Per this plan, the FAA provided the AEFS software to NASA, and AEFS training systems are installed at NASA Ames Research Center (ARC) and the NASA/FAA North Texas Research Station (NTX). The FAA implemented AEFS at the CLT tower in June 2017, and AEFS has been in continuous operational use at CLT since that time.

2.1.3.2 Surface Collaborative Decision Making (Surface CDM)

The following is an excerpt from the FAA's TFDM Capabilities website:[7]

> TFDM provides surface Collaborative Decision Making (CDM) to support Departure Reservoir Management (DRM) for surface metering and demand information displayed at Air Traffic Control Towers (ATCTs), Terminal Radar Approach Control Facilities (TRACONs), Air Route Traffic Control Centers (ARTCCs), and the Air Traffic Control System Command Center (ATCSCC). Surface CDM is the sharing of flight movement and related operational information among Airport Operators, Flight Operators, Flight Service Providers, and FAA Stakeholders and improves demand and

capacity predictions. It maximizes the use of available airport and airspace capacity, while minimizing adverse effects on Stakeholders, passengers, and the environment.

Referring again to Figure 1, the light gray arrow immediately below the ATD-2 arrow represents the FAA/industry Surface CDM effort that involved the FAA Surface Office, the Surface CDM Team, and other stakeholders. Figure 8 presents their building-block vision for extending CDM principles to the surface domain. The foundation is the two-way data sharing described in the excerpt above and beginning to be realized with TFMS R13. This foundation supports the Surface CDM Ration by Schedule (RBS) departure metering solution known as DRM, which can then be linked to the rest of the NAS via the 3T integration effort described above.

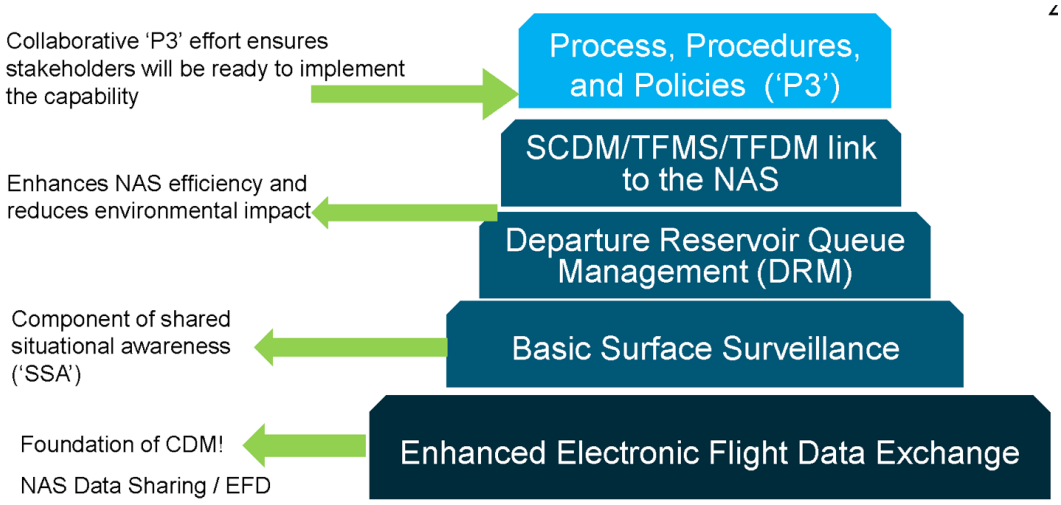

Figure 8 - The Surface CDM component of TFDM will implement a collaborative departure queue management solution.

The FAA Surface CDM concept engineering effort utilized a series of eight Human-in-the-Loop (HITL) exercises conducted between June 2012 and February 2013 to mature the Surface CDM ConOps. The ConOps was completed in July 2013 with formal publication in June 2014,[1] after endorsement by the CDM Stakeholders Group. The Surface CDM ConOps was incorporated into the TFDM ConOps published in September 2013. Following completion of the concept engineering effort, the FAA Surface Office led a group of stakeholders (Surface CDM Team and others) through a series of Process, Procedures and Policies (P3) exercises to identify P3 changes needed for effective implementation of the Surface CDM ConOps.

In May 2015, the FAA and NASA initiated a technology transfer effort to ensure that the ATD-2 sub-project fully leveraged all of the FAA and industry investments in the Surface CDM effort. The technology transfer included reports, briefing packages, storyboards, workshop minutes, documentation, and the software used for the HITL exercises. To ensure a successful technology transfer, the Surface CDM HITL development contractor (Metron Aviation) was tasked to work with the ATD-2 team to implement the software in NASA's development environment and integrate it with the ATD-2 IADS system. The DRM software delivered to NASA via this technology transfer forms the basis for the IADS strategic surface scheduler.

2.1.4 System Wide Information Management (SWIM)

Although not one of the 3Ts, SWIM is included in this section because it is the essential "glue" that enables communication among the 3Ts and with external customers, seen in Figure 9. The following is an excerpt from the FAA's NextGen SWIM website:[8]

> System Wide Information Management (SWIM) enables the sharing of information between diverse systems enabling the Next Generation Air Transportation System (NextGen) to deliver the right information to the right place at the right time. The program achieves this by providing the IT Service Oriented Architecture (SOA) enterprise infrastructure necessary for NAS systems to share and reuse information and increase interoperability. SOA is a way of organizing IT assets, policies, practices, and frameworks that enable application functionality to be provided and consumed as services that can be invoked, published and discovered. This infrastructure enables systems to publish information of interest to NAS users, request and receive information from other NAS services, and support NAS security requirements. Further, SWIM provides governance to NAS programs to ensure services are SWIM compliant and meet all FAA SOA standards.
>
> SWIM's approach allows software applications in the NAS to interact with one another through information services that can be accessed without knowledge of an application's underlying platform implementation. This simplifies interface requirements to existing NAS systems and ensures new systems can be built with minimum technology (hardware, software, and data definition) constraints. SWIM also enables the transition to net-centric NAS operations, and from tactical conflict management to strategic, trajectory-based operations.
>
> The System Wide Information Management (SWIM) Program is being implemented in segments. In each segment, a set of NAS services is being developed and integrated via SWIM. Enterprise infrastructure is added to support the implementation of capabilities associated with the segments. SWIM enterprise infrastructure will enable systems to request and receive information when they need it, subscribe for automatic receipt, and publish information as appropriate. This will provide for sharing of information among diverse systems.

Figure 9 shows various SWIM services grouped by implementation segment. NASA has "on-ramped" as a consumer to the various SWIM services such as the SWIM Terminal Data Distribution System (STDDS), the TFMS TFMData service, the SWIM Flight Data Publication Service (SFDPS), and the SWIM TBFM service. In addition to being a consumer of the SWIM services, ATD-2 IADS is planning to become a SWIM producer to deliver data to field demonstration partners.

SWIM is providing the Service Oriented Architecture (SOA) for all NAS and Non-NAS consumers of the data. The TFDM, TBFM, and TFMS programs are developing their SWIM Services. This means the data (from these systems) will be made available as a request/response by the user or system requesting that specific data. SWIM provides the capability of receiving data from multiple airports and multiple sources.

The SWIM Publishing environment works accordingly:

- Systems publish data sets to SWIM Queues

- SWIM Network Enterprise Messaging System (NEMS) nodes across FAA SWIM network use Consumer data requests and filtering rules to move data from SWIM Publish Queues to Consumer SWIM Topics
- Replaces varied interfaces with modern standards-based data exchange
- Provides SWIM Consumers access to info without directly connecting to individual systems
- Facilitates leveraging a single interface to receive multiple data products
- Provides enterprise security for incoming and outgoing data
- More information provided at: www.faa.gov/nextgen/swim

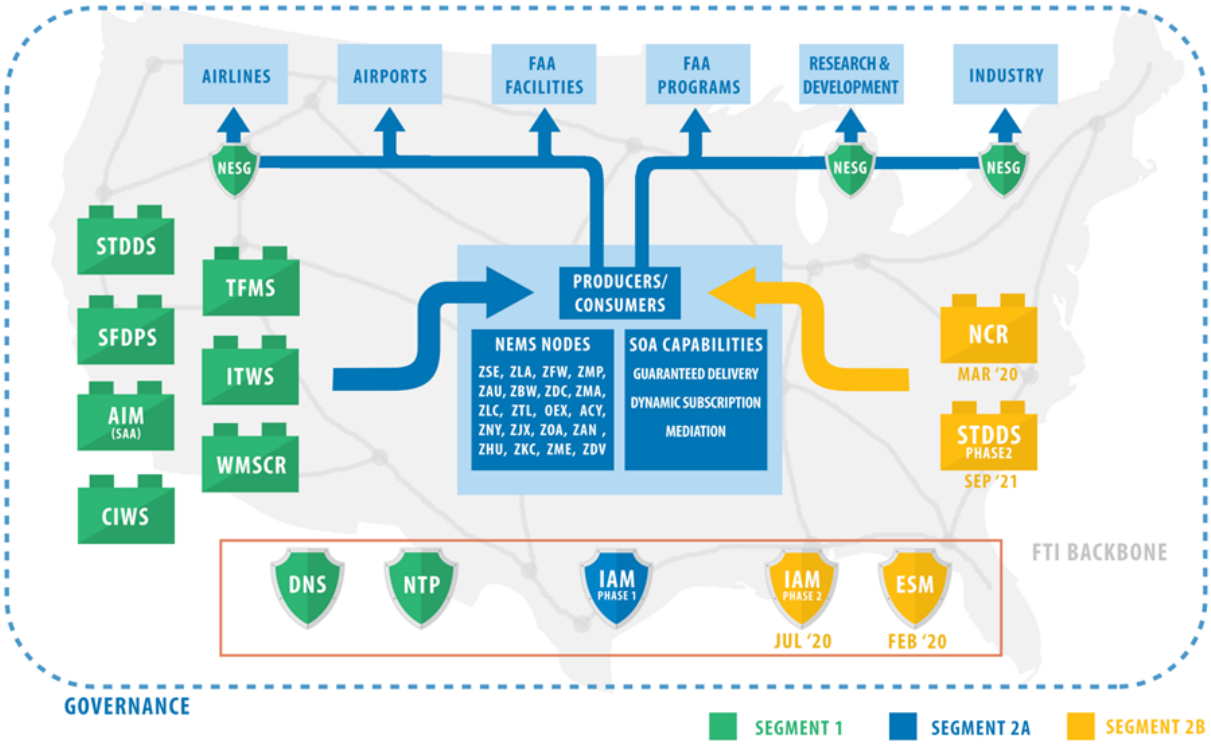

Figure 9 - System Wide Information Management (SWIM) is being implemented in segments [as briefed to NASA in July 2016].

2.2 NASA Contributing Technologies

The top two, light gray horizontal arrows in Figure 1 represent recent NASA research activities in the IADS domain (i.e., Spot and Runway Departure Advisor (SARDA) and Precision Departure Release Capability (PDRC)). The SARDA and PDRC concepts have been leveraged for ATD-2 IADS and some of their adopted functionality redistributed within the IADS architecture. The following two sections describe the Research and Development (R&D) work for these surface concepts and their history.

2.2.1 Spot and Runway Departure Advisor (SARDA)

The Spot and Runway Departure Advisor (SARDA)[9] uses trajectory-based surface predictions and advanced scheduling algorithms to provide departure metering advisories to controllers. Figure 10 shows the SARDA concept graphic and provides a high-level summary of the research activity.

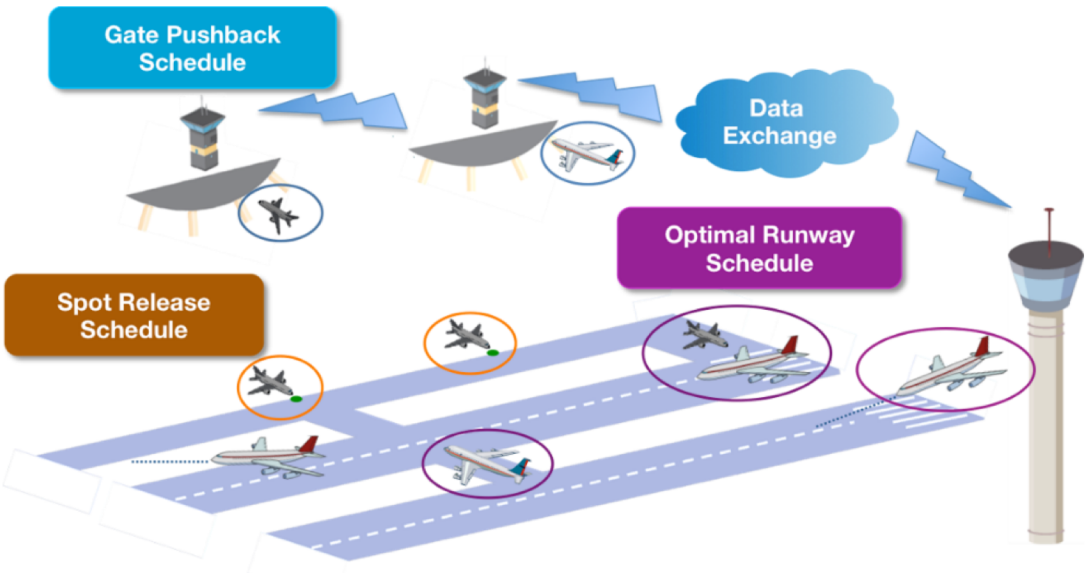

Figure 10 - The Spot and Runway Departure Advisor (SARDA) computes pushback advisories to help ramp controllers meet target times in the ramp and movement area.

As indicated in Figure 1, early SARDA research focused on movement area advisories for ATCT personnel. More recently, SARDA research focused on non-movement area (i.e., ramp) advisories for ramp controllers. The ramp-oriented portion of the SARDA research activity was accomplished in collaboration with US Airways, which later merged with American Airlines (AAL). The environment chosen for this collaborative research activity was the US Airways CLT hub. The research activity included a series of HITL experiments in NASA's high-fidelity Future Flight Central (FFC) simulation facility. NASA's SARDA team and their AAL partners were working towards a field evaluation of the SARDA technology at CLT when the research activity was folded into the larger ATD-2 field demonstration.

ATD-2 leverages the SARDA concept for a tactical scheduler that provides pushback advisories to help ramp controllers in the CLT AAL Ramp Tower meet target times in the ramp and movement areas. ATD-2 will also incorporate the Ramp Traffic Console (RTC) and Ramp Manager Traffic Console (RMTC) user interfaces developed under SARDA. The ATD-2 team has benefitted from the CLT domain expertise and flight operator relationships that the SARDA team developed during the previous research activity.

2.2.2 Precision Departure Release Capability (PDRC)

The Precision Departure Release Capability (PDRC)[4] research activity focused on using predicted takeoff times and departure runway assignments from a trajectory-based surface system to improve overhead stream insertion calculations performed by TBFM departure scheduling functions. Figure 11 shows the PDRC concept graphic and provides a high-level summary of the research activity.

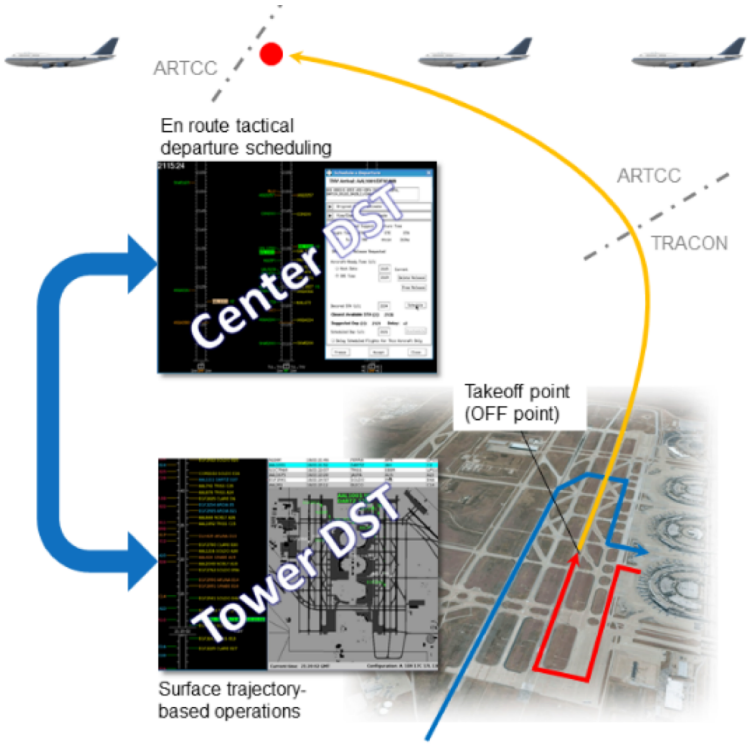

Figure 11 - Precision Departure Release Capability (PDRC) uses information from a trajectory based surface system to improve TBFM tactical departure scheduling.

As indicated in Figure 1, PDRC began with a FAA-to-NASA transfer of the operational TBFM software. NASA modified TBFM to interface it with a trajectory-based surface decision support tool that was effectively a surrogate for TFDM. The PDRC integrated system was then used to schedule Dallas/Fort Worth International Airport (DFW) departures that were subject to Approval Request/Call for Release (APREQ/CFR) constraints into Fort Worth Center airspace during the operational evaluation in 2012 and early 2013. PDRC research products were delivered to the FAA in 2013 for use in the TBFM and TFDM programs. A follow-on research activity known as PDRC++ extended this tactical departure scheduling solution to consider TRACON boundary constraints and departures from other airports in a metroplex environment.

ATD-2 benefits from the PDRC team's experience in interfacing TBFM with a trajectory-based surface system and in conducting operational evaluations involving TBFM tactical departure scheduling. Many aspects of the IADS physical architecture incorporate lessons learned from the PDRC operational evaluations. The prototype terminal tactical departure scheduling system developed under PDRC++ forms the basis for the Metroplex Coordinator being developed for ATD-2 Phase 3.

3 Operational View of ATD-2

The ATD-2 IADS system provides an integrated set of tools for IADS traffic management in metroplex environments. The high level operational view (OV-1) shown in Figure 12 consists of a graphic depicting the operational environment surrounded by images illustrating system components and user interfaces from the operational user perspective.

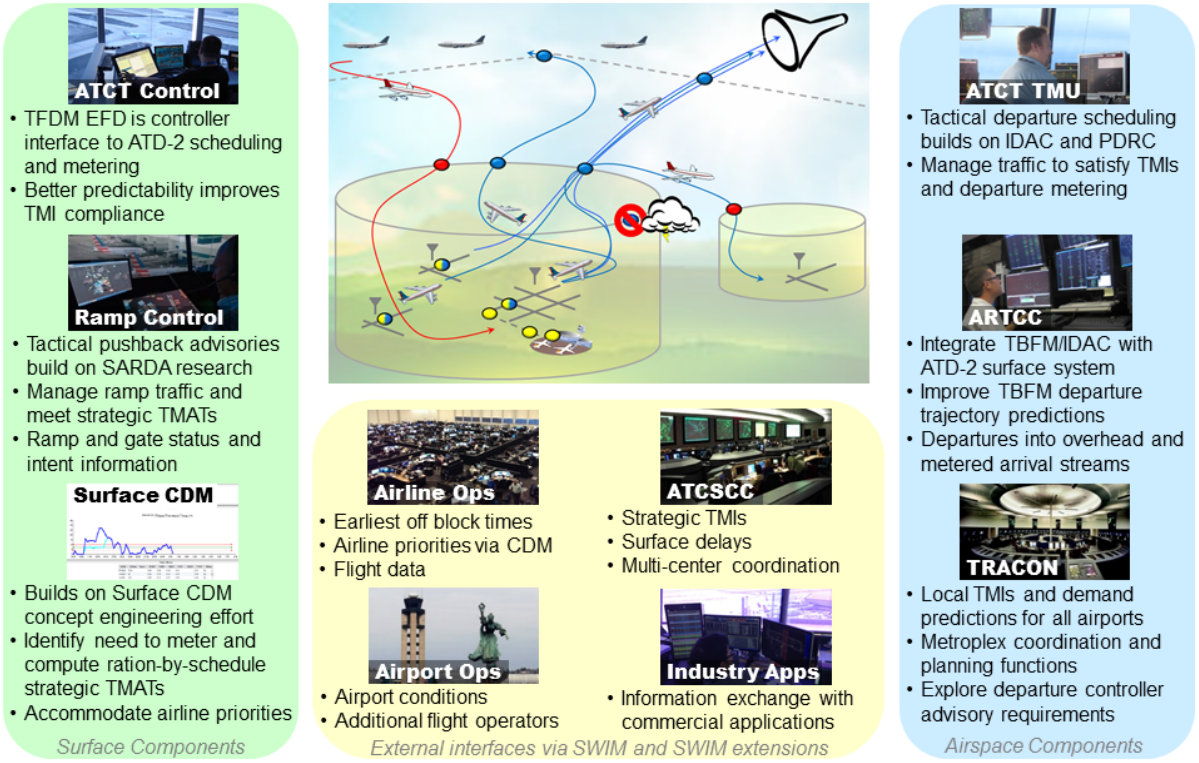

Figure 12 - The ATD-2 high level operational concept graphic (OV-1) shows the various user interfaces and system components.

The operational environment graphic in the upper center portion of Figure 12 shows air traffic departing from (blue arrows) and arriving to (red arrows) a metroplex terminal environment, along with traffic flow constraints and control points. Overhead stream insertion and strategic flow constraints are illustrated in en route airspace in the upper portion of the graphic. A complete description of the ATD-2 operational environment is provided in Appendix A.

The system components and user interfaces shown in Figure 12 are grouped into three colored boxes. The green box on the left contains surface components while the blue box on the right contains airspace components. These will be described in subsections to follow. The yellow box in the lower center illustrates interfaces to external systems that will be facilitated via the FAA's SWIM communications architecture. NASA's ATD-2 effort will address any additional data sharing requirements through SWIM-compatible extensions and communicate these new requirements to the FAA as part of the research transition process.

The next five subsections describe the primary components of the IADS system, beginning with the ATCT TMU image in the top right of Figure 12, and moving clockwise around to the ATCT Control image in the top left of the diagram.

3.1 Tactical Departure Scheduling

The two images in the upper right portion of Figure 12 represent the tactical departure scheduling portion of the IADS system. Specifically, the image labeled "ATCT TMU" shows a Tower TMC using the system to request a release time from the Center during an APREQ/CFR situation. The image labeled "ARTCC" shows a Center TMC using the TBFM interface to schedule the APREQ/CFR departure into the en route traffic flow. This part of the IADS system leverages NASA's PDRC research activity[4] and FAA investments in TBFM/IDAC.

Tactical departure scheduling is the essential link between the surface and airspace portions of the IADS challenge that ATD-2 is designed to address. TMCs in the Center, TRACON, and Tower will use this part of the IADS system to better plan and implement TMIs, with information provided by the surface (both strategic and tactical) elements of the IADS system. More specifically, information from the surface elements of IADS will provide the Center and TRACON TMCs with a better picture of surface demand and more precise predictions of takeoff times and departure runway assignments, which will improve management of constrained airspace and scheduling into busy overhead flows.

3.2 Metroplex Coordinator (MC) System

The image in the lower right of Figure 12 labeled "TRACON" represents the portion of the ATD-2 IADS system that extends tactical departure scheduling to include terminal airspace constraints and departures from multiple airports in the metroplex environment. Known as the Metroplex Coordinator (MC) system, the focus for this function will be the TRACON TMU, where TMCs will use the MC system to plan and execute terminal TMIs and coordinate with all towers within the metroplex. The MC system will also be used to facilitate joint planning between the TRACON and ARTCC TMCs. See Figure 14 for more details.

The ATD-2 demonstration at CLT will utilize only the TMI handling and reconciliation functions of the MC system. Demonstration of its scheduling and coordination capabilities requires a terminal environment with multiple airports.

3.3 Strategic Surface Scheduling for Surface Collaborative Decision Making (Surface CDM)

The image in the lower left portion of Figure 12 represents the strategic surface scheduling portion of the ATD-2 IADS system. Specifically, this image depicts the demand/capacity balance projections computed by the strategic scheduling system. This part of the IADS system leverages investments made by the FAA and the Surface CDM Team in developing the Surface CDM ConOps[1] as well as the prototype DRM system developed to support the Surface CDM concept engineering effort.

The strategic scheduling system continuously monitors the airport demand/capacity balance and recommends Departure Metering Programs (DMP) and associated Target Movement Area entry Times (TMAT) computed according to Ration by Schedule (RBS) principles. The strategic scheduler-generated TMAT times will be communicated to ATD-2's tactical surface scheduling subsystem.

3.4 Tactical Surface Scheduling

The image in the left portion of Figure 12 labeled "Ramp Control" represents the tactical surface scheduling portion of the ATD-2 IADS system. Specifically, this image shows the Ramp Traffic

Console (RTC) screen user interface in use by a ramp controller. This part of the IADS system leverages NASA's SARDA research activity[9] and investments made by US Airways/American Airlines in high-fidelity simulation experiments at NASA's FFC simulation facility. The RTC user interface displays pushback advisories to the ramp controller and allows the controller to communicate intent information to the IADS system.

A key feature of the IADS system is "fusion" of strategic and tactical approaches to departure metering. The tactical surface scheduling system will attempt to honor TMATs generated by the strategic scheduler as it computes pushback advisories. Likewise, precise trajectory-based taxi time predictions from the tactical scheduling system are used by the strategic scheduler as it monitors airport demand/capacity balance.

3.5 Tower Electronic Flight Data (EFD)

The image in the upper left portion of Figure 12 labeled "ATCT Control" represents the Tower EFD portion of the ATD-2 IADS system. Specifically, the image shows a Tower controller using the FAA's AEFS prototype at Phoenix Sky Harbor International Airport (PHX). In response to NextGen Advisory Committee recommendations, the FAA has committed to installing AEFS at several airports as part of the TFDM early implementation effort.

Tower EFD will be a crucial link between the IADS system and the Ground and Local Controllers, as they interact with the departure metering system and implement TMIs on the airport surface. FAA partner organizations will implement an EFD solution at CLT Tower and work with NASA to interface the Tower EFD system with the IADS system.

4 System View of ATD-2

This section presents a system view of the IADS prototype to help the reader better understand how the contributing technologies described above will be integrated in the ATD-2 field demonstration system. Figure 13 shows a simplified overview of the major components within the ATD-2 IADS architecture. Although elements of the architecture framework are presented here, the reader should be mindful that this is an overview document intended for a broad audience and not part of the formal system documentation.

The architecture is divided into two main sections that separate IADS into internal and external systems. A component is considered to be external to IADS if NASA is not expected to have control of the process initialization or maintenance at the operational facility.

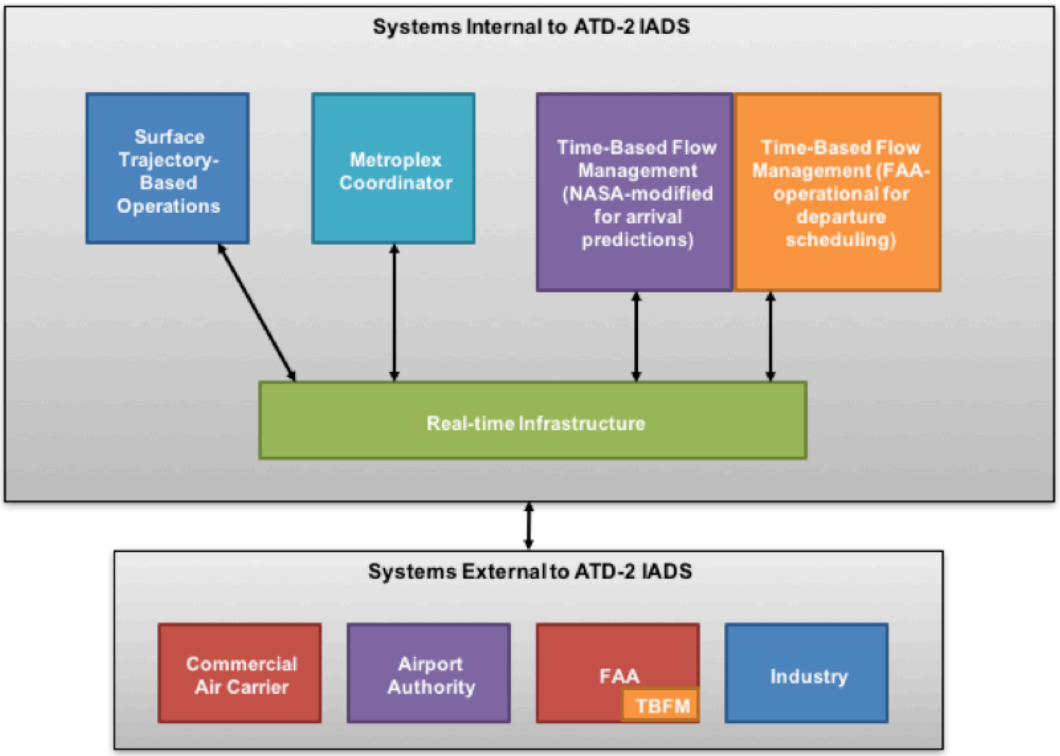

Figure 13 - This simplified view of the ATD-2 IADS architecture shows only the major components.

Figure 14 illustrates the end-state IADS logical architecture to the next level of detail. (Note: the RTC component is expected to be internal to the NASA systems during the Phase 1 field evaluation. Implementing the RTC as an internal component is a field demo artifact, but this implementation gives NASA more research agility. The RTC is a government-furnished example of an industry solution.) Internal IADS system processes shown in Figure 14 in dark blue are a part of the end state design, but are not expected as part of the Phase 1 field evaluation in 2017. The following sections discuss each component in greater detail.

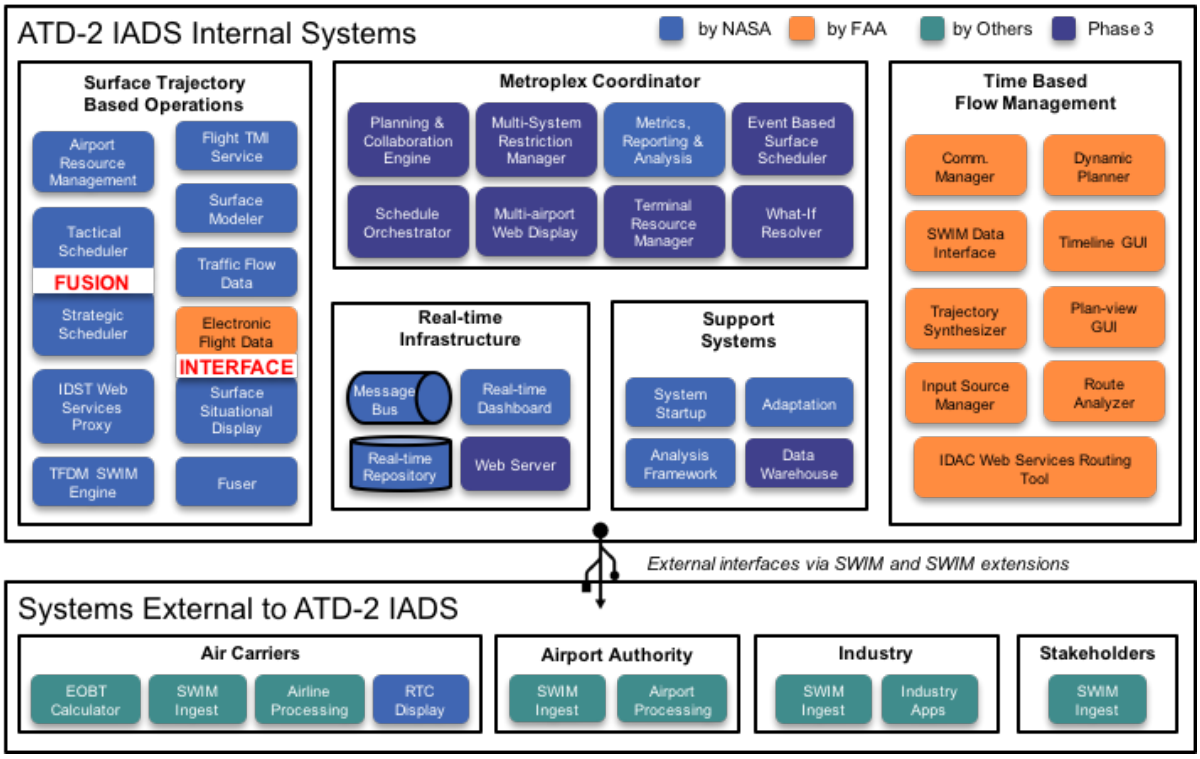

Figure 14 - The logical architecture for the IADS field demonstration system is shown to the next level of detail.

4.1 Surface Trajectory Based Operations (STBO)

The Surface Trajectory Based Operations (STBO) portion of ATD-2 IADS is the system element that encapsulates many of the internal IADS elements. The STBO system is a collection of surface trajectory-based capabilities that provide IADS automation for the airport surface. It includes capabilities such as strategic and tactical surface scheduling, electronic flight data capability, interaction with other NAS Decision Support Tools (DST) like TBFM, airport configuration and general awareness capabilities, and outgoing data feeds to industry. The STBO client is the primary user interface that enables the Tower personnel to interact with the system for such automation.

The Multi-Function Display (MFD) is the software that houses the STBO client, the RTC/RMTC, the Surface Metering Display (SMD) interface, and the real-time dashboard user interfaces. The various users/positions will have a primary/home/default display on their MFD, but users will be able to access and use any view. Figure 15 provides a detailed STBO block diagram for the baseline IADS, as implemented in Phase 1 (note, however, that the end state Ramp Traffic Control / Ramp Manager Traffic Control is considered to be external to STBO, but within IADS). The DRM, as conceptualized in the Surface CDM ConOps,[1] is broken down into more specific functional elements in the STBO system: surface metering (Tactical Scheduler), surface scheduling (Strategic Scheduler), and surface modeling (Surface Modeler).

STBO has a “What-if” scenario feature that shows the user what the effect of the considered change is predicted to be if the user were to implement the change. This is accomplished by the primary STBO instance making a request to a secondary STBO instance whose sole purpose is to

handle what-if scenario calculations. More details on the use of the what-if scenario feature may be found in section 4.1.3.8 of the ATD-2 ConUse document.[2]

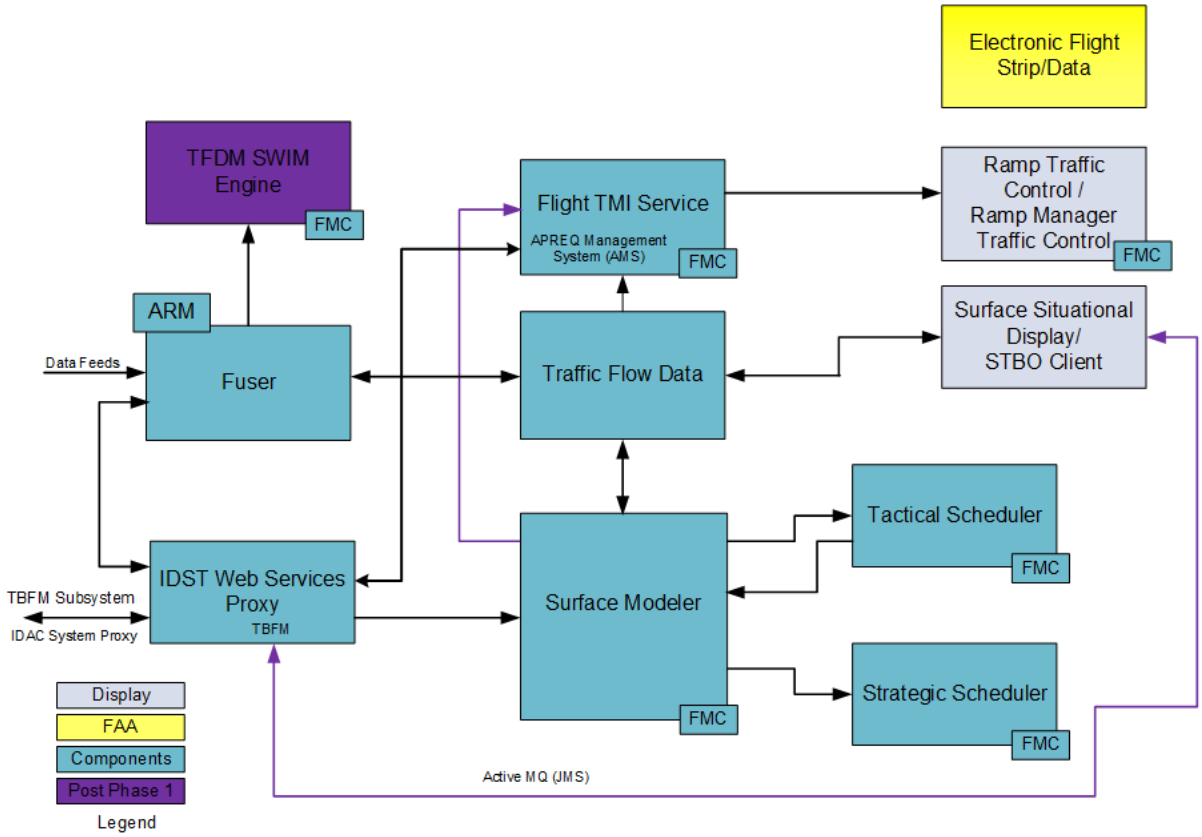

Figure 15 - The ATD-2 STBO Block diagram is shown as it is implemented in Phase 1.

4.1.1 Surface Modeler

The surface modeler tracks, updates, and disseminates information on key surface events. Actual surface event data (e.g., Actual OUT information) is used in conjunction with derived data and model processing logic to produce a single cohesive view of airport operations that is common among other ATD-2 IADS components. It contains enough information about the airport surface and how the ATCT handles traffic in different scenarios to generate good estimates of taxi time and wheels up* time for each flight. This approach is significantly different than having a lookup table that leverages empirical data that was not derived from trajectory based information. Trajectory Based Operations (TBO) are part of the FAA's NextGen strategy/roadmap.

The name "Surface Modeler" was chosen because it best fit the core function and minimized confusion among the other surface schedulers (tactical and strategic). The name 'model' was also chosen because this capability shares many similar duties to other NAS components that provide similar functions (e.g., NAS Common Situational Model (NCSM), in the TFMS system).

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* Wheels up refers to getting the wheels off the ground, so the aircraft becomes airborne.

4.1.1.1 Component General Description

The surface modeler calculates the unimpeded times for the STBO system and provides this output to other components for surface scheduling and metering purposes. This component maps to the Surface Scheduler in the TFDM specification, although some functions exist in the ATD-2 surface modeler that are currently not specified in the TFDM specification.

The surface modeler bases its calculations on the latest surface adaptation for a given airport. The surface adaptation contains the airport map (i.e., Geographic Information Systems data from airport authorities and other government agencies), as well as airspace fixes, parking gates, runways, spots, taxiways, taxiway polygons, intersections, runway configurations, departure scenarios, and upcoming taxiway outages or runway closures. The surface adaptation offers a complete computer-based representation of the physical airport and attempts to capture how the airport is used. It utilizes integrated software decision trees to reduce the adaptation complexity.

4.1.1.2 Functions

The core surface modeler functions include computing the three-dimensional (3D) (x,y,t) surface trajectory from the gate (OUT) to the runway (OFF) for departures, and from the runway (ON) to the gate (IN) for arrivals, based on the expected airport/runway configuration and gate configuration. The surface modeler will use surveillance data, when available, to detect the actual surface trajectory and update the estimates. The surface modeler will use the default shortest path when the coded taxi routes are not available in the adaptation, including using the airport resource information to select the available routes.

Another important function of the surface modeler is to determine the flight state, which is used for taxi trajectory prediction and flight scheduling. Table 1 lists the flight states, their definitions, and the logic for transitioning to that state.

Table 1 – Flight Status/States are necessary for taxi trajectory predictions and flight scheduling.

Flight State / Flight Status	Definition	Transition Logic
Unknown	Default not-set value	None
Scheduled Out	Departure date and time for flight has been published by flight operator	• Departure flight has a scheduled runway departure time, as generated by the IADS system. • OR: Departure flight had pushed back but is returning to gate. • OR: Departure flight was Suspended by automation (see "Suspended below) but an updated runway time is received.
Scheduled In	Arrival date and time for flight has been published by flight operator	• Arrival flight has a scheduled runway arrival time, as generated by the IADS system.

Flight State / Flight Status	Definition	Transition Logic
Pushback	Departure flight is in the process of pushing back or has left the gate, but is not yet taxiing in the ramp	• Departure flight has not yet completed pushback process but has actual OUT time from the flight operator. • OR: Departure flight received pushback clearance from ramp controller input. • OR: Surface surveillance detects that flight has pulled away from gate.

Out	Departure flight is taxiing in ramp	• Departure flight has pushed back AND:
		  ○ Departure flight received taxi clearance from ramp controller.
		  ○ OR: Surface surveillance detects departure flight tracks in ramp area.

Taxiing AMA	Departure flight is taxiing in Airport Movement Area (AMA)	• Departure flight has actual SPOT time (crossed spot into AMA). • OR: Surface surveillance detects departure flight tracks in AMA.
In Queue	Departure flight is in the runway queue	• Surface surveillance detects aircraft has entered runway departure queue area designated by adaptation.
Departed	Departure flight has taken off from airport (wheels up)	• Departure flight has actual OFF time. • OR: Departure flight speed and location (over runway or outside of airport boundary) indicates takeoff roll has begun.
Enroute Arrival	Flight is in ARTCC airspace	• Initial state for arrival flight with position tracks.
Terminal Area Arrival	Flight is in TRACON airspace	• Radar detects touch-and-go arrival aircraft. • OR: Radar detects arrival aircraft tracks in Terminal airspace (inside TRACON boundary, as defined in adaptation).
On Final	Arrival flight is lined up with runway and descending to land at destination airport	• Radar detects arrival aircraft tracks within threshold distance to land on arrival runway.
On	Arrival flight is detected to be on the airport surface and taxiing in AMA	• Surface surveillance detects arrival aircraft tracks within airport boundary. • OR: Arrival flight has actual ON time. • OR: CLT specific case: Arrival flight in ramp uses taxiways M-C briefly before returning to ramp.

Flight State / Flight Status	Definition	Transition Logic

In Ramp	Arrival flight is taxiing in ramp	• Arrival flight has landed AND:
		  ○ Surface surveillance detects arrival aircraft tracks in ramp area.
		  ○ OR: Arrival flight has actual SPOT time, but is not yet in the In Gate state.

In	Arrival flight has reached the gate	• Arrival flight has actual IN time. • OR: Surface surveillance detects arrival aircraft tracks within a configurable distance of gate (default 100 feet). • OR: Surface surveillance tracks are stale (time configurable), and last position is near gate, AND Flight is already in the Ramp (state was Ramp Taxi In). • OR: Arrival flight cleared to gate by ramp controller.
Suspended	Flight is postponed to a later time	• Departure flight is N minutes (time configurable) past its estimated departure, APREQ, or EDCT time. • OR: Arrival flight is N minutes (time configurable) past its estimated arrival time. • OR: Ramp controller marks the flights as Suspended.
Cancelled	Flight will not operate	• Flight operator indicates that flight is cancelled via SWIM TFMS data feed. • OR: Ramp controller marks the flight cancelled.
Return to Gate	Flight is assigned to Return to Gate (even though it was pushed back from the gate at some point prior to re-entry to the gate) due to various reasons	• Flight operator decides to move the flight back to the gate via SWIM TFMS data feed. • OR: Ramp Controller indicates the flight as return to gate and scheduler treats it accordingly.

4.1.1.3 Inputs/Outputs

As depicted in Figure 16, the Fuser (section 4.1.6) provides input data for the surface modeler from multiple data feed sources. The input data include flight plans, predicted runway, assigned gate, TFDM SWIM Engine data, TBFM data, surface surveillance, and flight specific events.

The Airport Resource Management (ARM) component (section 4.1.8) provides input data from available airport resources for the surface modeler, such as current airport configuration, runway

utilization intent from the FAA ATC, runway updates from the ATC or pilot due to operational necessity, and/or default runway assignments.

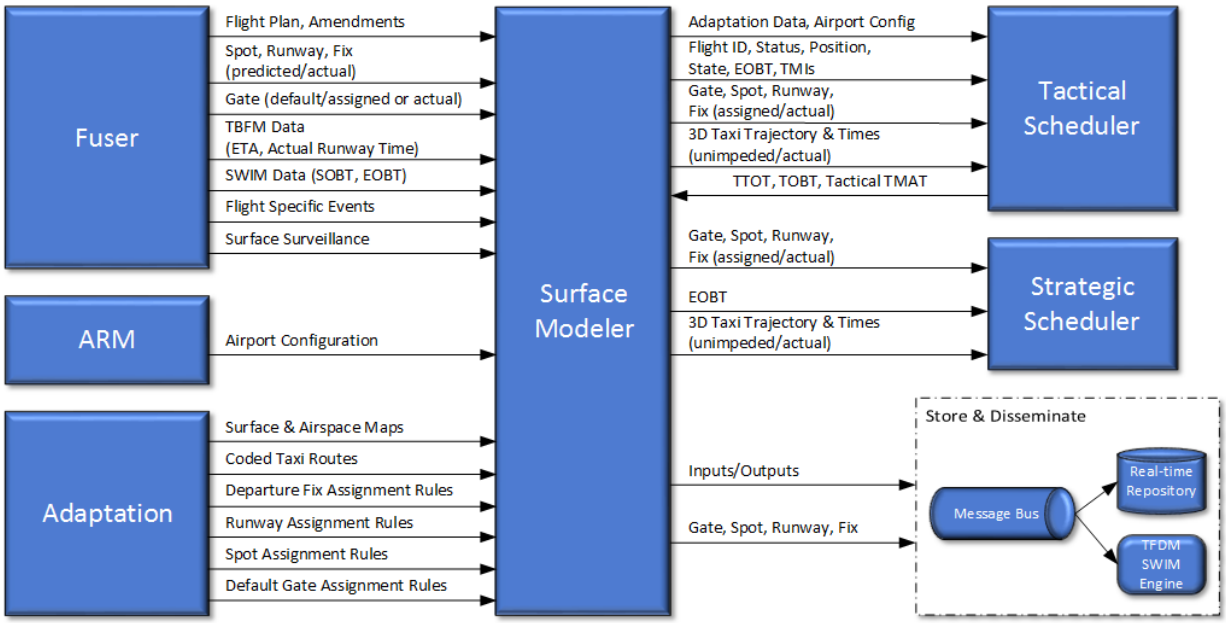

Figure 16 – The ATD-2 Surface Modeler component consumes/produces a variety of data.

The adaptation is read, processed, and merged with the flight plan data, the flight operator inputs, and the ATC inputs to calculate the flight-specific data (e.g., gate assignment, spot assignment, taxi route, taxi speed). The surface modeler utilizes a set of decision trees from the adaptation that provide the criteria or rules for assigning default flight-specific data values.

The Surface Modeler output is a combination of observed truth (actuals) and predictions. The output is expected to pass to both the tactical scheduler and the strategic scheduler, as well as to many user-facing interfaces (e.g., some surface model output updates the STBO client and the RTC, prior to going through the schedulers). The output for departures consists of the 3D surface trajectory and times from the gate through the spot to the runway. If the flight has left a location (e.g., gate, spot, runway), the time output is the actual time. If the flight has not yet reached a location, the time output is the unimpeded taxi time. For arrivals, the surface trajectory and times are from the runway to the gate: actual time if aircraft is past a location, unimpeded time if it is not past.

Note: Figure 16 illustrates logical data flow. It is not intended to capture the physical flow of messages sent between software processes. Data between the components actually flows through Java Message Service (JMS) publish/subscribe messaging, from which the other components read the data. The components do not have point-to-point communication.

4.1.2 Tactical Scheduler

The ATD-2 tactical scheduler provides de-conflicted surface trajectories and generates Target Off-Block Times (TOBTs), Target Movement Area entry Times (TMATs), and Target Takeoff Times (TTOTs) to provide specific event times for pushback, movement area entry, and wheels up to the users of the system. The de-conflicted surface trajectories from the tactical scheduler are calculated based on a mediation algorithm that determines the most accurate Earliest Off-

Block Times (EOBT), Scheduled Off-Block Times (SOBT), unimpeded taxi time, and Controlled Takeoff Times (CTOT) (e.g., APREQ/CFRs, Expect Departure Clearance Times (EDCTs)) provided by various data sources through SWIM, OIS, or negotiations with TBFM.

The process begins with surface trajectory prediction that receives aircraft state, flight intent, and trajectory modeling inputs. Aircraft state is provided by the surface modeler as described in the previous section. Pushback intent is communicated as the EOBT acceptable for a given flight, as well as hold advisories entered by the ramp controllers. Initial scheduled time (IOBT) is the initial EOBT value. The best EOBT at a given time is governed by the mediation rules, with EOBTs for AAL starting to become available about 30 minutes prior to SOBT. However, closer to actual departure time, EOBTs are refined and updated through flight plan inputs and other information provided by flight operators in the ramp tower or operational control center.

4.1.2.1 Component General Description

To flight operators, the tactical scheduler provides pushback advisories reflecting the latest flight status, the TMI constraints, and guidance on how to meet these times. Surface metering is the activity of holding flights in the non-movement area (ideally at the parking gate) to reduce problems associated with runway demand/capacity imbalance. Surface metering is expected to occur during peak traffic periods at the airport. There are two surface metering modes: sequence-based metering, which implements the count-based metering methodology that American Airlines ramp controllers at CLT are using (also known as "departure sequencing"), and time-based metering, which is the time-based pushback advisory for individual aircraft using the tactical scheduler that the ATD-2 system is implementing. When time-based surface metering is turned on, advisories are provided at least 10 minutes before pushback ready for applicable flights (see Scheduling Groups in section 4.1.2.2), and these advisories are recomputed every 10 seconds, with a freeze when the pilot calls in and the ramp controller places the flight in hold. The flight operator user interfaces are the Ramp Traffic Console (RTC) and the Ramp Manager Traffic Console (RMTC) Graphical User Interfaces (GUIs) (section 4.4).

To air traffic control, the tactical scheduler provides the latest prediction of what the arrival and departure demand will be on each of the runway resources, as well as playing an important role between the Tower TMC and the Center TMC for scheduling flights subject to a TMI. It retains the Controlled (Target) Takeoff Time resulting from this coordination. An enhanced STBO Surface Situational Display (section 4.1.10) and the EFD (section 4.1.9) function as the user interfaces for the Tower TMC.

One of the key features of the ATD-2 system is the "fusion" of both strategic and tactical approaches to surface scheduling and departure metering. The goal of the Phase 2 Fused IADS Demonstration is to develop a fused system, where the predictions of demand/capacity imbalance and the results of strategic scheduling will be used by the tactical scheduling in a seamless manner and vice versa.

4.1.2.2 Functions

The tactical scheduler provides the Target Off-Block Time (TOBT), Target Movement Area entry Times (TMATs), and associated countdown timers to the flight operators and ATC. The scheduler provides the Earliest Feasible Takeoff Time (EFTT) to TBFM, for use in generation of its airborne Estimated Time of Arrival (ETA) at the meter point and as a basis of tactical TMI negotiation. ATC provides the Controlled Takeoff Time (CTOT) to the tactical scheduler for its

inclusion in the overall airport scheduling, for the TMI-impacted flights only. The tactical scheduler then provides guidance to flight operators that assist in meeting that CTOT.

An RBS rule is employed by the scheduler for generating TTOTs if surface metering is on, which is consistent with the S-CDM ConOps. With TTOTs in hand, the next step is to calculate Target Movement Area entry Times (TMATs) and Target Off-block Times (TOBTs), using a delay propagation formula. The delay propagation formula reserves some excess taxi-out time on the surface that is absorbed through queuing in order to keep pressure on the runways for maximum throughput.

The TOBT, TMAT, and TTOT reflect all known constraints, including aircraft type (i.e., taxi-speed, wake vortex separation), the dual-use runways, Converging Runway Operations (CRO), any TMIs (CTOT), and conflicts at the end of the runway. The scheduler enables the flight operators to prioritize among their company's own flights. For non-TMI flights, the TTOT is updated based on the most recent trajectory input. The tactical scheduler heuristically constructs a runway departure sequence and applies proper runway separation to generate TTOTs.

The scheduler is always running and updating every 10 seconds with estimates for both arrivals and departures to the STBO client. Advisories are always displayed to ramp personnel for flights with CTOTs. However, the display of advisories to ramp users for surface metering guidance depends on the active metering mode. During time-based metering, gate-hold and pushback advisories are displayed on the RTC. When sequence-based or no metering modes are active, metering advisories are not displayed.

The tactical scheduler ingests its own site adaptation files plus predefined scheduler parameters. It is structured based on a simplified graph model of Nodes in a Network. A Node is a point at which some constraint must be met (e.g., gate, spot, taxiway intersection, runway, departure meter fix). The Nodes are joined into a network by segments (e.g., graph edges) that hold properties, such as transit times, delay margins, and uncertainty buffers. Graph nodes are not explored as in a traditional graph model (i.e., it's not trying to find an optimal path – rather the scheduler is following the path predicted by the surface modeler).

The tactical scheduler utilizes Scheduling Groups, shown in Figure 17, for departure flights to determine the applicable rules for flight readiness prediction, scheduling, metering, and display of advisories.

The Scheduling Groups are described below:

- Uncertain: This is the default initial group for all flights. Gate-hold and pushback advisories for flights in this group are not displayed in the RTC. A hashtag symbol (#) is displayed instead (except for APREQ and EDCT flights) as a placeholder until the flight moves into the Planning or Ready group.
- Planning: Flights with input data that meets the scheduling criteria for ATD-2 (i.e., provide EOBTs which meet the minimal quality standard, as specified in the site adaptation) are placed into the Planning group. The gate-hold and pushback advisories for these flights are displayed on the RTC.
- Ready: A flight transitions to the Ready group when the pilot calls in that it is ready to push back. Flights coming from the Planning group have their gate-hold times frozen and countdown to pushback started. For a flight coming from the Uncertain group, the ramp

controller clicks on the hashtag symbol after pilot call-in to get the gate-hold or pushback advisory from the tactical scheduler.

- Out: A flight transitions to the Out group when the ramp controller indicates via the RTC that it has pushed back from the gate or if the flight's pushback event has been detected.
- Taxi: A flight transitions to the Taxi group when the ramp controller indicates via the RTC or surveillance detects that it is taxiing to the runway.
- Queue: A flight transitions to the Queue group when surveillance detects that it has reached the runway departure queue as defined in the adaptation.
- Off: A flight transitions to the Off group when surveillance detects that it has started its departure roll on the runway.

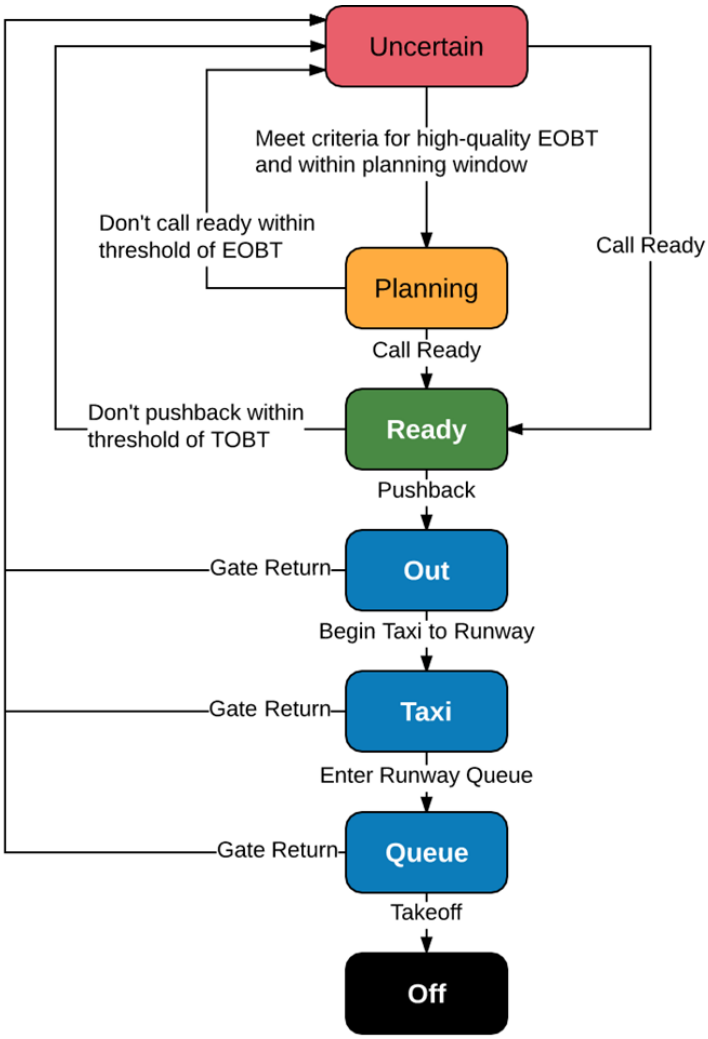

Figure 17 - The tactical scheduler utilizes Scheduling Groups for departure flights to determine the applicable rules for flight readiness prediction, scheduling/metering, and display of advisories.

Flights are scheduled by an "order of consideration" approach. The order of consideration is used to achieve either an RBS or First-Come, First-Served (FCFS) order, while considering the priority of flights and TMIs.

RBS, an algorithm that schedules flights by priority, is used for flights in the Uncertain or Planning groups. It operates under the premise that flights with higher certainty should have higher precedence in scheduling. RBS provides the ability for flight operators to reserve a place in line at the departure runway for a flight without physically being there. "RBS is an approach to ration competing flights scheduled to use a resource where the demand exceeds the capacity for that resource. The RBS approach ensures fairness in allocation of the resource to competing flights. The S-CDM capability uses the Initial Off-Block Time (IOBT) for prioritizing the flights under the RBS approach."[10]

FCFS, an algorithm that orders flights by undelayed time to the runway, is used when flights reach the Ready group. The FCFS algorithm is a nominal base case which orders departures by Undelayed Takeoff Time (UTOT). Flights with earlier UTOTs at the runway are scheduled ahead of flights with later times.

4.1.2.3 Inputs/Outputs

Figure 18 illustrates the primary data flow into and out of the tactical scheduler, from the standpoint of the primary producers and consumers of the data. Note: the actual physical data flow itself is through JMS publish/subscribe messaging. Thus, the components themselves are not required to perform process level handshaking and other point-to-point protocols.

The surface modeler component (section 4.1.1) provides the unimpeded taxi times to the tactical scheduler, along with its detailed flight-specific modeled input. The tactical scheduler uses this unimpeded time as the basis for developing its schedule. In this way, consistent trajectory input can be provided to both the tactical scheduler and the strategic scheduler (even if the strategic scheduler does not use it). This same design pattern applies to the strategic scheduler development (section 4.1.3).

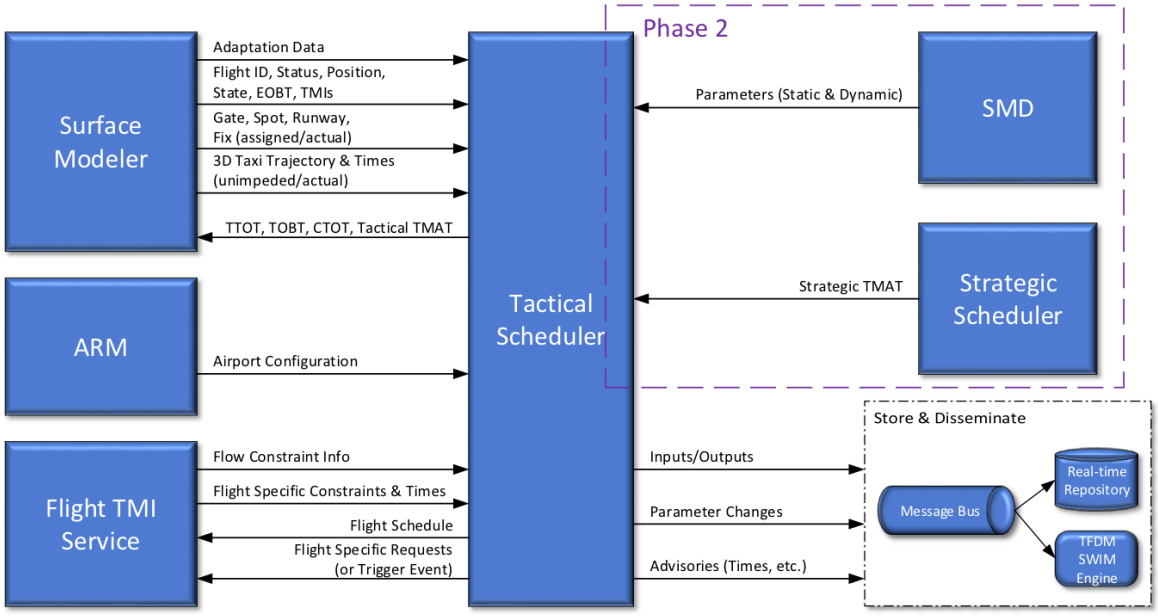

Figure 18 – The Tactical Scheduler component consumes/produces a variety of data.

The Airport Resource Management (ARM) logical component (section 4.1.8) supplies the airport configuration data (both the planned and current configuration). There are other constraints that the tactical scheduler uses which originate from ATC intent information.

The flight TMI service (section 4.1.11) provides common TMI scheduling for the STBO system. This service stores the TMI flight information on flights that have already been committed to (e.g., a controlled time exists in the system) and responds to new TMI scheduling requests.

The tactical/strategic fusion will be addressed when the TDD is updated for Phase 2. Data that is useful for operational analysis, simulation input, and/or detailed system debugging purposes will be archived and disseminated to other users, as required.

4.1.3 Strategic Scheduler

Additional design details for this component will be defined after Phase 1.

4.1.3.1 Component General Description

The strategic scheduler is one of the Surface CDM capabilities planned for ATD-2, and is also referred to as the Strategic Surface component of the system. To assist with strategic scheduling, a DRM system, that was developed by Metron Aviation as part of the Surface CDM concept engineering effort led by the FAA, was delivered to NASA as a standalone product for ATD-2. This system will be used to collect strategic scheduling data during Phase 1 that will guide design decisions for the Phase 2 fusion effort.

4.1.3.2 Functions

The strategic scheduler component evaluates the capacity/demand balance of the runways and recommends a departure metering program (DMP) if there is an imbalance. It applies the DMP parameters set by the air traffic controllers, via the SMD user interface, in evaluating the capacity/demand. The strategic scheduler calculates TMAT times, taking into consideration several factors. It will comply with the EDCTs and APREQ/CFR times, if applicable, as provided by the Flight TMI service. It will apply the surface trajectory prediction, consider the EOBT and gate assignment from flight operator supplied data, and consider flight operator provided preference while determining the TMAT time.

The strategic scheduler will adjust TMAT times based on flight operator preferences (e.g., inter-flight operator substitutions, priority lists). It will also use surveillance to detect actual spot and takeoff times, in order to evaluate TMAT conformance and other evaluation metrics.

4.1.3.3 Inputs/Outputs

The inputs and outputs to the strategic scheduler are depicted in Figure 19, which at this level appear to be very similar to the tactical scheduler. This is by design, and helps achieve a number of architectural objectives that are geared toward future harmonization amongst the schedulers, comparative analysis and research, system maintainability, scalability, and reuse.

The key distinctions between the strategic scheduler and the tactical scheduler data flow are the interactions with the SMD and the data disseminated for broader system use. The strategic scheduler provides notifications to the SMD of demand/capacity imbalances and associated DMPs, as well as notifications of when events like compression and reassignment are recommended.

Compression is a type of DMP adjustment used when the departure queue is predicted to fall below the Target Queue Length Lower Threshold. Compression prevents the departure queue from running dry, leading to missed departure slots. Reassignment of TMATs is an adjustment used when the queue length is predicted to go above the Target Queue Length Upper Threshold.[1]

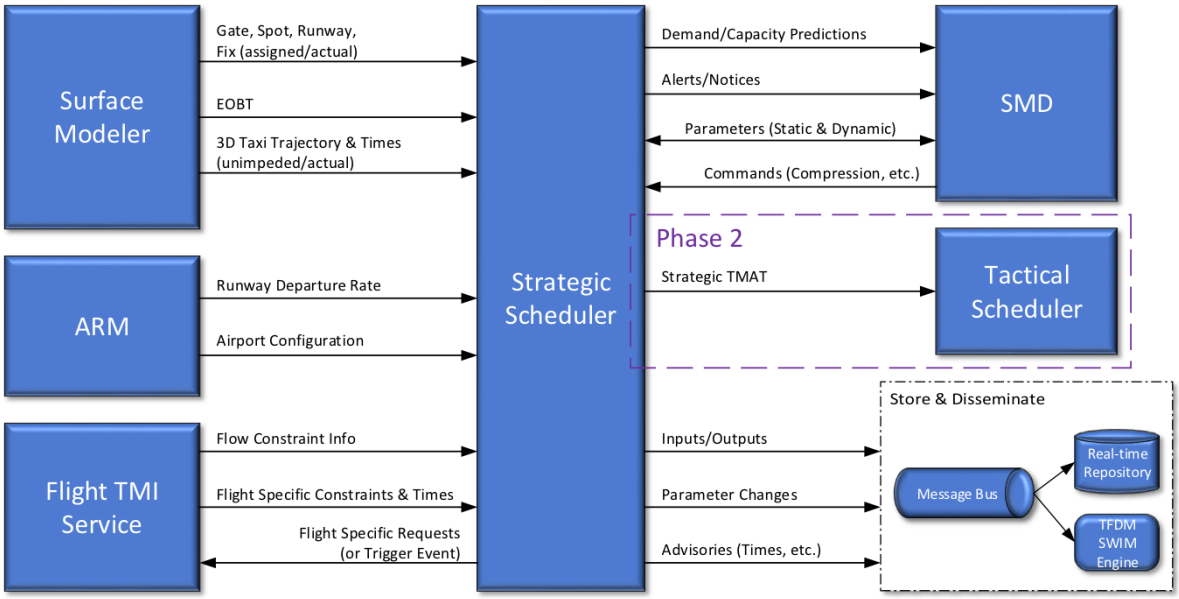

Figure 19 - The Strategic Scheduler component consumes/produces a variety of data.

Compression and re-assignment are handled automatically in the tactical scheduler. The strategic scheduler has specific rules as to how it will handle the interaction with the SMD position, which the tactical scheduler does not. This leads to additional data flow between the SMD and the strategic scheduler that does not exist for the tactical scheduler. Another important distinction between the tactical and strategic scheduler is the tactical scheduler can use a mix of RBS and FCFS logic, whereas the strategic scheduler uses only RBS principles.

The primary output product that ATD-2 uses from the strategic scheduler is the TMAT time. The strategic scheduler inputs/outputs, parameter changes, and advisories will be disseminated to the other system users/processes that are required and will be stored in the database.

4.1.4 Surface Metering Display (SMD)

Additional design details for this component will be defined after Phase 1.

4.1.4.1 Component General Description

A Departure Reservoir Coordinator (DRC) concept is described in Sections 4.3.2 and 4.8.7 of the Surface CDM document.[1] The DRC concept has been implemented as the Surface Metering Display (SMD) user interface and contains all the functions required to set default parameters, render strategic and/or tactical prediction information, and obtain commands and other required inputs from the SMD users.

4.1.4.2 Functions

The SMD user interface provides the user with predicted demand based on flight operator schedules and an estimated departure and arrival rate based on runway configuration information

of the airport resources. It notifies the user of a predicted capacity/demand imbalance and the recommended DMP to resolve it. The SMD displays the scorecard and reports on key TFDM scheduling metrics and operational data from the Metrics, Reporting & Analysis (MRA) service. It also provides the user with entry options for rejecting or accepting a DMP, adjusting the DMP parameters (list to be discussed), and potentially modifying a DMP recommendation. The SMD user maintains the overall responsibility for managing DMPs, but coordinates with flight operators to accommodate their preferences. The SMD user interface notifies the user of the flight operator's consent for a DMP and provides the notification/disposition of a request for an inter-flight operator and/or intra-flight operator substitution.

4.1.4.3 Inputs/Outputs

The SMD user interface is expected to be a front-end-only component logically decoupled from the rest of the ATD-2 architecture, in order to avoid placing business logic in a component that is intended primarily as a user interface. Adaptation data will be required to allow the SMD to load statically adapted parameters, which serve as defaults for the system (i.e., used in strategic and/or tactical scheduling). Storing and retrieving user preferences (e.g., the position and composition of display options) will also be required.

In Figure 20, the data flow into and out of the SMD is shown from the standpoint of the producers and consumers of the data. Updates to important common situational awareness artifacts and scheduling inputs will be shared with the SMD as they happen, as shown by the data flow between the ARM and the SMD. The SMD will provide important updates to parameters and commands to the schedulers, as necessary to achieve the Surface CDM concept and tactical scheduling.

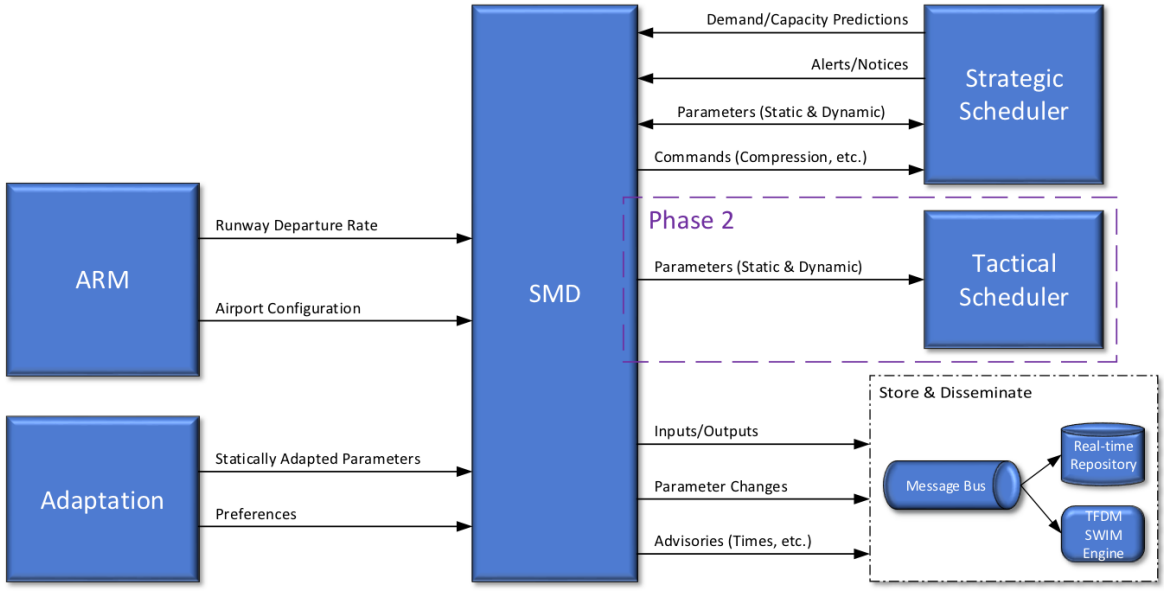

Figure 20 - The SMD user interface component consumes/produces a variety of data.

The strategic scheduler will provide schedule output to the SMD for demand/capacity imbalance information purposes, as well as flight specific information for those flights for which a time was agreed upon by the users (denoted as "Hard" times).

Data that may be useful for operational analysis, simulation input, and/or detailed system debugging purposes will be archived and disseminated to other users, as required.

4.1.5 TFDM SWIM Engine

Additional design details for this component, now called TFDM Terminal Publication (TTP), will be defined after Phase 1. Note: TFDM WSRD mentioned below has been renamed to the Terminal Publication Service.

4.1.5.1 Component General Description

The TFDM SWIM engine provides a prototype TFDM SWIM feed from the ATD-2 IADS system to external stakeholders, in a manner consistent with TFDM planning documents. This component emulates the future TFDM SWIM data feed, so that effort invested by flight operators to interact with ATD-2 will be transferrable to the future FAA system. An additional goal is to help identify new TFDM SWIM data elements that are desired by the flight operators and are not currently specified in the TFDM Web Service Requirements Document (WSRD).[11]

4.1.5.2 Initial Design considerations

The starting point for this component's requirements is the TFDM Web Service Requirements Document (WSRD).[11] The WSRD assumes that all outgoing data would be in Flight Information Exchange Model (FIXM)/Aeronautical Information Exchange Model (AIXM). However, much of the data intended to be shared by ATD-2 may not currently be specified in either model. ATD-2 will need to recommend new data elements, and that should also help mitigate risk and mature this interface.

ATD-2 will likely need a way to daisy-chain (i.e., repeat) this data feed. This allows a number of distribution options for the production SWIM engine feed that would otherwise be difficult (e.g., run a repeated SWIM feed at William J. Hughes Technical Center (WJHTC)), while also allowing development systems to feed off of operational data feeds with minimal impact to system performance.

ATD-2 will require a clean, concise, and preferably low maintenance way to keep track of all the data elements shared with industry and by system components. It seems likely that the external name for a data element and the internal name may be different, in which case mapping should be provided. All data passed to external consumers should be archived.

It may be necessary to replay data coming from the TFDM prototype feed. There will be tools developed to read, process, and utilize this feed that may benefit from this replay ability. However, this requirement is lower priority than getting the initial capability working.

Beyond items currently discussed in the TFDM WSRD, ATD-2 also envisions sharing several other types of data via this feed. These include:

- Tactical scheduling related information elements that may be akin to the new elements that PDRC enhanced scheduling added to the Flight Operations Surface Application (FOSA) interface, which were designed to provide flight operators with more information about the potential delay and size of the slot
- All of the ATC-related information (e.g., runway departure rate, airport configuration, APREQ/CFR entries)

- Data from the Multi-System Restriction Manager (from the Metroplex Coordinator system). While some of this information may be available in other feeds, the ATD-2 stream of data is seen as value-added, in that it tells the user all of the restrictions affecting a specific airport in one stream.
- All substantial flight specific updates (e.g., updates to TOBT, TMAT, TTOT), when the times change from one iteration to the next.

There is a real concern about overwhelming the flight operators with data, even though the data is desired.

The system architecture developed for the ATD-2 Fuser component (section 4.1.6) may be leveraged as a starting point for the TFDM SWIM prototype data feed.

4.1.5.3 Proposed SWIM Feed

ATD-2 plans to utilize a TFDM SWIM prototype at CLT and temporarily implement the FAA's TFDM requirements before TFDM is ready to be deployed. The ATD-2 system will deliver information to flight operators and other consumers via the SWIM infrastructure. At the time of this document's publication, ATD-2 and the FAA are in the process of investigating the method to use for the input and output of TFDM-type data for Phase II. ATD-2 will use the existing TFDM requirements to publish data to consumers and also make recommendations for new data elements as part of the technology transfer process so that the message sets may be extended.

4.1.6 Fuser

The Fuser processes and synthesizes inputs from disparate data sources to provide a consistent set of fused data to/from STBO. The Fuser incorporates flight matching across the data sources and assigns a Globally Unique Flight Identifier (GUFI) to each flight. It aggregates and mediates among all data sources to provide a coherent data set. Fused data is distributed to the rest of the IADS system and written to a PostgreSQL database to support analysis and debugging.

4.1.6.1 Inputs/Outputs

This section introduces the high-level data flow to and from the Fuser system, as illustrated in Figure 21. NAS traffic flow data originates from external sources. These sources are shown on the left, with the FAA sources shown in green and the flight operator/third party sources shown in yellow.

The external interface data feeds include:

- Operational Information Service (OIS) website
- System Wide Information Management (SWIM) Traffic Flow Management Data (TFMData) Service
- SWIM Terminal Data Distribution System (STDDS) Service (Airport Surface Detection Equipment – Model X (ASDE-X) track reports)
- Three separate Time Based Flow Management (TBFM) data sources:
  - SWIM TBFM Service
  - NASA TBFM Atlanta ARTCC (ZTL) Collaborative Arrival Planning (CAP) data feed

- FAA TBFM Washington ARTCC (ZDC) Integrated Departure Arrival Capability (IDAC) Data Fusion (DFSN) data feed

- Flight Stats data files
- American Airlines (AAL) Flight Hub data service

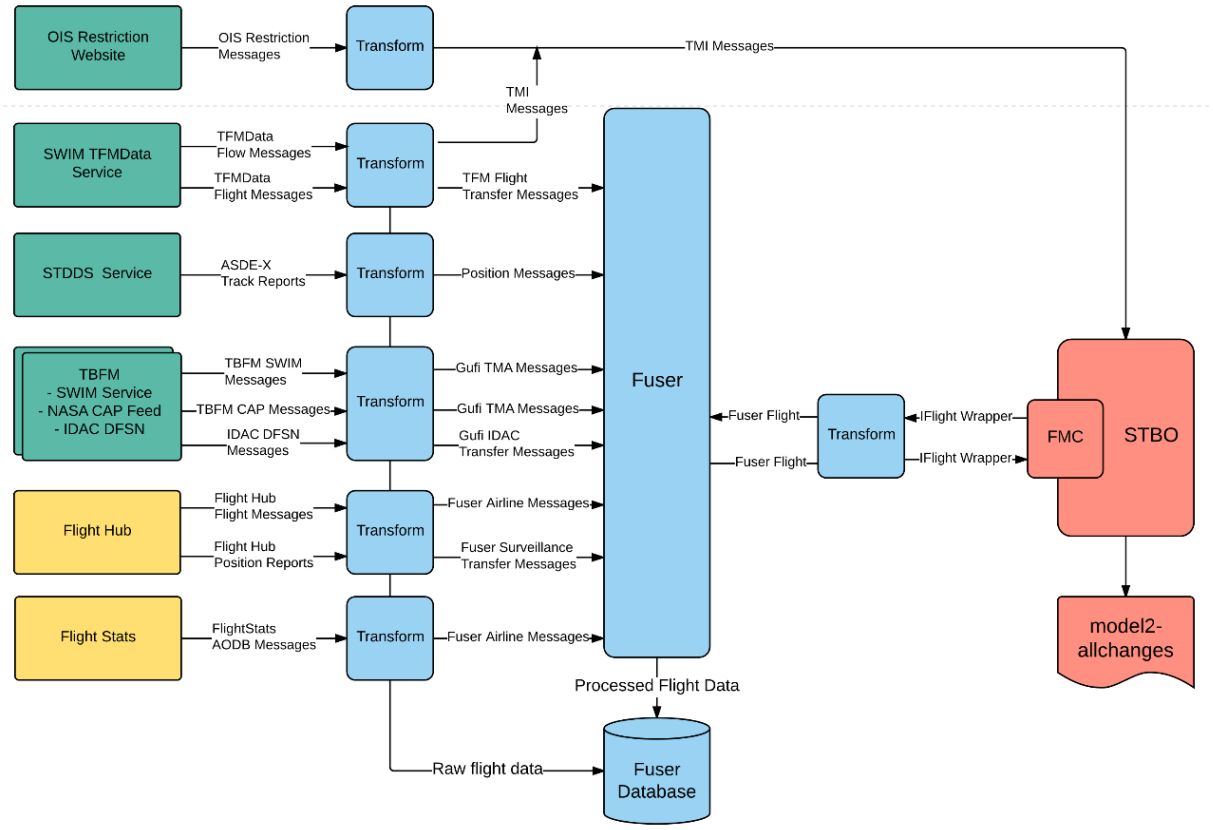

Figure 21 - This illustration shows the data flow to/from the Fuser.

Each of these data sources represents flight or restriction data in different formats. The raw message formats are transformed into flight formats that the Fuser can more easily process. The Fuser then merges flight data from these different data sources into a common flight format.

The Fuser sends the common format flight updates to STBO via the Flight Management Connector (FMC). The FMC converts messages from the Fuser format to the receiving STBO component format and manages communications between the Fuser and STBO components and processes.

STBO components add additional information to the flight information, such as predicting the runway or taxi time, and updates from STBO components are sent back to the Fuser via the FMC. The Fuser updates the common Fuser flight data with the STBO component updates, along with any other updates the Fuser has received for the flight.

All Fuser data changes are processed, fused, and distributed, as well as written to the database. The Fuser database includes metadata to support data traceability for all flight modifications. STBO logs any flight changes for which it is aware into a common data logging file.

4.1.6.2 Fuser System Components

The Fuser system can be grouped into four types of sub-components, including the external interface processors, the database processors, the core Fuser components, and the Fuser STBO interface components. Figure 22 serves to illustrate the communication flow between the sub-components of the Fuser system and relevant external systems, primarily the external data

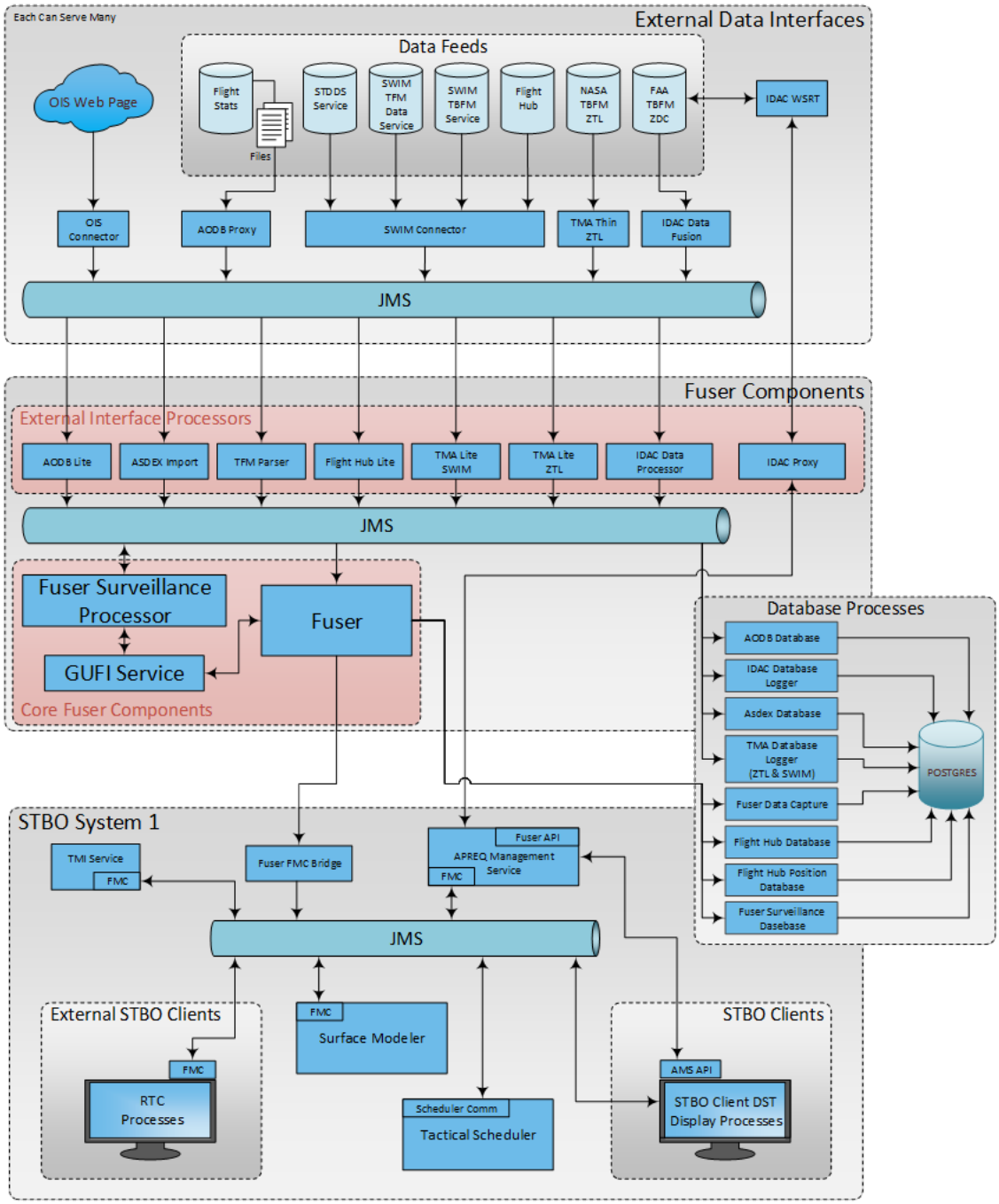

Figure 22 - The Fuser architecture overview shows the communication flow of the sub-components that comprise the Fuser system.

interfaces and the other components of the STBO system. The external data interfaces include the actual external system data feeds, as well as the ATD-2 client components that connect to them.

4.1.6.2.1 Fuser external interface components

The external interface processors are responsible for interfacing the Fuser with the external data sources and are listed in Table 2 below. Typically, these processors transform data to a common format and publish to the Fuser. Several of these processors also handle GUFI assignment.

Table 2 - ATD-2 Fuser components are described in detail.

Component	Description
AodbLite	Airlines Operational Database (AODB) Lite listens for AODB messages on a JMS topic as provided by the Flight Stats feed converted to AODB format. It expects to receive flight specific data from the flight operators. Each message is converted to a general use object structure and redistributed on a new topic to be picked up by the Fuser.
AsdexImport	AsdexImport listens for ASDE-X messages on a JMS topic as provided by the STDDS data feed. It transforms messages to a common format, handles GUFI assignment, and redistributes messages to the Fuser.
FlightHubLite	FlightHubLite listens for FlightHub messages on a JMS topic as provided by the AAL Flight Hub data feed. It expects to receive flight specific and position messages. Each message is converted into a general use, non-AAL specific object structure and redistributed on new topics to be picked up by the Fuser.
IdacProcessor	Processor that connects to the TBFM IDAC DFSN data feed, assigns a GUFI, and passes data to the Fuser. The IDAC DFSN data feed is an internal TBFM messaging topic that has been made available to this effort.
IdacWsProxy	Web service proxy for connection to the TBFM IDAC web services. The IdacWsProxy is used by the APREQ Management System to interface with TBFM.
TmaLite	TmaLite listens for TBFM messages on a JMS topic as provided by the either the TMA Collaborative Arrival Planning (CAP) feed or the SWIM TBFM service. It expects to receive flight specific and position messages. Each message is converted into a common format, assigned a GUFI, and redistributed to the Fuser. The full Fuser system runs two separate instances of TmaLite, each connected to a separate TBFM system: NASA ZTL TBFM, and the TBFM SWIM feed.
TfmFlightXmlParser	The TfmFlightXmlParser listens for “Flight” and “Flow” messages from the SWIM TFMData feed. Flight messages are transformed to a common format, assigned a GUFI, and published to the Fuser. Flow messages are transformed and published to the TMI Service. The TfmFlightXmlParser also stores the external messages to the database.

4.1.6.2.2 Fuser database processor components

The Fuser database processors, listed in Table 3, were designed to record Fuser data to a PostgreSQL database. The recorded data includes raw data from external interfaces and data that

is processed by the Fuser system. Note that some of the external interface processors and core Fuser components also serve database processing roles, if indicated in Table 2 or Table 4.

Table 3 - Fuser database processors record Fuser data to a PostgreSQL database.

Component	Description
AodbDatabase	The AodbDatabase listens for AODB-formatted messages from the Flight Stats data feed and writes to the Fuser database.
AsdexDatabase	The AodbDatabase listens for ASDE-X messages from the STDDS data feed and writes to the Fuser database.
FlightHubDatabase	The FlightHubDatabase consumes FlightHub Flight messages from the AAL Flight Hub data feed and writes to the Fuser database.
FlightHubPositionDatabase	The FlightHubDatabase consumes FlightHub Position messages from the AAL Flight Hub data feed and writes to the Fuser database.
FuserDataCapture	The FuserDataCapture consumes Fuser-produced messages and writes to the Fuser database.
FuserSurveillanceDatabase	The FuserSurveillanceDatabase listens for Fuser Surveillance messages from the FuserSurveillanceProcessor and writes to the Fuser database.
IdacDatabaseLogger	Database component for logging all messages from the IdacProcessor to the Fuser database.
TmaDatabaseLogger	TmaDatabaseLogger is a consumer of TMA messages from the TMA CAP and SWIM TBFM service data feeds. It writes messages to the Fuser database.

4.1.6.2.3 Fuser core components

The core Fuser components, listed in Table 4 below, fuse data from the external interfaces into a common flight data format.

Table 4 - Fuser core components fuse data into a common format.

Component	Description
Fuser	The Fuser component listens for incoming data from all of the external interface processor components. The Fuser transforms all data to a common schema, applies filtering and data mediation, merges to a current flight state, and sends the fused data to STBO.
FuserSurveillanceProcessor	The Fuser Surveillance Processor handles GUFI management for incoming messages on the Fuser Surveillance schema format and sends to the Fuser.
GufiService	The GUFI Service assigns and manages Globally Unique Flight Identifiers (GUFIs) for all Fuser components. The GUFI is the data element that is used for all flight matching by the Fuser, as there are several external flight data sources coming into the Fuser. This component also records all GUFI messages to the database.

4.1.6.2.4 Fuser STBO interface components

Finally, the components in Table 5 serve as an interface between the STBO and Fuser systems.

Table 5 - Fuser STBO components serve as an interface between STBO and the Fuser system.

Component	Description
FuserFmcBridge	The FuserFmcBridge passes data between the FuserClientApi and Flight Management Connector (FMC), which forwards the data on to other applications. The bridge takes Fuser Flight data from the Fuser, transforms it to FMC data using the FuserTransformServices, and passes it on to the Flight Management Connector (FMC) to be distributed to any listening applications. In reverse, the bridge takes FlightUpdates from FMC, transforms them to Fuser Flight format, and passes them to the Fuser for processing.

4.1.7 Traffic Flow Data Management (TFD)

Additional design details for this component will be defined after Phase 1.

4.1.7.1 Component General Description

The Traffic Flow Data Management (TFD) is a logical ATD-2 component that facilitates the data exchange of traffic information which is necessary to perform the Surface CDM operations, emulating the set of services envisioned in the future TFDM TFD process (section 3.2.2.2).[6] This capability includes a broad range of traffic flow data management functions (e.g., ability to manually enter various TMIs, identify flights affected by TMIs, support both automatic and manual APREQ/CFR scheduling, calculate holding time, etc.).

In ATD-2, TFD is really an abstraction used to map to TFDM. The TFDM specification could be satisfied in a number of ways. Although the component is listed in the STBO system, it may be most expedient to combine its requirements with those of the MC's multi-system restriction manager. At a minimum, these two systems' requirements should be considered from the standpoint of common processing, validation, storage, and dissemination.

4.1.7.2 Functions

The general concept of TFD processing includes the same three major groups as the ATD-2 TFD processing: data input/output; data processing that includes data fusion, scheduling and event processing; and information display.

4.1.7.3 Inputs/Outputs

As illustrated in Figure 23, the ATD- 2 TFD process receives key inputs manually from the Surface Situational Display (e.g., the STBO Client or Client replacement), as well as the consolidated TMI feed from the Metroplex Coordinator system. The consolidated TMI feed will likely incorporate multiple TBFM SWIM feeds, the TFMData Flow Information messages, and NTML feeds, or equivalent.

It is desired to have the users only enter a TMI once and it would then be replicated to other systems as required. It is also desired to enter the TMI in the closest, most logical system for the problem that the TMI is intended to resolve. For instance, if the TMI were an APREQ/CFR process from the Center, then ideally the system would react to entries made directly in TBFM, without the need for additional manual entries (in this case, perhaps by recognizing the Miles-in-Trail (MIT) as added to a stream when the Center adds it, using the TBFM F1 Streams panel). The components most likely to need the TMI restriction information are listed in Figure 23.

These components are expected to obtain this restriction information from the JMS publish/subscribe messaging, not as a point-to-point communication.

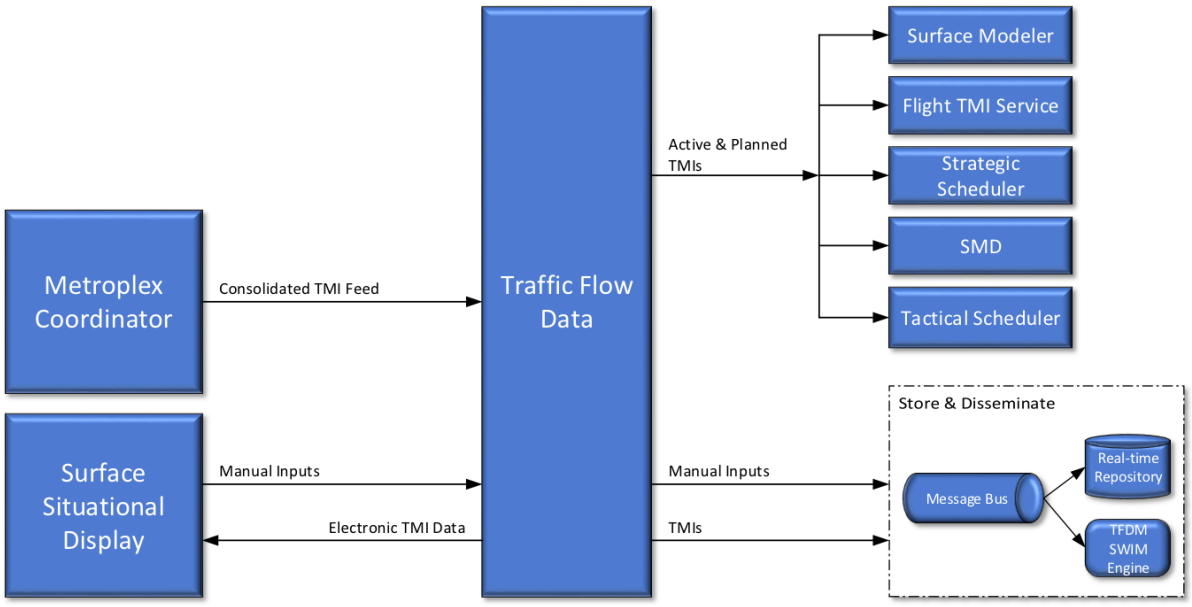

Figure 23 - The Traffic Flow Data Management component consumes/produces a variety of data.

System stakeholders and other system components are also expected to want the latest TMI information. This includes, but is not limited to, the flight operators, the airport authority, all the local ATC, the Command Center ATC, and the MC and TBFM systems. These stakeholders and system components are expected to obtain this TMI feed through the TFDM SWIM prototype data feed.

It is important that the raw user inputs, the electronic inputs, the derived outputs, and the messages sent regarding TMIs are stored for later analysis and replay capability.

4.1.7.4 Design considerations

In all cases, ATC input will need to override any restrictions derived from the input data (e.g., MC electronic information). When possible, it should pull the restriction information from the SWIM feed, which includes NTML inputs, but any manually entered TMI data should override the system electronic TMI data.

In addition to determining the current restriction in play, ATD-2 needs to display these restriction(s) on the STBO systems. This is expected to lead to a display requirement for:

- AEFS - The initial rollout of AEFS capability will likely be very close, if not exactly like, the FAA AEFS prototype system. As the ATD-2 evaluation continues and the system proves its reliability in the consistent display of TMIs, as well as the ability to provide enhanced data to AEFS, it will become a key user interface, as well.
- Surface Situational Display - Envision a place on the map or on another commonly used panel/window to display the current restrictions, yet something the TMC can suppress the display of, much like many of the other system display functions (e.g. show departure fixes or not, show taxiways or not).

- RTC – The RTC currently displays any restrictions in the system, including those that are entered manually into STBO as well as those that are ingested automatically from the OIS web page.
- SMD - It is important that the SMD display the current TMIs. At this point, the SMD display of the TMI feed is expected to be read-only. If the SMD is run by ATC, then it is expected they will use their read-write version of the Surface Situational Display to enter this restriction.

4.1.8 Airport Resource Management (ARM)

Additional design details for this component will be defined after Phase 1.

4.1.8.1 Component General Description

The Airport Resource Management (ARM) is a logical ATD-2 component describing the set of services that are envisioned in the future TFDM ARM process (reference TFDM specification, section 3.2.2.3). This capability includes a broad range of airport-related management functions, such as scheduling/updating the current and future airport configurations, setting/updating the Airport Arrival Rate (AAR), setting/updating the Airport Departure Rate (ADR), setting/updating the runway departure rates, assigning the default runways, balancing the runway loads, and setting/updating the airport resource status.

4.1.8.2 Functions

The ARM will generate and display the current and scheduled airport resource usage, potentially via the SMD user interface. It will generate and display the predicted runway schedule, to include flight specific data. It will also allow a user to set the airport resource capacity rates (ARCR).

4.1.8.3 Inputs/Outputs

As shown in Figure 24, the ARM component has a number of inputs. Depending on whether the Center sets the AAR in TBFM, this value may be passed along and utilized by the surface system.

It appears that the TBFM runway separation matrix may be useful, as the site uses that to govern TBFM arrival metering flow. This data should be available from the operational TBFM SWIM feed, which is expected to be consolidated and filtered by the MC, and provided in the consolidated TMI feed.

Similar to the TFD component, the ARM component receives input from the Surface Situational Display. Functions will be provided to encourage the TMCs in the ATCT and/or TRACON to utilize load balancing, or a specific runway utilization strategy. These functions may not be automated, but they should make it easier for the controller to spot and remedy load balancing issues early, and thus encourage TMC input.

It is envisioned that the airport authority will provide an electronic data feed of runway closures and/or maintenance information. The RMTC provides ramp closure information. All outputs should be passed along to the SWIM engine and/or stored in a real-time repository.

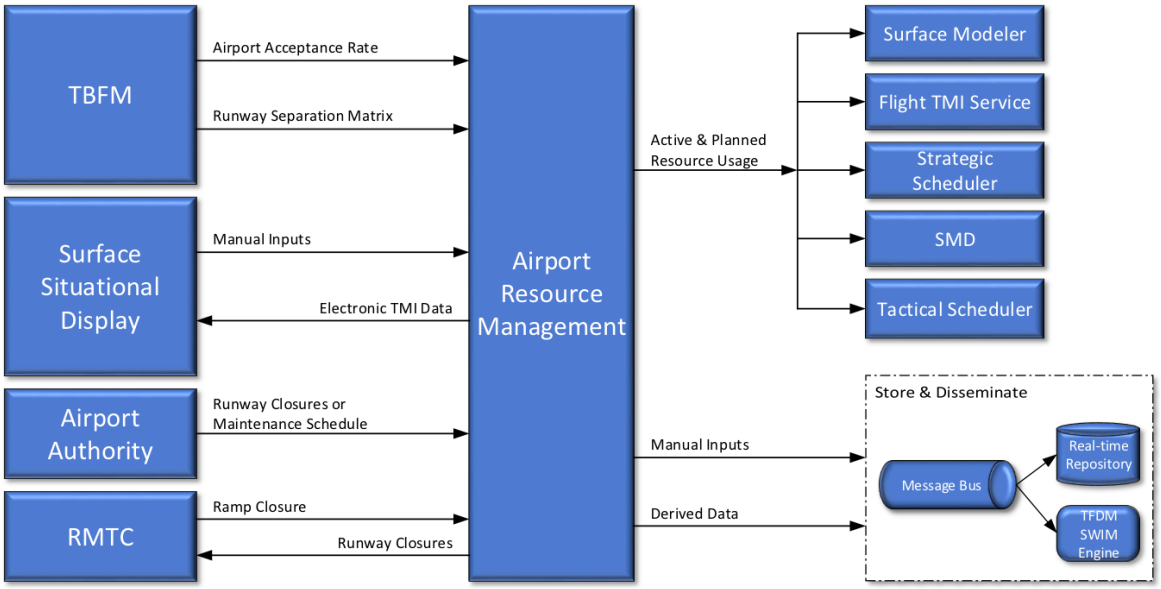

Figure 24 - The Airport Resource Management component consumes/produces a variety of data.

4.1.9 Electronic Flight Data (EFD)

Additional design details for this component will be defined after Phase 1.

4.1.9.1 Component General Description

The Electronic Flight Data (EFD) component of ATD-2 maps to the EFD capability currently being used by the FAA as a replacement to paper flight strip processing in the ATCTs. The FAA is committed to providing an EFD solution at CLT in support of the ATD-2 field demonstration, and elected to install the Advanced Electronic Flight Strip (AEFS) Software, developed by the Terminal Second Level Engineering (TSLE) (AJM-24) at the FAA Tech Center. It is operational code that has been in use at PHX, CLE, EWR, LAS, SFO, and has been deployed to CLT as part of the ATD-2 demonstration. It is considered to be a stop-gap solution until the full TFDM system is deployed.

4.1.9.2 Functions

In support of the ATD-2 field demo, the FAA has deployed the AEFS prototype to CLT to fulfill the EFD requirement. For Phase 1, AEFS and the ATD-2 IADS will run in parallel with manual data transfer between the systems. An interface between AEFS and ATD-2 IADS will be implemented for Phase 2.

4.1.10 Surface Situational Display

4.1.10.1 Component General Description

The Surface Situational Display's user interface, also called the STBO Client, tracks the movement of aircraft on the runways and taxiways, and aircraft in flight that are on approach for landing. It is one of the views selectable within the MFD and provides convenience features (e.g., a map, a timeline, a flights table) that help the users attain better situational awareness. The user interface includes a map, flights table, timelines, notifications panel, and toolbar. The airport

map shows the ramp, taxiways, and runways. The map can be zoomed out to view nearby airspace. The flights table contains detailed flight information, such as flight ID, aircraft type, date timeline for arrival and departure, destination, gate, spot, and TMI times. The timelines show arriving and/or departing flights on each runway. The notifications panel indicates user alerts.

4.1.10.2 Functions

The Surface Situational Display shows the airport layout and the real-time traffic currently using the airport. It presents all the calculated, estimated, and target times, which facilitates research into which users make use of what times, thus furthering development of the display requirements for the field.

The flights table is customizable to display as much or as little flight information detail as desired by users. Typical fields include flight ID, destination airport, aircraft type, flight status, gate, gate time, runway, runway time, departure fix, departure fix time, MIT, APREQ designation, EDCT time, and flight route. The ATD-2 functionality includes indication of Operational Necessity, cancelled flight, and Long On Board (LOB) awareness. The Operational Necessity functionality involves a runway change request made by either pilot or ramp for any operational reason for which the aircraft needs the longest runway for departure. The LOB functionality provides situational awareness to the ramp, ATCT, and TRACON concerning how long a departure flight has been on the surface since the door was closed, or how long an arrival flight has been on the ground without opening the door for the passengers to deplane. It provides a common method to measure and report LOB flights.

The Surface Situational Display's user interface fully emulates the TBFM IDAC interface to enable users to request APREQ release times from TBFM and perform other tower-related functions. Symbology is added to STBO timeline elements to identify flights with APREQs and the status of their clearance request process. The APREQ/CFR or EDCT time is reverse-highlighted to show compliance (green for on time, yellow for early, and red for late). For flights subject to both APREQ and EDCT restrictions, the STBO timeline displays the options for both – green boxes for APREQ slots and a yellow rectangle for the EDCT compliance window. The APREQ and EDCT options may not always overlap, in which case the controllers will follow the APREQ. Other timeline designations include display of Operational Necessity, MITs, Ground Stops, and closed departure fixes.

The notification panel informs users when important events occur. Notifications are displayed for runway utilization or flow direction changes, any fix/ramp/runway closures, and current TMIs, including MITs and Ground Stops. In Phase 2 of ATD-2, the Surface Situational Display will also notify users when a DMP is in effect.

4.1.10.3 Inputs/Outputs

Figure 25 depicts the inputs and outputs of the Surface Situational Display. A broad range of traffic flow data management functions can be manually entered via the Surface Situational Display and distributed to other systems via Traffic Flow Data (section 4.1.7). Similarly, airport management configuration options can be set from the Surface Situational Display and distributed via ARM (section 4.1.8).

The Surface Situational Display allows users to add, update, or remove TMI restrictions. These changes are sent to the Flight TMI Service (section 4.1.11) for consolidation and distribution throughout the system.

The Surface Situational Display works with TBFM (section 4.3) to negotiate an APREQ slot. The IDAC interface shows the available overhead stream slots (green boxes) in the middle of the STBO timelines and allows Tower controllers to select a slot to request from the Center. The Center TMC receives an APREQ request notification in the TBFM TGUI and can approve, re-negotiate, or reject the requested slot. The Tower TMC then receives the response and takes the appropriate action. Manual entry of release times is possible for all APREQ aircraft. Swapping release times between APREQ flights in the same stream class is allowed.

All outputs from the Surface Situational Display should be passed along to the SWIM engine and/or stored in a real-time repository. In Phase 2 of ATD-2, it is envisioned that the Active DMP from the strategic scheduler will be displayed on the Surface Situational Display.

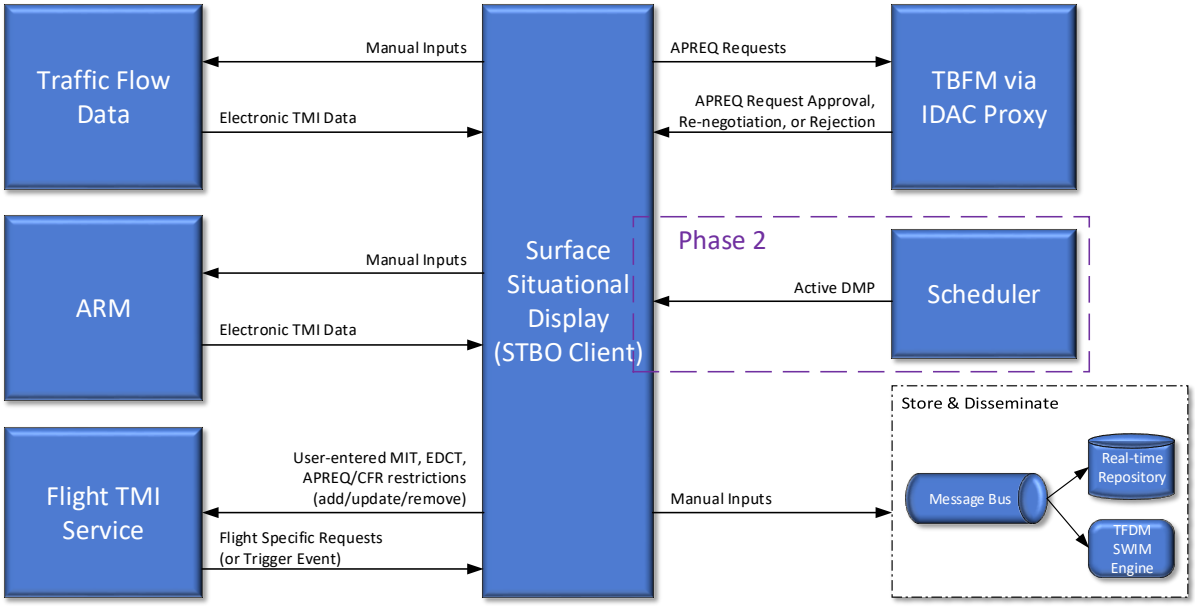

Figure 25 - The Surface Situational Display component consumes/produces a variety of data.

4.1.11 Flight Traffic Management Initiative (TMI) Service

4.1.11.1 Component General Description

The STBO Flight TMI Service consolidates the processing, management, and decisions related to all the flight specific TMIs for the STBO system. This logic will be applicable for flights subject to an APREQ/CFR, an EDCT, a MIT, and potentially, a Ground Stop and/or Ground Delay Program. A MIT can be applied at the Terminal boundary or at the destination airport.

Since TMIs can be entered or obtained in a number of ways including via TBFM (i.e., ATD-2's system for entering local TMIs), Operational Information System (OIS), and other systems, the Flight TMI Service allows the logic for flight specific constraints to be consistent across the STBO system and reduces the complexity of other components that would otherwise need to implement their own TMI logic.

4.1.11.2 Functions

The Flight TMI Service receives TMI information, identifies which flights are affected by a TMI, and associates the flight to the TMI. It may translate the MIT into a "time slot" for each impacted flight, and then add the TMI information to the flight's data and distribute it to the other components.

4.1.11.3 Inputs/Outputs

Figure 26 illustrates the characteristics of a system event driven update model and a request/reply model, which are both utilized in the Flight TMI Service component. Common to both models, all data required for the Flight TMI service to perform its duties are assumed to be available to the process. This can be either because it obtains all these data as a part of its normal functioning (as a standalone process would need to) or the required subset of data could be passed in to the process in some other way.

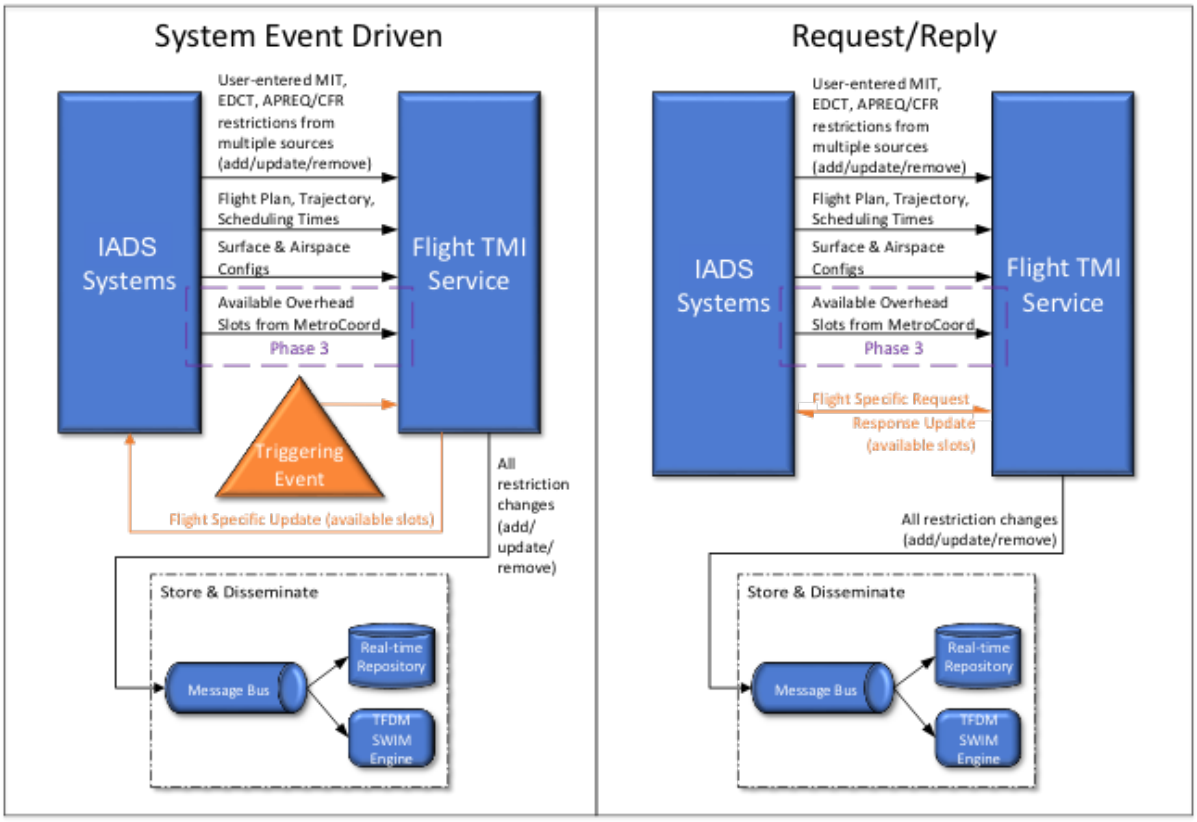

Figure 26 - An Event Driven data flow is shown in the left panel and a Request/Reply data flow mechanism is shown in the right panel for the Flight TMI Service component.

The key difference between the two models is that the system event driven model puts the Flight TMI Service in the position of always broadcasting/streaming updates to flights, based upon triggering events that required a new/modified/deleted TMI restricted flight departure time. In the request/reply model, it is expected that the individual system processes that require an updated time will be handled by logic external to the Flight TMI service (e.g., in each scheduler, the Fuser, and/or another process). Both of these update mechanisms may be required and are available via the TMI flight service.

The Flight TMI Service will ingest data from all topics that will be required to make informed decisions. Inputs include:

- Flight specific scheduled times
- Flight plan related information
- TMI restriction information (include start/stop times)
- Configuration information
- Static and dynamic values governing the expected treatment of APREQ/CFR and MIT flights (e.g., schedule all American flights with APREQ/CFR 10 minutes prior to pushback)
- Data that will show the available slots in the overhead stream

The users themselves may want to see these scheduling options and make a decision. For instance, in the case of an APREQ/CFR, a flight could schedule now and take a 10-minute delay on the surface, or take a second slot and absorb 10 minutes of delay at the gate with 5 minutes on the surface. This level of select-ability is not anticipated for the ATD-2 demonstration at CLT, but may warrant further study given its consistency with CDM and information sharing.

Other output questions to be resolved include a decision about timing issues, such as when a slot is presented to the scheduler but it becomes unavailable; ATD-2 will seek to minimize these issues.

The Flight TMI Service output should have constraints eliminated. The individual schedulers will figure out what to do with all of the information. All this data will need to be stored and passed along with the options via TFDM SWIM.

4.1.11.4 Design considerations

The Flight TMI Service will contain all the business logic needed for TMI management. ATD-2 adds complexity to the TMI handling that will be difficult to navigate if the business logic is dispersed beyond this TMI service. Keeping it co-located makes it easier to verify, maintain, and transition.

This TMI service will facilitate and/or be the focal point for multi-system communications (e.g., for IDAC APREQ/CFR scheduling, and for MIT at the Terminal boundary). It is the single authoritative source for how a TMI is handled, validating the TMI parameters and reconciling information that could be received from multiple sources (but does not de-conflict flights). It will contain an appropriate debugger to be able to investigate any issues with TMIs that are reported by the users or testers. It will also be able to run specific scenarios through this logic to ensure that they meet the ATD-2 requirements and should regress this capability easily when changes are made.

The Flight TMI Service processing receives data on TMIs issued to particular flights, and the status of the flights' current compliance to the specific TMI. This processing could be pushing out the times to other components, available via request/response, or both. It applies the business logic in response to system events (e.g., new TMIs, modified TMIs, deleted TMIs, new flights added to system, flight modifications). It will also leverage changes to make new/better decisions. For instance, in the nominal case of a time being frozen with incomplete information

(e.g., due to system timing issues an EDCT was set without yet knowing about a TMI), but which later required an update due to a system event, thus an opportunity for a better time is provided which now includes multiple constraints.

The Flight TMI Service may appear separately as TMI Service and APREQ Management Systems in more detailed ATD-2 system diagrams. They both comprise the Flight TMI Service described in this section.

4.2 Metroplex Coordinator (MC)

The Metroplex Coordinator (MC) is a Phase 3 consideration, so it is yet to be specified.

4.3 Time Based Flow Management

NASA's original field demonstration plan envisioned deploying NASA-modified TBFM systems to run in parallel with the operational TBFM systems at Washington ARTCC (ZDC) and Atlanta ARTCC (ZTL). However, the parallel deployment introduced undesirable complexities for ZDC and ZTL traffic managers. NASA collaborated with the FAA (led by NextGen and the TBFM program office) and the TBFM development contractor (Leidos, formerly Lockheed Martin), to develop a "minimally disruptive" solution for TBFM aspects of the ATD-2 field demonstration. This solution involves implementing an interface between the IADS surface component (i.e., STBO) and the operational TBFM systems at ZDC and ZTL. This section provides an overview of the STBO-to-TBFM interface. Additional details may be found in the Lockheed Martin design document.[12]

The version of TBFM utilized is standard TBFM v4.6 with only minimal changes (e.g., adaptation files, security certificate) to interface with the IADS STBO subsystem. Figure 27 shows NASA's "Super IDST" solution for interfacing IADS with an operational TBFM system.

The top portion of the figure represents a standard operational TBFM/IDAC installation wherein an IDST user interface located in the ATCT is used by a TMC to perform tactical departure scheduling operations with the Center's TBFM system. NASA has created an IDAC Web Services (WS) Proxy that allows the IADS STBO system to interact with the operational TBFM via its Web Services Routing Tool (WSRT), which brings out essentially the same functionality as the human-operated IDST. The solution is depicted at the bottom of Figure 27.

The ATD-2 team has developed a prototype of the IDAC WS Proxy and has successfully tested it with TBFM v4.6.0. The IDAC WS Proxy provides the following benefits to the ATD-2 field demonstration:

- The WSRT web services are designed to be used by the IDAC user interface
- Using the WS Proxy simplifies what the STBO components need to know
- Prevents STBO from needing to know about the configuration of IDAC
- It allows for mocked-up testing
- It isolates STBO from possible changes to the WSRT

The IADS-to-TBFM communications depicted in Figure 27 are summarized from the Lockheed Martin design document[12] in the sections below.

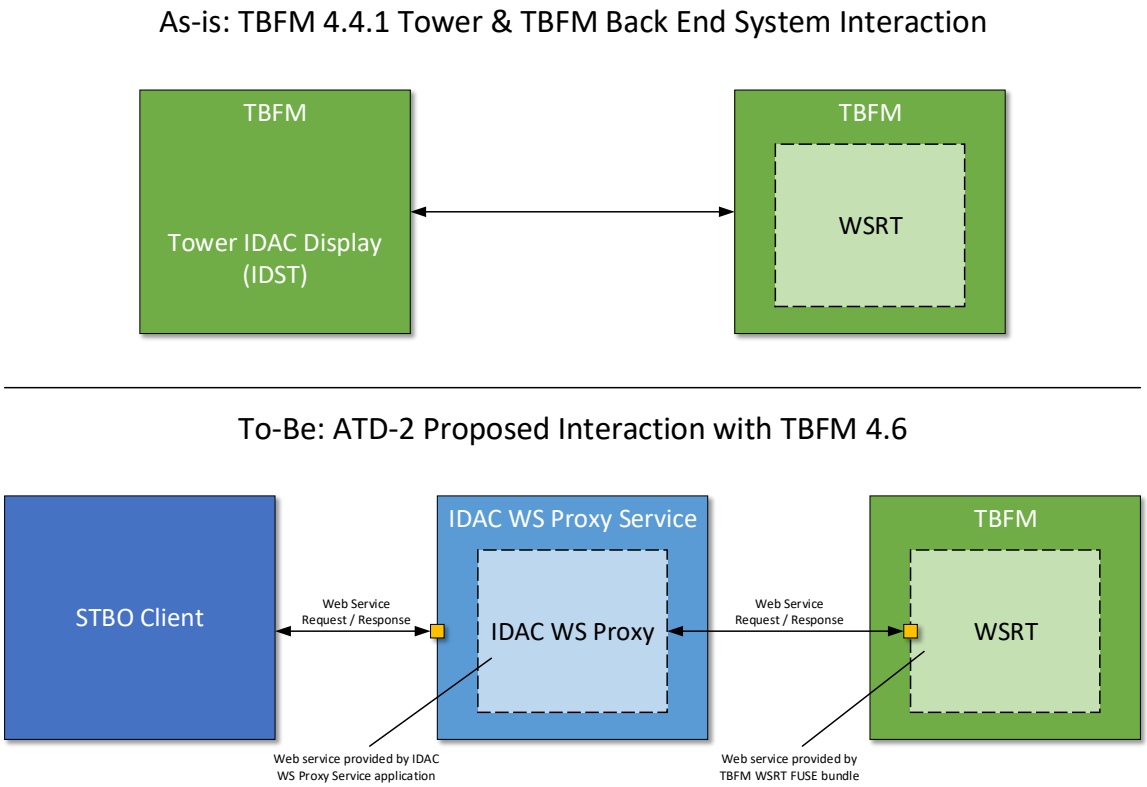

Figure 27 – The current TBFM Tower and back end system interaction is contrasted with the "Super IDST" solution proposed by NASA.

4.3.1 Information Flow from TBFM to IADS

The IADS system will require knowledge of all departure Jet flights known to the TBFM system that are potentially subject to IDAC scheduling. Since TBFM only sends to its IDST today the flights currently subject to IDAC scheduling, this requirement will result in the need for a larger data set of flights than what is currently relayed to the TBFM IDST. The published flight stream should also include the following information:

- Scheduling time and state information
- Constraint and Constraint Satisfaction Point (CSP) assignment information
- Identifier/owning facility information necessary for IADS requests to TBFM to be accepted
- General metering constraint information

Additional operational data of interest includes a pre-packaged data set known as Reconstitution data. This data, provided upon request, includes the most up-to-date Flight Data, Airport Configuration, Adaptation and Playback information.

4.3.2 Information Flow from IADS to TBFM

During ATD-2 testing, the IADS system will emulate IDAC's Integrated Departure Scheduling Tool (IDST) input capabilities for flights. TBFM will use its existing capability to accept and implement these requests. Two types of inputs will be provided and will include the following information:

- Regular, automatic updates of coordination times and Departure Configuration updates
- Irregular, manual updates of available space, departure negotiation, and departure swap requests, along with departure airport configuration updates

Figure 28 shows the relationships between FAA and NASA systems in the IADS prototype system as proposed for the ATD-2 field demonstration. The dashed line separates FAA equipment and NASA equipment. The FAA systems are shown in orange, while NASA systems are shown in blue. Note that there are four TBFM systems depicted in this figure. The two on the left are the FAA's operational TBFM instances at ZDC and ZTL. The two TBFM instances on the right are NASA-modified, TBFM software running on NASA equipment. These two NASA-modified TBFM instances are used to provide data to the IADS STBO subsystem and have no connection with or impact on FAA systems. This arrangement ensures that communications between the IADS STBO subsystem and the FAA TBFM systems at ZDC and ZTL are limited to just those messages necessary to perform tactical departure scheduling.

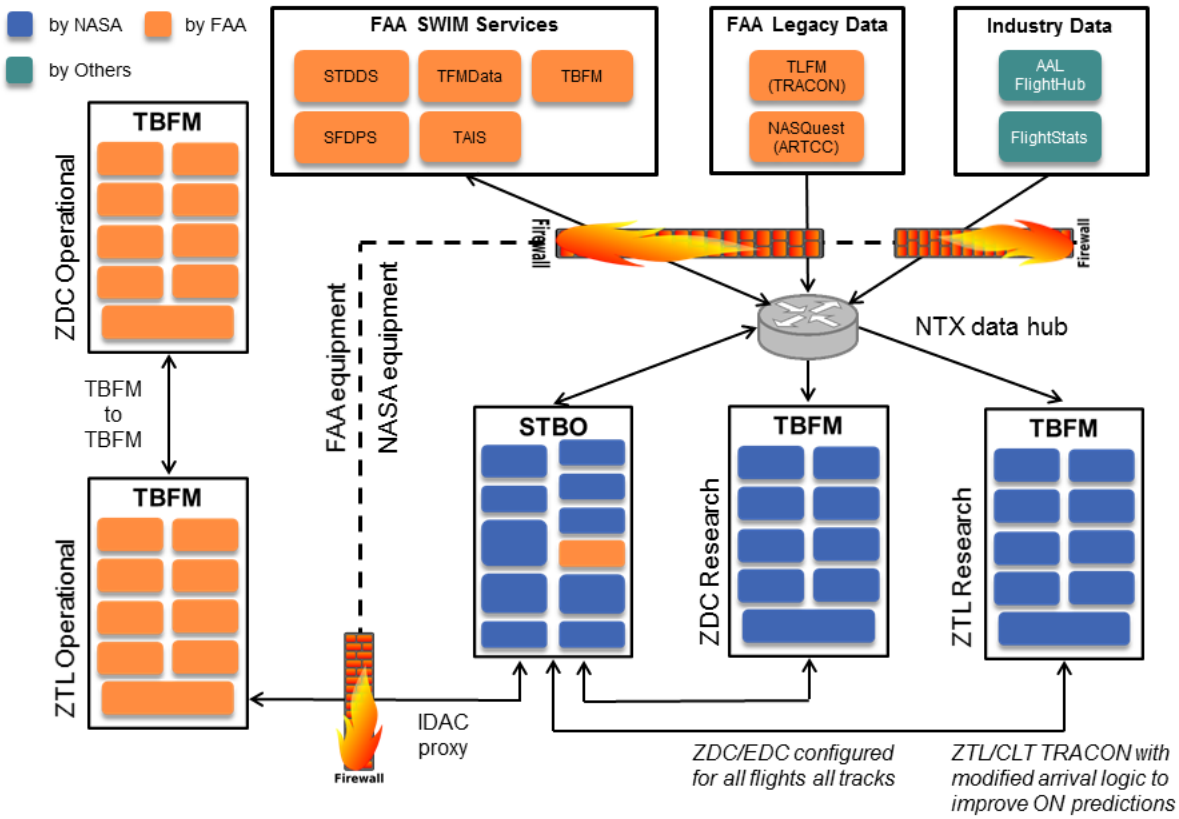

Figure 28 - The relationship among the TBFM and STBO systems is shown in the NASA proposed solution.

Note also that the IDAC Proxy described above is depicted below the STBO box, communicating with the FAA TBFM systems via a firewalled connection. Essentially, the ATD-2 STBO system is acting as a stand-in for a future TFDM system. NASA believes that the TBFM/IDAC IDST user interfaces will eventually be deprecated in favor of TFDM at appropriately equipped towers. A virtue of this proposed solution is that ATD-2 can serve as a pathfinder for this interaction between TBFM and TFDM.

Figure 29 illustrates the solution pursued by Lockheed Martin/Leidos, as presented in a TBFM Integration Systems Issues Group (SIG) study.[13] The right side of this figure shows two operational TBFM instances. ZDC is at the top and ZTL is at the bottom. The left side of the figure depicts the ATD-2 STBO system running at CLT, along with the IDAC Proxy described above. This approach envisions the ATD-2 STBO communication with the ZDC TBFM system being routed via the ZTL TBFM system, using the TBFM-to-TBFM (T2T) capability. This effort is being targeted for TBFM v4.6.

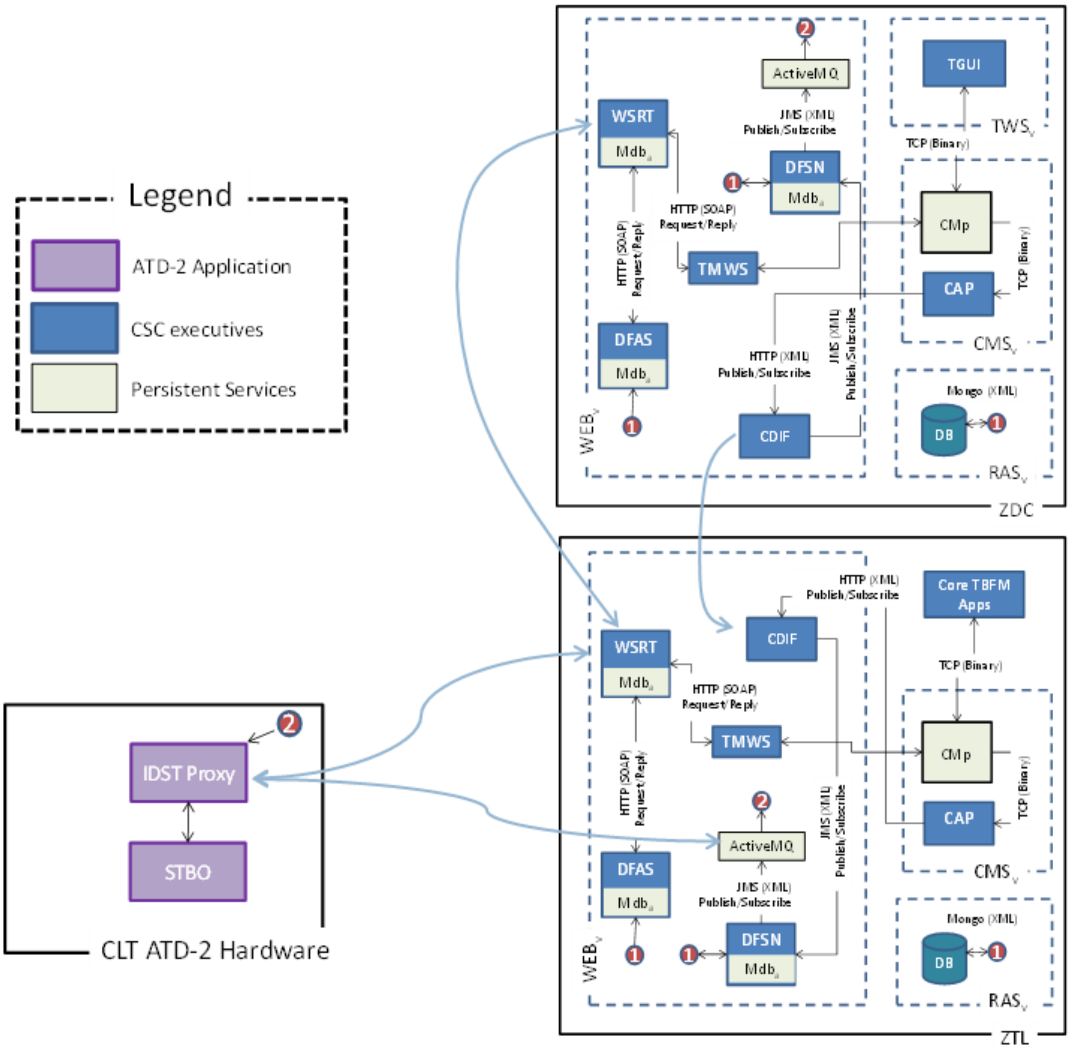

Figure 29 - Lockheed Martin proposes a solution leveraging TBFM-to-TBFM capability.

4.4 IADS Ramp User Interfaces

For the ATD-2 field evaluations, NASA will provide IADS ramp user interfaces for the flight operators. The RTC and the RMTC play a key role in supporting an IADS data exchange and integration capability that is foundational to data sharing across domains, agencies, and viewpoints. They provide common situational awareness and decision support functionality for the ramp controllers and the ramp managers – with capabilities such as display of aircraft movement in the ramp and taxiways and surface metering advisories. In the end state, these user interfaces are envisioned to be part of a flight operator system.

The RTC and the RMTC are views that can be chosen within the MFD, and consist of a status bar and an airport surface map. The status bar indicates the current airport configuration, the ramp status, and the metering mode. It also has a notification area where alerts are displayed. The map displays aircraft tracks with detailed flight information including the flight ID, aircraft type, gate, spot, runway, current flight ownership (ramp sector or Tower), and scratchpad. Departure flights also display the departure fix, TMI times (if any), and the scheduled pushback time. The scratchpad field is used to enter information, such as critical flight designations, to be shared with other ramp controllers. The maps can be zoomed in to view a specific sector of the ramp or zoomed out to view the entire airport surface.

4.5 Real-time Dashboard

The real-time dashboard application is part of the ATD-2 system, independent of the STBO client, that enables users to view metrics across airport operations. The real-time dashboard will be available as a part of each operationally deployed system and can provide key metrics to a variety of users within the FAA, the flight operators, the CLT airport facilities, and ZDC. The dashboard was developed to provide insight into capacity, efficiency, and predictability, as well as the effectiveness of scheduling and metering. This capability will also enable detailed displays of metrics, both numerically and graphically, along with features that enable electronic reporting of issues.

Current capabilities of the real-time dashboard application include a quick-look panel reporting TMI events applicable to the airport, such as APREQs, MITs, Ground Stops, and Departure Fix Closures. Numerous plots provide an in-depth analysis of metrics, such as departure and arrival monitoring, predicted excess queue time, taxi status, arrival/departure rate, and throughput. A "quick" analysis of these metrics is also provided on the quick-look panel.

5 Interface View of ATD-2

This section provides an overview of the physical interfaces of the IADS system prototype as it is being implemented for the ATD-2 field demonstration. NASA, the FAA NextGen Organization, and the FAA Communications, Information, and Network Programs (CINP) Team developed this material as part of an Enterprise Infrastructure Services (EIS) Assessment of the ATD-2 field demonstration prototype system.[14]

NASA's information systems security plan for ATD-2 employs an abstraction known as the NextGen Emulation System (NEXUS) to define information system boundaries and two types of interfaces: User Interfaces (UI) and Data Interfaces (DI). Figure 30 is a geographic depiction of the various NASA installations involved in the ATD-2 field demonstration. ATD-2 IADS system interfaces are listed for each of the installations, and classified as either UI or DI interfaces according to the NEXUS definitions in Appendix D: Security, NEXUS, and Interfaces.

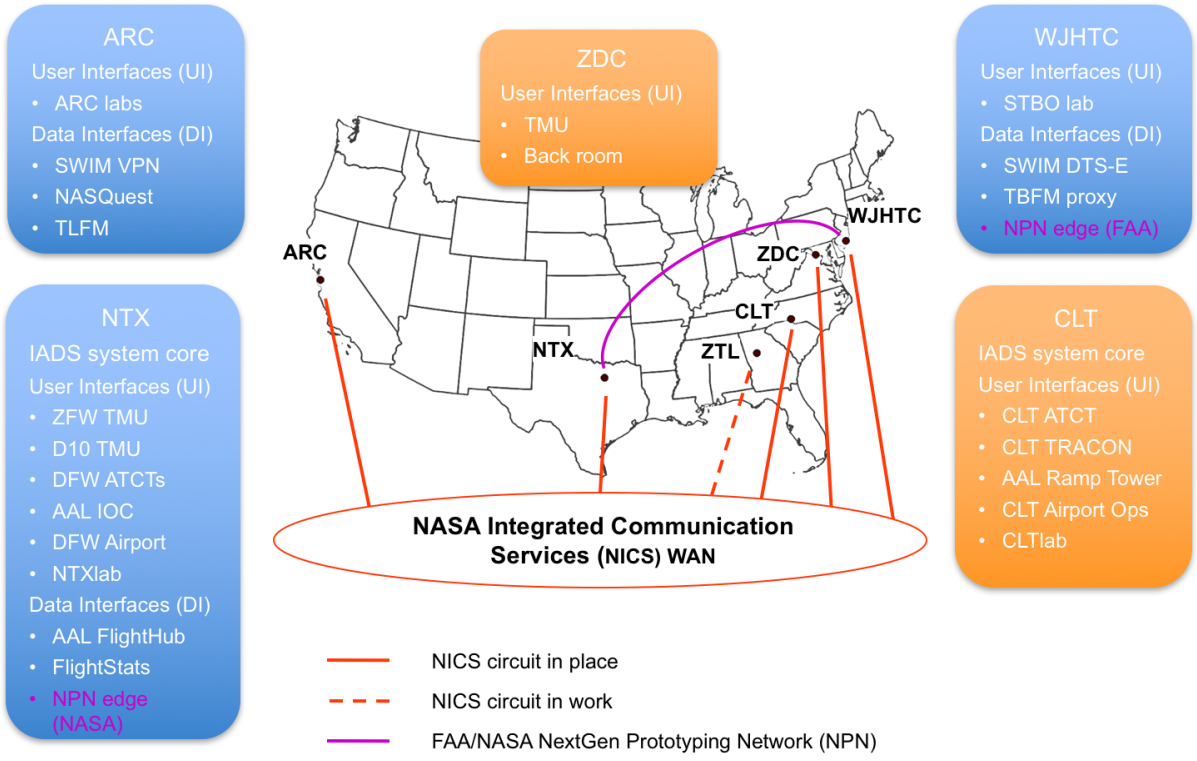

Figure 30 - This geographic depiction shows the locations of the NASA installations that will support the ATD-2 field demonstration.

5.1 Network infrastructure

The NASA installations shown in Figure 30 are served by two different wide area networks (WANs): NICS and NPN. The NICS WAN (shown in red) is named for the NASA Integrated Communications Services contract, which provides networking and other communications services throughout the agency. NICS is overseen by NASA's Communications Services Office (CSO). The NPN WAN (shown in purple) is part of the FAA's NextGen Prototyping Network, which provides secure, high-bandwidth connectivity for NextGen Test Bed facilities.[15] The NPN is the primary link between NASA and FAA information systems for ATD-2, with the interconnection point located at NTX.

5.2 NASA Ames Research Center (ARC)

General: Located at Moffett Field, CA, ARC is one of 10 NASA research and space flight centers. ARC is the home base for the ATD-2 research and development team and is the focal point for simulation experiments, software development, and V&V testing for ATD-2. ARC will have a limited role in supporting daily use of the ATD-2 IADS prototype system in the field.

Data Interfaces (DI): The NASQuest and TBFM TRACON Live Feed Manager (TLFM) data feeds are currently delivered from WJHTC to an FAA-managed server at ARC. A SWIM Internet VPN feed to ARC serves at the tertiary SWIM data feed for ATD-2.

User Interfaces (UI): Located in various labs for IADS prototype system monitoring and technical support.

5.3 NASA North Texas Research Station (NTX)

General: NTX is NASA laboratory on the premises of FAA Fort Worth ARTCC (ZFW) in Fort Worth, TX with research systems embedded in various operational facilities in and around Dallas/Fort Worth International Airport (DFW) including: ZFW, DFW TRACON (D10), DFW ATCTs, DFW Airport, and American Airlines (AAL) Integrated Operations Center (IOC) facility. The ATD-2 field demo team is based out of NTX, and the IADS prototype system data hub and other key back-end processes are housed at NTX. As noted above, NTX is the interconnection point between the NPN and NICS WANs.

Data Interfaces (DI): All NASA/FAA data connections routed through the NPN may be thought of as having DIs at NTX, since it is the NASA end-point for the NPN. However, the DIs are physically implemented via NASA-managed servers located at WJHTC. NTX also hosts DIs for the AAL FlightHub data feed, and the commercial FlightStats data service. Finally, an Internet VPN SWIM connection to the Oklahoma City (OEX) NESG will be established to NTX to serve as a backup to the DTS-E SWIM connection delivered via the NPN.

User Interfaces (UI): IADS prototype multi-function displays (MFDs) at ZFW TMU, D10 TMU, and the DFW East and West ATCTs were implemented in ATD-2 predecessor research and continue in use for field demo risk reduction and as foundation for ATD-2 Phase 3. IADS MFDs will be implemented at the AAL IOC. Finally, IADS MFDs are located in the NTX lab for system monitoring and technical support.

5.4 Washington ARTCC (ZDC) and Atlanta ARTCC (ZTL)

General: Figure 30 includes a box labeled "ZDC & ZTL" to denote the NASA installations at these facilities. During the ATD-2 field demonstration, the ZDC and ZTL TMCs' primary interactions with the ATD-2 IADS prototype system will be via the FAA operational TBFM system. The TBFM/IADS interface is described in Section 4.3.1 and 4.3.2.

Data Interfaces (DI): None

User Interfaces (UI): IADS MFDs in the TMU to provide supplemental information during field demo operations and in the back-room area for shadow testing and training.

5.5 Charlotte Douglas International Airport (CLT)

General: CLT is the primary site for the ATD-2 field demonstration. Multiple components of the IADS prototype system will be installed in various facilities at CLT including:

- FAA Airport Traffic Control Tower (ATCT)
- FAA Terminal RADAR Approach Control (TRACON)
- American Airlines Ramp Tower (Ramp Tower)
- CLT Airport Operations Center (Airport Ops)
- NASA equipment rack in CLT New Terminal server room (Server Room)
- NASA lab in CLT Old Terminal Building (CLTlab)

The IADS system components at CLT will be linked via a NASA-managed Local Area Network (LAN) that leverages CLT Airport cable plant infrastructure (i.e., fiber and copper network cables) provided to NASA under terms of the CLT/NASA Space Act Agreement.

The NASA NICS WAN shown in Figure 30 terminates in the Server Room where certain IADS prototype system core components run on rack-mounted servers.

Data Interfaces (DI): An interconnection between NASA and CLT Airport information systems to enable data exchange specified by the CLT/NASA Space Act Agreement.

User Interfaces (UI): An interconnection between NASA and CLT Airport information systems to enable data exchange specified by the CLT/NASA Space Act Agreement.

5.6 FAA William J Hughes Technical Center (WJHTC)

General: The WJHTC is an FAA R&D, test, and evaluation facility located at Atlantic City International Airport (ACY), NJ. IADS prototype system data feed infrastructure and servers to support testing are located there.

Data Interfaces (DI): NAS Enterprise Security Gateway (NESG) connections to SWIM (FNTB and Ops), NASQuest proxy server, and TBFM proxy server. See Figure 31 for additional details.

User Interfaces (UI): IADS MFD in STBO lab to support testing.

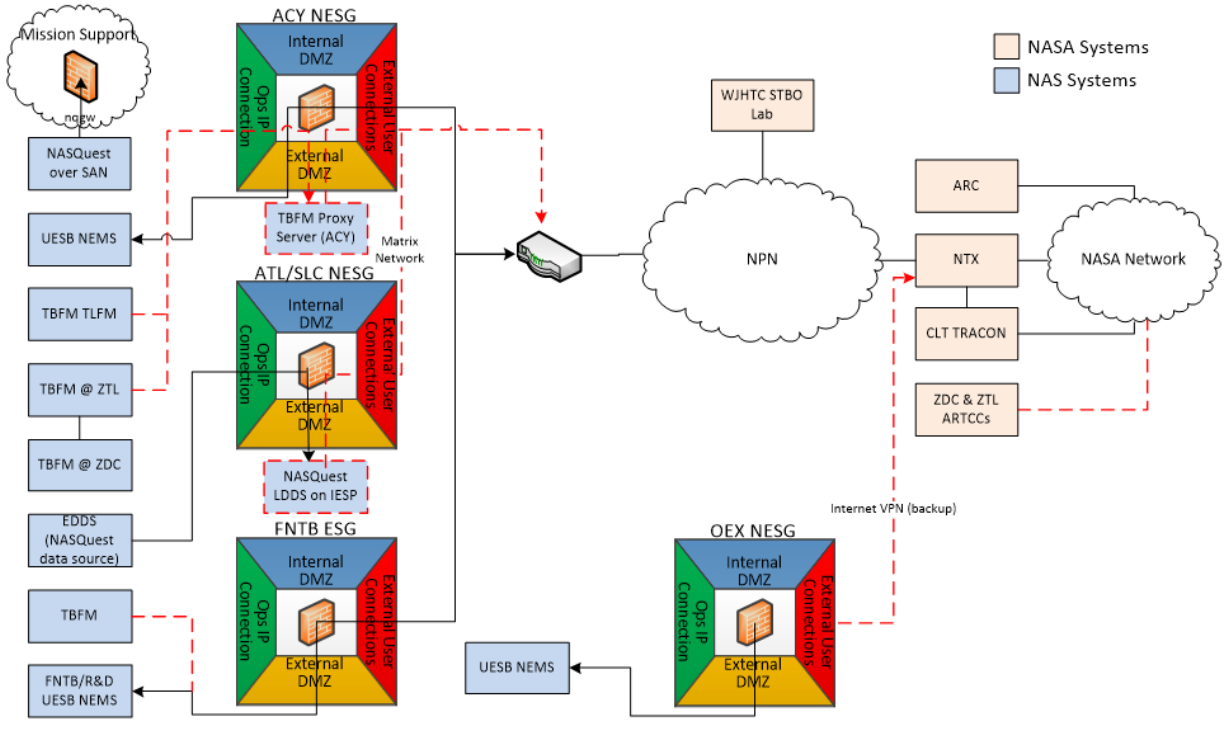

Figure 31 – This figure highlights the interfaces between FAA and NASA information systems for the ATD-2 field demonstration.

6 Summary

This document provided an overview of the technology for the Phase 1 Baseline Integrated IADS prototype system of NASA's ATD-2 sub-project, which began demonstration in 2017 at Charlotte Douglas International Airport (CLT). Development, integration, and field demonstration of relevant technologies of the IADS system directly address recommendations made by the NextGen Integration Working Group (NIWG) on Surface and Data Sharing and the

Surface CDM concept of operations developed jointly by the FAA and flight operators. NASA is conducting the ATD-2 research activity and field demonstrations in close coordination with the FAA, flight operator partners, CLT airport, and the National Air Traffic Controllers Association (NATCA).

The ATD-2 Phase 1 capabilities consist of:

- Strategic and tactical surface scheduling to improve efficiency and predictability of airport surface operations
- Tactical departure scheduling to enhance merging of departures into overhead streams of traffic via accurate predictions of takeoff times and automated coordination between the Tower and the Center
- Improvements in departure surface demand predictions in TBFM
- A prototype EFD system provided by the FAA via the TFDM early implementation effort
- Improved situational awareness and demand predictions through integration with TFMS, TBFM, and TFDM (3Ts) for electronic data integration and exchange and a dashboard displaying pertinent analytics in real-time

For the Phase 1 demonstration, components of the IADS system have been deployed at the CLT Tower, the CLT AAL Ramp Tower, ZDC, the American Airlines IOC, and the CLT Airport Operations. Deployment occurred in the summer of 2016 to support operational shadow evaluations prior to the actual Phase 1 demonstration in 2017. Later, a prototype TFDM SWIM data feed will be added to enable data sharing among stakeholders. The anticipated benefits through operational use of the IADS system include improved efficiency and predictability of surface and departure operations. These benefits will result in reduced delays, fuel savings, improved situational awareness, and a reduction in workload for the Tower and Center operations via 3T electronic data sharing and automation assisted coordination of flights. Also anticipated are increased situational awareness and reduced workload for the ramp personnel via pushback advisories and the use of new ramp user interfaces.

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Appendix A: IADS Operational Environment

Figure 32 illustrates the operational environment for the IADS metroplex traffic management concept. The upper portion of the figure depicts en route airspace controlled by an Air Route Traffic Control Center (i.e., Center). The dashed line represents the boundary between the local Center, and one or more adjacent Centers. The cylinders in the lower portion of the figure represent terminal airspace. In the U.S., terminal airspace is often controlled by a TRACON facility. The larger cylinder on the left represents the local metroplex terminal airspace (situated in the local Center) for the IADS concept.

The smaller cylinder on the right represents a destination terminal airspace. The destination terminal airspace may be in the local Center, an adjacent Center, or even further downstream. Three airports are shown in the local terminal airspace: one well-equipped airport and two less-equipped airports.

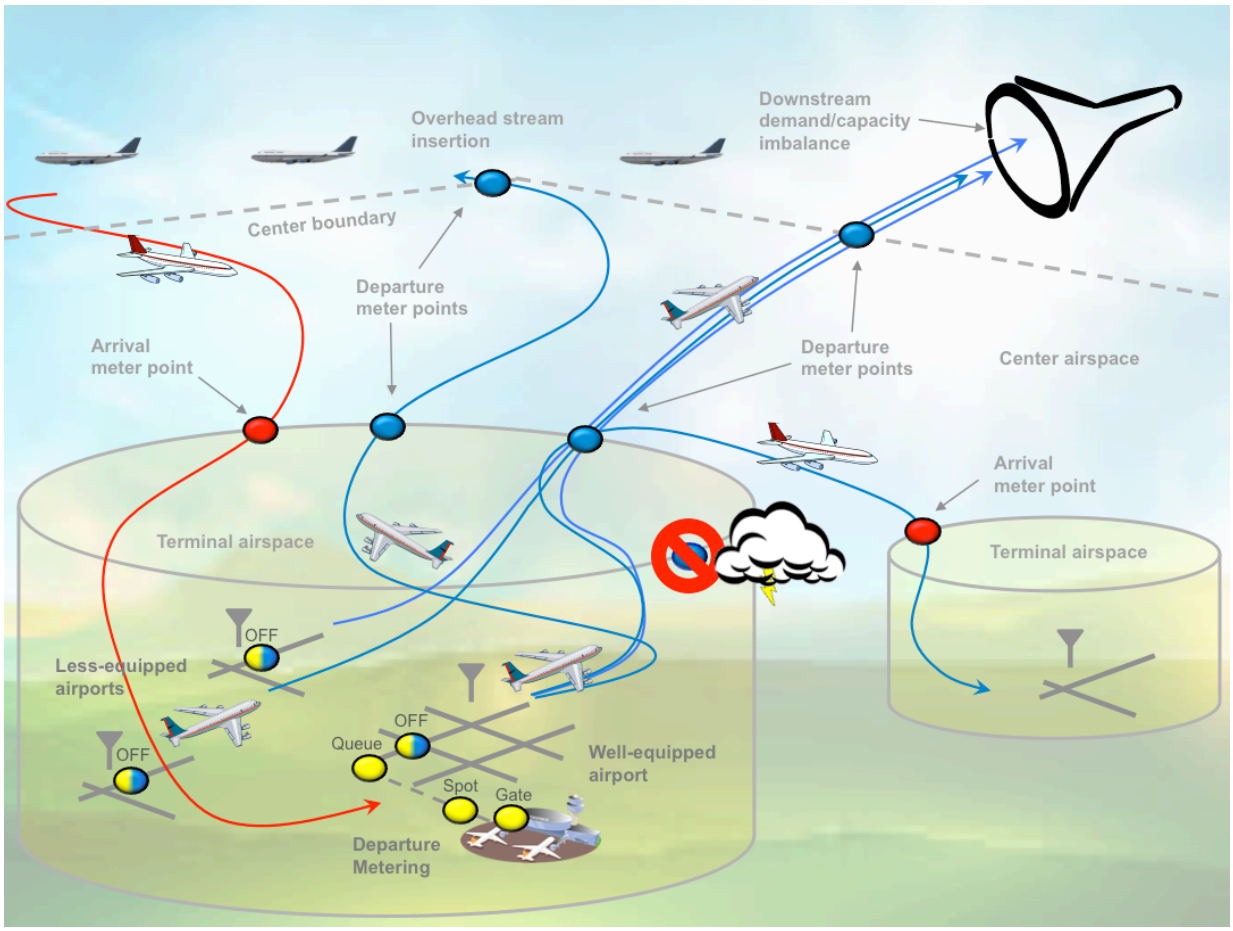

Figure 32 - A simplified view of the ATD-2 sub-project operational environment for the Phase 1 Baseline IADS Demonstration illustrates a variety of surface and airspace control points, plus impacts due to weather and downstream demand/capacity imbalances.

Note that Figure 32 has been simplified for illustration purposes. A metroplex can contain multiple airports that together can place significant departure demand on airspace resources. For example, the Northern California (NorCal) TRACON (NCT) metroplex features the large and well-equipped San Francisco International Airport (SFO), but also includes medium-sized, less-

equipped airports in Oakland (OAK) and San Jose (SJC), and numerous general aviation and military airports. Well-equipped airports are defined as those having comprehensive surveillance in the AMA, and therefore are capable of supporting trajectory-based surface automation. Typically, well-equipped airports are large and often subject to heavy demand from multiple flight operators. In addition, well-equipped airports will generally have more sophisticated automation aids in flight operator Ramp towers and FAA Towers (e.g., electronic flight strips) than their less-equipped counterparts.

Figure 32 depicts trajectories departing from (blue) and arriving to (red) the local terminal airspace. The colored ovals illustrate some of the points (i.e., meter points) at which air traffic is scheduled, either by the automation or via manual procedures. Red ovals are arrival meter points. Blue ovals are departure meter points. Yellow ovals are surface meter points. The takeoff (i.e., OFF) points, represented by yellow and blue ovals, are important control points for the IADS concept, as they are the interface points between surface and airspace scheduling.

The funnel located at the top right of Figure 32 represents a downstream demand/capacity imbalance that results in departure restrictions on the local terminal airspace. These restrictions could be applied at the meter point on the Center boundary and/or the departure fix at the terminal boundary (e.g., miles- or minutes-in-trail). Alternatively, the downstream traffic conditions could trigger strategic programs (e.g., a ground stop or ground delay) affecting departures from one or more airports in the local terminal airspace.

The thundercloud on the terminal boundary represents a typical dynamic weather event that may close one or more departure fixes, putting additional demand on fixes that remain open. The red arrival meter point entering a destination terminal airspace at the right of Figure 32 shows how departures from the local terminal could also be subject to arrival metering constraints at their destination, even prior to takeoff.

Appendix B: ATD-2 Sub-Project Field Demonstration Strategy

The ATD-2 sub-project field demonstration is organized into three phases, as depicted in Figure 33, which is an excerpt from the ATD-2 Integrated Master Schedule (IMS). The figure shows that the series of operational evaluation and use periods are set to begin in September 2017 and run continuously through September 2020. The IADS system capability increases with each phase of the evaluation, and each phase is preceded by shadow evaluation periods during which system readiness will be assessed. The shadow evaluation periods and the associated readiness decision points are indicated by the blue and green callouts in Figure 33. The gold stars on the schedule denote schedule commitments that NASA has made to their field demonstration

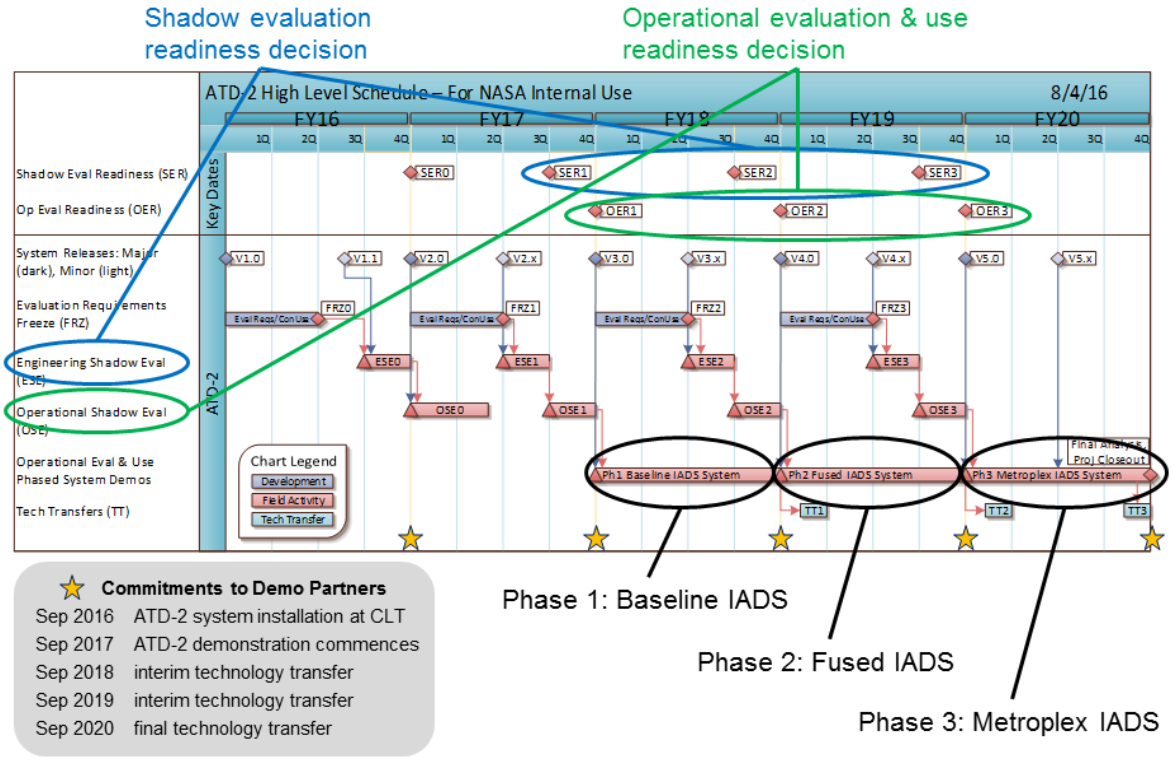

Figure 33 - The ATD-2 sub-project employs a field demonstration strategy built upon three distinct phases, each representing an increased system capability.

partners.

The following subsections provide more information on each of the demonstration phases.

B.1 Phase 1: Baseline IADS

The Phase 1 Baseline IADS Demonstration will include all the components of IADS running in an operational environment, illustrated in Figure 34. It will provide the initial integrated capability demonstration of (1) de-coupled tactical surface scheduling and predictive strategic surface scheduling, (2) tactical departure scheduling to an en route meter point, (3) improved departure surface demand predictions, and (4) a prototype EFD provided by the FAA via the TFDM early implementation effort. In addition, during the Phase 1 demonstration, a prototype TFDM SWIM data feed will be incorporated.

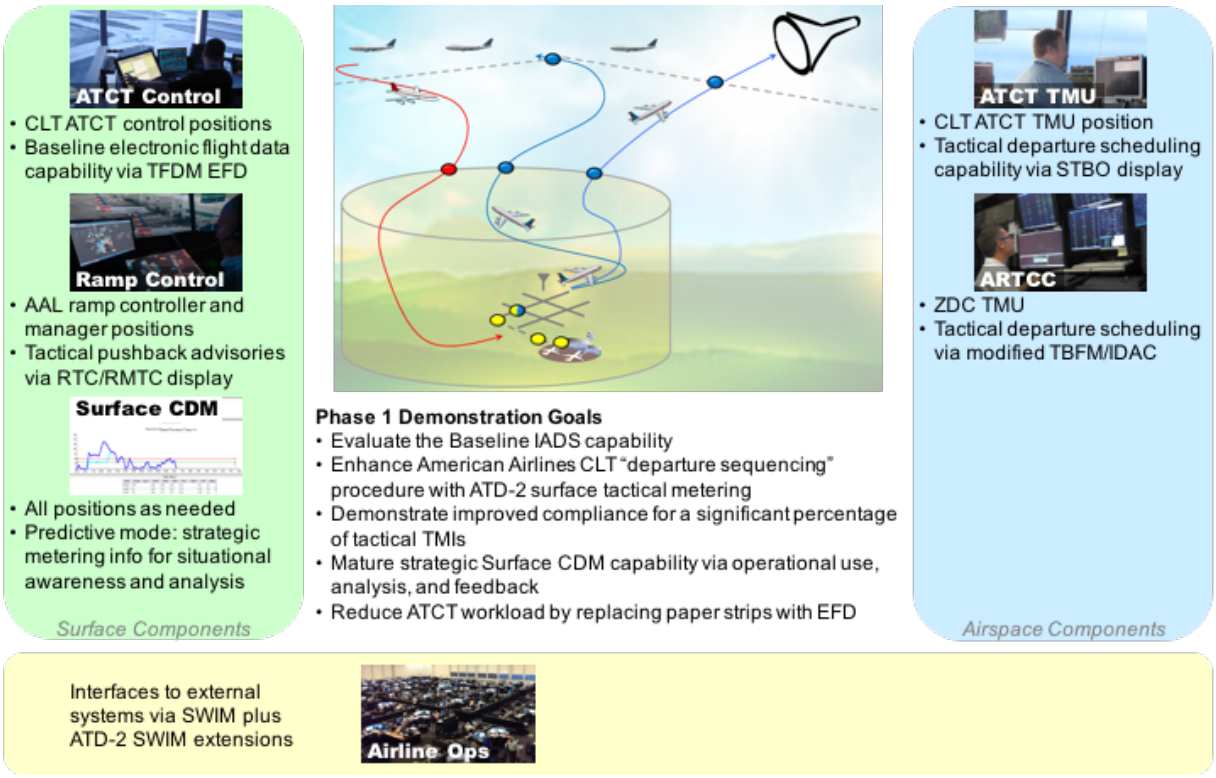

Figure 34 - This operational overview of the IADS system highlights both the participants at various facilities and the system improvements for the Phase 1 Baseline IADS Demonstration.

B.2 Phase 2: Fused IADS

The system used to support the Baseline IADS Demonstration will be enhanced and expanded in significant ways to support the Fused IADS Demonstration, illustrated in Figure 35. Principal characteristics and key functionality of the Fused IADS Demonstration that will differentiate it from the Baseline IADS are:

- Prescriptive[†] strategic surface scheduling.
- Fusion of strategic and tactical surface scheduling capabilities.
- Expansion of airspace deployments to include adjacent Center automation.
- Substantial updates to the Baseline IADS Demonstration capability, including updates to tactical surface scheduling, tactical departure scheduling, Electronic Flight Data (EFD), RTC/RMTC, departure trajectories, and TFDM SWIM prototype feed.

[†] Prescriptive is used here to indicate that the strategic system metering advisories will be used to meter traffic in situations with significant demand/capacity imbalances. Fused system tactical pushback advisories will honor strategic TMATs.

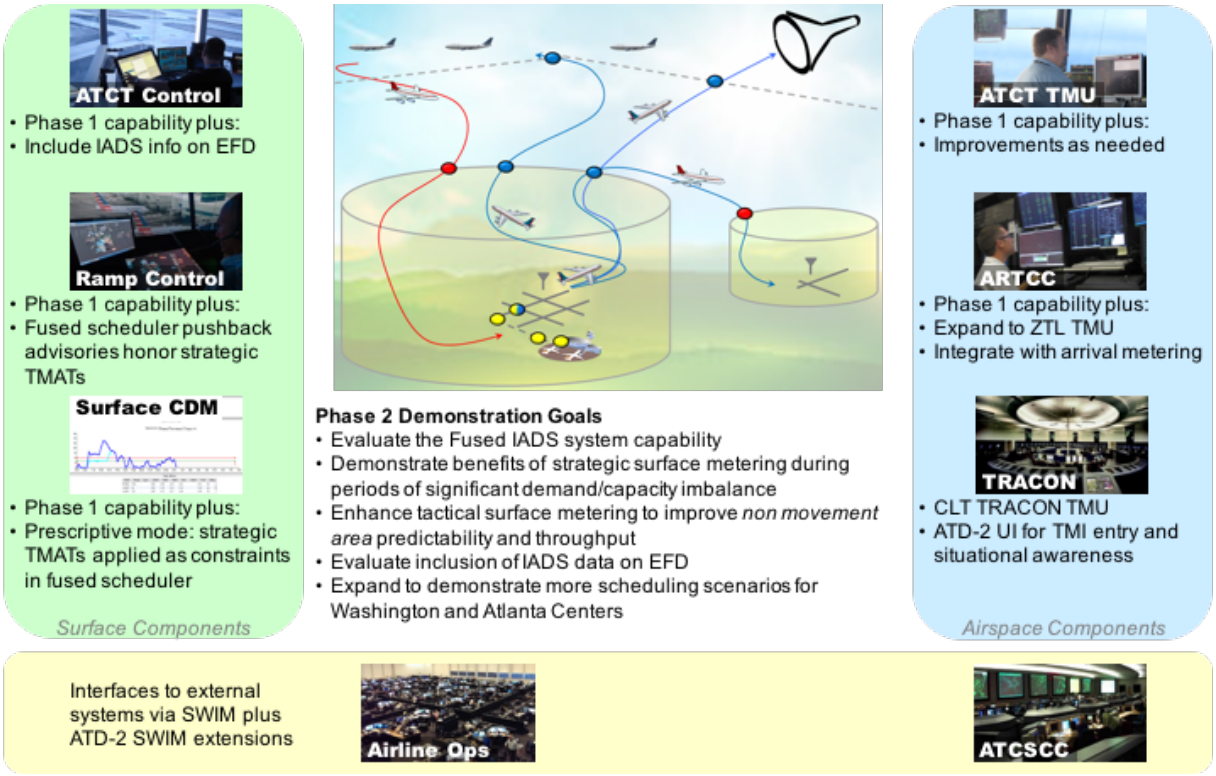

Figure 35 - This enhanced operational overview of the IADS system highlights both the participants at various facilities and the system improvements for the Phase 2 Fused IADS Demonstration.

B.3 Phase 3: Metroplex IADS

The Metroplex IADS Demonstration represents the culmination of the IADS system capability as demonstrated in field and high-fidelity simulation, illustrated in Figure 36. It incorporates the IADS tactical departure scheduling for the metroplex and integrates Tower electronic flight data with IADS scheduling (both surface and airspace).

Principal characteristics and key functionality of the Metroplex IADS Demonstration that will differentiate it from the Fused IADS are:

- Improvements resulting from data received during strategic expansion. Substantial updates to the Fused IADS Demonstration capability, including tactical surface scheduling, tactical departure scheduling, EFD, RTC/RMTC, departure trajectories, and TFDM SWIM prototype feed.
- IADS terminal departure scheduling from multiple airports to outbound TRACON meter points in a relevant operational environment.
- High-fidelity demonstration of all integrated system capabilities.

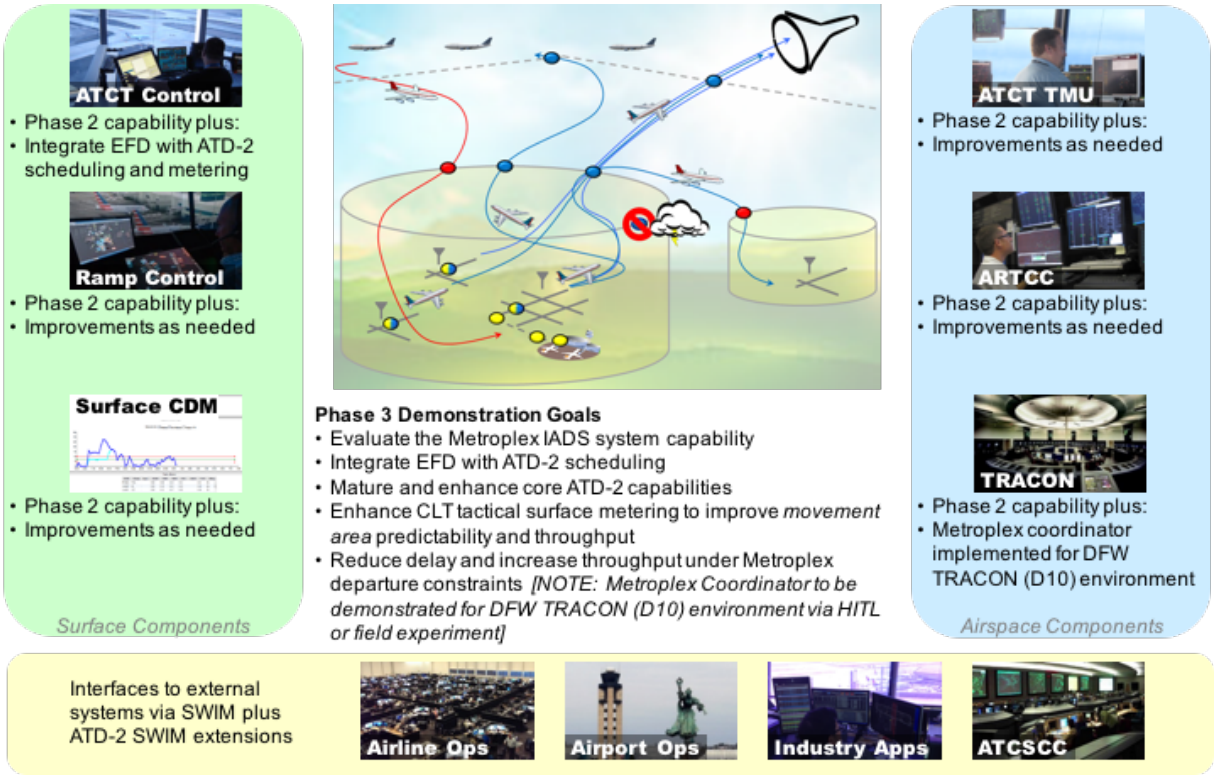

Figure 36 - This full operational overview of the IADS system highlights both the participants at various facilities and the system improvements for the Phase 3 Metroplex IADS Demonstration.

Appendix C: Surface Data Elements

This appendix provides additional information on the 11 surface data elements that the flight operators have committed to supplying via TFMS Release 13, illustrated in Figure 37. Descriptive information on the surface data elements was taken from FAA SWIM Connect 2015.[16]

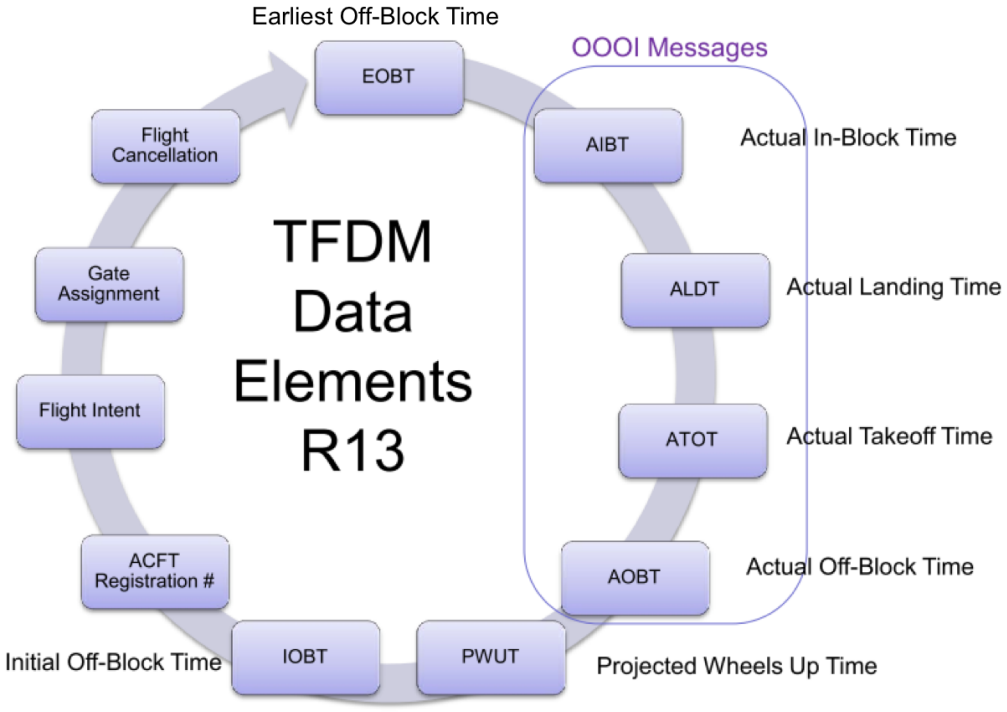

Figure 37 - These 11 surface data elements will be provided via TFMS Release 13.[17]

C.1 Actual Off-Block Time (AOBT)

The time when an aircraft pushes back from its assigned gate or parking location, or when it commences movement with the intent to taxi for departure, will be reported by the flight operator. This is the actual time at which the flight has sent a 'block out' message from the gate or parking location. This information will be used to help determine the accuracy of a flight operator's Earliest Off-Block Time (EOBT).

Expected TFDM Use:

- Update surface scheduling system based on AOBT
- Update flight state data for sharing with external systems
- Update flight state to evaluate gate availability

Expected Operational Benefits:

- Improved surface scheduler accuracy
- Sharing of flight state data to improve situational awareness for TRACON/ARTCC

- Updated gate availability needed to reduce gate conflicts and manage capacity/demand imbalances

C.2 Actual Takeoff Time (ATOT)

The time at which a flight lifts off from the runway (i.e., wheels up time, when the flight becomes airborne) will be reported by the flight operator or by TRACON automation. If more than one value is sent, the most recently submitted time will be contained in this field. Otherwise, the value will be null. This time stops the DOT3 time for departing flights.

Expected TFDM Use:

- Update surface scheduling system based on ATOT
- Update flight state data for sharing with external systems

Expected Operational Benefits:

- Improved surface scheduler accuracy
- Sharing of flight state data to improve situational awareness for TRACON/ARTCC

C.3 Actual Landing Time (ALDT)

The actual time that an arriving flight lands on the runway will be provided by the flight operator. Sharing arrival information provides essential information to facilitate gate conflict and demand/capacity imbalance predictions. This element is the DOT3 arriving aircraft time trigger.

Expected TFDM Use:

- Update flight state data to evaluate gate availability

Expected Operational Benefits:

- Updated gate availability needed to reduce gate conflicts and manage capacity/demand imbalances

C.4 Actual In-Block Time (AIBT)

The actual time that a flight reaches its gate or parking stand (i.e., the flight has blocked in at the gate) will be provided by either the flight operator or the aircraft surface surveillance. Sharing arrival information provides essential information to facilitate both gate conflict predictions and demand/capacity imbalance predictions.

Expected TFDM Use:

- Update flight state data to evaluate gate availability

Expected Operational Benefits:

- Updated gate availability needed to reduce gate conflicts and manage capacity/demand imbalances

C.5 Aircraft Tail/Registration Number

The flight operator will provide a unique, alphanumeric string that identifies a civil aircraft (e.g., N1237A), consisting of the Aircraft Nationality or Common Mark and an additional

alphanumeric string assigned by the state of registry or common mark registering authority. "Aircraft Registration Mark" in FIXM Core.

Expected TFDM Use:

- Enable gate conflict and demand/capacity imbalance monitoring by connecting arrival flight information to related departure flight information

Expected Operational Benefits:

- System can detect and alert when changes to an arrival flight's schedule may impact a departure flight's schedule

C.6 Earliest Off-Block Time (EOBT)

The earliest time a flight would be able to push back from its gate or taxi from its parking stand for departure in the absence of metering will be provided by either the Ramp Control personnel or the flight operator. The system can forecast surface demand vs. capacity, based on the flight operator's best estimation of push back time. The fidelity of the EOBT is required for proper surface predictions and processes.

Expected TFDM Use:

- Update surface scheduling system based on EOBT data
- Use to evaluate demand/capacity imbalances and need for metering

Expected Operational Benefits:

- Improved surface scheduler accuracy
- Improved demand predictions
- Improved resource utilization via metering

C.7 Flight Cancellation

The flight operator will send a message that indicates a flight has been cancelled, specifically to ensure that resources are not engaged and/or fully utilized for it.

Expected TFDM Use:

- Update demand predictions
- Allow stakeholders to substitute other flights in place of cancellations

Expected Operational Benefits:

- Improved demand predictions to ensure metering programs fully utilize capacity
- Provide users flexibility to utilize capacity from cancelled flights to meet business objectives

C.8 Flight Intent

The flight intent information provides common situational awareness about a specific flight with regard to de-icing at the ramp/AMA or the gate, holding at the ramp or in the AMA, or an

expected gate return or pushback times. Any plans with this intent will be provided by the flight operator.

Expected TFDM Use:

- Provide system alerts to ATC of flights intending to de-ice, hold, push back early, or return to the gate

Expected Operational Benefits:

- Situational awareness for ATC to identify flights intending to:
  - De-ice in the AMA/ramp or the gate area
  - Push back early that need to hold in either the ramp or the AMA until the expected times
  - Return to the gate or provide a pushback time

C.9 Gate Assignment

The Flight or Airport Operator gate assignment for a flight will be provided to lead to more accurate ramp transit time (RTT) calculations, and therefore, a more accurate Estimated Time of Departure (ETD).

Expected TFDM Use:

- Update demand predictions
- Allow stakeholders to substitute other flights in place of cancellations

Expected Operational Benefits:

- Earlier detection of potential gate conflicts
- More accurate ETD calculation to improve compliance with control times
- Improve accuracy of surface metering predictions

C.10 Initial Off-Block Time (IOBT)

The initial off-block time for a flight will be provided by the flight operator. This data element will be used to save the original off-block time of the flight, and will be useful for flight data matching.

Expected TFDM Use:

- Use IOBT to identify initial resource demand
- Use IOBT to identify flights eligible for substitution (EOBT > IOBT)

Expected Operational Benefits:

- Improved surface scheduler accuracy
- Identifying substitutable flights gives flight operators flexibility to meet business objectives

C.11 Earliest Runway Time of Departure (ERTD)

The flight operator estimate of runway departure time will not include any traffic management initiatives. Thus, it is a projection of non-TMI aircraft wheels up time.

Expected TFDM Use:

- Update demand estimates and predictions

Expected Operational Benefits:

- TFDM will provide a higher-fidelity version of ERTD at airports with TFDM surface automation
- May still be useful at those airports with no (or minimal) TFDM capabilities

Appendix D: Security, NEXUS, and Interfaces

This appendix provides background information on the NASA information system security plan that applies to ATD-2 IADS system installations.

NASA information systems supporting the ATD-2 field demonstration are elements of an information system owned by the Aeronautics Directorate at NASA Ames Research Center (ARC). The relevant NASA security plan is identified as "System Security Plan for the ARC Aeronautics Directorate Systems CD-999-M-ARC-3238."[18] Per NIST SP 800-30,[19] the ARC Aeronautics Directorate Systems have been designated as MODERATE, and corresponding security controls are implemented per NIST SP 800-53.[20]

The security plan includes an abstraction known as the NextGen Emulation System (NEXUS) research platform (see Figure 38) which addresses the case of NASA information systems embedded in research partner (e.g., FAA and flight operator) operational facilities.

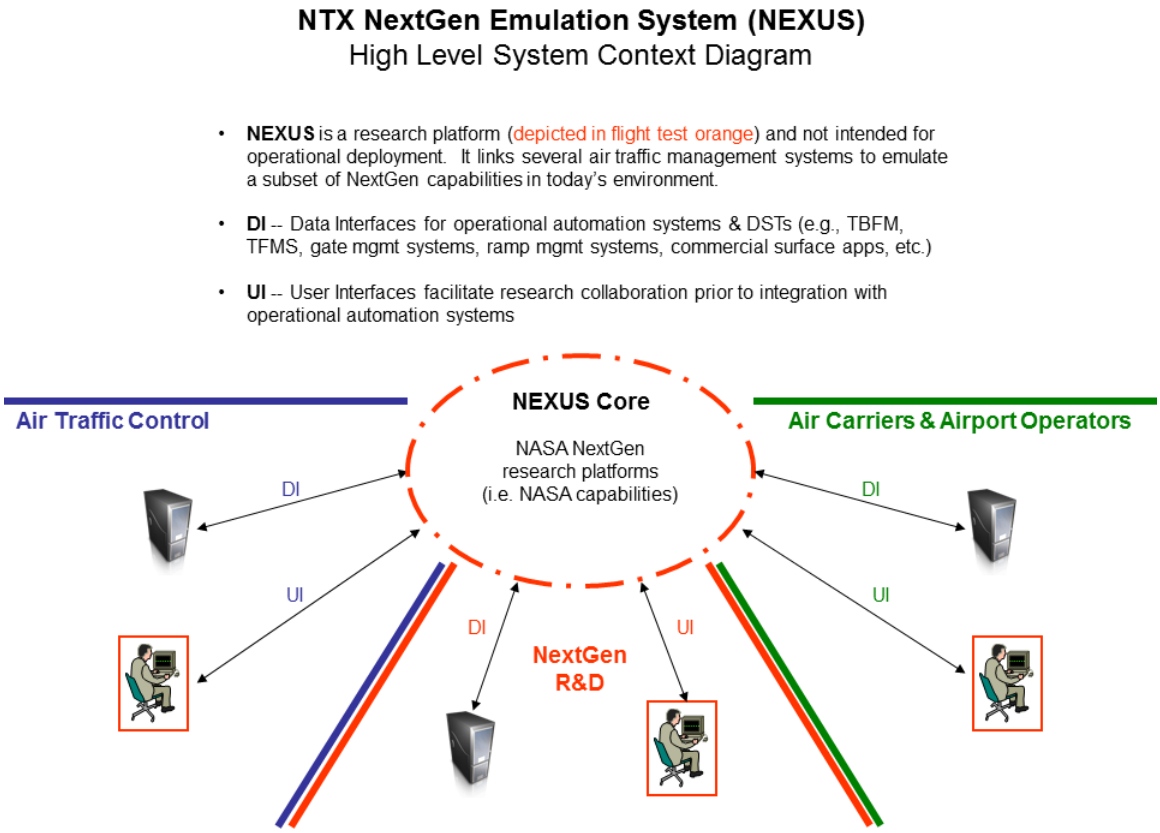

Figure 38 - NASA's information system security plan uses the NextGen Emulation system (NEXUS) abstraction to define system boundaries and two classes of system interfaces.

Applying the NEXUS abstraction to ATD-2 field demonstration installations it is evident that core components of the ATD-2 IADS system reside in the "NEXUS core" illustrated by the dashed oval in Figure 38. These core components are physically implemented on NASA information systems at NTX and CLT. The ATD-2 IADS system utilizes both types of interfaces depicted in the NEXUS diagram and described below:

Data Interface (DI)

- Involves an interconnection between NASA and research partner information systems
- Protected with appropriate safeguards (i.e., firewalls) and agreements
- IADS examples: SWIM interface at NESG, TBFM proxy server, NASQuest, AAL FlightHub

User Interface (UI)

- Involves an extension of the NASA information system (i.e., network) into the research partner facility but does NOT involve interconnections
- May utilize research partner physical cable plant elements (e.g., fiber or copper runs), but these are fully-dedicated for NASA use and carry no other logical networks
- IADS user interfaces are described as multi-function displays (MFDs) because they are capable of displaying numerous user interfaces from IADS component systems
- IADS examples: MFDs at the ATC Tower (back room and cab), Center (back room and TMU), Ramp Tower, Airport Operations

Appendix E: Acronyms

This appendix contains acronyms that are used repeatedly throughout the ATD-2 Phase 1 Baseline IADS Demonstration sub-project and this Technology Description Document.

Acronym	Term
3D	Three-Dimensional
3Ts	FAA's TBFM, TFMS, and TFDM
4D	Four-Dimensional
AAL	American Airlines
AAR	Airport Arrival Rate
ACFT	Aircraft
ADG	Airplane Design Group
ADR	Airport Departure Rate
ADW	Arrival Departure Window
AEFS	Advanced Electronic Flight Strip
AFP	Airspace Flow Program
AIBT	Actual In-Block Time
AIXM	Aeronautical Information Exchange Model
ALDT	Actual Landing Time
AMA	Airport Movement Area
AMAT	Actual Movement Area entry Time
AOBT	Actual Off-Block Time
AODB	Airport Operational Database
APREQ/CFR	Approval Request/Call for Release
ARC	Ames Research Center
ARCR	Airport Resource Capacity Rates
ARM	Airport Resource Management
ARMD	Aeronautics Research Mission Directorate (NASA)
ARMT	Airport Resource Management Tool
ARTCC, or Center	Air Route Traffic Control Center
ASDE-X	Airport Surface Detection Equipment – Model X
ASDI	Aircraft Situation Display to Industry
ATC	Air Traffic Control
ATCSCC, or Command Center	Air Traffic Control System Command Center
ATCT, or Tower	Airport Traffic Control Tower
ATD-1	ATM Technology Demonstration 1
ATD-2	Airspace Technology Demonstration 2
ATG	Airspace Target Generator
ATL	Hartsfield-Jackson Atlanta International Airport
ATM	Air Traffic Management
ATOT	Actual Takeoff Time
BOS	General Edward Lawrence Logan International Airport
CAP	Collaborative Arrival Planning
CD	Clearance Delivery

Acronym	Term
CDM	Collaborative Decision Making
CDR	Coded Departure Route
CLE	Cleveland Hopkins International Airport
CLT	Charlotte Douglas International Airport
CMS	Controller Managed Spacing
ConOps	Concept of Operations
ConUse	Concept of Use
CPDLC	Controller-Pilot Data Link
CRO	Converging Runway Operations
CSP	Constraint Satisfaction Point
CSV	Comma Separated Value
CTD	Controlled Time of Departure
CTOP	Collaborative Trajectory Options Program
CTOT	Controlled Takeoff Time
CTRD	Certified Tower Radar Display
D0	Common flight operator on-time departure metrics
DFW	Dallas/Fort Worth International Airport
DCL	Departure Clearance
DFSN	Data Fusion
DI	Data Interface
DMP	Departure Metering Program
DOT	Department of Transportation
DQM	Departure Queue Management
DRC	Departure Reservoir Coordinator
DRM	Departure Reservoir Management
DSP	Departure Sequencing Program
DSS	Decision Support Systems/Decision Support Service
DST	Decision Support Tool
EDC	En route Departure Capability
EDCT	Expect Departure Clearance Time
EDIF	ETMS Data Interface
EFD	Electronic Flight Data
EFSTS	Electronic Flight Strip Transfer System
EFTT	Earliest Feasible Takeoff Time
EOBT	Earliest Off-Block Time
ERAM	En Route Automation Modernization
ERTD	Earliest Runway Time of Departure
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
ETMS	Enhanced Traffic Management System
ETOT	Estimated Takeoff Time
EWR	Newark Liberty International Airport
FAA	Federal Aviation Administration
FANS	Future Air Navigation System

Acronym	Term
FCA	Flow Constraint Area
FCFS	First-Come, First-Served
FDIO	Flight Data Input/Output
FEA	Flow Evaluation Area
FFC	Future Flight Central
FID	Final Investment Decision
FIXM	Flight Information Exchange Model
FLM	Front Line Manager
FMC	Flight Management Connector
FOSA	Flight Operations Surface Application
GA	General Aviation
GC	Ground Controller
GDP	Ground Delay Program
GIS	General Information Service
GIS	Geographic Information Systems
GS	Ground Stop(s)
GUFI	Globally Unique Flight Identifier
GUI	Graphical User Interface
HITL	Human-in-the-Loop
IADS	Integrated Arrival, Departure, and Surface
ID	Identification
IDAC	Integrated Departure Arrival Capability (TBFM)
IDS	Integrated Display System
IDST	Integrated Departure Scheduling Tool
IMC	Instrument Meteorological Condition
IMS	Integrated Master Schedule
IN	Arrival at Gate
IOBT	Initial Off-Block Time
IOC	Integrated Operations Center
IRD	Interface Requirement Document
IRP	Independent Review Panel
ISAS	Integrated Surface and Airspace Simulation
J-22	TFDM Specification Artifact
JFK	John F. Kennedy International Airport
JMS	Java Message Service
KPPs	Key Performance Parameters
LAS	*Las* Vegas McCarran International Airport
LC	Local Controller
LGA	LaGuardia Airport
LOB	Long on Board
MC	Metroplex Coordinator
MIT	Miles-in-Trail
MOPs	Measures of Performance
MP	Meter Point

Acronym	Term
MRA	Metrics, Reporting & Analysis (DRM component)
N-value	Target number of flights in queue
N90	New York TRACON
NAC	NextGen Advisory Committee (FAA)
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Controllers Association
NCT	Northern California (NorCal) TRACON
NextGen	Next Generation Air Transportation System
NIWG	NextGen Integration Working Group
NM	Nautical Miles
NorCal	Northern California
NTML	National Traffic Management Log
NTX	NASA/FAA North Texas Research Station
NEXUS	NextGen Emulation System
OAG	Official Airline Guide
OAK	Metropolitan Oakland International Airport
OER	Operational Evaluation Report
OFF	Departure at Runway
OIS	Operational Information System
ON	Arrival at Runway
OpNec	Operational Necessity
OUT	Departure off Gate
OV-1	High Level Operational View
P3	Process, Procedures and Policies
PCT	Potomac Consolidated TRACON
PDC	Pre-departure Clearance
PDRC	Precision Departure Release Capability
PGUI	Planview Graphical User Interface
PHX	Phoenix Sky Harbor International Airport
PIC	Pilot in Command
PWUT	Projected Wheels Up Time
R	Restricted TFMData messages
R&D	Research and Development
R&T	Research and Technology
R13	TFMS Release 13
RAPT	Regional Airspace and Procedures Team
RBS	Ration by Schedule
RDR	Runway Departure Rate
RFP	Request for Proposal
RFRT	Request for a Release Time
RMTC	Ramp Manager Traffic Console
RNAV	Area Navigation
RTBFM	Research TBFM

Acronym	Term
RTC	Ramp Traffic Console
RTT	Ramp Transit Time
RTT	Research Transition Team
SIAP	Standard Instrument Approach Procedure
SARDA	Spot and Runway Departure Advisor
SDSS	Surface Decision Support System
SDT	Scheduled Departure Time
SFDPS	SWIM Flight Data Publication Service
SFO	San Francisco International Airport
SID	Standard Instrument Departure
SIG	Systems Issues Group
SIR	Screening Information Request
SJC	Norman Y. Mineta San Jose International Airport
SMA	Surface Movement Advisor
SMD	Surface Metering Display
SME	Subject Matter Expert
SMS	Surface Management System
SOBT	Scheduled Off-Block Time
SRR	System Requirements Review
STA	Scheduled Time of Arrival
STARS	Standard Terminal Automation Replacement System
STBO	Surface Trajectory Based Operations
STDDS	SWIM Terminal Data Distribution System
Surface CDM	Surface Collaborative Decision Making
SWIM	System Wide Information Management
T2T	TBFM-to-TBFM
TBD	To Be Determined
TBFM	Time Based Flow Management System
TBO	Trajectory Based Operations
TDD	Technology Description Document
TDLS	Tower Data Link Service
TFC	Taxi for Convenience
TFD	Traffic Flow Data Management
TFDM	Terminal Flight Data Manager
TFM	Traffic Flow Management
TFMDI	TFM Data to Industry
TFMS	Traffic Flow Management System
TGUI	Timeline Graphical User Interface
TMA	Traffic Management Advisor
TMAT	Target Movement Area entry Time
TMC	Traffic Management Coordinator
TMI	Traffic Management Initiative
TMU	Traffic Management Unit
TOBT	Target Off-Block Time

Acronym	Term
TQET	Target Queue Entry Time
TRACON	Terminal RADAR Approach Control
TS	Trajectory Synthesizer
TSAS	Terminal Sequencing and Spacing (formerly TSS)
TSLE	Terminal Second Level Engineering (AJM-24)
TTOT	Target Takeoff Time
UDB	Unscheduled Demand Buffer
UDP	Unified Delay Program
UI	User Interface
UTOT	Undelayed Takeoff Time
VMC	Visual Meteorological Condition
Wake RECAT	Wake Turbulence Recategorization
WJHTC	William J. Hughes Technical Center
WS	Web Services
WSRD	Web Services Requirements Document
WSRT	Web Service Requirements Tool
XML	Extensible Markup Language
XSD	XML Schema
ZDC	Washington Air Route Traffic Control Center
ZJX	Jacksonville Air Route Traffic Control Center
ZTL	Atlanta Air Route Traffic Control Center