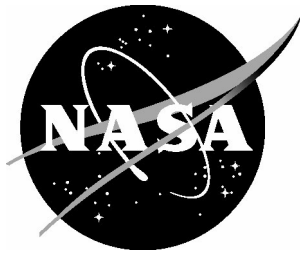


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# Airspace Technology Demonstration 2 (ATD-2) Phase 1 Concept of Use (ConUse)

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February 2018

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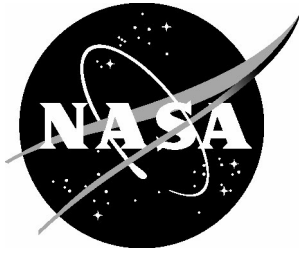
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# Table of Contents

<b>1</b>	<b>INTRODUCTION .....</b>	<b>1</b>
1.1	IDENTIFICATION .....	1
1.2	BACKGROUND.....	1
1.3	DOCUMENT PURPOSE AND SCOPE .....	2
1.4	DOCUMENT ORGANIZATION.....	4
<b>2</b>	<b>OPERATIONAL NEED.....</b>	<b>5</b>
2.1	CURRENT SYSTEM .....	5
2.1.1	General.....	5
2.1.2	CLT Airport Surface Operations .....	6
2.1.3	CLT Airspace Operations .....	10
2.1.4	Traffic Management Initiatives Impacting CLT Operations.....	12
2.2	LIMITATIONS OF CURRENT OPERATIONS .....	18
2.2.1	Airport Departure Demand Exceeding Capacity.....	18
2.2.2	TMI Coordination and Compliance.....	18
2.2.3	Flight-Time Predictability.....	20
<b>3</b>	<b>IADS SYSTEM JUSTIFICATION.....</b>	<b>21</b>
3.1	JUSTIFICATION FOR CHANGES .....	21
3.2	BENEFIT MECHANISMS OF THE IADS SYSTEM .....	22
3.2.1	Efficiency Benefit Mechanisms.....	22
3.2.2	Predictability Benefit Mechanisms.....	23
3.2.3	Human-Factors Benefits Mechanisms .....	24
3.2.4	Benefit Mechanisms for Local Operational Improvements .....	24
3.3	ASSUMPTIONS .....	25
<b>4</b>	<b>CONCEPT FOR THE PROPOSED IADS SYSTEM.....</b>	<b>27</b>
4.1	DESCRIPTION OF THE PROPOSED SYSTEM .....	27
4.1.1	Operational Environment.....	27
4.1.2	Operational View of IADS System .....	28
4.1.3	IADS System Conceptual Elements for Phase 1 Demonstration.....	30
4.1.4	User Groups and Other Involved Personnel.....	39
4.2	OPERATIONAL POLICIES, PROCEDURES, AND CONSTRAINTS .....	40
4.2.1	Adjustments due to Automated Data Exchange and Integration.....	40
4.2.2	Adjustments for Strategic Surface Scheduling Capabilities and Procedures .....	41
4.2.3	Adjustments for Tactical Surface Scheduling Capabilities and Procedures.....	41
4.2.4	Adjustments for Tactical Departure Scheduling Capabilities and Procedures .....	41
4.2.5	Adjustments for Pilot Procedures - Surface Metering and APREQ/CFR.....	41
4.2.6	Involvement of Other Airport Operations.....	41
4.2.7	Potential Conflict with Established Departure Metrics.....	42
4.2.8	Non-AAL Flight Operators, General Aviation, Cargo and International Flights.....	42
<b>5</b>	<b>OPERATIONAL SCENARIOS.....</b>	<b>43</b>
5.1	STRATEGIC SURFACE SCHEDULING .....	43

<b>5.2</b>	<b>TACTICAL SURFACE SCHEDULING .....</b>	<b>45</b>
5.2.1	Ramp Traffic Console (RTC) for the Ramp Controller .....	45
5.2.2	Ramp Manager Traffic Console (RMTC) for the Ramp Manager .....	47
5.2.3	Tactical Surface Metering .....	48
<b>5.3</b>	<b>TACTICAL DEPARTURE SCHEDULING .....</b>	<b>50</b>
5.3.1	Management of TMIs and Scheduling Modes by the Center .....	51
5.3.2	TMI Information in STBO Client Display .....	51
5.3.3	Overview of IADS APREQ/CFR Processing.....	52
<b>5.4</b>	<b>TOWER AND RAMP COORDINATION THROUGH DATA EXCHANGE AND INTEGRATION .....</b>	<b>57</b>
<b>5.5</b>	<b>DASHBOARD – REAL-TIME REPORTING.....</b>	<b>60</b>
<b>5.6</b>	<b>SAMPLE USE CASES .....</b>	<b>62</b>
5.6.1	Use Case 1: Tactical Surface Metering for Non-TMI Flights .....	62
5.6.2	Use Case 2: Tactical Surface Metering (Non-TMI) - Early Gate Pushback .....	64
5.6.3	Use Case 3: Tactical Surface Scheduling for Flights with TMI Restrictions.....	65
5.6.4	Use Case 4: APREQ/CFR Flow – Nominal Procedure .....	65
5.6.5	Use Case 5: APREQ/CFR Flow – Re-Scheduling for Flights Before Pushback.....	65
5.6.6	Use Case 6: APREQ/CFR Flow – Re-Scheduling for Flights After Pushback .....	67
5.6.7	Use Case 7: Departure Runway Change due to Departure Fix Closure.....	68
<b>6</b>	<b>POTENTIAL IMPACTS.....</b>	<b>70</b>
6.1	OPERATIONAL IMPACTS.....	70
6.2	ORGANIZATIONAL IMPACTS.....	71
<b>7</b>	<b>SUMMARY .....</b>	<b>72</b>
<b>8</b>	<b>REFERENCES .....</b>	<b>73</b>
<b>APPENDIX A: IADS OPERATIONAL ENVIRONMENT .....</b>		<b>76</b>
<b>APPENDIX B: ATD-2 SUB-PROJECT FIELD DEMONSTRATION STRATEGY .....</b>		<b>78</b>
<b>B.1</b>	<b>PHASE 1: BASELINE IADS .....</b>	<b>78</b>
<b>B.2</b>	<b>PHASE 2: FUSED IADS.....</b>	<b>79</b>
<b>B.3</b>	<b>PHASE 3: METROPLEX IADS.....</b>	<b>80</b>
<b>APPENDIX C: ACRONYMS.....</b>		<b>82</b>

## List of Figures

Figure 1 - The planview of the CLT airport shows the orientation of the four runways and the various terminal areas and taxiways.....	6
Figure 2 - The CLT airport operates in either a South or North flow configuration.....	7
Figure 3 - Aircraft count for gate arrival (IN) and gate departure (OUT) events are averaged for October 2016, showing distinct peaks and valleys throughout the day. The shaded area represents the range between 10th and 90th percentiles.....	8
Figure 4 - The CLT ramp area is divided into four sectors (West, South, East, and North), with Spots 25-29 shown along the constrained taxi corridor.....	9
Figure 5 - CLT TRACON departure sectors and RNAV departure routes are shown.....	11
Figure 6 - CLT sectors and jetways show transiting traffic near CLT (with a South flow configuration for the CLT departures).....	12
Figure 7 - Outbound tactical departures from CLT are scheduled by ZDC to a metering arc within ZDC Center airspace.....	14
Figure 8 - Departures subject to APREQ/CFR were scheduled by both Washington Center and Atlanta Center.....	15
Figure 9 - The APREQ/CFR scheduling enacted by both ZDC and ZTL can be further broken down into outbound scheduling and inbound scheduling.....	16
Figure 10 - APREQ/CFR events at CLT are traced through the current day system.....	17
Figure 11 - 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 interactions.....	27
Figure 12 - The operational overview of the IADS system highlights the participants and system improvements for the Phase 1 Baseline IADS Demonstration.....	28
Figure 13 - The Departure Reservoir Management (DRM) function of the Surface CDM ConOps is represented by three functional elements in the IADS system.....	30
Figure 14 - The capacity prediction automatically updates the capacity of each runway, using various inputs, without relying on manual entries.....	32
Figure 15 - Surface metering monitors demand/capacity imbalance and provides tools to determine when to turn on metering and how the excess taxi time is propagated to the gate.....	36
Figure 16 - Timelines, plots, and DMP recommendations and notifications (notional) will allow the interested user groups to monitor the predictions made by the DRM capability.....	44
Figure 17 - The Ramp Traffic Console (RTC) display helps the ramp controller manage traffic in the ramp area more efficiently.....	45
Figure 18 - The Ramp Traffic Console (RTC) display shows gate conflict alerts and hardstand assignments.....	46
Figure 19 - The flight menu for flight intent contains entries for spot, runway, hardstand, and flagging for a priority flight.....	47
Figure 20 - The Ramp Manager Traffic Console (RMTC) display provides many functions and capabilities in an automated format to the Ramp Manager through multiple feature windows.....	48
Figure 21 - Flights with APREQ/CFRs are shown in the flight list and highlighted in the timeline.....	52

Figure 22 - This illustration shows the flow of data between key stakeholders and systems during the pre-scheduling phase of the APREQ/CFR process. ....	53
Figure 23 - This illustration shows the flow of data between key stakeholders and systems during the scheduling and compliance phase of the APREQ/CFR process. ....	54
Figure 24 - Slots depicted in green on the STBO Client runway timeline are available for an APREQ/CFR request.....	55
Figure 25 - The STBO Client consists of multiple windows, which can be scaled independently to the user’s preference. The TM Actions button on the toolbar allows the user to schedule/make changes to TMIs and runway utilization. ....	57
Figure 26 - The RMTC and RTC provide a situational view of the airport surface and allow the user to interact with flights in the ramp area. ....	58
Figure 27 - Real-time dashboard view of the toolbar in conjunction with the STBO Client.....	60
Figure 28 - The real-time dashboard can be displayed as either a horizontal or a vertical toolbar. ....	61
Figure 29 - The quick-look pull-down menu and the horizontal dashboard depict the airport health and provide an overview of the current airport operations. ....	62
Figure 30 - This illustration shows the flow of events for tactical surface scheduling between key stakeholders and systems for non-TMI flights. ....	63
Figure 31 - This illustration shows the flow of events of APREQ/CFR re-scheduling between key stakeholders and systems for flights before pushback. ....	66
Figure 32 - This illustration shows the flow of events for APREQ/CFR re-scheduling between key stakeholders and systems for flights after pushback.....	67
Figure 33 - This illustration shows the flow of events for changing a flight’s departure runway due to a departure fix closure.....	69
Figure 34 - 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. ....	76
Figure 35 - The ATD-2 sub-project employs a field demonstration strategy built upon three distinct phases, each representing an increased system capability. ....	78
Figure 36 - 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.....	79
Figure 37 - 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.....	80
Figure 38 - 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.....	81



**List of Tables**

Table 1 - The capabilities to be deployed in the ATD-2 sub-project Phase 1 demonstration will be accessed by different users in various facilities. ....39



# 1 Introduction

## 1.1 Identification

This document presents an operational Concept of Use (ConUse) for the Phase 1 Baseline Integrated Arrival, Departure, and Surface (IADS) prototype system of NASA's Airspace Technology Demonstration 2 (ATD-2) sub-project, which began demonstration in 2017 at Charlotte Douglas International Airport (CLT). NASA is developing the IADS system under the ATD-2 sub-project in coordination with the Federal Aviation Administration (FAA) and aviation industry partners. The primary goal of ATD-2 sub-project is to improve the predictability and the 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 initial phase of the ATD-2 sub-project, which is the focus of this document, will demonstrate the Phase 1 Baseline IADS capability at CLT in 2017.

The Phase 1 Baseline IADS capabilities of the ATD-2 sub-project consists 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 traffic streams via accurate predictions of takeoff times and automated coordination between the Airport Traffic Control Tower (ATCT, or Tower) and the Air Route Traffic Control Center (ARTCC, or Center)
- Improvements in departure surface demand predictions in Time Based Flow Management (TBFM)
- A prototype Electronic Flight Data (EFD) system provided by the FAA via the Terminal Flight Data Manager (TFDM) early implementation effort
- Improved situational awareness and demand predictions through integration with the Traffic Flow Management System (TFMS), TBFM, and TFDM (3Ts) for electronic data integration and exchange, and an on-screen dashboard displaying pertinent analytics in real-time

The surface scheduling and metering element of the capability is consistent with the Surface CDM Concept of Operations published in 2014 by the FAA Surface Operations Directorate.<sup>1</sup>

Upon successful demonstration of the Phase 1 Baseline IADS capability, follow-on demonstrations of the matured IADS traffic management capabilities will be conducted in the 2018-2020 timeframe. At the end of each phase of the demonstrations, NASA will transfer the ATD-2 sub-project technology to the FAA and industry partners.

## 1.2 Background

NASA, the FAA, and industry have been developing IADS concepts and technologies for many years. NASA's research activities in the IADS domain include the Spot and Runway Departure Advisor (SARDA),<sup>2,3</sup> the Precision Departure Release Capability (PDRC),<sup>4</sup> and the Terminal

Sequencing and Spacing (TSAS)<sup>5</sup> research projects. Early SARDA research focused on movement area traffic advisories for the Airport Traffic Control Tower (ATCT, or Tower) personnel. Recent SARDA research, in collaboration with American Airlines (AAL), has focused on non-movement (i.e., ramp) traffic advisories for Ramp Control (i.e., ramp controllers and Ramp Manager). The PDRC 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 Time Based Flow Management (TBFM) departure scheduling functions. PDRC research was transitioned to the FAA in 2013 for use in the TBFM and TFDM programs. TSAS research is the combination of TBFM for terminal area scheduling and Controller Managed Spacing (CMS). The TSAS research was successfully transferred to the FAA in 2014 for use in TBFM.

The FAA Next Generation Air Transportation System (NextGen) plans call for the National Airspace System (NAS) IADS capabilities to be implemented via a trio of decision support systems (DSS).<sup>6</sup> TFMS, TBFM, and TFDM are the primary systems in this group that are commonly called the "3Ts." 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. The reader is referred to section 2.1 of the ATD-2 Technology Description Document (TDD) for more information regarding the 3T integration effort.<sup>7</sup>

In 2014, the NASA pre-formulation team developed the initial ATD-2 sub-project objectives by engaging with a broad sampling of NAS stakeholders to understand the existing shortfalls in arrival, departure, and surface operations, and the perceived benefits of an IADS solution.<sup>7,8</sup> The ATD-2 sub-project objectives were further refined via collaboration with the FAA and flight operator partners.

In October 2014, the FAA delivered an executive report to Congress entitled NextGen Priorities Joint Implementation Plan.<sup>9</sup> This report documented FAA commitments in response to the NextGen Advisory Committee (NAC) recommendations.<sup>10</sup> One of the recommendations urged the FAA to establish an initial airport surface departure metering capability that would reflect the FAA's Surface CDM Concept of Operations. The FAA responded by committing to a feasibility assessment, which resulted in a March 2015 FAA/NASA agreement to evaluate departure metering as part of a larger field demonstration of IADS capability. This was followed by a field demonstration site assessment effort wherein the ATD-2 sub-project team evaluated candidate airports proposed by the NAC, the FAA, and NASA. In May 2015, the FAA announced CLT as the field demonstration site for the IADS capability.

The ATD-2 five-year project plan underwent formulation review by NASA's Aeronautics Research Mission Directorate (ARMD) in November 2015. The independent review panel (IRP) consisted of air traffic management experts from the FAA and NASA. The IRP recommended that the ATD-2 sub-project proceed from formulation to implementation.

### **1.3 Document Purpose and Scope**

The purpose of the ATD-2 sub-project ConUse document is to provide an overview of the IADS concept and detailed descriptions of how each group of users will interact with the proposed system. Specifically, this document will focus on the conceptual elements for the ATD-2 Phase 1 Baseline IADS Demonstration at CLT that includes:

- Data exchange and integration: Allows multiple users to interact with one another, and share data and decision information through the IADS system.
- Surface modeling: Combines airport geometry with flight specific intent information to produce a continuously updated 3D (x, y, time) surface trajectory for each flight.
- Tactical surface scheduling: Uses surface modeler inputs to produce the Target Takeoff Time (TTOT), the Target Movement Area entry Time (TMAT), and the Target Off-Block Time (TOBT).
- Tactical surface metering: Enables the user to adjust demand, given the capacity prediction, by shifting excess queue time from the runway queue to the gates or other points.
- Strategic surface scheduling: Monitors demand/capacity imbalances and recommends departure metering programs.
- Real-time dashboard: Provides users with insights on efficiency and predictability, as well as the effectiveness of scheduling and metering.
- Tactical departure scheduling: Provides accurate predictions of OFF times and airspace trajectories for departure aircraft, and automated coordination of overhead stream insertions between the Tower and the Center.
- “What-if” scenario feature: Shows the effect of a proposed change in traffic management settings, such as Traffic Management Initiative (TMI) restrictions and flight properties, without actually implementing the change.
- EFD: Leverages the FAA’s early implementation prototype of the TFDM EFD to replace paper flight strips for Tower controllers, providing enhanced situational awareness and a reduced workload.

The IADS system capability demonstration at CLT will be conducted in three phases, as detailed in Appendix B: ATD-2 Sub-project Field Demonstration Strategy. This version of the ConUse focuses on the Phase 1 Baseline IADS Demonstration. Updated versions of this ConUse document will be created that focus on the future operational evaluations planned for Phase 2 (2018) and Phase 3 (2019), with considerations for future improvements that include: a fusion of strategic and tactical surface scheduling, integration of EFD with the IADS system, and the incorporation of a terminal departure capability for a metroplex environment.<sup>11</sup> This ConUse document is supplemented by the ATD-2 Technology Description Document (TDD)<sup>7</sup> and the training and procedures documents<sup>12,13,14,15</sup> that provide more detailed descriptions of the technology and procedures being developed for the IADS system.

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, the flight operators, the CLT airport operators, and the Surface CDM community.
- The NASA/FAA IADS Research Transition Team (RTT), who is facilitating the research transition process.

- The FAA NextGen implementers, who may use this ConUse, 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 programmatic context, and an overview of the ConUse document.
- Section 2 describes the operational need, including current operations, limitations of existing operations, and the existing operations that require change.
- Section 3 presents the justification for change, the benefit mechanisms, and the assumptions and constraints.
- Section 4 presents an overview of the proposed system, including user classes, personnel, and policies.
- Section 5 details operational scenarios and use cases intended to demonstrate the operation of the proposed system and illustrate how the proposed system improves upon the current system.
- Section 6 details operational and organizational impacts associated with the new system.
- Section 7 contains a summary.
- Section 8 contains references cited and documents consulted.
- Appendix A describes the operational environment for the IADS system.
- Appendix B contains a high-level description of the three phases of the ATD-2 field demonstrations.
- Appendix C contains acronyms used in this document and throughout the ATD-2 sub-project.

## **2 Operational Need**

This section discusses the current operations of the CLT airport and airspace system. It also identifies the limitations and challenges for effective surface and departure traffic management in today's operational environment, which are considered for a systematic approach to the IADS system.

The examples presented in this section are based on analysis of current day CLT operations. A separate NAS-wide study is underway to document the benefits of applying ATD-2 IADS technologies to environments other than CLT.

### **2.1 Current System**

This section briefly describes the current operations and Air Traffic Management (ATM) system at CLT that are pertinent to the objectives of the IADS system for the Phase 1 Baseline IADS Demonstration in 2017. The description of airport surface operations (section 2.1.2) provides a brief overview of the CLT Airport Movement Area (AMA) and Ramp Control, and explains how the traffic control personnel handle air traffic under various operational conditions. Also discussed are the runways and how they are used; although they are part of the airport surface, they serve as the transitional point between the airport surface and the airspace environment, and thus merit further description.

The description of airspace operations (section 2.1.3) provides a brief overview of the CLT Terminal RADAR Approach Control (TRACON), the Atlanta Air Route Traffic Control Center (ARTCC) (ZTL), and the Washington ARTCC (ZDC), as well as the Traffic Management Initiatives (TMIs) impacting CLT operations. Detailed information regarding current operations and the technologies/tools used for traffic management is found in the operational profile report produced by the NASA ATD-2 team<sup>16</sup> and the FAA's TFDM Operational Evaluation Report (OER) for CLT.<sup>17</sup>

#### **2.1.1 General**

Situated between the Washington DC metroplex (~300 NM away) and the Hartsfield-Jackson Atlanta International Airport (ATL) (~200 NM away), CLT underlies one of the busiest air traffic corridors on the east coast. CLT is located in the northeast corner of ZTL airspace, approximately 59 miles from the ZTL boundary with ZDC on the east side, and sits on the border of the Jacksonville ARTCC (ZJX) on the south side. This location significantly influences operations at CLT and makes CLT the subject of frequent TMI constraints from each of the three ARTCCs.

The CLT Airport Activity Report of January 2017 reports that the CLT Tower controls around 1,400 operations per day.<sup>18</sup> Preliminary numbers from Airports Council International (ACI) show CLT as #7 in movements worldwide for 2016.<sup>19</sup> The total count of CLT TRACON operations on a Visual Meteorological Condition (VMC) day is around 1,500 daily. Thus, the vast majority of traffic managed by the TRACON is destined for, or departing from, CLT.

The distribution of CLT traffic operations by carrier, based on data collected for the same period, shows that AAL and regional flight operators operate nearly 85% of the flights into and out of CLT. Besides the main terminal for commercial and regional flight operators, CLT also has the Wilson Air Center (a fixed base operator that provides services to corporate and private flights),

the North Carolina Army Guard, and the North Carolina Air National Guard. These general aviation (GA) and military flights comprise about 4% of CLT traffic.

### 2.1.2 CLT Airport Surface Operations

As shown in Figure 1, the airport has three north/south parallel runways (18L/36R, 18C/36C, and 18R/36L) and a fourth runway (5/23) diagonally oriented to the parallels that intersects RWY 18L/36R. The three parallel runways are adequately spaced for triple simultaneous independent approaches when the requisite Final Monitor positions are staffed (Final Monitor controllers monitor the path of aircraft during Standard Instrument Approach Procedures (SIAPs)). Simultaneous independent approaches are authorized between the two outboard parallel runways without the requirement for Monitor positions since they are separated by more than 9000 feet, the minimum requirement for such operations. Since March 2015, CLT has used Wake Turbulence Recategorization (Wake RECAT) procedures to manage inter-arrival and inter-departure spacing at the runways.

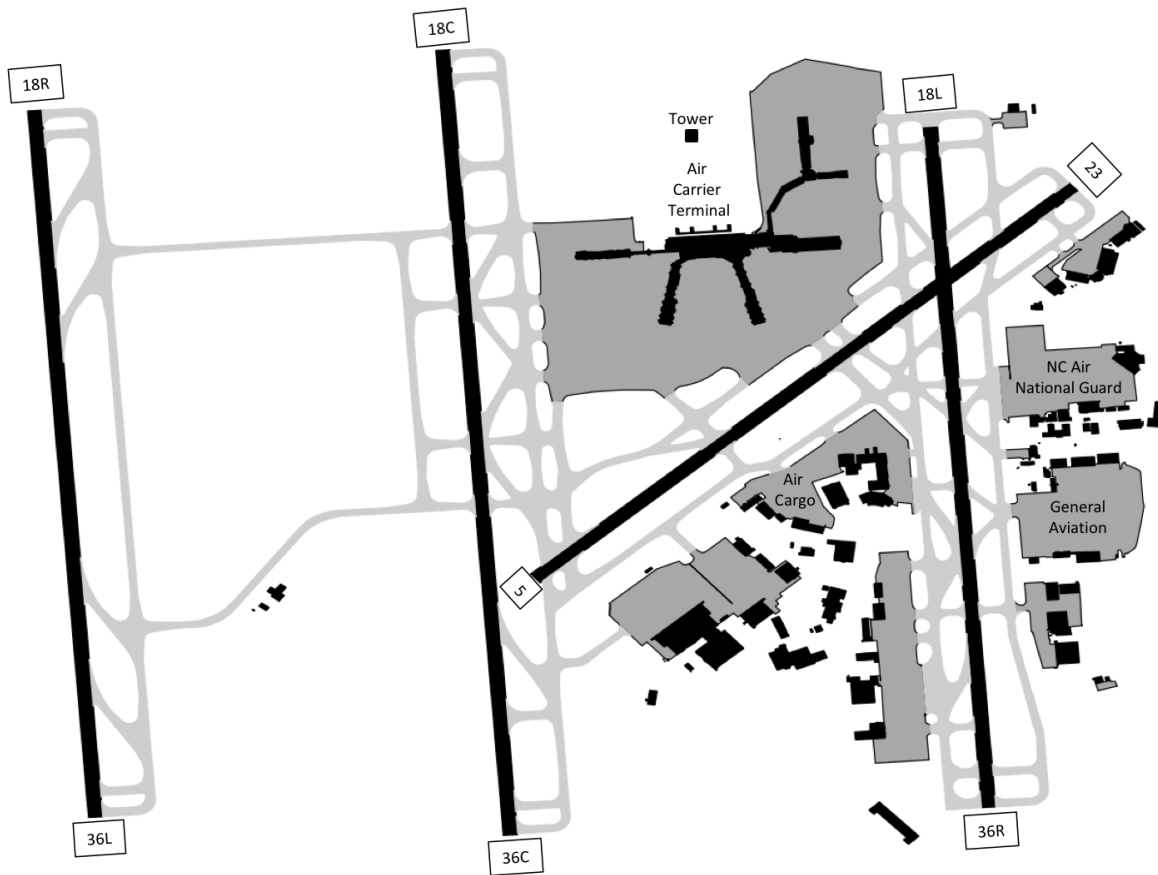


Figure 1 - The planview of the CLT airport shows the orientation of the four runways and the various terminal areas and taxiways.

The airport operates in either a “North” or “South” flow configuration; the configurations are shown in Figure 2. The diagonal runway, RWY 23, is used in a South flow configuration for arrivals. RWY 5 (the opposing end) is not used for arrivals or departures during normal daylight/evening operations, but it is used as a taxiway in a North flow operation. However,



during nighttime noise abatement procedures, RWY 5 is used for both arrivals and departures when North flow operations are in effect.

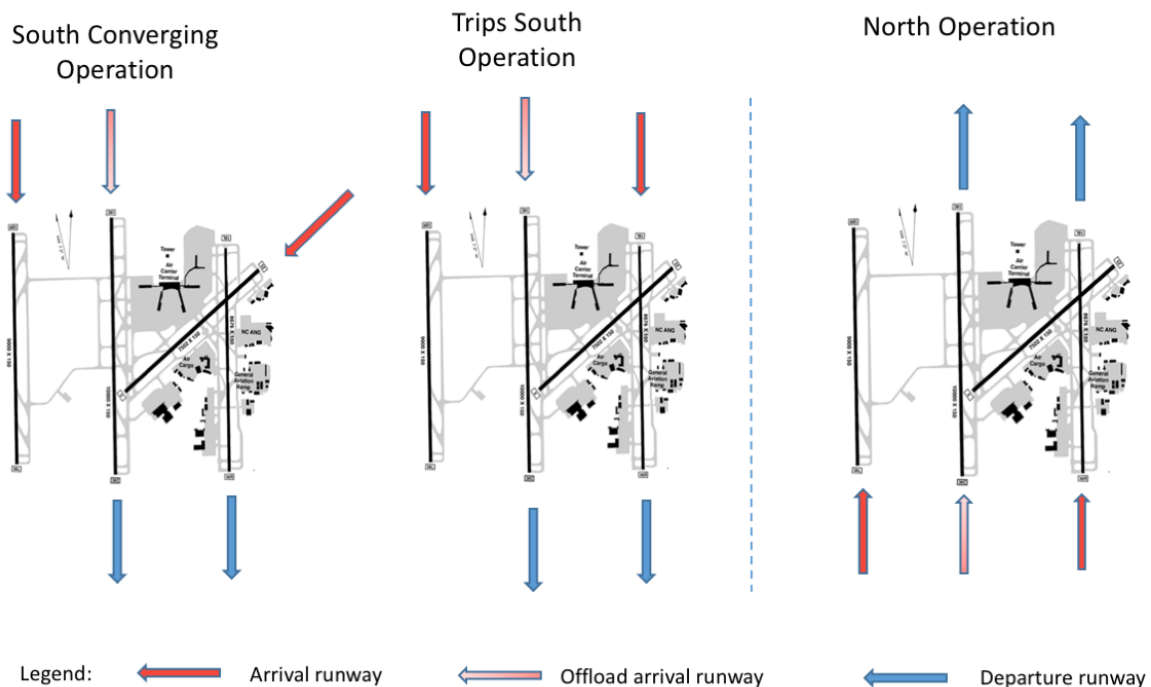


Figure 2 - The CLT airport operates in either a South or North flow configuration.

South flow operations utilizing RWY 23 are known as converging runway operations, which also have a low noise impact for the airport. Converging operations are preferred due to higher airport throughput rate (e.g., an Airport Departure Rate (ADR) of 80 vs an ADR of 69 during non-converging ops). During converging operations, Local Control must adhere to the Arrival/Departure Window (ADW) procedure.\* This procedure requires aircraft departing RWY 18C to commence takeoff roll prior to a RWY 23 arrival passing a point 1.8 NM from the RWY 23 threshold. Markings are provided on the Certified Tower Radar Display (CTRD) to aid controllers in the application of the ADW. The ADW imposes a constraint on RWY 18C departure operations. Alleviating this constraint requires moving arrivals from RWY 23 to another runway, or moving departures that would normally utilize RWY 18C to RWY 18L. Either of these options may be utilized if conditions permit, and based on the traffic circumstances.

Air traffic services on the AMA are provided by the Charlotte Tower. Positions in the Tower are consistent with those found at other towers serving major airports: Traffic Management Coordinator, Front Line Supervisor, Cab Coordinator, Local and Ground Controllers, and Clearance Delivery.

Traffic at CLT is characterized by definite peaks and valleys. Figure 3 shows the average number of aircraft that have departed from gates and arrived at gates every 15 minutes during the month

\* See Ref. 20, section 3-9-9 (PDF page 147). See also BG-54 (PDF page 668).

of October 2016. There are clear distinctions between departure and arrival banks throughout the day. Each departure and arrival bank lasts approximately an hour each with a slight overlap existing between banks. Ramp Control strives to clear the departures from the gates before an arrival bank builds up, so that ramp congestion and gate conflicts can be minimized.

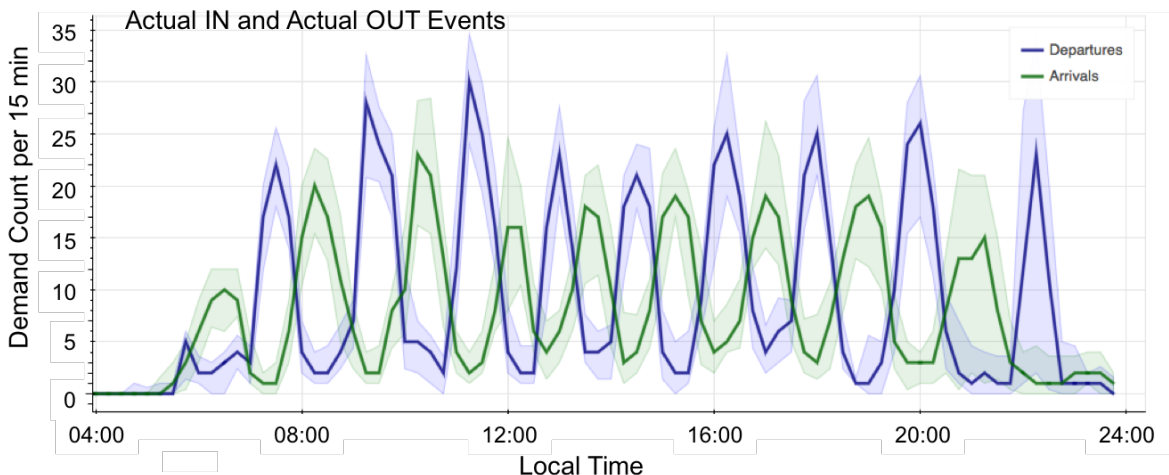


Figure 3 - Aircraft count for gate arrival (IN) and gate departure (OUT) events are averaged for October 2016, showing distinct peaks and valleys throughout the day. The shaded area represents the range between 10th and 90th percentiles.

During departure push periods, the AAL-managed CLT Ramp may utilize a count-based, manual metering solution known as departure sequencing. In departure sequencing, the Ramp Control holds departure aircraft at the gate to reduce congestion on the airport surface (e.g., ramp areas, taxiways, and runway queues), thus reducing engine fuel burn. A commercial surface traffic management decision support tool (DST) facilitates the departure sequencing procedure.

The Ramp controllers have two lists, the en-route-to-runway list and the gate-hold list, for each runway. The en-route-to-runway list enumerates the aircraft in the process of taxiing to the runway and their total count. The gate-hold list identifies the flights that are put on hold, where gate-hold time is tracked by the commercial DST.

When an aircraft calls for pushback clearance and there are already a pre-determined number of aircraft (currently 15) in the en-route-to-runway list, the ramp controller instructs the pilot to standby for sequencing and puts the aircraft on hold. When the queue is at a point where a flight can be released for pushback or the hold time limit has been reached (currently 10 minutes), the ramp controller instructs the aircraft to push and manually moves the flight from the gate-hold queue to the en-route-to-runway queue on the commercial DST surface display.

Communication between the CLT AAL Ramp and the CLT ATC Tower is accomplished primarily via phone calls to coordinate traffic flow restrictions (e.g., Miles-in-Trail (MIT) restrictions) and runway configuration changes, as well as the use of certain taxiways (e.g., taxiways M and C for arrival aircraft during a departure push). These phone communications are sometimes subjected to excessive delays, since answering phone calls is a low priority to those involved in constant radio communication with moving traffic.

The Clearance Delivery (CD) position also contacts the pilots when the flight is subject to an Approval Request/Call for Release (APREQ/CFR), to communicate the release time. Ramp Control is normally excluded from that communication. Occasionally, when the CD has not been

able to communicate the takeoff time to the pilots, and when the delay is significant enough, the Tower Traffic Management Coordinator (TMC) may also reach out to the Ramp, so that the pilots can be informed. (The detailed APREQ/CFR procedure in today's operations is explained in section 2.1.4.2.)

Figure 4 shows an aerial photo of the CLT ramp area. The ramp area is divided into four sectors (West, South, East, and North sectors). The corresponding ramp controller controls the traffic in each sector. The ramp operations at CLT are constrained due to physical limitations of the ramp area.

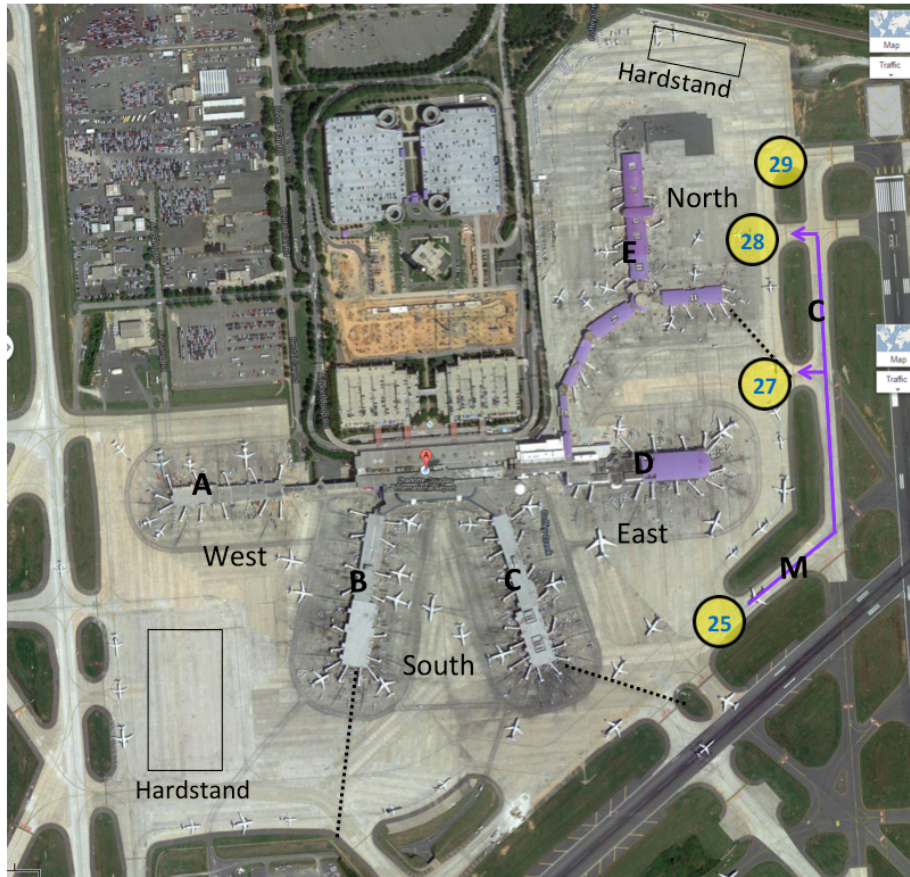


Figure 4 - The CLT ramp area is divided into four sectors (West, South, East, and North), with Spots 25-29 shown along the constrained taxi corridor.

Some characteristics of the current ramp operations are:

- CLT has limited ramp space with alleys between concourses, which limit traffic to one direction at a time.
- Pushbacks from concourse end gates can further restrict internal ramp traffic flows.
- The single-direction-at-a-time taxiway off the end of Concourses D and E restricts internal ramp traffic flows and requires coordination between ramp controllers.
- Aircraft in Airplane Design Group (ADG)<sup>21</sup> III or above (e.g., B737-700, A320, A767, A330) are restricted to a single direction flow off the end of C Concourse.

- There are limited holding areas, also called “hardstands” in CLT: one on the west side and one on the north end of the ramp. These hardstands are used for holding aircraft temporarily for various purposes. For example, the ramp controller may send a departure aircraft to one of these hardstands when there is a gate conflict with an arriving aircraft, or if a departure aircraft under a TMI restriction has a long wait until its release time.
- In a South flow configuration, the Taxiway M-C route (shown in Figure 4) is often used for arrivals going to the gates in E Concourse, when there are a substantial number of departures from E Concourse going to RWY 18C. This bypass sends arrivals back into Tower control from Ramp Control; thus, it requires additional coordination with the Tower. The purpose of using this bypass taxi route is to assist in resolving the major bottleneck of the ramp traffic around the single-lane area, a narrow corridor between Spots 25 and 29.

### **2.1.3 CLT Airspace Operations**

Charlotte terminal airspace is managed by the Charlotte TRACON, where control responsibility is subdivided based on three functions: Arrival Control (Feeder and Final), Departure Control, and Satellite Control. There are three Feeder Sectors (one East and two West), a Final Controller for each arrival runway, two Departure Controllers (also East and West), and three Satellite Sectors, although they are normally combined at one position.

In a south flow configuration, the dedicated arrival runways are normally RWY 18R (West Feeder) and RWY 23 (East Feeder) for the converging operation. Each of the two runways has a separate Final controller. Note that a third runway, RWY 18C, can be used for triple simultaneous arrivals. RWYs 18L and 18C are used for departures.

In a north flow configuration, the arrival runways are RWY 36L (West Feeder) and RWY 36R (East Feeder). Triple simultaneous arrivals can also be conducted in a north flow operation by using RWY 36C. RWYs 36C and 36R are used for departures. RWY 36R is a dual-use runway for arrivals and departures, with ~4.5 NM (4 NM is optimal) in trail between arrivals with nominal winds, to accommodate a departure between each arrival.

There are two departure sectors, East and West, with airspace extending to the vertical limits of the terminal airspace, 16000 ft. (see Figure 5). In addition to managing departures, Departure Control is responsible for all overflights above 8000 ft. Satellite Control usually works the “low and slow” aircraft, including both arrivals and departures to satellite airports.

There are eleven Area Navigation (RNAV) Standard Instrument Departure (SID) routes, and five non-RNAV departure routes. Commercial jets almost exclusively file RNAV SIDs, whereas turboprop aircraft file mixed routes. The departure sectors and the SID routes are depicted in Figure 5. Departure Fixes are depicted in brown.

In north flow, by default, departing aircraft flying SID routes in the East Departure sector will depart from the east runway. Likewise, departing aircraft flying SID routes in the West Departure sector will take off from the center runway. However, the Traffic Management Coordinators may decide to assign flights to another runway in the interest of operational efficiency (either for ATC or the aircraft). For instance, departures flying on the BEAVY, ICONS, or KWEEN SID routes may be assigned to the center runway, and departures flying on the JOJJO, KRITR or WEAZL SID routes may be assigned to the east runway.

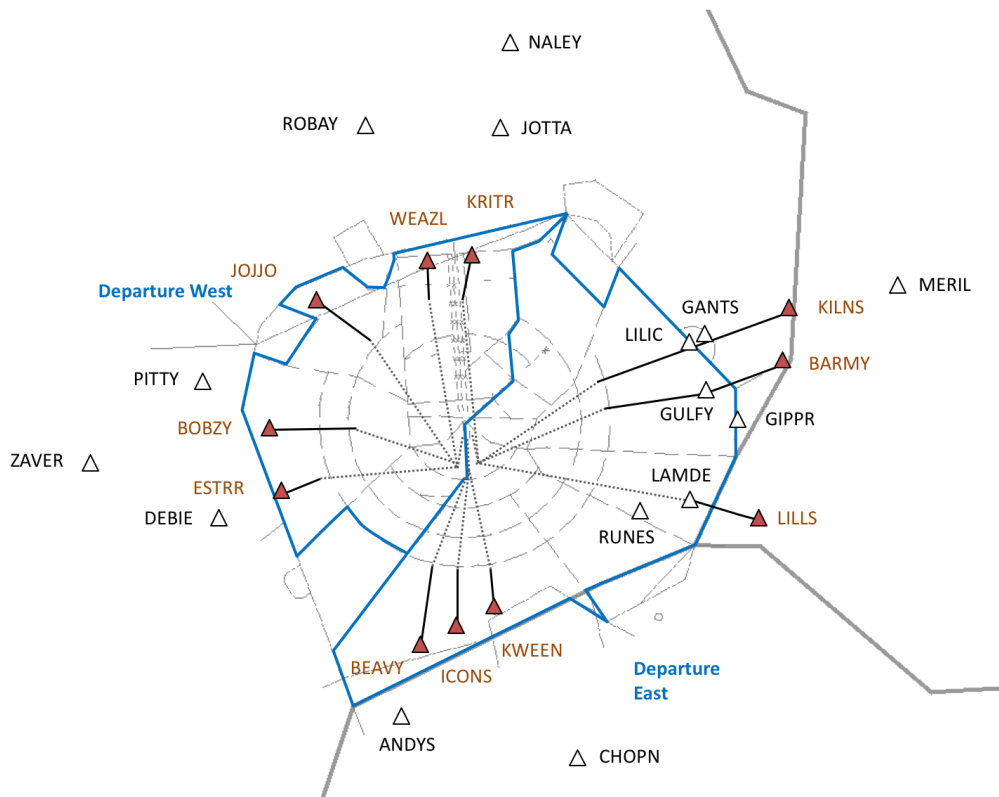


Figure 5 - CLT TRACON departure sectors and RNAV departure routes are shown.

Noise abatement procedures require that pre-defined tracks be maintained until two miles beyond the departure end of the runway. This applies to all departing jet aircraft at all times, and large four-engine propeller aircraft during night hours. Beyond this point, controllers often use direct routings in the interest of efficiency and to provide an operational advantage in spacing departures.

The CLT terminal area is situated in ZTL airspace. Figure 6 depicts the ZTL, ZDC, and ZJX center boundaries. Low altitude sectors (AOB FL230) are shown in orange. High altitude sectors are shown in brown. The CLT terminal area is situated at the corner of three Centers: Atlanta, Washington, and Jacksonville. In addition, CLT is situated near a convergence of flows coming from ZJX and ZTL into ZDC. Figure 6 depicts the flows in the three Centers.

The main traffic flows in ZTL are composed of traffic transiting the Center at cruise altitude, and arrivals and departures primarily in and out of ATL and CLT. Figure 6 depicts the sectors and jetways associated with departures from CLT. One of the main flows of traffic in ZTL airspace is traffic on a southwest to northeast axis. Traffic funnels into ZDC, going to both the Washington metroplex and New York metroplex areas, commonly saturating the southwest sectors of ZDC. The volume of traffic from CLT on the KILNS and BARMY departures, along with the overhead traffic from ZTL and ZJX, creates challenges for inserting departures and merging traffic in the ZDC airspace.

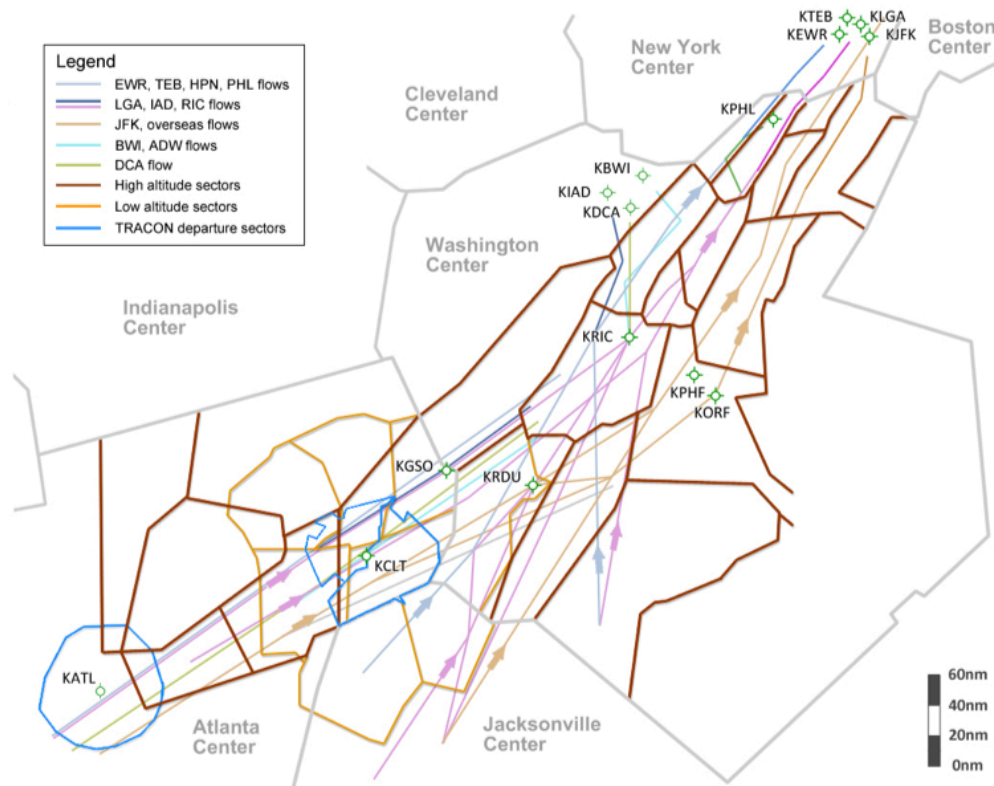


Figure 6 - CLT sectors and jetways show transiting traffic near CLT (with a South flow configuration for the CLT departures).

### 2.1.4 Traffic Management Initiatives Impacting CLT Operations

TMIs aim to regulate air traffic flows to manage imbalances between demand and capacity in the NAS. TMIs can be divided into *strategic* and *tactical* categories, based on the impact level of the constraint and who initiates the restriction.

*Strategic* TMIs issued by the Air Traffic Control System Command Center (ATCSCC, or Command Center) generally come in the form of Ground Delay Programs in which aircraft are delayed at their departure airport to resolve demand and capacity imbalances at their arrival airport. Flights are assigned departure times, known as Expect Departure Clearance Times (EDCTs), to indirectly regulate their arrival time at the impacted airport. Airspace Flow Programs (AFPs) are also a type of TMI that are used to control the flow of traffic, particularly in en route airspace. Flights subject to an AFP are also assigned EDCTs. The Command Center convenes with air traffic control facilities and flight operations centers every two hours about the appropriate TMIs, and communicates them via advisories. An EDCT is a controlled OFF time that has a compliance window of five minutes before through five minutes after the target takeoff time (-5/+5 min). In most cases, the pilot receives EDCT information from flight operations prior to aircraft pushback from the gate.

*Tactical* TMIs are issued by local facility traffic management personnel, which can include Center, TRACON, or Tower traffic managers. Tactical TMIs resolve local demand/capacity imbalances in the NAS that do not rise to the level of a national/strategic constraint. Most commonly, the Center Traffic Management Unit (TMU) personnel enter tactical TMIs into the National Traffic Management Log (NTML). Two widely used tactical TMIs are MIT and

APREQ/CFR restrictions. These restrictions generally apply to departure flights headed to specific destinations, crossing TRACON departure fixes and/or meter points at the Center boundary. Such restrictions have a start and end time, and they are documented in the NTML. The Center TMC generally uses TBFM to communicate and manage these restrictions. An APREQ/CFR results in a controlled OFF time that has a default compliance window of two minutes before through one minute after the target OFF time (-2/+1 min), unless otherwise coordinated.<sup>†</sup> More detailed information regarding MIT and APREQ/CFR restrictions are found in the following sections.

Although there are other types of TMIs, such as Ground Stops (GS), and weather reroute solutions (e.g., National Playbook or Coded Departure Routes), the primary focus of the Phase 1 Baseline IADS Demonstration is to accommodate the MITs, the APREQ/CFRs, and the EDCTs resulting from strategic TMIs that most commonly affect the departures from CLT.

#### **2.1.4.1 MIT**

MIT restrictions are a tactical TMI used to control the volume of traffic into a region of airspace. A MIT restriction addressed in the IADS system research typically will be a restriction value, enforced at the Center-TRACON and/or the Center-Center boundary. MIT restrictions are often specific to a route, meter point, or destination airport.

An analysis of MIT restrictions affecting CLT departures during the month of April 2015 was conducted, based on data from NTML and TFMS. Results show that MIT restrictions were imposed on CLT every day. The length of time that MIT restrictions were in effect was 106 min on average, but varied widely, ranging from 15 min to 465 min. Of all the reasons listed for issuing MIT restrictions, the volume of traffic was the most common (80%, 224/280 published reasons), followed by the weather (20%, 56/280). Most of the MIT restrictions issued by ZDC to CLT are to comply with downstream restrictions from the NY and DC TRACONs.

ZDC TMCs commonly implement MIT restrictions to manage sector traffic volume and to comply with downstream MIT restrictions. In addition, ZDC may increase MIT restrictions due to the numerous flows of metroplex traffic entering ZDC, as well as compression in the arrival flow at the ZDC boundary.

Frequently, MIT restrictions are not sufficient to manage the traffic volume and compression. Because of that, ZDC also issues APREQ/CFR restrictions to CLT and other airports.

#### **2.1.4.2 APREQ/CFR**

APREQ/CFR is a tactical departure scheduling procedure designed to coordinate the departure's release time from the origination airport to facilitate stream insertion or the merging of traffic at a downstream schedule point. An APREQ/CFR results in a controlled OFF time that has a default compliance window of two minutes before through one minute after the target OFF time (-2/+1 min), unless otherwise coordinated.<sup>‡</sup>

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<sup>†</sup> See Ref. 20, 4-3-4 (page 4-3-7, PDF page 185).

<sup>‡</sup> See Ref. 20, 4-3-4 (page 4-3-7, PDF page 185).

In the current system, TBFM allows two types of tactical departure scheduling via an APREQ/CFR: *Inbound* and *Outbound* scheduling (outbound depicted in Figure 7).

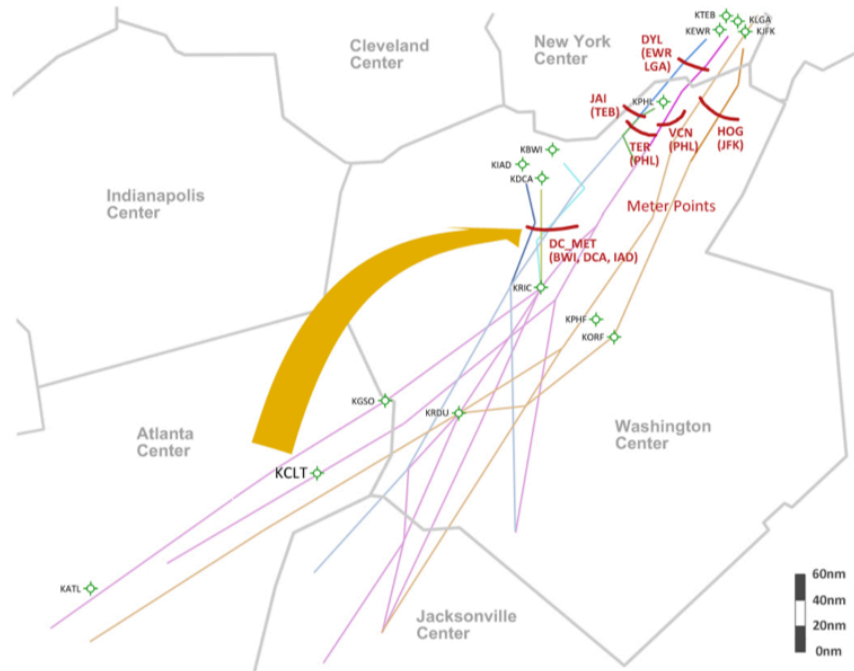


Figure 7 - Outbound tactical departures from CLT are scheduled by ZDC to a metering arc within ZDC Center airspace.

For instance, the ZTL TMCs schedule flights departing from CLT into the metered arrival stream of ATL (inbound), and ZDC TMCs schedule flights departing from CLT to a meter point on the ZDC Center's boundary (outbound). Inbound scheduling, for flights arriving into CLT, is not part of the Phase 1 Baseline IADS Demonstration.

Outbound tactical departure scheduling at CLT uses the TBFM En route Departure Capability (EDC) function to tactically schedule flights departing from airports inside the TBFM system into the Center's airspace. TBFM EDC uses the four-dimensional (4D) trajectory synthesizer capability, including aircraft performance models and current wind forecast, to calculate an OFF time that will enable the aircraft to rendezvous with the identified slot at the meter point.

The Center TMC will typically schedule the departure's crossing time at a meter point to meet the MIT restriction that is passed back by the downstream facility. Figure 7 shows the outbound tactical scheduling situation for the CLT departures bound to ZDC's adjacent facilities, such as the Potomac Consolidated TRACON (PCT), the New York TRACON (N90), and the Philadelphia TRACON (PHL). The colored lines depict the cross-country overhead streams of traffic destined to PCT, N90, and PHL airspace. Overhead streams transit ZTL and ZJX airspace, merge in ZDC, and cross a metering arc (in red) before entering the TRACON airspace.

The gold arrow depicts the stream of CLT BARMY and KILNS departures that must merge with the overhead stream of Washington-bound traffic. These departures merge with the overhead stream before crossing the DC\_MET arc, located at the southern edge of PCT airspace. This arc serves as a meter reference point for TBFM's EDC function.



Until the summer of 2015, the ZTL TMC scheduled CLT departures bound to ZDC airspace to ZTL’s boundary to meet the ZDC-imposed MIT restrictions. Since the summer of 2015, however, ZDC started coordinating APREQ/CFR restrictions directly with CLT Tower to schedule departures bound for Washington, New York, and Philadelphia airports to a metering arc within ZDC airspace. Since then, the use of MIT restrictions has reduced and the use of APREQ/CFR restrictions has increased. On average, CLT scheduled over 1,500 departures that were subject to APREQ/CFR per month in 2016 (see Figure 8). About 57% of all these departures were scheduled by ZDC and 43% by ZTL. A portion of the 2016 months are not reported, due to missing data.

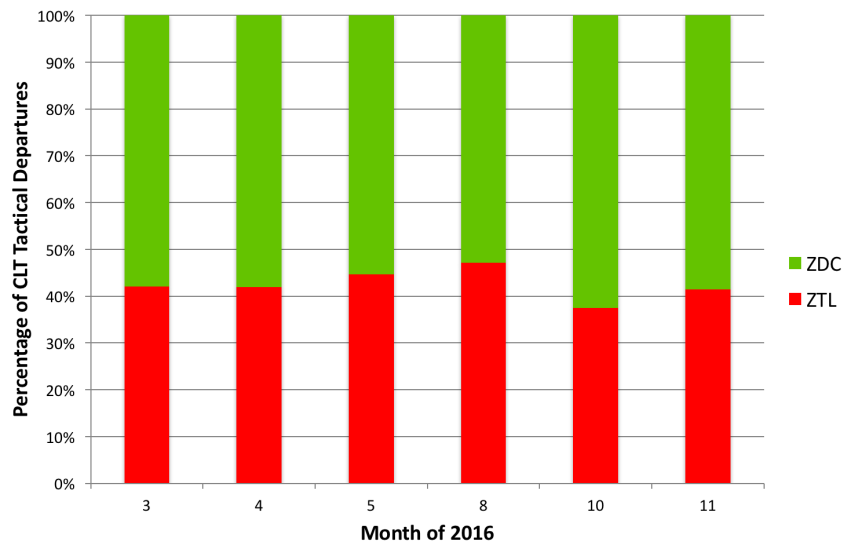


Figure 8 - Departures subject to APREQ/CFR were scheduled by both Washington Center and Atlanta Center.

Figure 9 breaks down the APREQ/CFR scheduling performed by ZDC and ZTL in 2016 into more detail. Each center scheduled the departures into an arrival metering system (inbound scheduling) or at outbound meter points (outbound scheduling). On the ZDC side, about 38% of all departures were scheduled to ZDC’s outbound meter points (ZDC outbound); and about 19% of all departures were scheduled by ZDC to the Newark (EWR) and Philadelphia (PHL) arrival metering systems (ZNY inbound). EWR arrival metering is managed by the New York TRACON (N90), while PHL arrival metering is managed by the PHL TRACON. ZDC manages flows from the south to both the EWR and PHL TRACON boundaries. ZDC has the capability to schedule internal and CLT departures to these airports. On the ZTL side, about 32% of all departures were scheduled in the ATL arrival metering system (ZTL inbound), and about 11% were scheduled to ZTL’s outbound meter points (ZTL outbound).

Due to the majority of flights scheduled in ZDC’s outbound system and ZDC’s deployment of the TBFM/Integrated Departure Arrival Capability (IDAC), the ATD-2 sub-project has focused on ZDC flows in Phase 1, and has developed a solution to add CLT to the airports that schedule departures in ZDC’s IDAC system. IDAC automates the process of TBFM time-based departure scheduling (see section 2.1.2 of the ATD-2 TDD for more information).<sup>7</sup>

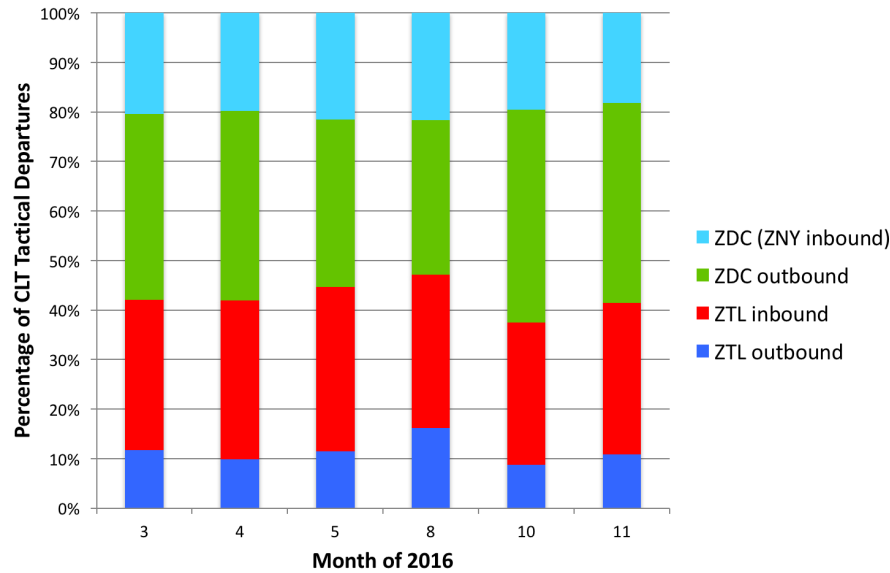


Figure 9 - The APREQ/CFR scheduling enacted by both ZDC and ZTL can be further broken down into outbound scheduling and inbound scheduling.

Today, the CLT Tower TMC calls the Center that has requested the APREQ/CFR restriction (either ZTL or ZDC) to ask for a Request for a Release Time (RFRT), prior to releasing departures headed to the restricted destinations. The respective Center TMC accomplishes the scheduling process.

Current tactical departure scheduling procedures during an APREQ/CFR restriction require increased communication/coordination between the Tower and the Center TMC. The typical APREQ/CFR procedure for CLT is as follows (see Figure 10 for an APREQ/CFR event trace):

- The Center coordinates the APREQ/CFR restriction with the TRACON and Tower TMCs via NTML.
- The Tower, or TRACON, TMC enters the APREQ/CFR restriction in the currently available coordination tool (e.g., NAS Information Display System (NIDS)).
- The Tower's Clearance Delivery (CD) position advises the Pilot to contact the CD for a release time as soon as the aircraft is ready to push back, or within 10 minutes prior to pushback, either via a Pre-Departure Clearance message or via the CD's radio frequency.
- The CD asks the Pilot at what gate the aircraft is parked and the estimated off-block time (in case the pilot calls prior to pushback ready). Then the CD advises the TMC of the flight's pushback time.
- The Tower (generally the TMC) calls the Center TMC and requests a release time, given the TMC's subjective estimate of the flight's takeoff time.
- The Center TMC manually enters the ready time given by the Tower into the TBFM EDC, and schedules the flight to the meter point in the overhead stream. The Center verbally communicates the Scheduled Departure Time (SDT) to the Tower with a void time. The void time provides an indication when the release window will end. Release windows typically extend from two minutes prior to one minute after the assigned SDT,



flight will be recorded as delayed by Air Traffic Control (ATC) (includes 10 minutes for flight to taxi from any spot to any runway, plus an additional 15 minutes).

## **2.2 Limitations of Current Operations**

Managing departure operations in busy airport and airspace environments is a challenge for multiple reasons. Most notably, there is limited data sharing and system integration amongst stakeholders (flight operators and air navigation service providers), who do not share a common situational awareness, and each of whom have their own objectives which often conflict, or compete, with one another. These conditions contribute to reactive decisions under short planning horizons, and results in overall reduced efficiency and predictability. In this section, some of the major limitations of current departure operations are described. Many of these limitations were identified through broad stakeholder surveys conducted during the pre-formulation phase of the ATD-2 sub-project.<sup>8</sup>

### **2.2.1 Airport Departure Demand Exceeding Capacity**

At most airports today, departures are managed in a largely reactive manner, based on the order that aircraft arrive at the spots and call for taxi clearance. In this ‘first-come, first-served’ (FCFS) operation, pilots are motivated to push back from the gate as early as possible in an attempt to meet on-time performance metrics. With many flights having similar ticketed departure times, congestion on the airport surface can result, unless planning tools are available to even out the demand. Further contributing to congestion, both pilots and Ramp Control can be ignorant of TMI restrictions prior to pushback; pilots may choose to push back well in advance of the wheels up times imposed by Traffic Management Initiatives.

CLT experiences regular periods throughout the day where nominal traffic demand, based on flight operator published schedules, exceeds available surface capacity. Furthermore, this nominal traffic demand often exceeds available airspace capacity, requiring TMIs to constrain traffic flows from CLT along specific departure routes, especially those toward airports in the northeast corridor. Surface congestion resulting from imbalances between demand and capacity can result in inefficient stop-and-go taxi operations that delay actual takeoff times and limit airport departure throughput.

Analysis of operational shortfalls at CLT based on 2014 data revealed that, on average, aircraft stopped 4.5 times during the taxi between the gates and the runways, with an average stop duration of four minutes.<sup>22</sup> Here, a stop was defined as when an aircraft's speed fell below one knot for more than one minute and could have included slow progressions in a queue.

An analysis of actual taxi-out times, measured between pushback and takeoff, compared with corresponding unimpeded times along the same taxi routes, revealed that the average excess taxi-out time on the airport surface was 6.3 min per flight across all operations from January through March of 2017. This excess time correlated with an excess fuel consumption of 2,040 metric tons over the same period. Previous analysis pointed to traffic volume independent of weather and visibility as the most common cause of delays at CLT.<sup>23</sup>

### **2.2.2 TMI Coordination and Compliance**

TMIs are implemented in order to manage departure flows into constrained airspace regions and destination airports, but there are inefficiencies in the way TMIs are planned, coordinated, and complied with in today's operations. Due mostly to uncertainties in gate departure time,

departure demand is difficult to predict accurately. This can lead to TMIs, often resulting in unnecessary delays and wasted capacity. Even when effective TMIs are established, congestion on the airport surface and limited coordination of TMI information between the flight operators and Tower controllers make compliance difficult. Limited compliance with TMIs on the surface can lead to corrective control actions in the airspace to insert aircraft into the en route stream and avoid overloading airspace fixes and sectors. Such corrective control actions can add to controller and pilot workload, lead to surface and airspace delays, and increase fuel consumption and emissions. Furthermore, uncertainties in TMI compliance can lead traffic managers to implement overly conservative TMIs that limit airspace capacity.

The most common TMI restrictions that affect departure operations are MIT spacing requirements at departure fixes and Scheduled Departure Times assigned due to APREQ/CFR and EDCT procedures.

MIT restrictions to manage demand and capacity across multiple facilities are limited in their application and execution. When MIT restrictions are applied to multiple flows over designated periods of time, they lack the flexibility needed to account for small fluctuations in traffic demand, in particular within a given departure flow. As a result, flights may be unnecessarily delayed at the airport when traffic demand no longer justifies the MIT affecting their departure route. There is also limited awareness between stakeholders about the MITs put in place at departure fixes, which compromises situational awareness and potentially limits flight efficiency, especially when capacity is severely limited due to weather. Finally, accurately complying with MIT restrictions is also highly challenging in today's environment, where controllers must rely on experience and best practices to stage departures for takeoff and translate spacing off the runway to desired spacing in the airspace.

APREQ/CFR procedures today are cumbersome, and lack both predictability and situational awareness. Both the Tower and the Center need to coordinate every departure's Scheduled Departure Time verbally over the phone. The Tower relies on experience and best practices to manually estimate the departure's OFF time (i.e., the Earliest Feasible Takeoff Time (EFTT)). The Center then relies on the time the Tower verbally provides to look for the earliest time available in the overhead stream. Due to congestion and queuing on the airport surface, the manually-estimated OFF time is subject to large uncertainty.

There are other factors both on the aircrew and the ATC sides that add to the complexity in OFF time estimations. For instance, the Tower may assign a release time to a flight, based on the estimated pushback time provided by the pilots. However, if the pilots encounter a problem that delays their pushback (e.g., a mechanical, baggage, passenger, or ground crew issue), the Tower may not be aware of the delay and the pilots may not be aware of the need to communicate the issue to Tower. On the ATC side, the Center TMC is often not aware that the departure may be able to meet an earlier OFF time, which could result in reduced surface congestion. Likewise, the Tower personnel are not aware of earlier slots in the overhead stream that may open up.

The lack of integration between the flight operator tools, TBFM, and surface automation also impacts APREQ/CFR procedures. Currently, the Center relies on demand predictions based on departure times that are provided in the flight plans, and the Tower relies on the pilot's verbal request of release time to initiate the APREQ/CFR procedure. The lack of planning and predictability in demand prior to pushback leads to unnecessary waiting and difficulties in staging aircraft to comply with the restrictions themselves. Also, the Center TMC has limited

awareness of the intended trajectory and the sequence of departures in the queue (e.g., the ZTL TMC currently uses a commercial DST surface display to see the position of aircraft on CLT's AMA).

Accurately complying with release times presents a considerable challenge in the presence of surface congestion and the resulting uncertainty in aircraft movements. Compounding the challenge are occasional inconsistencies between strategic EDCT times and tactical APREQ/CFR times for aircraft subject to both types of constraints. An examination of TMI compliance at CLT in 2014 showed that 42% of flights took off outside of the desired +/- five minute EDCT compliance window, and that 58% of flights took off outside of the default APREQ/CFR compliance window of two minutes before through one minute after the target OFF time. Studies have shown that many airports across the NAS have similar levels of TMI compliance as CLT.

Often it is operationally necessary to underutilize certain flows to avoid cumulative downstream oversaturation. However, the preliminary findings suggest throughput shortfalls that could be remedied through improved TMI coordination.

### ***2.2.3 Flight-Time Predictability***

In today's operations, there is significant uncertainty in the departure phase of flight due to uncertainty in pushback times and variance in movement times during taxi-out and climb. Analysis of CLT operations from January through March 2017 revealed a standard deviation in taxi-out time of 7.7 minutes. Climb trajectories from CLT show that flights are often taken off of their RNAV routes and sent direct to downstream fixes. While this practice improves the efficiency of flights that receive shortcuts, it induces a lack of predictability in the time the aircraft reaches the overhead stream, which leaves the overhead sector controller with suboptimal flow insertion scenarios. This lack of predictability also leads to inaccuracies with regard to real-time or near-term traffic demand predictions.

The lack of predictability in takeoff times can also limit the performance of arrival metering in TBFM, when flights depart near to or within the TBFM freeze horizon. Additionally, a lack of predictability in flight transit time from the runway to the meter point may also come from missing flight intent information (e.g., runway assignment, runway configuration) for specific flights, which may increase the uncertainty for compliance at the meter points.

Departure uncertainty not only affects flight predictions on a near term basis, but also affects flight operator block time decisions in the longer term. Scheduled block times (i.e., the gate-to-gate times published by flight operators between city pairs) have trended upwards in recent years in response to increasing NAS uncertainty, particularly in the departure domain.<sup>24,25</sup> While larger block times help flight operators manage on-time performance, they limit fleet utilization and increase personnel and fuel costs. In addition, inflated block-times often result in flights arriving earlier than expected and having to compete with departures for gate resources.

### **3 IADS System Justification**

This section seeks to substantiate the changes required in today's operational environment that will be addressed by the IADS system, to enhance operational efficiency, predictability, and throughput. It also describes the benefit mechanisms of the IADS system, as well as assumptions and constraints.

#### **3.1 Justification for Changes**

The deficiencies and challenges in today's airport and airspace operations at CLT, summarized in the previous section, justify the implementation of new technologies and procedures proposed by the IADS system. The shortfall analysis,<sup>23</sup> conducted in the ATD-2 sub-project planning phase, provides quantitative measures of deficiencies in three major focus areas: operational efficiency, predictability, and throughput. The need for changes to the current system to improve these areas can be summarized as follows:

- The efficiency of surface operations can be improved by the accurate prediction of flight ready time and better planning of aircraft surface movement, thus reducing runway queue size, excess taxi-out time, and fuel burn. Planning for aircraft surface movement through strategic demand/capacity balancing and tactical surface scheduling would assist the controller's decision for departure pushback.
- The primary challenge faced by Ramp Control, in order to improve overall airport operations, lies in deciding the pushback sequence of aircraft during peak departure periods, especially when multiple aircraft are ready to depart simultaneously. The lack of common situational awareness and the uncertainty in taxi time predictions for departures during peak periods can make it challenging for Ramp Control to determine the time and sequence in which aircraft should pushback for efficient surface operations. The automated runway capacity prediction, tactical surface scheduling, and metering capability of the IADS system will generate pushback advisories for the ramp controller for efficient surface operations.
- The primary challenge associated with present-day tactical departure scheduling for APREQ/CFR flights is that the predictions of earliest feasible takeoff time used in this process are manually estimated with incomplete knowledge of pushback readiness and without the knowledge of future surface traffic demand. Improved OFF time predictions by the IADS system will significantly reduce missed overhead stream insertion opportunities for departure aircraft under APREQ/CFR restrictions, and further increase throughput of the en route sector traffic.
- The predictability of the flight transit time from the runway to the meter point can be improved by using the airport configuration and the runway assignment information for each departure. Currently, TBFM/IDAC does not have the capability to optimize the departure trajectory from the specific departure runway. For example, it does not differentiate departures from RWY 18L and RWY 18C at CLT, so only the departure direction is used in scheduling the aircraft to the meter point. The calculation of the Scheduled Departure Time depends on flight transit time estimates. The IADS system's improved surface modeling capability and the sharing of airport configuration and departure runway assignment information with TBFM will improve the calculation of ETAs at the meter points.

- The communication of TMIs between the Tower and the Center is limited today. The IADS system will enhance awareness of the airport surface traffic situation. It will provide better information when identifying the need, exploring alternatives, and preparing the justification for a TMI. It will help with monitoring, evaluating, and making adjustments as needed, including cancellation. Automated functions to coordinate MIT, EDCT, and APREQ/CFR procedures will also contribute to eliminating voice calls between the facilities.
- In today's operations, the mechanisms for Ramp Control and the Tower personnel to exchange information and coordinate traffic management decisions are cumbersome. For example, coordination for runway configuration changes, departure fix closures, or notifications of TMIs still rely on voice communications, which can result in an increased workload and more potential for human errors. The IADS system will replace most voice communications with an electronic data interface to exchange data between the Ramp and the Tower.
- In today's Tower operations, paper flight strips are predominantly used to manage flight data and updates to flight information often require the controllers to manually update the strips, thus causing inefficiency in the transfer of updated flight data. In the Phase 1 Baseline IADS Demonstration, the current day paper strips will be replaced by the prototype TFDM EFD, which displays the latest flight information in a digital format. In later demonstration phases, the EFD will be integrated with the IADS system and share information via an electronic data interface, providing an easier transfer of updated information.

### **3.2 Benefit Mechanisms of the IADS System**

This section describes the key expected benefit mechanisms of the IADS system. It is anticipated that the IADS system will improve the efficiency and predictability of operations on the airport surface while maintaining or improving throughput. Improvements on the airport surface can lead to benefits in the airspace and eventually lead to benefits on a NAS-wide scale.

NASA has developed Measures of Performance (MOPs) and Key Performance Parameters (KPPs) for assessing the benefits-related impact of the IADS system. KPPs are a subset of the MOPs, and are regarded as primary technical measures for tracking the overall success of the ATD-2 sub-project and the maturation of its IADS technology.<sup>27</sup>

#### **3.2.1 Efficiency Benefit Mechanisms**

Efficiency benefits pertain to the reduction of aircraft movement times and associated excess queue times, fuel consumption, and direct operating costs. For departures, movement times include transit times between gates and runways and flight times between runways and downstream fixes in the airspace. Efficiency improvements are mostly enabled through IADS data sharing and integration, together with surface scheduling and metering during peak traffic conditions to balance demand and capacity. Key anticipated benefit mechanisms include:

- *Reduced taxi times due to time-based metering:* The IADS system provides surface scheduling and metering to balance demand and capacity during peak traffic periods. When needed, metering prescribes holding at the gate or in the non-movement area to reduce queuing on taxiways and minimize overall surface congestion. Holding at the gate



prior to the engine start can reduce taxi movement times and the associated fuel consumption and emissions. Gate holds due to metering are expected to be offset by related reductions in taxi movement times, leading to no change in takeoff times and potentially reducing takeoff delays.

- *Less TMI-induced delay due to improved airspace scheduling:* Trajectory-based takeoff time predictions that incorporate improved EOBT intent from flight operators facilitate earlier and improved scheduling of flights subject to APREQ/CFR restrictions. TMI scheduling is further improved through the integration of the IADS decision-support tools with the FAA's IDAC for airspace scheduling directly from the Tower. Improved TMI scheduling can lead to more favorable and achievable scheduled departure times, with less TMI-induced delay and less need for rescheduling due to missed slots.
- *Reduced taxi times due to staging of flights from gates to meet TMIs:* By incorporating TMIs into its departure scheduling, the IADS system allows Ramp Control to stage flights from the gate to meet TMI takeoff time restrictions. This can reduce the need for holding and resequencing of flights on the airport surface, thereby reducing movement times and associated fuel burn and tarmac hold times.
- *Less maneuvering in the airspace due to better TMI compliance at takeoff:* Better compliance with APREQ/CFR restrictions at takeoff can lead to fewer and less disruptive maneuvers once flights are airborne, to adhere to downstream traffic-flow constraints for overhead stream insertion and the balancing of airspace demand and capacity. This can result in more efficient climb trajectories with fewer required level-offs, speed changes, and vectoring. Less maneuvering and associated delay may also result for other traffic flows that are merging with departures at en route meter points.

### **3.2.2 Predictability Benefit Mechanisms**

Predictability improvements pertain to reducing the variance of transit times for both departures and arrivals, and improving the prediction of future aircraft locations and events. Key anticipated benefit mechanisms include:

- *Better TMI planning due to improved compliance and improved departure demand forecasts:* Better compliance can reduce the occurrences of missed/spoiled slots in the airspace, leading to better airspace capacity utilization. Improved compliance could eventually lead to tighter release tolerances and spacing requirements at meter points, which can increase airspace capacity and reduce delays for existing traffic levels. In planning TMIs, improved initial departure demand predictions from the IADS system could lead to fewer and less conservative TMIs, with less capacity-reducing buffers to compensate for uncertainty.
- *Better runway capacity management due to data exchange and prediction:* The acquisition and sharing of runway intent data, together with improved trajectory predictions, can lead to better runway capacity planning and usage decisions. This can result in reduced taxi times for departure and arrival flights, particularly those operating from dual-use runways.
- *Better flight operator resource planning due to improved flight prediction:* Using improved flight predictions from the IADS system, flight operators can make more

informed decisions affecting passenger connections, equipage, and personnel resources. In particular, improved arrival and departure predictions can lead to better gate resource management, potentially reducing the frequency and duration of gate conflicts. This can result in fewer delays and better on-time performance.

- *Shorter flight operator-scheduled block times due to better predictability:* Improved departure predictions with the IADS system can lead to better gate-to-gate flight duration predictions. Sustained predictability improvements could eventually lead to shorter scheduled block times with reduced buffers to account for uncertainty. Reduced scheduled block times can lead to savings in direct-operating costs, allow better usage of flight operator equipage and personnel resources, and reduce the occurrence of early arrivals competing with departures for gates.

### **3.2.3 Human-Factors Benefits Mechanisms**

There is also a wide range of improvements anticipated from the IADS system from the users' perspectives that include:

- Improved situational awareness due to data sharing among users and accessing of required data via SWIM.
- Reduced workload due to the automatic computation of predicted OFF time and automated communication between the surface and en route systems.
- Reduced workload for the ramp controller by using gate pushback advisories generated by tactical surface scheduling.
- Reduced workload for the TRACON/Center controllers, due to improved scheduling of departures at constrained fixes and better compliance of OFF times.
- Improved situational awareness and coordination among the Tower controllers, due to the use of EFD, which displays the latest flight information and TMI information.
- Improved situational awareness and coordination among Ramp Control due to the use of the Ramp Traffic Console (RTC) and the Ramp Manager Traffic Console (RMTC), which display the latest flight information and TMI information.
- Improved situational awareness and coordination between the Ramp and the Tower due to integration of Tower information, such as runway assignment and runway configuration, into the RTC and RMTC.

### **3.2.4 Benefit Mechanisms for Local Operational Improvements**

To develop a full benefits picture, the concept of local operational benefits was developed to capture operational benefits and insights on a more granular level. These hard-to-quantify benefits may otherwise be difficult to capture using traditional data analysis techniques. As the ATD-2 sub-project focuses on improving aviation system demand and capacity forecasts, a process and corresponding set of metrics must be developed to capture the benefits of the operational improvements due to these forecasts. The goal of this subset of the benefits work is to develop a close collaboration with the CLT users and to provide them with the data and metrics that would be best suited to reflect the operational realities that are faced on a daily basis. Key anticipated benefit mechanisms include:

- Better surface capacity management and improved situational awareness through quantification and prediction of arrival and departure banks: The analysis and prediction of aircraft banks can provide both the Tower and the Ramp with information regarding possible deviations from normal operations so that adjustments can be made to mitigate surface congestion. This information can lead to better runway capacity planning and usage decisions, and can result in reduced delays for departure and arrival flights.
- Improved situational awareness and coordination among Ramp Control through gate conflict predictions: The STBO\*\* Client and the RTC provide ramp controllers with information regarding immediate gate conflicts as well as those that may occur in a longer time horizon, up to thirty to forty-five minutes prior to an arrival aircraft landing. This information can lead to better surface and ramp usage, as well as improved planning, and can result in reduced taxi-in times and delays for arrival flights.

### 3.3 Assumptions

The following are assumptions used in the development of this ConUse for the Phase 1 Baseline IADS Demonstration at CLT. These assumptions are primarily about external inputs that the IADS system must receive in order to produce intended operational benefits.

- Flight operators will provide EOBTs for their flights to TFMS, according to the specification for the Surface CDM data elements, for surface scheduling.<sup>26</sup> The IADS system will receive this information via a SWIM interface to calculate the demand prediction, the taxi time estimation, and pushback advisories. Alternatively, the IADS system may receive EOBTs directly from the flight operator data feed.
- Flight operators will provide the updated gate/spot assignment and any flight cancellation information via a SWIM interface or a direct flight operator data feed. Flight operators will optionally provide the list of priority flights. This information can also be provided to the IADS system by Ramp Control through the user interface. Note: ‘Priority flights’ herein refers to the flights that are designated by the flight operators, due to their business objectives. The IADS system's tactical surface scheduling enables a swap among flights from the same flight operator, based on their priority.
- Flights subject to TMIs (e.g., Ground Delay Program (GDP), APREQ/CFR, and MIT restrictions) will be identified for the IADS system via NTML or via inputs from the Tower TMC through the user interface. TFM Data (via SWIM) will provide the IADS system with the EDCT times for the flights affected by a GDP.

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\*\* The Surface Trajectory Based Operations (STBO) system is a collection of surface trajectory-based capabilities that provide IADS automation for the airport surface operation. It includes capabilities such as strategic and tactical surface scheduling, EFD capability, interaction with other NAS Decision Support Tools (DST) like TBFM, airport configuration and general awareness capabilities, and outgoing data feeds to industry. See the ATD-2 Technology Description Document for more information.<sup>7</sup>

- Surface traffic management information (e.g., runway utilization intent, runway closures, departure fix closures) will be provided to the IADS system via manual entry by the Tower TMC.
- TBFM-generated, de-conflicted, runway landing times (i.e., unfrozen Scheduled Times of Arrival (STAs)) and TRACON controller scratchpad entries of runway assignments for aircraft arriving in CLT will be available to the IADS system.
- Aircraft surface track data from Airport Surface Detection Equipment – Model X (ASDE-X) are available both in the ramp area<sup>††</sup> and the AMA. Aircraft track data in the terminal and en route airspace will be available via the Standard Terminal Automation Replacement System (STARS) and the En Route Automation Modernization (ERAM) systems, respectively.
- The FAA will deploy and maintain the early implementation prototype of the TFDM EFD at CLT prior to the Phase 1 demonstration, according to the Joint Project Management Plan.<sup>28</sup>
- All required incoming data feeds that NASA requires to run the IADS system will be available and of sufficient quality and stability to enable IADS functions.

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<sup>††</sup> ASDE-X data for both the movement and the non-movement (ramp) area is available through the SWIM Terminal Data Distribution System (STDSS). The ramp area surveillance is augmented through a separate data feed to the IADS system from American Airlines.

## 4 Concept for the Proposed IADS System

This section outlines the concept of the proposed IADS system for the Phase 1 Baseline IADS Demonstration. The primary focus for the 2017 timeframe is to demonstrate the baseline IADS capability that includes data exchange and integration, surface modeling, surface scheduling and metering, and automated APREQ/CFR coordination between the Tower and Center.

In the Phase 1 demonstration, the initial features of strategic surface scheduling are implemented in predictive mode and evaluated with live traffic data. The tactical surface scheduler generates target times of departure flights at runways, spots, and gates using the latest runway utilization intent, flight status, and TMI information. Tactical surface metering capability includes functions to manage metering decisions and provide Ramp Control with pushback advisories. The tactical departure scheduler automates the coordination between CLT and ZDC for APREQ/CFR restrictions, using improved OFF time predictions. The TFDM EFD provides the Tower personnel with flight data in a digital format, replacing paper strips and achieving better situational awareness.

### 4.1 Description of the Proposed System

This section describes the IADS operational environment, gives an overview of the IADS system components, and outlines the user groups and other personnel involved.

#### 4.1.1 Operational Environment

Figure 11 illustrates the operational environment for the IADS system in the Phase 1 Baseline IADS Demonstration. The upper portion of the figure depicts en route airspace controlled by the

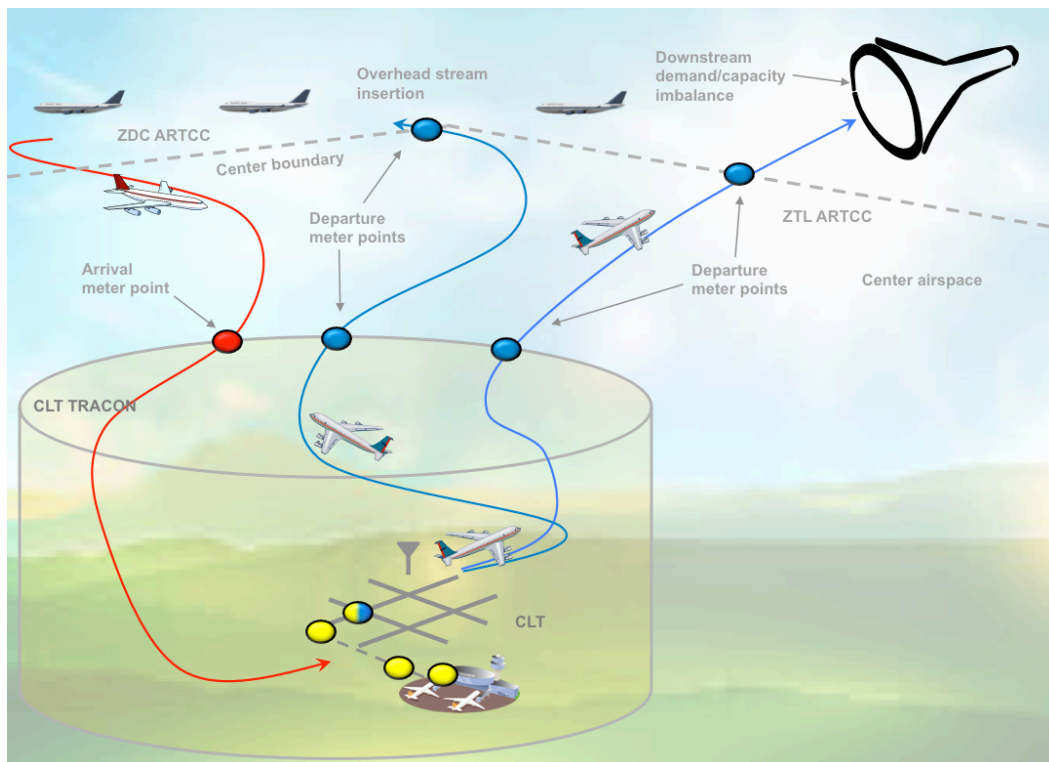


Figure 11 - A simplified view of the ATD-2 sub-project operational environment for the Phase 1 Baseline IADS Demonstration illustrates a variety of surface and airspace interactions.

Centers. The dashed line represents the boundary between the Home Center (e.g., ZTL) and the adjacent Center (e.g., ZDC). The cylinder in the lower portion of the figure represents terminal airspace controlled by the CLT TRACON facility. The CLT Tower manages surface traffic in the AMA, and the AAL-operated Ramp manages traffic in the CLT ramp area.

The operational environment graphic shows aircraft trajectories departing from (blue) and arriving to (red) the terminal airspace. The colored ovals illustrate some of the meter points at which air traffic is scheduled, either by automated systems or manual procedures. Red ovals are arrival meter points. Blue ovals are departure meter points. Yellow ovals are surface meter points. The OFF points, represented by half yellow/half 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 11 represents a downstream demand/capacity imbalance that results in departure restrictions on the local terminal airspace.

#### 4.1.2 Operational View of IADS System

Figure 12 shows the operational overview of the IADS system for the Phase 1 demonstration, highlighting where the core capabilities of the system will be located and who the key users of the system will be. The blue shaded region shows the users of airspace components and the green shaded region shows the users of surface components of the IADS system. The yellow shaded region shows the users of external systems that interface with the IADS system.

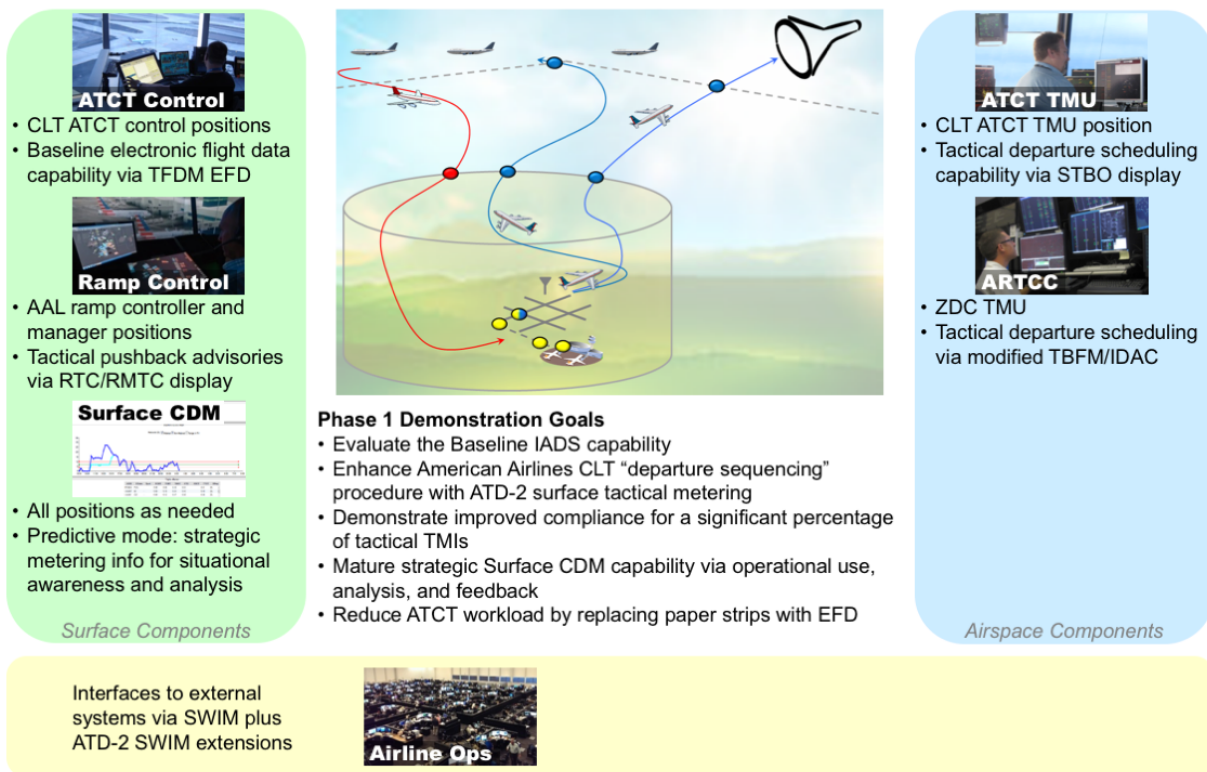


Figure 12 - The operational overview of the IADS system highlights the participants and system improvements for the Phase 1 Baseline IADS Demonstration.

#### **4.1.2.1 Tactical Surface Scheduling**

The Ramp Control image (in the middle left side of Figure 12) represents the tactical surface scheduling capability of the IADS system. Specifically, this image shows the Ramp Traffic Console (RTC) user interface in use by a ramp controller. The purpose of the tactical surface scheduling is to schedule takeoff times of departure flights, provide the ramp controller with gate-hold/pushback advisories that reduce surface congestion, and respond to surface and airspace constraints. The RTC user interface displays pushback advisories to the ramp controller when surface metering is on, and allows the controller to communicate intent information to the IADS system. The flights under APREQ/CFR or EDCT restrictions will also receive pushback advisories from the tactical surface scheduler that will satisfy the release times with less time spent on the surface.

This part of the IADS system leverages NASA's SARDA research activity<sup>3</sup> and investments made by US Airways/AAL in high-fidelity simulation experiments at NASA's Future Flight Central (FFC) simulation facility.

#### **4.1.2.2 Strategic Surface Scheduling**

The Strategic Surface Scheduling graphic (in the lower left side of Figure 12) represents the strategic surface scheduling capability of the IADS system. Specifically, this image depicts the demand/capacity balance projections computed by the Departure Reservoir Management (DRM) system. This part of the IADS system leverages investments made by the FAA and the Surface CDM Team in developing the Surface CDM ConOps.<sup>1</sup>

The DRM metering capability continuously monitors the airport demand/capacity balance (either by overall airport or individual runways as metering resources) and recommends Departure Metering Programs (DMPs) and associated Target Movement Area entry Times (TMATs), computed according to Ration by Schedule (RBS) principles.

#### **4.1.2.3 Tactical Departure Scheduling**

The two images in the upper right portion of Figure 12 represent the Tactical Departure Scheduling capability of the IADS system. The picture labeled "ARTCC TMU" shows a Center TMC using the TBFM interface to schedule an APREQ/CFR departure into the en route traffic flow. The picture labeled "ATCT TMU" shows the surface side of this APREQ/CFR scenario, with a Tower TMC using the STBO display to coordinate a release time with the Center. This part of the IADS system leverages NASA's PDRC research activity<sup>4</sup> and the FAA investments in TBFM/IDAC.

Tactical departure scheduling is the essential link between the surface and airspace portions of the IADS challenge that the ATD-2 sub-project is designed to address. In the Phase 1 Baseline IADS Demonstration, the tactical departure scheduling capability will be installed at the CLT Tower and at ZDC to facilitate automated APREQ/CFR coordination and demonstrate improved compliance for a significant percentage of tactical TMIs. TMCs in the Center and Tower will use this part of the IADS system to better plan and implement TMIs, with information provided by the surface elements of the IADS system.

#### **4.1.2.4 Electronic Flight Data (EFD)**

The image in the upper left portion of Figure 12 represents the TFDM EFD portion of the IADS system. Specifically, the picture shows a Tower controller using the FAA's Advanced Electronic

Flight Strips (AEFS), an early implementation prototype of TFDM EFD, at Phoenix Sky Harbor International Airport (PHX).<sup>29</sup> In response to the NAC recommendations, the FAA has committed to installing a prototype of the TFDM EFD at several airports as part of the TFDM early implementation effort.<sup>9</sup>

The prototype TFDM EFD will be a crucial link between the IADS system and the Tower controllers as they interact with the system and implement TMIs on the airport surface. However, in the Phase 1 demonstration, there will be no direct interface between the EFD and IADS system. In the Phase 2 and Phase 3 demonstrations, the EFD will be integrated with the IADS system for data exchange between the two systems.

**4.1.2.5 TFDM SWIM Prototype Data Feed**

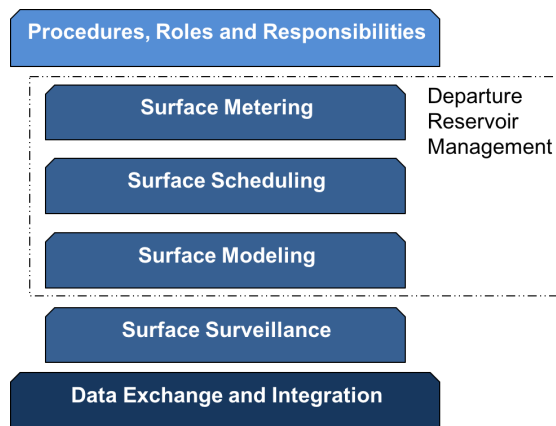
The IADS system will provide a TFDM SWIM prototype data feed (see the image in the bottom portion of Figure 12) and serve as a pathfinder for TFDM data exchange with industry. The primary purpose of the TFDM SWIM prototype data feed is to make data available to the stakeholders collaborating on the ATD-2 sub-project. The information provided in the IADS system TFDM SWIM prototype data feed is consistent with that envisioned by the future TFDM system.

In the Phase 1 Baseline IADS Demonstration, the TFDM SWIM prototype data feed is expected to provide all the TMI data related to CLT, surface scheduling related information, flight specific estimates generated by the system, and other flight data required by external parties wishing to build applications that provide value-added services to CLT stakeholders.

**4.1.3 IADS System Conceptual Elements for Phase 1 Demonstration**

This section provides a high-level description of key conceptual elements of the IADS system for the Phase 1 demonstration. The concept has been matured through interactions with user groups, multiple shadow evaluations, and high-fidelity human-in-the-loop simulations.

Figure 13 shows layers of the conceptual elements of the IADS system. This is a modified version of the building-block depiction of the Surface CDM capabilities, as defined in the FAA Surface CDM ConOps. This version of the diagram breaks down the conceptual components of the Surface CDM Departure Reservoir Management (DRM) into more specific functional elements. These functional elements are described in more detail in the ATD-2 TDD.<sup>7</sup>



*Figure 13 - The Departure Reservoir Management (DRM) function of the Surface CDM ConOps is represented by three functional elements in the IADS system.*



Data exchange is foundational. For example, the detailed arrival and departure demand information shared by the IADS system is important to runway utilization planning by the Tower TMC.

The Surface CDM ConOps focuses on a surface scheduling and metering capability to resolve demand/capacity imbalances on the airport surface. The IADS concept integrates this capability with the TBFM/IDAC scheduling necessary to satisfy the APREQ/CFR release times and other airspace constraints.

Surface scheduling supports surface metering by generating the target times at control points on the surface, including the runway, spot, and gate. Surface metering is active when outputs from surface scheduling (primarily TOBTs in Phase 1) are broadcast to the ramp controllers for issuing hold/push advisories. Metering is the mechanism that ensures conformance to the scheduled times (i.e., how demand is ultimately adjusted via the schedule).

#### ***4.1.3.1 Data Exchange and Integration***

Data exchange and integration is a foundational capability of the IADS system for the Phase 1 demonstration. There is a single IADS system running that allows multiple users to interact with one another through the automation. Users share the same data, exchange information, and make decisions collaboratively. Through this capability, users working at different facilities, such as the Tower and the Ramp, will have common situational awareness, thus enabling reduced voice communications in daily operations. Additional information on ATD-2 data exchange and integration can be found in sections 4.1.5-4.1.7 of the ATD-2 TDD.<sup>7</sup>

The following list provides an example of the types of information shared via the IADS system. These data exchange and integration items were identified during the ATD-2 Agile requirements refinement effort which consisted of shadow sessions with the CLT ATC Tower and the AAL Ramp Control. This information includes:

- Runway utilization
- Runway assignments
- Handling of MIT restrictions
- EDCTs
- APREQ/CFR
- Ground stops
- Runway closures
- Departure fix closures
- Gate assignments
- Flight cancellations
- Gate conflicts
- Ramp closures
- Long on Board (LOB) common awareness

The Tower TMC can input runway utilization plans or TMI restrictions (e.g., MIT, APREQ/CFR, and Ground Stop) through the TM Actions drop-down menu under the STBO Client toolbar. Ramp Control can also input their decisions or requests (e.g., runway assignment, flight cancellation and ramp closure) through their RTC/RMTC user interfaces. These inputs are then shared with the Tower and displayed on the STBO Client. Other items, such as the Long on

Board common awareness, represent system-generated information for situational awareness purposes to alert both controllers and managers. More information on each of these data exchange elements is found in section 5.4.

#### 4.1.3.2 Demand and Capacity Prediction

Demand and capacity predictions are very important to the system, especially during surface metering. The IADS system performance will be only as good as the input data. Accurate manual estimates for Airport/Runway Arrival Rate (AAR and RAR) and Airport/Runway Departure Rate (ADR and RDR) are difficult to produce and update as frequently as needed for surface metering. Inaccurate ADR/AAR and RDR/RAR values will result in a surface metering solution that does not satisfy the traffic management goals.

By design, the capacity prediction logic in the IADS system does not require manual entry of an ADR/AAR or RDR/RAR. Lessons learned from other tactical metering concepts, like TBFM, show that manual rate estimates can lead to errors in system capacity estimates. The ATD-2 sub-project is applying this lesson to tactical scheduling and metering performed by the IADS system. The key to accurate capacity estimates are good inputs and the automated calculations in the IADS system, as shown in Figure 14.

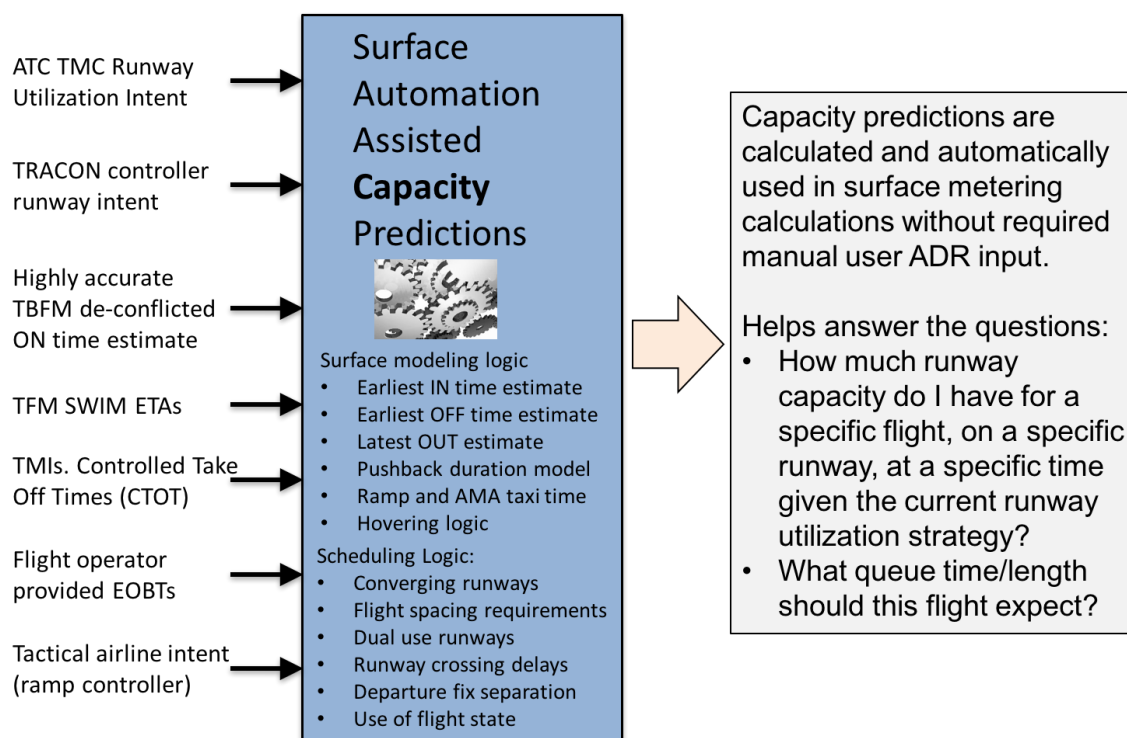


Figure 14 - The capacity prediction automatically updates the capacity of each runway, using various inputs, without relying on manual entries.

- The ATC TMC’s runway utilization intent includes current and future configuration/flow information. In addition, it specifies how the TMC intends to use the runway resources within the expected flow (e.g., converging runway operations or parallels). The IADS system allows the TMC to specify these key intent inputs by directly clicking on the

STBO Client timeline at the time the event is expected and picking from a drop-down list of pre-specified runway utilization options.

- The TRACON controller's runway assignment comes into the system from the STARS scratchpad entry. At CLT, TRACON controllers enter this value and it has been found to be very helpful in the early determination of runway assignment. The IADS system responds to this TRACON intent information by updating the arrival runway in the Research TBFM (RTBFM) system, where RTBFM updates the runway ETA and STA for this flight. The updated runway is also shown on the STBO Client timeline for overall situational awareness of this TRACON controller decision.
- The ON time estimates that the IADS system uses are from a RTBFM system that has been tuned to provide highly accurate ON time estimates. Analysis has shown that the most accurate tactical arrival ON time estimates come from the unfrozen TBFM STA. This is because the TBFM system provides some de-confliction with other TRACON arrival flights, based on the latest information available.
- The TFM SWIM ETAs are also important, especially for longer lead time predictions required for the strategic time frame. Since TBFM typically has only the first tier/adjacent Center feeds, the TFM ETAs provide additional information in areas where flights might be actively tracked into CLT, but are not yet in the RTBFM system for its prediction. The STBO Fuser component processes and synthesizes inputs from disparate data sources to provide a consistent set of fused data to STBO (see section 4.1.6 of the ATD-2 TDD<sup>7</sup>) and incorporates a mediation logic that judges the best ETA/ON time it has from multiple sources, and thus it only makes use of the TFM ETAs if no RTBFM STA is available. This logic also offers some redundancy for the system. Note that RTBFM is a field demonstration artifact and would not be part of an end-state implementation. RTBFM runs in parallel with the FAA Operational TBFM system and is used only to provide data to the IADS system and is not directly used by the TMCs or controllers.
- A knowledge of TMIs is important, especially for capacity predictions regarding the flights that already have a Controlled Takeoff Time (CTOT) specified by ATC. If a flight has an APREQ/CFR release time or an EDCT, it essentially has an appointment at the runway around which other flights must be scheduled. CTOTs use capacity that is not available for non-CTOT flights when considering demand/capacity imbalances. In that regard, this 'known quantity' of existing TMIs is important when it comes to capacity prediction.
- An EOBT provided by the flight operator gives the IADS system a much better estimate of when the flight will push back than a gate time from the flight plan. While EOBTs are widely understood to be essential for accurate departure *demand* estimates, they are also an important part of the IADS system instantaneous *capacity* estimation. For instance, if it is known that a number of flights that are departing in a bank are later than their planned/scheduled departure time, this might affect the Tower TMC's decision regarding runway utilization. In this case, the TMC may prefer a runway utilization strategy that allows more arrivals to land first, since the departures are later than normal. This change in runway utilization strategy in turn affects the departure runway capacity, which could lead to different taxi-out time estimates for each departing flight. In this way, capacity

prediction and demand forecasts are closely linked, and rely upon the system planners to use this information to achieve their objectives.

- Information obtained from the flight operators about flights that have begun their pushback process is important to capacity prediction. The IADS system currently allows the CLT ramp controllers to provide pushback and hold intent via the RTC display. This intent can give the system insights that may not be gleaned directly from system-generated OUT messages that often come through door closure and brake release events. The ‘cleared to taxi’ decision indicator in RTC also provides intent that the flight is released to taxi in the ramp area, and thus, the IADS system will begin its ramp taxi calculations from this point.

All these inputs are fused together and delivered as consistent input to the Surface Modeler, which then adds key trajectory-based calculations based on these events. The model provides unobstructed taxi time estimates based on its knowledge of where the flight currently is and where it wants to go (e.g., spot through departure runway). If a flight is later than expected, the trajectory start point is updated based on ‘hovering’ rules,<sup>‡‡</sup> which essentially offset the start time using the current time and position of the flight. A detailed functional description of the Surface Modeler is given in section 4.1.1 of the ATD-2 TDD.<sup>7</sup>

The surface scheduler then takes this input and improves predictions by applying spacing rules that are in effect for the specific aircraft type and meteorological conditions. The scheduler also applies any special rules that may be in use such as: converging runway operations modeled spacing, dual-use runway operations modeled spacing, runway crossings that may lead to more departure queue time, and departure fix separation rules. A functional description of the tactical scheduler is in section 4.1.2 of the ATD-2 TDD.<sup>7</sup>

The outputs of the IADS system capacity prediction are immediately usable in surface metering, without any additional manual entries from users. The departure demand that is being analyzed for potential surface metering makes use of the available slots from the capacity prediction and the scheduler calculates the estimated time-in-queue on a flight-by-flight basis, given the latest capacity and the best estimate of when the flight could get to the runway. This in turn enables traffic managers to see expected average excess queue times at the runway for various look-ahead times and decide whether or not surface metering is warranted.

#### **4.1.3.3 Surface Modeler**

Surface modeling is the next layer shown in Figure 13, building on top of surveillance and data exchange. With data from external sources, such as surface surveillance, TBFM, TFMS, and flight operator data feeds, along with user inputs (through data exchange and integration), the IADS Surface Modeler updates the state of each flight and predicts the gate, spot, runway, and taxi route.

Ultimately, the Surface Modeler’s function is to predict unobstructed trajectories of aircraft on the surface and generate estimated takeoff times for the surface scheduler to use in computing

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<sup>‡‡</sup> ‘Hovering’ rule is defined as: If the scheduled/target pushback time of an aircraft has passed while the aircraft’s pushback event has not been detected by the surveillance, the trajectory start time is offset to the current time, with the aircraft position unchanged.

target times for takeoff, spot release, and gate pushback. The Surface Modeler relies on accurate gate departure time estimates based on Earliest Off-block Times (EOBTs) and other flight readiness status, such as pilot call-in, to predict takeoff times. The Surface Modeler also receives ON time estimates and landing runway assignments from TBFM for the arrival aircraft to use for trajectory prediction and scheduling. More details on the Surface Modeler can be found in section 4.1.1 of the ATD-2 TDD.<sup>7</sup>

#### **4.1.3.4 Surface Scheduling**

The IADS Surface Scheduler generates Target Takeoff Times (TTOTs) for departure flights based on taxi routes and times predicted by the Surface Modeler, with constraints from previously described capacity predictions applied.

Since the Surface Scheduler generates TTOTs based on a flight's gate departure time, it is important to have accurate EOBTs in order to predict accurate TTOTs. In reality, however, not every flight's EOBT is of high quality. In order to allocate runway times equitably and fairly in the tactical timeframe, the IADS Surface Scheduler handles flights differently depending on the demonstrated accuracy of their EOBTs (see section 5.2.3.2 for more information).

A ration-by-schedule (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. This is analogous to TBFM propagating STAs to the meter fix from runway times, using the TRACON delay buffer in order to differentiate the time between the most expeditious and what is normal during high demand. Note: If surface metering is off, TMATs and TOBTs are regarded as proposed target times.

The IADS Surface Scheduler accommodates priority flights (without manual swapping) by changing the sequence of runway departures of flights within the same flight operator, without affecting other carrier flights. Automated priority handling is more feasible in a tactical timeframe where a simple and rapid process is required. A more detailed functional description of the tactical surface scheduler can be found in section 4.1.2 of the ATD-2 TDD.<sup>7</sup>

#### **4.1.3.5 Surface Metering**

Metering advisories provide the control that adjusts demand to meet capacity. For CLT, the tactical metering on/off decision is primarily made by the Ramp Manager. When metering is on, TOBTs are converted into gate-hold or push advisories for the ramp controller. The TMATs are also provided to the ramp controller.

Through the scheduling process, flights with CTOTs (e.g., APREQ/CFR, EDCT) will not be subject to gate-hold metering, in order to avoid potential double delay due to both metering and TMI restrictions. Flight operators can also designate certain flights, such as heavy jets, as exempt from metering holds. This can be done through either the adaptation or a manual entry by the Ramp using the RTC/RMTC.

The Phase 1 Baseline IADS Demonstration at CLT focuses tactical metering control on the pushback advisory (i.e., TOBT). However, it is recognized that not all airports have a mechanism/person to receive pushback advisories or to provide pushback instructions to the

flight deck, hence at those airports surface metering must rely on conformance to TMATs. Principles of surface metering can be more generally applied to other airports in the NAS to adjust demand via spot-release times (TMATs).

#### 4.1.3.5.1 Surface Metering Process Flow

Figure 15 shows the flow of the surface metering process that consists of:

- Predicting the demand/capacity
- Monitoring any demand/capacity imbalances and determining if metering is needed
- Enabling surface metering through execution of the pushback advisories generated by the tactical surface scheduler
- Evaluating the metering effectiveness

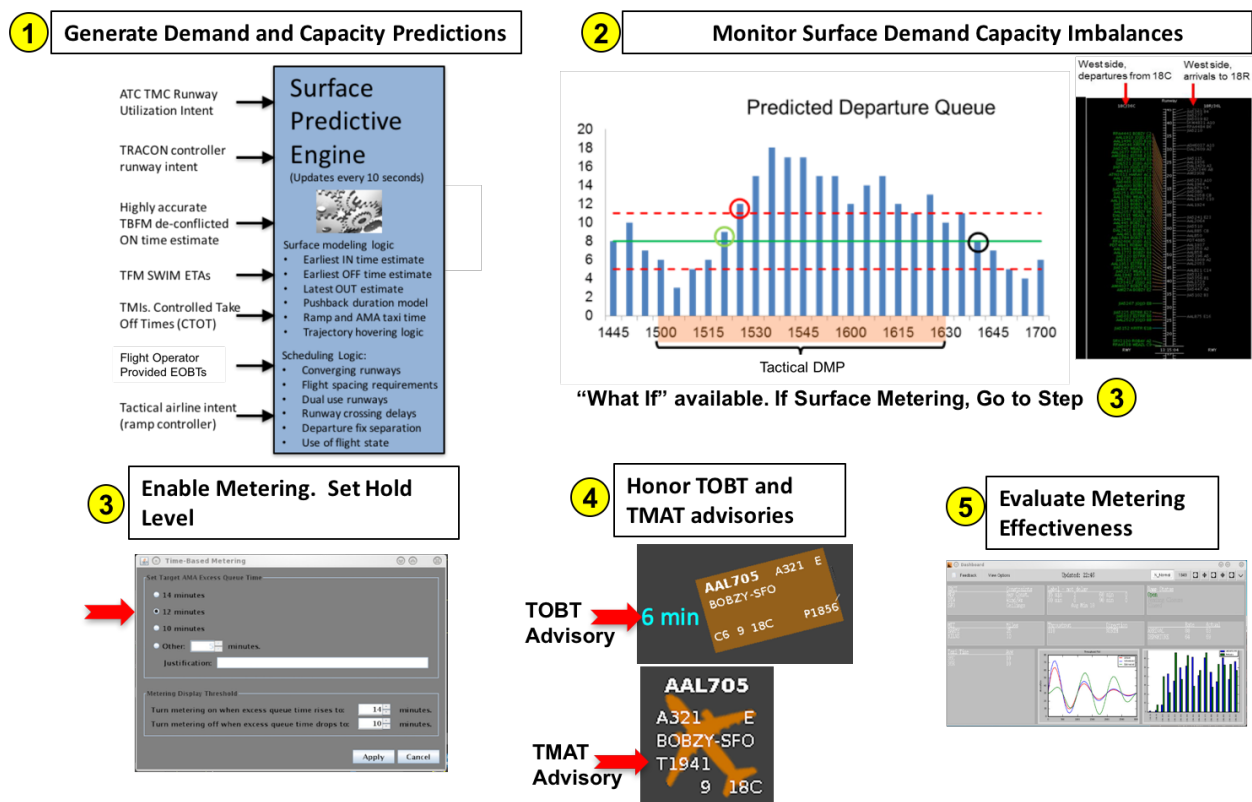


Figure 15 - Surface metering monitors demand/capacity imbalance and provides tools to determine when to turn on metering and how the excess taxi time is propagated to the gate.

Each step in the metering process is further explained in the following text.

Step 1. Generate the demand and capacity predictions.

- Generate the capacity estimate using ATC intent and surface system algorithms. This leverages future runway utilization intent from ATC and heuristics that model airport operations, like those mentioned in section 4.1.3.2.

- Generate the demand estimate using EOBTs, a model of pushback duration, the trajectory-based taxi time calculations, and manual inputs from the operators that help ensure quality estimates.

Step 2. Monitor the surface demand/capacity imbalances.

- Determine if surface metering is warranted.
- If yes, go to the next step. If no, continue monitoring.
- Note, in the Phase 1 demonstration, this is a manual process. As we learn more intent from CLT and the monitoring improves, monitoring will be combined with existing Surface CDM ideas on Departure Metering Program (DMP) notifications.

Step 3 and 4. Enable the surface metering and honor advisories.

- If surface metering is warranted, the decision maker (e.g., the Ramp Manager coordinating with ATC) can decide to enable metering at a certain hold level.
- Enabling metering does not always immediately initiate advisories in the IADS system. Logic is built into the IADS system to incorporate the metering requirements and automatically turn it on at the appropriate time, based on this input.
- The scheduling algorithms use input from the stakeholders to determine how much excess queue time should be propagated to the gate. For instance, if the excess queue time value is set to 12 minutes, then when a flight achieves 13 minutes of runway queue time, one minute (13 minus 12) would be propagated back to the gate.
- Gate-hold/push advisories and TMA Ts are displayed on the ramp controller's display (the RTC) when metering advisories are initiated. The ramp controller honors the advisories.
- If the stakeholders decide to turn metering off, they will see no surface metering advisories.

Step 5. Evaluate the effectiveness of surface metering.

- Objective data and metrics are essential to improving the surface metering system.
- The MOPs, local operational improvement benefits efforts, and real-time reporting efforts provide objective data to assess system performance against desired stakeholder objectives.
- At CLT, ensuring that arrival delays are not increased when metering departures is an important success criterion. This will be measured on a case-by-case, and bank-by-bank, basis.
- Controllability measures are key. The controllability is measured by the overall system response to the excess queue time propagation entered, the delivery of gate holds, and the departure queue size.

The triggering mechanism for surface metering in the IADS system is the amount of excess time expected in the runway queue. This is roughly analogous to queue size, but is more robust to daily variances that can occur for different aircraft types or different meteorological conditions (e.g., Instrument Meteorological Condition (IMC), Visual Meteorological Condition (VMC)). It

is hypothesized that excess queue time can be controlled with greater accuracy than departure queue count. The control of departure queue size involves predicting the specific aircraft comprising the queue, which requires taxi estimates, aircraft de-confliction, and a geometric definition of the queue. Attempting to determine which flight will be in the queue at a certain time introduces error that is not present in the pure excess queue time/de-confliction method.

At CLT, ramp taxi congestion may account for some of the excess taxi-out time a flight incurs between pushback and takeoff. This is another reason why excess queue time is likely to be a more useful metric than queue size, as the net effect of the total excess taxi-out time a flight incurs in both the ramp and AMA is a more achievable target than the fine-tuned control of queue size. Note: From initial results in the ATD-2 Integrated Surface and Airspace Simulation (ISAS) Human-in-the-Loop (HITL) conducted in March 2017,<sup>30</sup> the North flow queue size appears to be much more controllable than the South flow queue size, given the higher ramp taxi time predictability in North flow (due to less ramp taxi time on average).

The amount of excess taxi-out time a flight will take before departing is constant at any given instant in time. The only thing that should change by adjusting the hold setting is how much of that excess taxi-out time the stakeholders want to take at the gate. This decision affects both the flight operator business model and the amount of traffic that ATC must manage in the departure queue.

#### ***4.1.3.6 Real-Time Dashboard***

The real-time dashboard provides a range of users and stakeholders with a common view of key metrics regarding current and future airport operations that enables both analysis and evaluation of airport demand and capacity. The dashboard is designed to function as a tool that, with a glance, can provide operational users an understanding of airport operations and overall system health at a high level. In addition to this high-level view of airport health, more granular analysis and reporting will be conducted to provide detailed insight on capacity, efficiency, and predictability, as well as the effectiveness of scheduling and metering.

The dashboard capability is separate from the STBO Client and the RTC display, but is configured as a toolbar to maximize display real estate. The toolbar can be expanded to indicate detailed views of the data, both numerically and graphically. Key metrics include traffic counts, taxi times, and throughput, which are available in pull-down menus from the dashboard. In addition, the toolbar features a report generation function that applies different filters to the data and can generate data output within operational reports that may be tailored by the user. The ability to provide electronic feedback to researchers is also incorporated into the dashboard through a straightforward feedback form button. More information on this subject is found in section 5.5. Additional information on the real-time dashboard is contained in section 4.5 of the ATD-2 TDD.<sup>7</sup>

#### ***4.1.3.7 Tactical Departure Scheduling***

Tactical departure scheduling is the capability that facilitates non-verbal coordination of the APREQ/CFR process between the Tower and the Center. This capability leverages FAA investments in the TBFM/IDAC capability.



Departure scheduling is integrated with TBFM/IDAC to request a release time (i.e., wheels up time<sup>§§</sup>) into the overhead stream of traffic in the Washington Center. The STBO Client timeline emulates TBFM/IDAC’s Integrated Departure Scheduling Tool (IDST) (i.e., the interface Tower TMCs use to select a slot at the meter point and receive the corresponding release time without verbal communication with the Center TMC).

The IADS technology enabling this capability is the accurate prediction of the Earliest Feasible Takeoff Time (EFTT) and the generation of the target pushback time (i.e., TOBT) by the Surface Scheduler to meet the CTOT. This enables holding of the aircraft at the gate for the right amount of time. The STBO Client sends a notification to the Tower TMC to facilitate earlier APREQ/CFR coordination while the aircraft is still at the gate.

The release time is automatically shared with the Ramp. An APREQ/CFR flight is marked on its flight strip, and the release time and the corresponding target pushback time is displayed on the RTC/RMTC as soon as the time is available. Additional information on the tactical departure scheduling is contained in section 4.3 of the ATD-2 TDD.<sup>7</sup>

**4.1.3.8 What-If Scenario Feature**

STBO has a “What-if” scenario feature that shows the user what the effect of a considered change is predicted to be, if the user were to implement the change. The purpose of the What-if system is to provide a capability for the Tower TMC to modify settings, such as TMI restrictions and flight properties, without affecting the host system. This test environment provides a method for the Tower TMC to better understand how constraint modifications may affect the system without needing to actually apply the constraints to the real world. Modeling results between the two systems are isolated from each other. See section 4.1 of the ATD-2 TDD<sup>7</sup> for more information on the What-If scenario feature.

**4.1.4 User Groups and Other Involved Personnel**

The scope of this ConUse is specifically limited to the ATD-2 sub-project field evaluation environment for the Phase 1 Baseline IADS Demonstration research activity. Table 1 lists the facilities, the personnel, and the specific features of the IADS system with which these users will interact in the field evaluation. All of the users also have access to the real-time dashboard. Each of these user interactions will be more fully discussed within the operational scenario descriptions in section 5.

*Table 1 - The capabilities to be deployed in the ATD-2 sub-project Phase 1 demonstration will be accessed by different users in various facilities.*

Facility	Personnel	Capability
CLT Tower	Ground and Local Controller	<ul style="list-style-type: none"> <li data-bbox="743 1623 1276 1654">• TFDM EFD for surface traffic control</li> </ul>

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<sup>§§</sup> Wheels up refers to getting the wheels off the ground, so the aircraft becomes airborne. See Reference 20, section 4.3.4.e.

	TMC	<ul style="list-style-type: none"> <li>• STBO Client display with TBFM/IDAC for APREQ/CFR coordination</li> <li>• RTC display in observer mode only</li> <li>• TFDM EFD for surface traffic management</li> </ul>
	CD	<ul style="list-style-type: none"> <li>• TFDM EFD for surface traffic management</li> </ul>
CLT TRACON	TMU	<ul style="list-style-type: none"> <li>• STBO Client display</li> <li>• RTC display in observer mode only</li> </ul>
Center (ZDC)	TMU	<ul style="list-style-type: none"> <li>• STBO Client display in observer mode only</li> <li>• Enhanced TBFM/IDAC for APREQ/CFR coordination with CLT Tower</li> </ul>
AAL Ramp Tower	Ramp Controller	<ul style="list-style-type: none"> <li>• Ramp Traffic Console (RTC)</li> </ul>
	Ramp Traffic Manager	<ul style="list-style-type: none"> <li>• Ramp Manager Traffic Console (RMTC)</li> <li>• STBO Client display in observer mode only</li> </ul>
AAL Integrated Operations Center (IOC)	Research Observer	<ul style="list-style-type: none"> <li>• Ramp Traffic Console (RMTC) in observer mode only</li> <li>• STBO Client display in observer mode only</li> </ul>
CLT Airport	Airport Authority and Facility Manager	<ul style="list-style-type: none"> <li>• STBO Client display and RTC display in observer mode only</li> </ul>
Other flight operators operating at CLT	Manager	<ul style="list-style-type: none"> <li>• TBD</li> </ul>

## 4.2 Operational Policies, Procedures, and Constraints

This section describes policies and procedures that may be affected by the changes in operational concepts proposed for the IADS system. It also discusses data collection and the archiving policy related to the operational evaluation activity for the project.

### 4.2.1 Adjustments due to Automated Data Exchange and Integration

The Phase 1 Baseline IADS system provides the capability for electronic data exchange and integration between the Tower and the Ramp. The Tower TMC will use the STBO Client display to input traffic management decisions, such as runway utilization plan and TMI restrictions. The Ramp will use the RTC/RMTC to input decisions regarding runway assignment request, surface metering, and ramp closures, etc. The inputs made through these user interfaces will be shared electronically without phone calls. Training will be provided to both the Tower TMCs and Ramp Control covering use of the tools.

#### ***4.2.2 Adjustments for Strategic Surface Scheduling Capabilities and Procedures***

For the Phase 1 Baseline IADS Demonstration, strategic surface scheduling will be exercised in predictive mode, where the DRM prediction of demand/capacity balance will be monitored without user interaction. The data generated by the DRM capability will be recorded and stored for both in-situ analysis and post-data analysis. It is anticipated that a web-based DRM display will be made available at the Ramp and the participating flight operators' operations facilities (e.g., AAL IOC) for observing the DRM predictions (e.g., proposed DMPs and proposed TMATs).

#### ***4.2.3 Adjustments for Tactical Surface Scheduling Capabilities and Procedures***

The tactical surface scheduling and metering capability provides gate pushback advisories to the CLT ramp controllers, displayed on the RTC. The Ramp Manager will also be provided a RMTC display. Training will be provided to Ramp Control covering use of the tools as well as transition procedures, prior to the operational evaluation.

#### ***4.2.4 Adjustments for Tactical Departure Scheduling Capabilities and Procedures***

The tactical departure scheduling capability of the IADS system will provide the CLT Tower TMC with a new user interface to coordinate APREQ/CFR restrictions with the Center TMC. The Tower tool will be based on the STBO Client display, integrated with the TBFM/IDAC capability.

The tactical departure scheduling capability of the IADS system will also provide the flight operators with information, such as flights subject to APREQ/CFRs, release times, and the associated TOBTs once release times are scheduled.

The tactical departure scheduling capability is expected to provide reliable estimations of OFF times while aircraft are parked at the gates. Therefore, it allows APREQ/CFR coordination with the Center TMC and the flight deck/flight operator to take place more effectively than it does in today's operation, given the use of automation.

#### ***4.2.5 Adjustments for Pilot Procedures - Surface Metering and APREQ/CFR***

For the Phase 1 Baseline IADS Demonstration, pilots will contact the Ramp when they are ready to pushback, as per the current-day procedures. Ramp Control will be equipped with more information to support the pilot workload and planning and to ensure schedule conformance. For example, the expected runway assignment and any departure fix closure information will be communicated to the pilot while in the ramp area via current-day communication channels with the Ramp. The wheels up time for tactical flow control will be communicated by Clearance Delivery before pushback, and will be provided to both the pilot and Ramp Control to support shared situational awareness. Pilots will receive training to encourage early information sharing with the Ramp, of both the aircraft readiness state (i.e., anticipated mechanical delays) and any request for runway necessity.

#### ***4.2.6 Involvement of Other Airport Operations***

The Phase 1 Baseline IADS Demonstration will also require the involvement of all airport operator personnel that impact flight readiness. For example, the on-time boarding of the aircraft requires support from the gate agents and the flight attendants. The Turn Coordinator needs to be aware of gate conflicts earlier, to make changes in the gate assignment for an arrival flight in

conflict. On-time pushback requires support from a wide range of service operators, including fueling, catering, flight attendants, airport ramp agents, baggage handlers, tug operators, and marshallers/wing walkers. The Phase 1 Baseline IADS Demonstration will benefit if flight operators are encouraged to support schedule conformance across all facets of operations.

#### ***4.2.7 Potential Conflict with Established Departure Metrics***

The Department of Transportation (DOT) has specific criteria for reporting “on-time” performance to the public. To meet on-time criteria, the aircraft must arrive at its gate at the destination airport within 14 minutes of its scheduled arrival time (i.e., "A+14"). In order to ensure DOT on-time performance, flight operators strive to meet on-time departures (i.e., aircraft departing the gates at the flight operator scheduled departure times, or the "D0" performance metric) or meet flight operator scheduled takeoff times. The surface departure metering tool could potentially affect the D0 departure performance metrics during the evaluation period, due to gate-holding. However, the concept of the IADS system is that delay in a departure flight’s pushback due to gate-holding would not adversely affect the flight’s takeoff time or the airport throughput, thus arrival time at its destination airport should not be affected. This concept will be verified through operational data analysis.

The FAA Surface Operations Office has been conducting a study to address the conflicts between the DOT on-time performance measures and Surface CDM as one of the risks linked to operational procedures, processes, policies (P3),<sup>31</sup> and is trying to develop a consensus among stakeholders on alternative performance measures. Further discussion regarding the impact of the IADS system on performance metrics and mitigation strategies is anticipated.

#### ***4.2.8 Non-AAL Flight Operators, General Aviation, Cargo and International Flights***

It is anticipated that both international and non-AAL commercial passenger flight operators operating at CLT will participate in key ATD-2 sub-project research activities for the Phase 1 Baseline IADS Demonstration and beyond. International flights use gates in Concourse D, where the customs service facility is located. Non-AAL domestic flight operators operating in CLT use gates in Concourse A. A flight operator must agree to participate in the IADS surface scheduling in order to be subject to gate-holds and receive pushback advisories accordingly.

The Tower directly controls GA and cargo flight operations. Participation of these operators in the ATD-2 sub-project research activity remains to be determined.

## 5 Operational Scenarios

This section provides both the operational context of the IADS system for the Phase 1 Baseline IADS Demonstration capability and the descriptions of how the users will interact with the system. Section 5.1 is devoted to the strategic surface scheduling capability in predictive mode. Section 5.2 describes user interactions with the tactical surface scheduling and metering that will provide pushback advisories and many useful features to Ramp Control. Section 5.3 provides detailed step-by-step procedures that the tactical departure scheduling capability will provide for APREQ/CFR coordination. Section 5.4 provides a detailed description of the coordination between the Tower and the Ramp, through data exchange and integration, therefore enhancing the common situational awareness among users and facilitating electronic coordination. Section 5.5 describes the real-time reporting feature called the dashboard, where the display of various metrics on airport operations are provided for all users and stakeholders. Lastly, section 5.6 provides sample use cases to illustrate the sequence of events of a departure flight and the user interactions throughout the course of the flight.

### 5.1 Strategic Surface Scheduling

The Departure Reservoir Management (DRM) function of the strategic surface scheduling capability generates the predicted demand and capacity estimates for airport surface operations in the future, and recommends a Departure Metering Program (DMP) when the predicted demand exceeds the capacity of specified airport resources. The concept for the strategic surface scheduling capability is consistent with the Surface CDM ConOps developed by the FAA and industry.<sup>1</sup>

The key inputs required by the DRM are:

- The DRM requires inputs from the user to set the parameters for scheduling, including the target queue length, queue length thresholds (upper and lower), and the planning horizon.
- The DRM also requires inputs to specify the capacity of the airport for both arrivals and departures in terms of AAR/RAR and ADR/RDR. Note: In Phase 2, the fused strategic and tactical metering capability will use the system generated capacity information instead of manual entries.
- The DRM receives the demand information from flight operators in terms of the Scheduled Off-block Time (SOBT) and the Earliest Off-block Time (EOBT) for each departure flight.

Using these inputs, the DRM generates the proposed target times for departure flights to enter the AMA (i.e., proposed TMATs), in order to meet the target queue length set by the DRM. The recommended DMPs and the proposed TMATs are sent to the flight operators. Figure 16 shows the main display of the DRM capability (notional).

The DRM software, developed by Metron Aviation under contract to the FAA during the Surface CDM Concept Engineering effort, was transferred to NASA and integrated with the IADS system. In the Phase 1 Baseline IADS Demonstration, the DRM capability will be running in a predictive mode, without sending data (e.g., proposed DMP notifications and proposed TMATs) back to the IADS system. The DRM strategic scheduling capability is used primarily for

observation and research purposes, in which the researchers will conduct data analysis to assess the characteristics and performance of the DRM function.

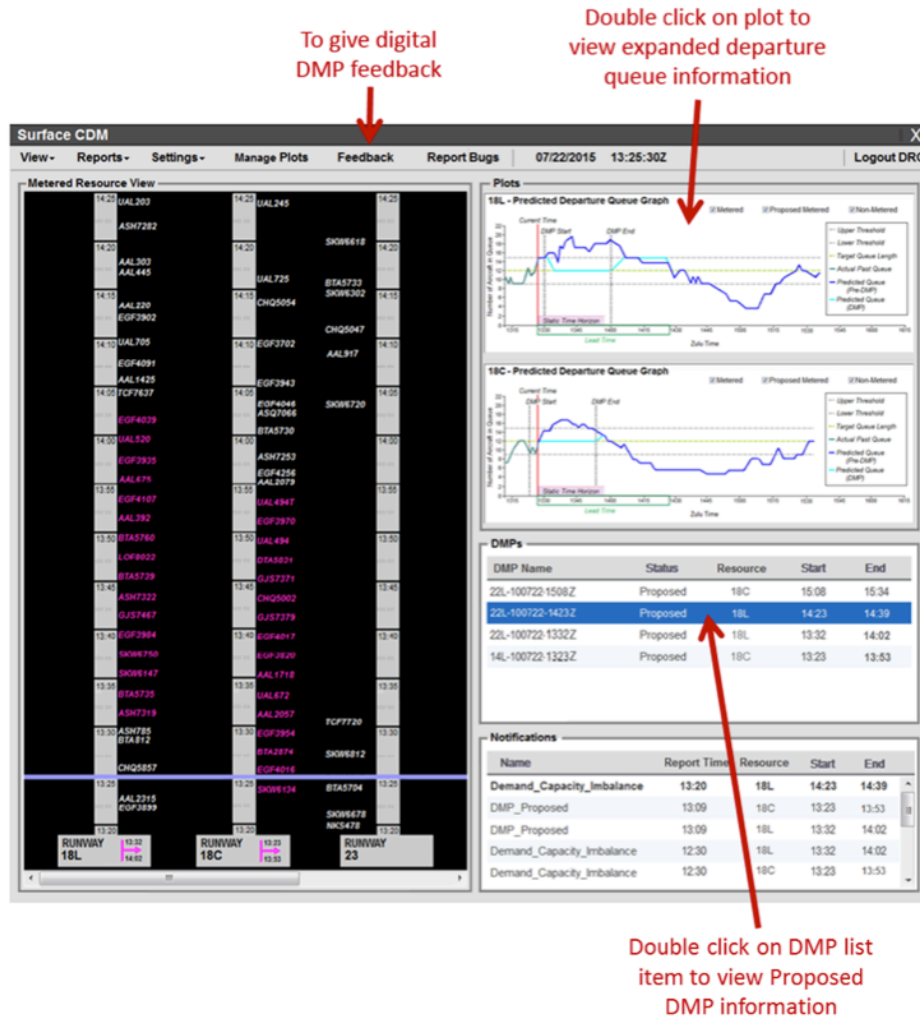


Figure 16 - Timelines, plots, and DMP recommendations and notifications (notional) will allow the interested user groups to monitor the predictions made by the DRM capability.

One of the key features of the IADS system is the “fusion” of both strategic and tactical approaches to departure metering, which is one of the core capabilities for Phase 2 IADS demonstration. It is noted that the tactical surface scheduling capability of the Phase 1 Baseline IADS Demonstration has incorporated some of the key principles of S-CDM ConOps in the scheduling algorithm, including:

- Assigning gate holds (i.e., TMATs and TOBTs) based on RBS principles
- Calculating and displaying TMATs on the ramp controller display (RTC)
- Performing automatic substitution, based on EOBT updates
- Enabling automatic intra-flight operator swap for priority flights identified by the flight operators

In the Phase 1 demonstration, data analysis will be conducted to evaluate both the tactical and strategic scheduling capabilities and identify gaps in either of the surface scheduling capabilities. 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. See section 4.1 of the ATD-2 TDD<sup>7</sup> for more details on how the DRM concept is being implemented in ATD-2.

## 5.2 Tactical Surface Scheduling

Tactical Surface Scheduling has user interfaces to display the gate-hold time and the push advisories for surface metering, and other relevant data exchange information shared between the Ramp and the Tower. These user interfaces for Ramp Control at the CLT Ramp have evolved from the SARDA HITL experiments conducted in close collaboration with AAL.<sup>3</sup>

The following sections provide a description of Tactical Surface Scheduling and the associated interfaces. For a more in-depth description of these capabilities, please refer to the ATD-2 sub-project Freeze 1 read-ahead document covering RTC/RMTC basic training.<sup>14</sup>

### 5.2.1 Ramp Traffic Console (RTC) for the Ramp Controller

Figure 17 shows a screen shot of the RTC for the South Sector ramp controller. The RTC integrates multiple data sources, including ASDE-X surveillance data, SWIM data, and flight operator operational data, to display aircraft movement both in the ramp area and the AMA, along with detailed flight information. This provides common situational awareness and decision support capabilities for Ramp Control.

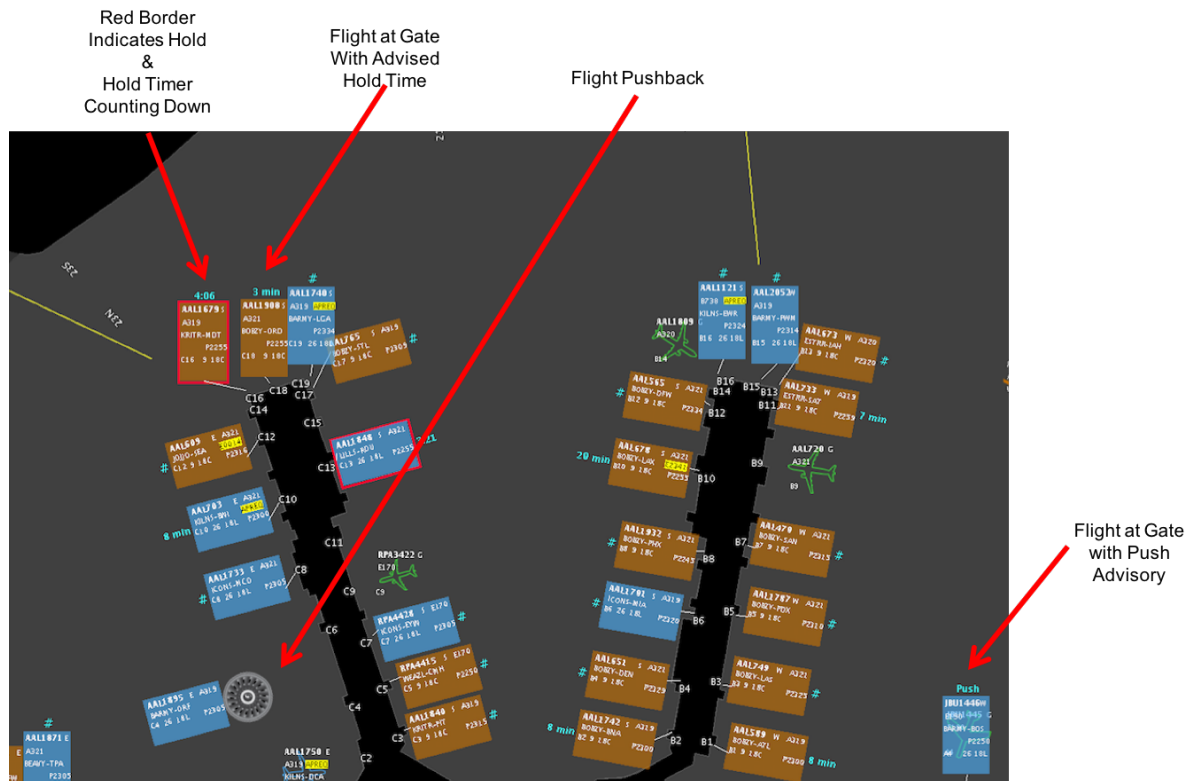


Figure 17 - The Ramp Traffic Console (RTC) display helps the ramp controller manage traffic in the ramp area more efficiently.

The RTC provides many features to the ramp controllers to help manage traffic in the ramp area efficiently (i.e., the spot assigned by the ramp controller, updates to the runway assignment entered by the Tower, or a marker that indicates an aircraft has been assigned to the hardstand by the ramp controller). The RTC shown in Figure 17 also displays updated aircraft state information (e.g., pushback, hold, and at-gate).

Departure flights parked at the gate are represented as flight strips. After a flight is pushed back, it is displayed as a hollow aircraft icon until it is under ASDE-X surveillance. The user can click on a flight strip to make updates to the flight data and to move an icon on the display to its known location until it is under ASDE-X surveillance. Once a flight is under surveillance, its location is automatically updated. Aircraft icons and flight strips are color-coded. Arrivals are green, eastbound departures are blue, and westbound departures are brown.

Departure flight data elements shown on the RTC for each flight strip include: flight number, aircraft type, destination airport, departure fix, departure gate in the ramp, expected spot (based on departure runway), scheduled pushback time, any TMI times, and current ownership of the flight (Ramp sector or Tower). The user has the option to display either scheduled off-block time (SOBT), earliest off-block time (EOBT), or target off-block time (TOBT) on each flight strip. The most updated TMI time available for that flight is shown, if there is one. Arrival flight data elements provided on the RTC include: flight number, aircraft type, assigned gate, and current ownership (sector, GC, or LC). Arrival aircraft status, gate conflict information, and hardstand assignments are also readily available, as shown in Figure 18.

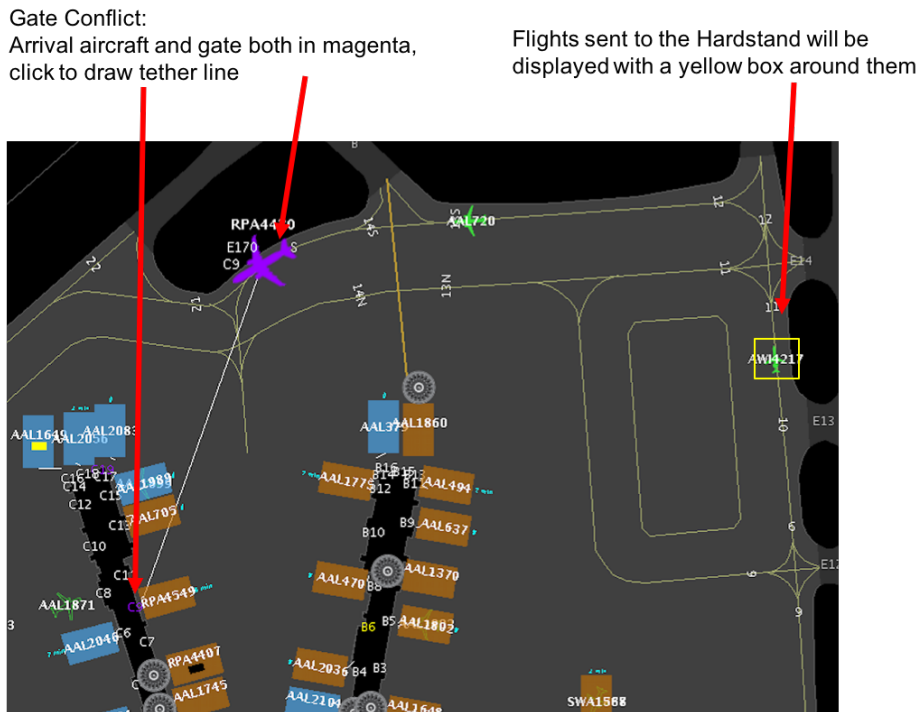


Figure 18 - The Ramp Traffic Console (RTC) display shows gate conflict alerts and hardstand assignments.

The RTC also displays TMI information. When TMIs are first entered into the system, general notifications regarding restrictions are displayed as alerts in the Notification Panel. For example, notifications about MITs and Ground Stops (GS) will appear in the Notification Panel. Flight



specific TMI information, such as an EDCT or an APREQ/CFR time and MIT, is displayed on the flight strip.

### 5.2.1.1 Capture Tactical Intent from Ramp Control

Ramp Control can update a number of flight data elements for any flight using the Flight Menu (see Figure 19). These include the spot assignment and a runway assignment for operational necessity. A flight can be put on the Priority Flight list, and a scratchpad notation can be put on a flight. Any TMI information that is populated by the system will also be displayed in the Flight Menu.



Figure 19 - The flight menu for flight intent contains entries for spot, runway, hardstand, and flagging for a priority flight.

The Flight Menu can be used to assign a flight to the hardstand. If the flight that is designated to be held in the hardstand is a departure, the tactical surface scheduler will be notified of this assignment. Later, the tactical surface scheduler will inform the ramp controller when the aircraft needs to be released from the hardstand/holding area, in order to reach the designated spot by its scheduled spot entry time. The ramp controller can send the aircraft directly to the spot if the hardstand is full or if the available hardstand is too far out of the way for the flight. In a gate conflict situation, the ramp controller may decide to send the aircraft to the spot, instead of sending it to the hardstand/holding area, and absorb the hold elsewhere in the ramp area.

### 5.2.2 Ramp Manager Traffic Console (RMTC) for the Ramp Manager

The RMTC user interface shown in Figure 20 contains the same functions as the RTC, with the addition of the RMTC Tools Menu for Setting Metering Mode, Creating the Priority Flight List, and the ability to close the ramp. One of the responsibilities of the Ramp Manager is to communicate with the Tower and disseminate traffic information back to the ramp controllers. In doing so, the Ramp Manager inputs relevant information to the system via the RMTC user interface, shown in Figure 20, while also setting the metering mode and managing the Priority Flight List, as necessary. For example, the Ramp Manager can update the metering mode and convey that decision to the ramp controllers, which automatically sends a notification to the Tower TMC and updates the notification on the RTC/RMTC displays.

The three metering modes are: 1) no metering, 2) sequence-based metering, and 3) time-based metering. The first two modes are meant to help with situational awareness among all the players and help with data collection for comparison with the time-based metering mode. The time-based metering allows the tactical surface scheduler to provide gate hold and push recommendations.

From Tools Menu, Create Priority Flight List or Set Metering Modes

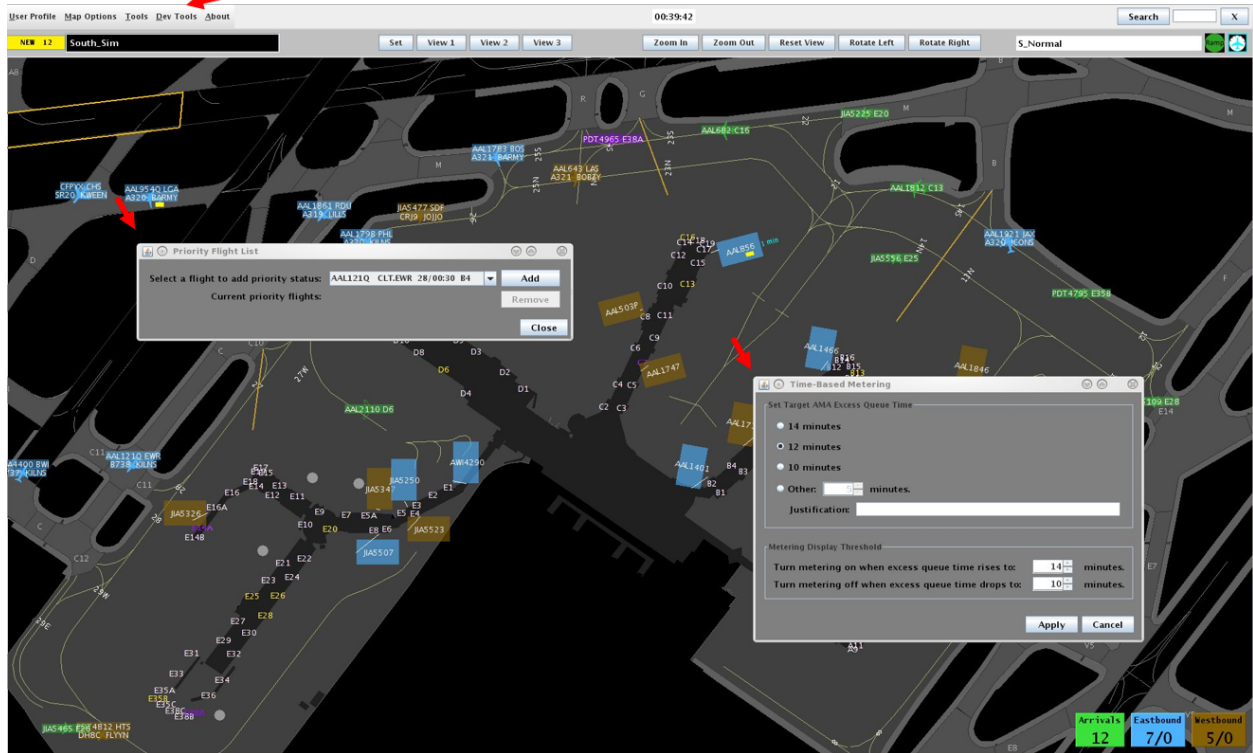


Figure 20 - The Ramp Manager Traffic Console (RMTC) display provides many functions and capabilities in an automated format to the Ramp Manager through multiple feature windows.

Also, information regarding ATC-related changes (e.g., runway configuration changes, notification of APREQ/CFR restrictions) will be exchanged between the ATC Tower and the RTC/RMTC. A detailed description regarding the data exchange and coordination between the Tower and the Ramp is found in section 5.4.

### 5.2.3 Tactical Surface Metering

This section is focused on the tactical surface metering feature of the Phase 1 Baseline IADS Demonstration. Both the RMTC and the RTC provide Ramp Control with a graphical user interface for the tactical surface metering capability, enabled by the tactical surface scheduler. This allows the users to manage the gate-hold metering when the traffic demand exceeds the runway capacity during banks of departures.

#### 5.2.3.1 Tactical Surface Metering Modes

For the Phase 1 Baseline IADS Demonstration, the RMTC provides the Ramp Manager with the option to choose between time-based and sequence-based metering, when gate-hold metering is necessary.

- The time-based metering provides a gate-hold or push advisory to the ramp controller for individual flights, generated by the tactical surface scheduler. The Ramp Manager can control how excess taxi-out time is apportioned between the surface (i.e., ramp and AMA) and the gate, according to the current selected strategy for throttling demand.
- The sequence-based metering (also known as “departure sequencing”) is the metering option that Ramp Control is executing in current ramp operations, based on the target queue length determined by the Ramp Manager. Both the RTC and the RMTC support this metering option during the Phase 1 demonstration, in order to make a smooth transition to time-based metering. Only the time-based metering is described in detail in the following section.

### 5.2.3.2 *Time-Based Metering*

The tactical surface scheduler generates Target Off-Block Times (TOBTs), and the RTC displays a gate-hold or push advisory when metering is turned on. In doing so, the tactical surface scheduler allocates runway departure slots on the timeline according to an RBS rule, with the order of consideration applied, based on the quality of the flight’s EOBT.

- ‘Planning’ group - The flights that have high-quality EOBTs enter into the scheduling group called the ‘Planning’ group when the clock time reaches the threshold time (i.e., the scheduling horizon) prior to their EOBTs (e.g., 10 minutes). Once flights have entered the ‘Planning’ group, the gate-hold or push advisory is displayed on the RTC. Advisories are updated every model cycle (e.g., 10 seconds).
- ‘Uncertain’ group - The flights with low-quality EOBTs or outside the scheduling horizon of the ‘Planning’ group belong to the scheduling group called the ‘Uncertain’ group. The RTC does not display a gate-hold or push advisory for the flights in the ‘Uncertain’ group until the pilots call in that they are ready. When the pilot calls in ready for pushback, the ramp controller submits a request to the scheduler to generate target times (TTOT, TMAT, TOBT) and the gate-hold/pushback advisory is displayed on the RTC.

The flight operators are expected to provide the EOBTs to the IADS system, currently via the TFDM topic containing the Surface CDM data elements available through the SWIM TFMS feed, and the criteria to determine the quality of the EOBTs of flights needs to be established through in-depth analysis, based on historical data and/or fast-time simulations. The design of the tactical surface scheduler allows the length of the scheduling horizon for the ‘Planning’ group to be customized for different airports or flight operators to accommodate the level of EOBT accuracy. The description of the scheduling groups and the transition between groups are found in the ATD-2 TDD.<sup>7</sup>

The tactical surface scheduler is expected to run all the time, but the Ramp Manager, in coordination with the ATC Tower, can turn the time-based metering on and off, according to the strategy for demand/capacity balancing. When the Ramp Manager decides to turn on time-based metering, he or she will choose the target excess queue time from three options depending on the traffic situation: 12 min (mapped to ‘Nominal gate hold’), 14 min (mapped to ‘Less gate hold’), or 10 min (mapped to ‘More gate hold’). In addition, the Ramp Manager needs to specify upper and lower metering display threshold values. The ‘Less gate hold’ option allows more flights to be on the airport surface, whereas the ‘More gate hold’ option allows the flights to be held at the

gates longer, thus resulting in less excess taxi-out time on the surface. The ‘Nominal gate hold’ option seeks to utilize the existing runway capacity with the available demand. These parameters to set the level of gate holding for the tactical surface scheduler’s delay propagation logic were determined through both analysis and human-in-the-loop simulations. The metering display thresholds determine when gate hold metering advisories will be displayed on the RTC. The metering advisories are displayed when excess queue time exceeds the upper threshold value, and stop displaying when excess queue time drops below the lower threshold. In case the Ramp Manager wants to choose a target queue excess time outside of the three pre-determined options mentioned above, the Ramp Manager is required to state a justification. Figure 20 shows the RMTC, with the time-based metering option on, and the level of gate-holding set to 12 minutes of excess queue time with 14 and 10 minutes for upper and lower metering display thresholds, respectively.

#### 5.2.3.2.1 Exempt, Priority, and TMI flights under Surface Metering

*Exempt flights* – Exempt flights are not subject to gate-hold metering. For example, both international and GA flights may be included in this flight category. An agreement among the stakeholders may be required in order to determine which flights will qualify as an exempt flight. Alternatively, Ramp Control can also designate a specific flight as an exempt flight on the RTC or the RMTC. An exempt flight will not display any guidance from the surface metering tool, allowing the ramp controller to push or hold the flight as they deem fit when the pilot calls in ready for departure.

*Priority Flights* - The Ramp Manager can create a list of priority flights on the RMTC. Alternatively, Ramp Control can designate a flight as a priority flight using the Flight Menu on the RTC or the RMTC. In today’s airport operations, priority flights are determined based on a flight operator’s own policy. In the Phase 1 demonstration, priority flights are scheduled ahead of other flights within the same flight operator during surface metering.

*TMI Flights* - TMI flights (e.g., EDCT, APREQ/CFR flights) are not subject to surface metering in order to avoid a potential double delay due to both metering and the TMI restriction. It is noted that a gate-hold or push advisory for TMI flights is always displayed on the RTC, regardless of whether surface metering is on or off, in order to assist the ramp controller. As soon as the Controlled Takeoff Time (CTOT) of a TMI flight (e.g., the EDCT or APREQ/CFR release time) is available to the tactical surface scheduler, the Target Off-block Time (TOBT) is calculated by subtracting the nominal taxi time and the Controlled Time of Departure (CTD) buffer from its CTOT, which will ensure the flight reaches the runway threshold within the compliance window.

### 5.3 Tactical Departure Scheduling

This section provides descriptions of the tactical departure scheduling components of the IADS system, which are built upon NASA's PDRC technology integrated with the FAA's TBFM/IDAC.

The STBO Client is the primary system interface for the Tower TMC. It provides situational awareness of surface traffic and helps manage coordination of the APREQ/CFR flights. The step-by-step process of the APREQ/CFR coordination between the Tower and the Center TMCs is explained via user interface examples. The APREQ/CFR coordination procedure, which varies based on the scheduling mode selected by each facility, is also explained. For a more in-depth

description of these capabilities, please refer to the ATD-2 sub-project Freeze 1 read-ahead document covering the STBO Client training.<sup>13</sup>

### **5.3.1 Management of TMIs and Scheduling Modes by the Center**

The Center TMC enters MIT values in the stream class menu within TBFM. The stream class defines the specific flows crossing specific meter points. Note: These MIT values are not the same as a MIT that CLT may be subjected to at the TRACON boundary. The Center TMC also specifies whether the stream class is subject to APREQ/CFR, and specifies the approval mode.

There are three approval modes:

- *Call for Release:* The same APREQ/CFR process as today. This requires the Tower to call the Center TMC to request a release time.
- *Semi-Automatic:* The release times are requested by the Tower via the tactical departure scheduler, pending approval from the Center TMC. The Center TMC has the ability to accept the request as it is, reschedule it, or cancel the request.
- *Automatic:* The release times that are requested by the Tower via the tactical departure scheduler are automatically approved by TBFM.

The Center TMU coordinates all MIT at the CLT TRACON boundary and the APREQ/CFR restrictions for CLT departures with the TRACON, Tower, and Command Center via NTML. Stakeholders have access to this information.

With the IADS system and the TBFM interface, TBFM receives improved EFTTs of departures, based on the flight operator's EOBTs and predicted taxi times. This improves the predictability of the demand at the meter point. The interface also allows the coordination of the APREQ/CFR to be handled non-verbally.

Note: In Phase 1, not all of the CLT departures with APREQ/CFR restrictions will be handled by IADS automation at the Center. The CLT departures that will be scheduled into an arrival metering system will likely not be included in this phase. Thus, a portion of the APREQ/CFR departures will need to be coordinated verbally between the Tower and Center TMCs. These verbally negotiated APREQ/CFR release times are then manually entered into the system and made available to the Ramp.

### **5.3.2 TMI Information in STBO Client Display**

In the Phase 1 Baseline IADS Demonstration, the EDCT, MIT and APREQ/CFR restrictions will be automatically communicated and updated in STBO, using the NTML restriction information and disseminated through the TFDM SWIM prototype data feed. The Tower TMC will be able to manually enter or override any restriction information. This information will be passed along to the tactical surface schedulers, as well as the tactical departure scheduler. The EDCT and APREQ/CFR will also be displayed on other surface displays (e.g., RTC, RMTC).

Flights with EDCT or APREQ/CFR restrictions will be indicated on a flight list and will have the EDCT or APREQ/CFR information displayed on the runway timeline (see Figure 21). The STBO Client interface design will help users be cognizant of which APREQ/CFR flights are being handled by the IADS system, and which of those APREQ/CFR flights handled by the system require additional verbal coordination.

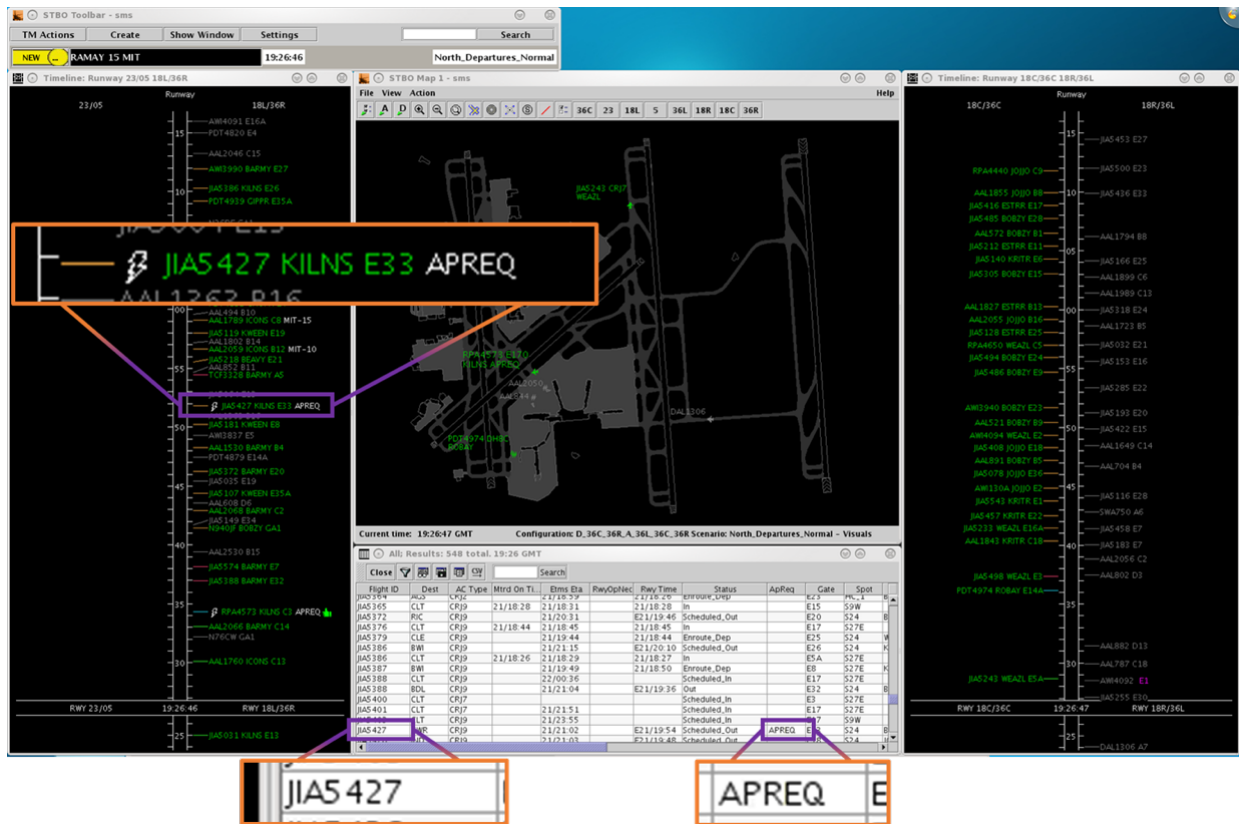


Figure 21 - Flights with APREQ/CFRs are shown in the flight list and highlighted in the timeline.

### 5.3.3 Overview of IADS APREQ/CFR Processing

The tactical departure scheduler automates the coordination of the APREQ/CFR procedure. The SWIM data feed between the surface schedulers and TFMS allows for STBO to obtain the flight operator’s data (e.g., the EOBT, gate assignment, and flight intent). The SWIM data feed between the surface scheduler and TBFM allows for (1) STBO to receive APREQ/CFR restrictions, (2) STBO to request takeoff times or release times from TBFM that correspond to available slots in the overhead stream, and (3) TBFM to transmit release times to STBO. Finally, the integration with the surface scheduler allows for a seamless computation of the TOBT.

This non-verbal process facilitates the coordination between the Ramp, the Tower, and the Center TMCs. Thus, it reduces uncertainty, workload, and surface delay.

The steps of the APREQ/CFR process can be divided into a pre-scheduling phase and a scheduling and compliance phase. In the following subsections, all steps involved in both phases of the APREQ/CFR coordination in a nominal situation are described at a high level.

#### 5.3.3.1 APREQ/CFR – Pre-Scheduling Phase

The pre-scheduling phase involves all the steps and data exchange prior to the Request for a Release Time for multiple flights. It encompasses the flight operator’s data, the predictions of OFF times, and the assignment of the APREQ/CFR restrictions. Figure 22 depicts the flow of the data. Key stakeholders and systems are indicated in the boxes on the left. Arrows pointing to the right indicate time.

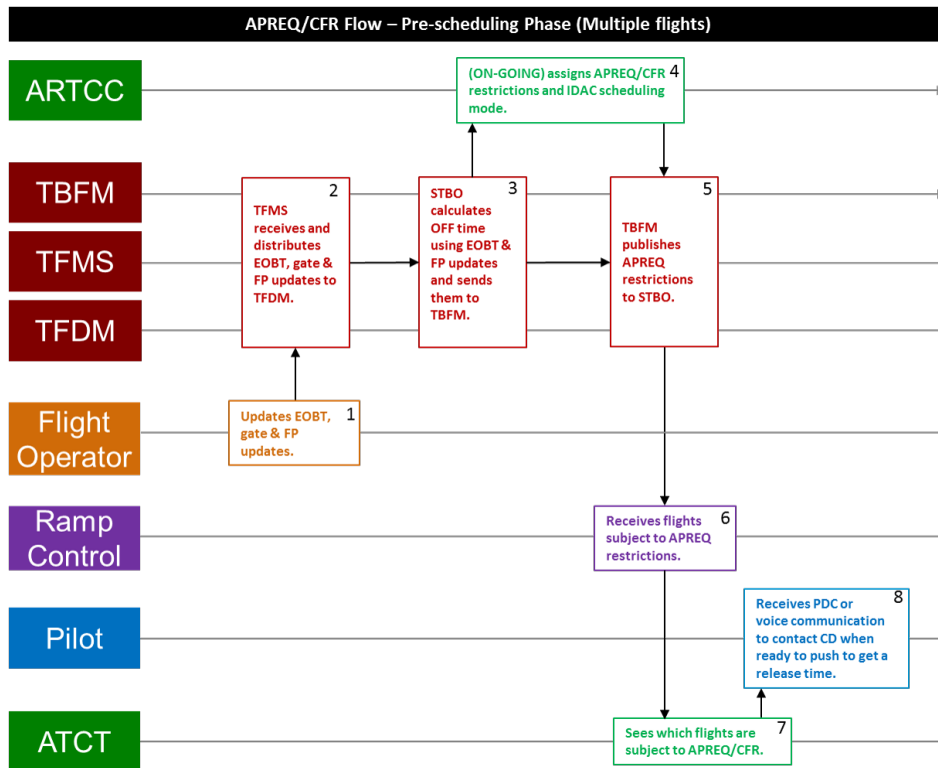


Figure 22 - This illustration shows the flow of data between key stakeholders and systems during the pre-scheduling phase of the APREQ/CFR process.

The steps are described as follows:

- Step 1: Flight operators provide and update the EOBTs, gate assignments, and flight plan updates to FAA systems.
- Step 2: The same data are then fed to STBO via the SWIM feeds.
- Step 3: STBO uses the flight data and predicts the surface demand and taxi times. STBO computes OFF times. These times are then shared with TBFM via the SWIM data feed.
- Step 4: The number of departures and their OFF times are regularly updated in TBFM through the interface with STBO. The Center's TMC assigns an APREQ/CFR, along with approval and scheduling modes, to relevant stream classes (see section 5.3.1) in TBFM. At the same time, the Center assesses the demand, issues APREQ/CFR restrictions in NTML, and sets the appropriate restrictions in TBFM. Note that the APREQ/CFR restrictions may be assigned before better predicted OFF times are known by the Center.
- Step 5: SWIM feeds restrictions data from TBFM and published APREQ/CFR restrictions in NTML to STBO.
- Step 6: STBO then communicates the APREQ/CFR restrictions to the RTC/RMTC.
- Step 7: Both the Tower and the Ramp are notified by STBO of the APREQ/CFR restrictions and which flights are impacted. (The STBO Client informs the Tower about TMIs and of flights that are subject to TMIs.) Pre-determined runway assignments can also be specified at that point.

- Step 8: A Pre-departure Clearance (PDC) is issued electronically or by voice to the pilot with an advisory that their flight requires the wheels up release time prior to departure. Step 8 may be accomplished independently of the inclusion of the flight operator’s EOBTs and gate assignments. Note: In the future, aircraft operating in CLT that are equipped with the Future Air Navigation System (FANS) will receive Controller-Pilot Data Link (CPDLC) Departure Clearance (DCL) via the Tower Data Link Service (TDLS) system.

### 5.3.3.2 APREQ/CFR – Scheduling and Compliance Phase

The scheduling and compliance phase involves all the steps needed to coordinate both the APREQ/CFR and the timely departure of the flight. Figure 23 depicts the steps of the process for one flight, with the following sub-sections further detailing the activities within each step.

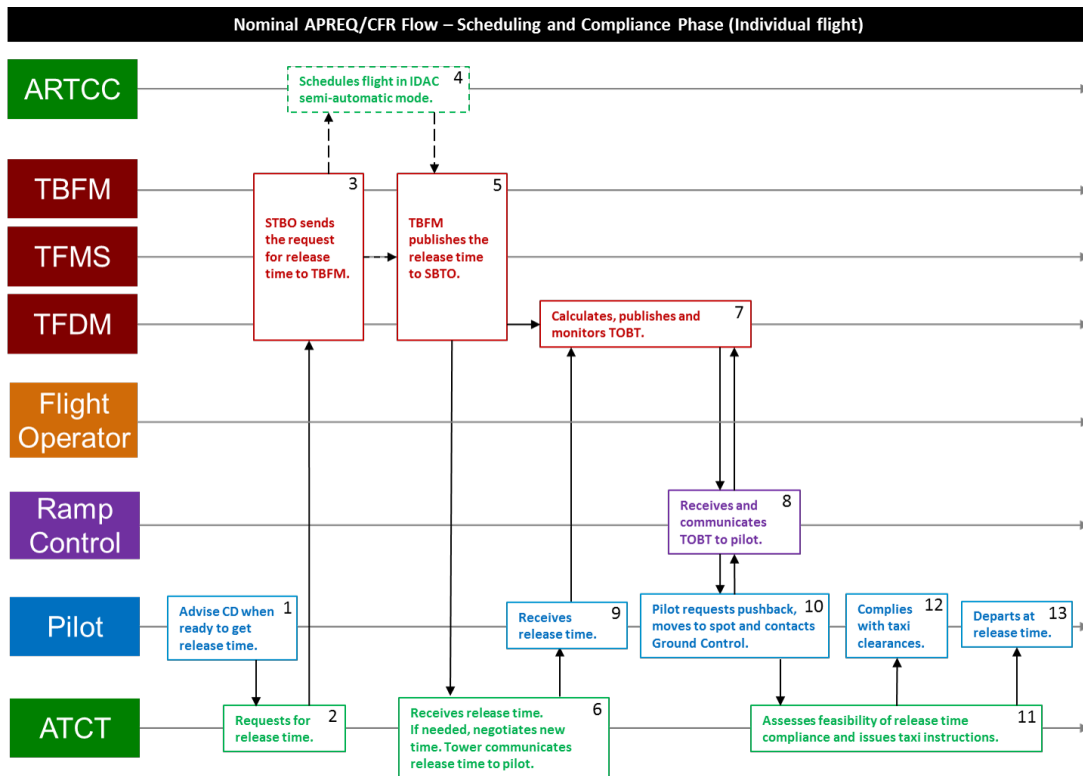


Figure 23 - This illustration shows the flow of data between key stakeholders and systems during the scheduling and compliance phase of the APREQ/CFR process.

#### 5.3.3.2.1 Request for a Release Time (RFRT) (Steps 1-3)

- Step 1: The pilot notifies Clearance Delivery (CD) in the Tower that they are ready for pushback at the pushback time. CD informs the pilot to stand by to receive a release time (also known as the wheels up time).
- Step 2: After the Tower receives a call from the pilot, the Tower TMC uses the STBO Client to schedule the aircraft using the RFRT. The RFRT is a proposed Scheduled Departure Time (SDT) that corresponds to a Scheduled Time of Arrival (STA) at the Center’s meter point. The SDT corresponds to the first available slot in the schedule, as depicted in green in the middle of the timeline in Figure 24.



The STBO Client leverages the TBFM/IDAC Integrated Departure Scheduling Tool (IDST) capability for APREQ/CFR coordination. From the Center standpoint, the CLT requests will appear as if the Tower TMC is using IDST (IDAC tower GUI).

An EDCT may also be appended to the flight. In this case, the STBO Client will highlight the EDCT +/- 5 minute window. This functionality supports the Tower to meet both the APREQ/CFR and the EDCT restrictions.

- Step 3: STBO sends the RFRT to TBFM.

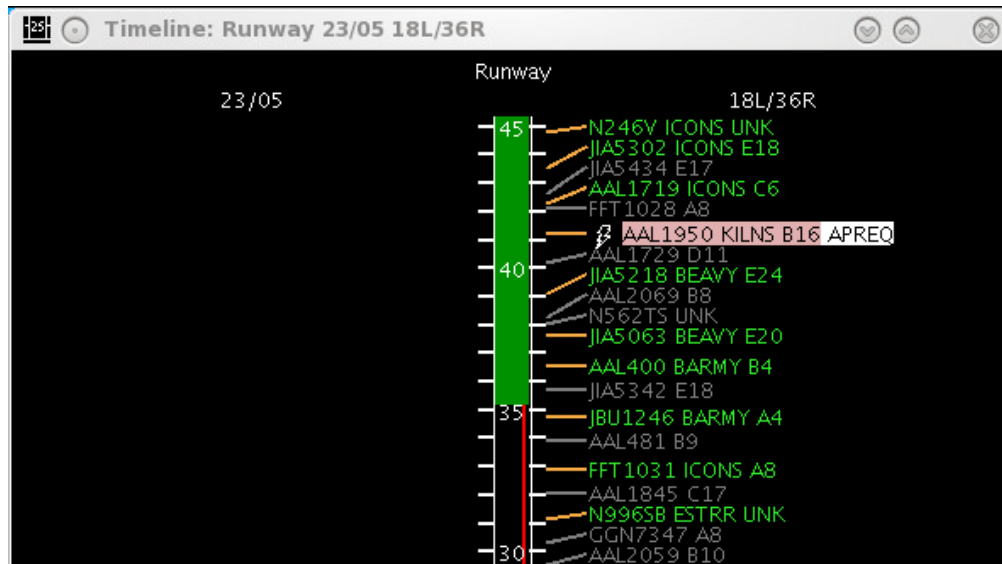


Figure 24 - Slots depicted in green on the STBO Client runway timeline are available for an APREQ/CFR request.

#### 5.3.3.2.2 Response to a Request for a Release Time (Steps 4-5)

- Step 4: The Center TMC handles the RFRT, based on the APREQ/CFR and approval mode assigned to the stream class (see section 5.3.1). In the automatic mode, TBFM approves the RFRT automatically, and the Tower is notified. In the semi-automatic mode, the Center TMC is prompted to respond to the Tower's RFRT.

The Center TMC uses a menu on the TBFM TGUI to accept, reject, or cancel the RFRT. Alternately, if the STA requested by the Tower is not satisfactory, the Center TMC can enter a different STA. Once the Center TMC accepts the STA, TBFM sends the corresponding SDT to the STBO Client.

- Step 5: TBFM sends the SDT to STBO automatically.

#### 5.3.3.2.3 Response to a Scheduled Departure Time (Steps 6-10)

- Step 6: The Tower TMC determines whether the SDT sent by TBFM is acceptable or not. Two cases are possible: a) the Center approves the time the Tower requested, or b) the Center manually assigns another SDT rather than the time the Tower requested.
  - If the Center approves the Tower-requested time, the STBO Client displays the SDT for the flight.*

- ii. *If the Center approves a different time*, STBO Client alerts the Tower to the new time. The Tower TMC then chooses one of the following options:
  - *Scheduled Departure Time is acceptable*. The Tower TMC acknowledges the time. The STBO Client then displays the SDT for the flight.
  - *Scheduled Departure Time is not acceptable*. The Tower TMC can send a Request for a Release Time to the Center using the STBO Client. Numerous iterations of the electronic coordination process can take place; the Tower and the Center specify how unacceptable times should be coordinated.

Note: Either the Tower or the Center can cancel the Request for a Release Time at any time.

- Step 7: Once the SDT is approved in the STBO Client, the STBO Client sends the SDT to the surface scheduler. The surface scheduler computes a TOBT. The surface scheduler continues to monitor the demand and predictions, and updates the TOBT to meet the SDT, if necessary.
- Step 8: Ramp Control receives an indication on their respective displays that the flight was assigned a SDT and a TOBT. The ramp controller coordinates with the pilot to prepare the aircraft to meet its TOBT.
- Step 9: Upon receiving or seeing the SDT, the CD communicates the SDT (i.e., wheels up time) to the pilot. This step happens independently of Steps 7 and 8.
- Step 10: The pilot contacts the Ramp when the flight is ready to push back. As the flight becomes active, the predicted OFF time and the delay on the timeline update in STBO. If the flight complies with the TOBT, the difference between the SDT and the Actual Takeoff Time (ATOT) should be minimal.

#### 5.3.3.2.4 Departure Release Control and Monitoring (Steps 11-13)

- Step 11: In the Phase 1 Baseline IADS Demonstration, the Tower TMC and the GC are provided with the flights' SDTs. It is expected that the Tower TMC manually enters the release time on TFDM EFS/AEFS, and the information is electronically shared with the CD and the GC's AEFS. The GC issues taxi clearances and the Tower TMC monitors the progress of the APREQ/CFR flights on the STBO Client.

Compliance Indicator: The STBO Client monitors the flight's progress on the surface and indicates to the Tower TMC whether the flight is estimated to comply with the departure window (i.e., two minutes before through one minute after the SDT).

- Step 12: The aircraft complies with the taxi clearances. The pilot notifies the GC and the LC of any off-nominal situations preventing the aircraft from taking off.
- Step 13: The LC issues the departure clearance to the pilot. Once the departure takes off, the TRACON controller and the en route controller control the departure to merge it into the overhead stream.

Note: In Phase 1, ZTL will not be handling CLT departures' SDT with TBFM IDAC automation. This means that a portion of the CLT departures with APREQ/CFR will not be handled electronically, as described above. In these cases, the SDT will be communicated to the tower TMC over the phone. However, once the tower receives an SDT, the TMC will be able to enter

the time in the STBO. The tactical scheduler will then provide the TOBT to the Ramp. The manual entry of the SDT will ensure all departures are included in the tactical surface schedulers and help to maintain predictability and efficiency. The STBO interface design will help the Tower be cognizant of the flights that require verbal coordination.

For additional use cases related to the APREQ/CFR scheduling process, see section 5.6.4 – 5.6.6.

### 5.4 Tower and Ramp Coordination through Data Exchange and Integration

This section provides a description of the coordination between the Tower and the Ramp via the data exchange and integration capability of the IADS system. The STBO Client, shown in Figure 25, and the RTC/RMTC (RTC shown in Figure 26), are the primary user interfaces for the Tower and Ramp Control to interact with the automation. They allow the users to exchange information and decisions regarding their respective operations electronically, and thus provide both parties with improved common situational awareness and significantly reduced voice communications. For a more in-depth description of these capabilities, please refer to the ATD-2 sub-project Freeze 1 read-ahead document covering ATD-2 procedures.<sup>12</sup>

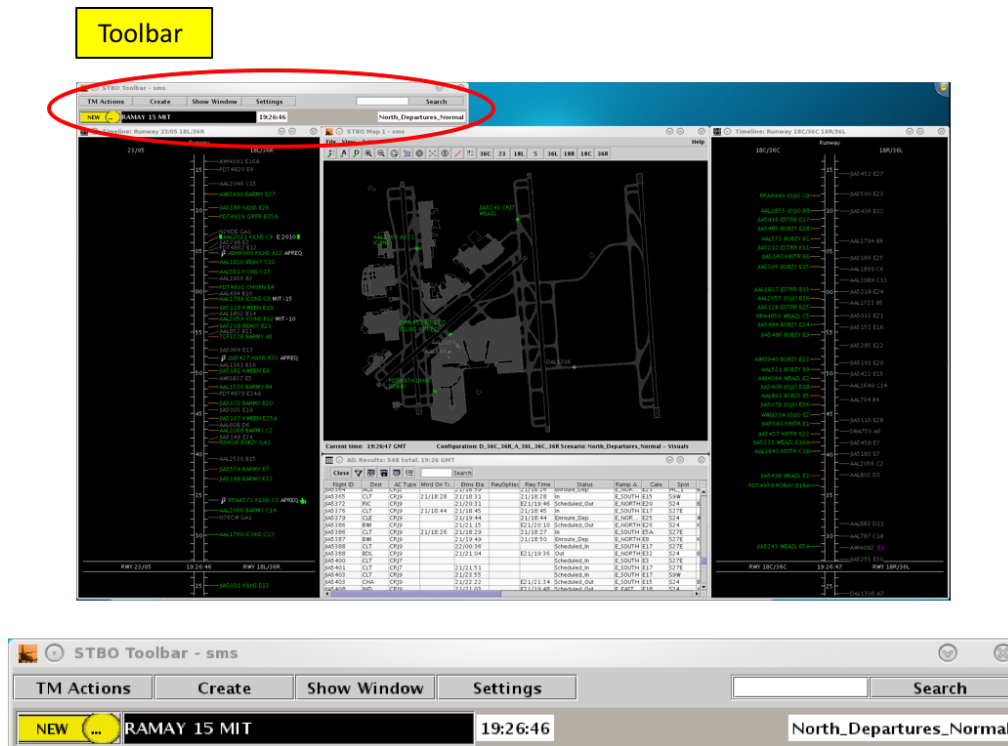


Figure 25 - The STBO Client consists of multiple windows, which can be scaled independently to the user’s preference. The TM Actions button on the toolbar allows the user to schedule/make changes to TMIs and runway utilization.

Figure 25 shows the Tower display of the STBO Client consisting of multiple windows, including a timeline, a map display, and a flights table. They are independent of each other and can be scaled to the user’s preference. The TM Actions button on the toolbar allows the user to interact with the system - to input restrictions, schedule runway utilization plan changes, and to receive notifications. Most of their inputs generate notifications that are consistently shown in the STBO Client’s notification panel and that of the RTC/RMTC.

Figure 26 shows the Ramp display of the RTC/RMTC. The RTC/RMTC is a single-window view of the airport surface. It provides flight-specific information, as well as counts and lists of aircraft moving on the surface, aircraft that are holding, and priority flights.

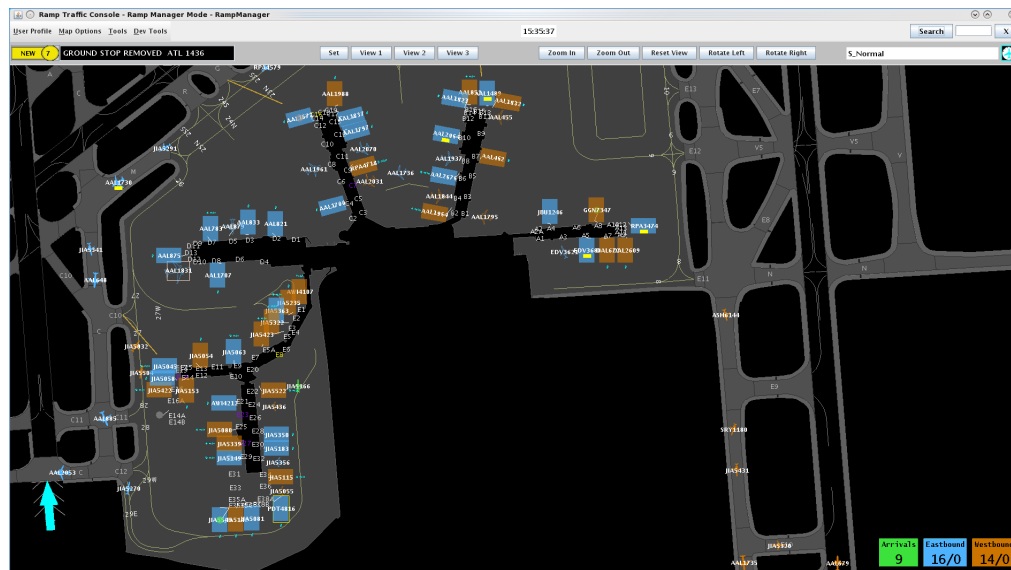


Figure 26 - The RMTC and RTC provide a situational view of the airport surface and allow the user to interact with flights in the ramp area.

When time-based metering is on, the RTC/RMTC offers advisories to assist users in deciding when to clear flights for pushback. Ramp Control can interact with the RTC/RMTC to make changes to the state of a flight, and the Ramp Manager can use the RMTC to close and open the ramp area during lightning conditions. The RTC/RMTC also notifies the user about new events that impact CLT operations.

The following sections provide a description of user interactions with the system, and Ramp coordination that is facilitated through the IADS data exchange and integration capability.

*Runway Utilization* – The Tower TMC can schedule the airport runway utilization plan on the STBO Client. The tool allows the user to input changes to the airport runway configuration and the runway utilization. The airport runway configuration is the flow direction for runway traffic usage, while the runway utilization defines the use of the runways at a more detailed level than the airport configuration. The Ramp is notified on the RTC/RMTC of any changes to the airport runway configuration and utilization plan.

*Runway Change for Operational Necessity* – The Ramp is expected to change the runway for an aircraft when requested by the pilot for operational necessity, which is when an aircraft requires a particular runway to take off. An example is a heavy aircraft may require a runway that is longer than the assigned default runway because of its weight. In this situation, the pilot must contact the Ramp to specify the required runway. Once input into the system by the ramp controller, all users are able to see the runway change.

*Long on Board (LOB) Common Awareness* – ‘Long on Board (LOB)’ refers to the DOT rule prohibiting flight operators from allowing flights to remain on the tarmac for more than three hours before passengers deplane. Failure to follow this rule can result in costly penalties. The

IADS LOB feature helps both the Tower and the Ramp monitor the time on the tarmac, and generates alerts to both the Ramp and the Tower as the time reaches pre-determined thresholds (e.g., 60/90/120 minutes).

*Handling MIT Restrictions* – The STBO Client allows the Tower TMC to manually input new MIT restrictions that have not been populated by the IADS system automatically. The finalized MIT restriction information is transmitted to the RTC/RMTC. The ability to exclude flights from a TMI will also be introduced into the system in Phase 1.

*Ground Stops* – Ground Stops are commonly used to reduce demand on destination airports or other airspace resources. Departures affected by a Ground Stop will be temporarily held on the ground until the restriction is lifted. A Ground Stop allows time to accommodate excess airborne inventory and for the implementation of a longer-term solution, such as a Ground Delay Program (GDP), if needed. Ground Stop information is available to the IADS system through the TFMS TFM Data feed. Alternatively, the Tower TMC can manually input a Ground Stop restriction into the STBO Client, which will disseminate the information to the Ramp for common situational awareness.

*Runway Closures* – The STBO Client provides the Tower TMC with the ability to schedule a runway closure. Runway closures may be scheduled for construction or a planned or unplanned maintenance purpose. A runway may also be closed for snow removal. The Ramp is notified of any scheduled runway closures. The runways that are closed are marked appropriately on both the STBO Client and RTC/RMTC for common situational awareness.

*Departure Fix Closures* – The Tower TMC can schedule a departure fix closure in the STBO Client. The common reasons for a departure fix closure may include severe weather or traffic congestion around the fix. When scheduling a departure closure, the Tower TMC can: 1) select a departure fix for closure and 2) reroute the flights affected by a fix closure to a different fix using Coded Departure Routes (CDRs). A CDR is a preplanned route of flight that can be rapidly issued, coordinated, and communicated to pilots, controllers, and the FAA automation.<sup>32</sup> Information about departure fix closures is shared with the Ramp by marking the fixes as closed on the flight strips. It is also shown on the data tag of the STBO Client Timeline.

*Flight Cancellations* – STBO receives flight cancellation messages from both TFDM SWIM and the flight operator data feeds (e.g., AAL's Flight Hub). STBO relays a flight cancellation message to the Ramp when a flight is cancelled. Ramp Control can also make manual entries into RTC/RMTC to mark a flight cancelled. Information about flight cancellations are displayed to both the Ramp and the Tower TMC.

*Ramp Closures* – A potential cause for ramp closure is lightning incidence or warnings. Lightning is a life-threatening danger to ground crew, therefore regulations specify that the entire ramp area must be closed when lightning strikes in the area of the airport or when detection equipment gives a lightning warning. The RMTC provides the Ramp Manager with a means to specify the ramp status (e.g., Open, Pending Closure, or Closed). This status is updated on both the RTC/RMTC and Tower TMC displays, via notification icons.

*Gate Conflicts* – A gate conflict occurs when a gate occupied by a departure flight is needed by an arrival flight. This situation can occur when an arrival flight arrives earlier than its scheduled arrival time in good weather conditions, or a departure flight is held at the gate due to a TMI

restriction (e.g., EDCT or APREQ/CFR). The STBO Client and the RTC/RMTC display gate conflict information with a configurable setting for time to the conflict.

## 5.5 Dashboard – Real-Time Reporting

Real-time as well as post-operations reporting provides a range of users and stakeholders with a common view of key metrics that enable the analysis and evaluation of airport operations. Analysis and reporting will be conducted to provide insight on capacity, efficiency, and predictability, as well as the effectiveness of scheduling and metering. This capability is separate from the STBO Client and the RTC and appears as an on-screen dashboard, initially configured as a toolbar (see Figure 27), which can be expanded to indicate detailed views of the data, both numerically and graphically.

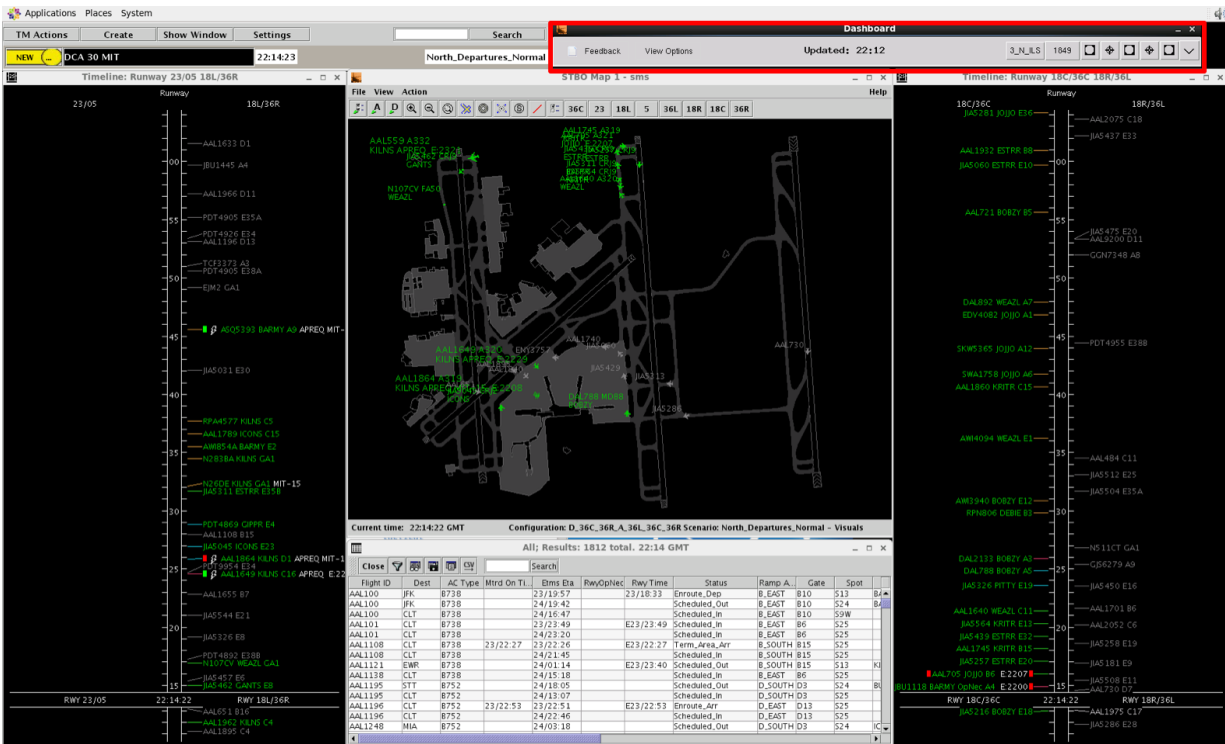


Figure 27 - Real-time dashboard view of the toolbar in conjunction with the STBO Client.

The real-time dashboard utilizes queries from a database, which includes numerous input feeds that support the IADS system, post-operations, and real-time analysis. The benefit of pulling from a shared database allows real-time queries to reflect current operational states as well as user entries to either the STBO Client and/or the RTC. The initial prototype of the dashboard was developed in conjunction with CLT operational personnel input on requirements such as the look and feel, functionality, and desired metrics. The requirements, scope, and capabilities of the dashboard will continue to be refined through user input across all phases of the ATD-2 sub-project.

The real-time dashboard will display metrics in four main categories: airport health and situational awareness, monitoring metrics, benefits metrics, and data quality. Airport health and situational awareness indications include configuration and flow information, as well as the status of the ramp and the current metering mode. Monitoring metrics include throughput,

predicted and actual runway capacity rates, taxi time values for the movement and non-movement area, as well as excess queue time and queue length values. A set of benefits metrics is being defined to indicate potential cost as well as emissions savings that are incurred through utilization of certain operations and procedures. Data quality metrics will indicate the quality of the data feeds into the system, to provide further information in the case of a data outage. The real-time dashboard toolbar will display metrics information on a graphical user interface. The toolbar is indicated by a red box in the screenshot of a display containing both the STBO Client and the dashboard.

The toolbar can be displayed either horizontally or vertically, in order to mitigate potential real estate constraints on the displays. A closer view of the horizontal and vertical version of the dashboard is shown in Figure 28. Either the horizontal or vertical view will allow users to easily note basic airport operating information, such as configuration, metering status, ramp status, and throughput. Icons to indicate this information will match those on the STBO Client and the RTC for consistency and ease of understanding. In addition, a feedback button will be available on the toolbar in order for users to provide details on issues observed, as well as general comments.



Figure 28 - The real-time dashboard can be displayed as either a horizontal or a vertical toolbar.

Various metrics will be available through a pull-down menu on the dashboard, which is accessible from an arrow button at the far-right edge of the horizontal toolbar. This pull-down menu offers the user a selection of metrics for a more in-depth view. The first option for the pull-down menu is a quick-look panel. This quick-look pull-down menu offers a single panel that will provide information to the user regarding the airport health, monitoring metrics, and details regarding TMIs. The information seen in Figure 29 is a snapshot of the dashboard in its current iteration that includes several metrics.

In addition to the quick-look panel, the pull-down menu offers detailed views of specific metrics, such as throughput and taxi time, which can be presented with varying time horizons: the last fifteen minutes, the last rolling hour, and the last cardinal hour as both average line graphs and box and whisker plots, in order to show the variation and spread of the data. These graphical representations along with numerical information on metrics, such as taxi times, arrival and departure counts, and throughput, are available to assist the user in understanding the current operations.

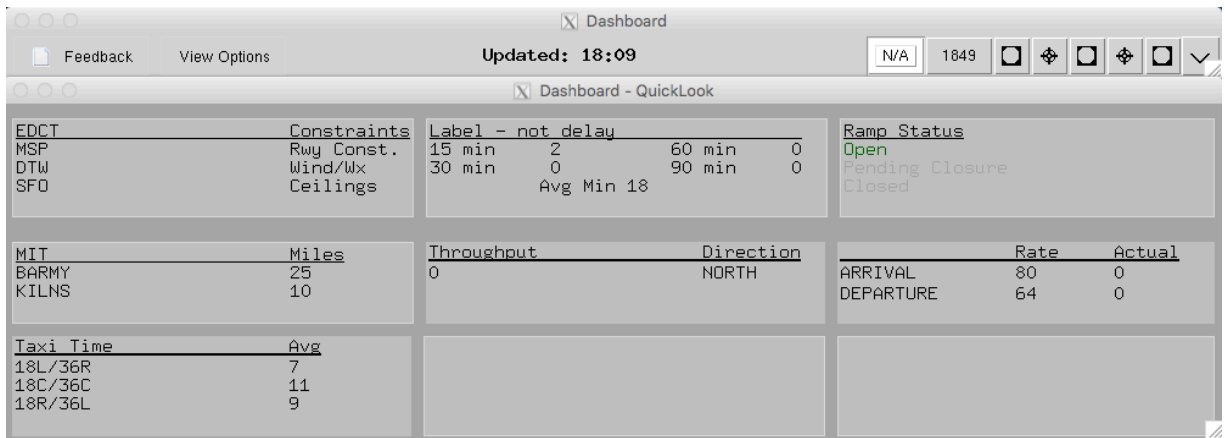


Figure 29 - The quick-look pull-down menu and the horizontal dashboard depict the airport health and provide an overview of the current airport operations.

A demand capacity graph will also be available. This line graph will indicate the amount of excess queue time on average for flights in the next 30- to 45-minutes. This information can be utilized by Ramp Managers to inform their decisions to turn surface metering on and off, based on user-defined thresholds. In addition, several other pull-down menus are being developed; each menu offers data numerically and graphically for a particular subset of metrics, along with the capability to download metrics across specific intervals.

For a more in-depth description of these capabilities, the user is referred to the ATD-2 sub-project Freeze1 read-ahead material covering real-time dashboard training.<sup>15</sup>

## 5.6 Sample Use Cases

This section provides use cases to illustrate the sequence of events for departure flights, and the user interactions with the IADS system throughout the course of the flight. Note: The use cases included in this section are limited to those for which the tactical scheduling components of the Phase 1 Baseline IADS capability will impact the movement of individual aircraft.

### 5.6.1 Use Case 1: Tactical Surface Metering for Non-TMI Flights

In this use case, it is assumed that flights are subjected to time-based metering during a departure bank, but they do not have flight restrictions imposed through TMIs. At CLT, roughly 90% of the flights will experience this use case. The facilities and users involved in this use case are identified in Figure 30.

- Step 1 & 2: The flight operators provide gate and EOBT updates via TFMS/SWIM to the tactical surface scheduler of the IADS system.
- Step 3: The IADS tactical surface scheduler internally computes/updates the TTOT, TMat, and TOBT (in order of calculation), according to the RBS rule, with the pre-determined order of consideration between flights in the ‘Planning’ and ‘Uncertain’ groups.
- Step 4: For the ‘Planning’ group flights, the ramp controller receives the TOBT in the form of a gate-hold or push advisory displayed next to the strip on the RTC. Flights in the



‘Uncertain’ group (as explained in section 5.2.3.2) will have a hashtag symbol (#) displayed next to the strip on the RTC, instead of a gate-hold or push advisory.

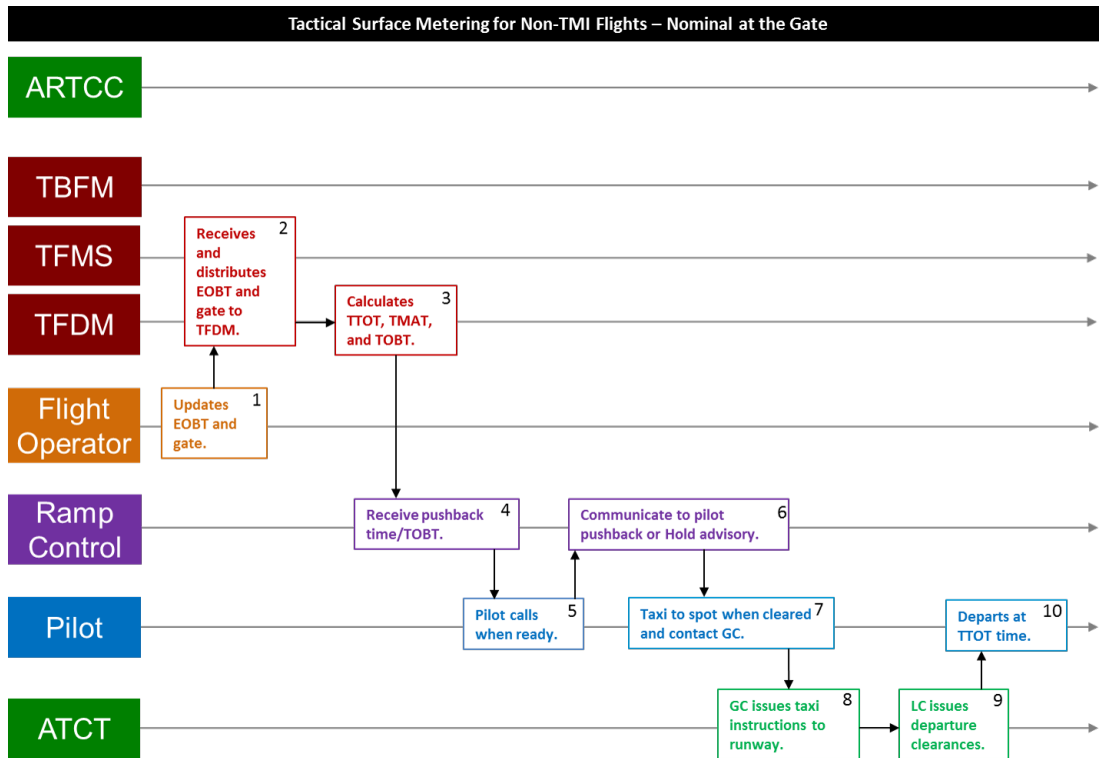


Figure 30 - This illustration shows the flow of events for tactical surface scheduling between key stakeholders and systems for non-TMI flights.

- Step 5 & 6: When the pilot calls in ready for pushback, the ramp controller takes the following actions, depending on the scheduling group that the flight belongs to at the time of the pilot call:
  - Case 1: Flights in ‘Planning’ group:
    - Push advisory – The ramp controller dwells the mouse on the strip, right clicks, and selects ‘pushback flight’ option to clear the flight for pushback.
    - Gate-hold advisory – The ramp controller dwells the mouse on the strip, right clicks, and select ‘hold’ option to indicate a gate-hold. The controller then communicates to the pilot that surface metering is in effect and provides the expected pushback time. A timer begins to count down and when the hold time for the flight expires, a push advisory will be displayed. The ramp controller clears the flight to push back and provides the expected runway. The pilot pushes back without delay.

Note: If the pilot does not call in ready and the clock time passes a pre-determined time period (e.g., 5 minutes) beyond the flight’s EOBT, then the flight will be removed from the ‘Planning’ group and put in the ‘Uncertain’ group.

- Case 2: Flights in ‘Uncertain’ group: The ramp controller clicks the hashtag symbol (#) next to the strip to submit a request for an advisory. Instantaneously, the tactical surface scheduler calculates and returns an advisory, so either a gate-hold or a push advisory will be displayed next to the strip. The ramp controller responds to the advisory, following the same steps as for the flights in the ‘Planning’ group (Case 1). If the ramp controller does not take any action for a pre-determined time period (e.g., 5 minutes) after the flight has received an advisory, the flight will be moved back to the ‘Uncertain’ group.

In both cases, if the ramp controller has issued a pushback clearance by selecting the pushback option, but the aircraft does not push back for a pre-determined time period (e.g., 5 minutes), the flight will be moved to the ‘Uncertain’ group. Note: This would require the surface surveillance to detect aircraft pushback movement in the gate area, which is not currently available, but is expected within the Phase 1 demonstration time frame.

- Step 7: After pushback is completed, the pilot calls in a request to proceed to the AMA (e.g., spot), and the ramp controller clears the flight to proceed to the spot. In CLT, the pilot is required to switch frequencies between the ramp sectors, before the aircraft reaches the spot and control of the aircraft is transferred to the Tower.
- Step 8: Once the aircraft is approaching the spot, the pilot is told by the ramp controller to contact the CLT GC. The pilot switches the frequency to GC to check in. The GC issues a clearance for the aircraft to taxi to the runway.
- Step 9 & 10: Once the aircraft taxis near the runway, the aircraft is transitioned to the LC. The LC issues a departure clearance and the aircraft departs from the runway.

### ***5.6.2 Use Case 2: Tactical Surface Metering (Non-TMI) - Early Gate Pushback***

In this use case, Steps 1 through 6 are the same as in Use Case 1, except that there is a conflict at the gate with an arrival aircraft. Therefore, the departure aircraft needs to push back and stage in the waiting area (i.e., the hardstand) or the ramp controller may clear the aircraft to taxi to the spot, in order to make the gate available to the arrival aircraft. (If the departure flight is not ready to push back, the arriving aircraft needs to be rerouted to the waiting area or to a different gate that is available to the arriving aircraft.)

In the Phase 1 demonstration, the tactical surface scheduler does not factor in a gate conflict when computing the TOBT. In other words, the RTC continues to show a gate-hold or push advisory, based on its nominal TOBT. Therefore, it is the ramp controller’s decision to send the aircraft to the spot or to the hardstand, based on the length of the gate-hold time. In either situation, the strip shows the TMAT to guide the ramp controller in meeting the spot arrival time.

In case the departure is assigned to the hardstand due to a large lead time until its TMAT, the RTC’s Flight Menu is used to mark the aircraft (i.e., a yellow box around the flight strip or the aircraft icon). Then, a new advisory will be shown for that departure at the hardstand to alert the ramp controller, so that it can reach the spot in time to meet its TMAT. Pilots will monitor the Ramp frequency. The Ramp will provide adequate time for the pilots to start engines and prepare the cabin before initiating movement. Once the aircraft is released from the hardstand, the rest of the steps before aircraft takeoff (Steps 7 through 10) are the same as in Use Case 1.

### **5.6.3 Use Case 3: Tactical Surface Scheduling for Flights with TMI Restrictions**

In the case where a MIT restriction is placed on a flight, all the steps in Figure 30 are followed. However, for Step 3, the TTOT, TMA<sub>T</sub>, and TOBT are computed by the tactical surface scheduler, taking into account the required separation at the departure fix.

In the use case where an EDCT or APREQ/CFR release time is assigned to the flight, the earlier end of the compliance window (i.e., EDCT – 5 minutes or APREQ/CFR release time – 2 minutes) becomes the TTOT for Step 3 in Figure 30, and the tactical surface scheduler calculates the TMA<sub>T</sub> and TOBT accordingly. All operators (pilots, Ramp, and Tower) will share common schedule information of TMI restrictions. For pilots, the Pre-Departure Clearance (either electronically or verbally communicated by Clearance Delivery) will indicate when the flight is subject to EDCT or APREQ/CFR restrictions. The departure clearance will include the EDCT time; however, since APREQ/CFRs are tactical in nature and are not available at the time of the PDC, pilots will be told to call Clearance Delivery before pushback for the wheels up time.

The rest of the steps are followed in the same way as in the nominal Use Case 1. As mentioned in section 5.2.3.2.1, the flights with an EDCT or an APREQ/CFR restriction are not subject to surface metering.

In case a TMI flight has an advisory with a long gate-hold time and an arrival aircraft needs the gate, the ramp controller may decide to assign the departure to a hardstand/holding area and clear it for pushback before the TOBT. (In case there is no room in the hardstand/holding area, the ramp controller may send the aircraft to a spot, so the GC may stage the aircraft in the holding area in the AMA.) Once the aircraft is staged in the hardstand, the tactical surface scheduler monitors the aircraft for its EDCT time or APREQ/CFR release time, and provides the ramp controller with an alert regarding when to communicate with the pilot and release the aircraft from the hardstand.

For all cases of TMI flights, the ramp controller receives notification of the TMIs placed on these flights on the RTC, depicted in the flight strip on the RTC (see Figure 17 for the flights under APREQ/CFR restriction and those assigned an EDCT).

### **5.6.4 Use Case 4: APREQ/CFR Flow – Nominal Procedure**

Section 5.3 describes in detail the sequence of events for flights with an APREQ/CFR restriction under nominal circumstances.

### **5.6.5 Use Case 5: APREQ/CFR Flow – Re-Scheduling for Flights Before Pushback**

This case represents the situation when a Scheduled Departure Time cannot be met and needs to be rescheduled while the flight is still parked at the gate or the hardstand. In this situation, the flight is under the control of the Ramp and the flight is predicted to miss its Scheduled Departure Time because the flight's pushback is delayed or severe congestion is expected in the planned taxiway. Therefore, a new Scheduled Departure Time is needed based on the updated EFTT.

The following steps describe the re-scheduling process (see Figure 31).

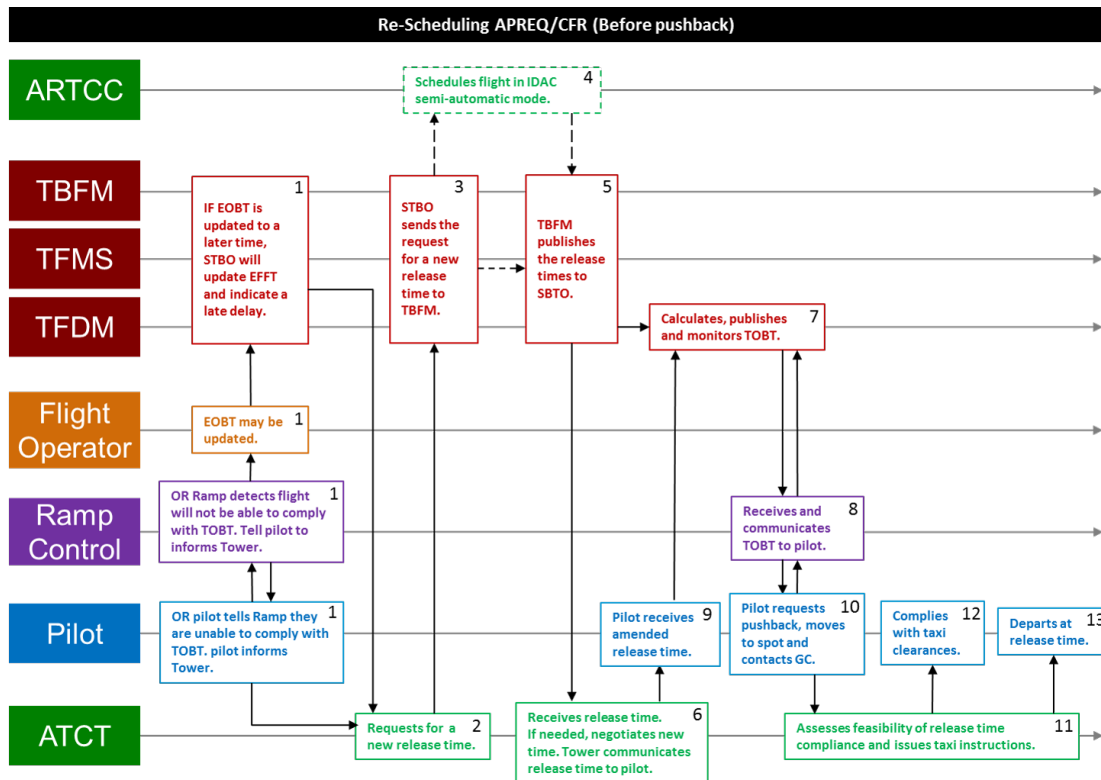


Figure 31 - This illustration shows the flow of events of APREQ/CFR re-scheduling between key stakeholders and systems for flights before pushback.

- Step 1: The detection that the flight will miss its Scheduled Departure Time can come from: a) the Automation, b) the Ramp, or c) the Flight Deck.
  - a) **The Automation:** The STBO’s surface scheduler monitors the status of flights under an APREQ/CFR restriction and can detect that a flight will miss its Scheduled Departure Time. The surface scheduler constantly updates the EFFT of all flights, given the flight’s EOBT and its assumed trajectory on the surface. If the EOBT is updated to a later time, or if the demand on the taxiway is higher than expected, the EFFT may fall behind its Scheduled Departure Time release window. In that case, the early/late indicator in STBO will display that the flight is late for the planned trajectory (See section 5.3.3.2.4).
  - b) **The Ramp:** Ramp Control monitors the status of the APREQ/CFR flights and can detect that a flight will miss its TOBT, and thus its Scheduled Departure Time, before the automation can. The EOBT may be updated in the automation. The Ramp notifies the pilot.
  - c) **The Flight Deck:** The pilots know about the Scheduled Departure Time and may detect that the flight will not be able to comply. The Pilot contacts the Ramp and Clearance Delivery. If the EOBT is updated to a later time in the automation, then the STBO Client will also display the EFFT to a later time.
- Step 2: The Tower cancels the current APREQ/CFR SDT and sends a new Request for a Release Time via STBO. The Tower looks for a new release time and submits it to the

Center. To reschedule efficiently, the EOBT needs to be updated, so the EFTT can be used to submit a new Requested Takeoff Time. The Requested Takeoff Time needs to be at the EFTT, or later.

- Steps 3 to 13 are identical to the nominal APREQ/CFR process, with the exception that the pilot receives an amended release time (e.g., amended Scheduled Departure Time).

### 5.6.6 Use Case 6: APREQ/CFR Flow – Re-Scheduling for Flights After Pushback

This case represents the situation when a Scheduled Departure Time cannot be met and needs to be rescheduled, and the flight is no longer parked at the gate or the hardstand. The flight has pushed back, either maneuvering towards the assigned spot or has entered the taxiway, and it is no longer under the control of the Ramp. The rescheduling is thus handled directly by the Tower. In this situation, the likely steps for re-planning an APREQ/CFR are shown in Figure 32, and described below.

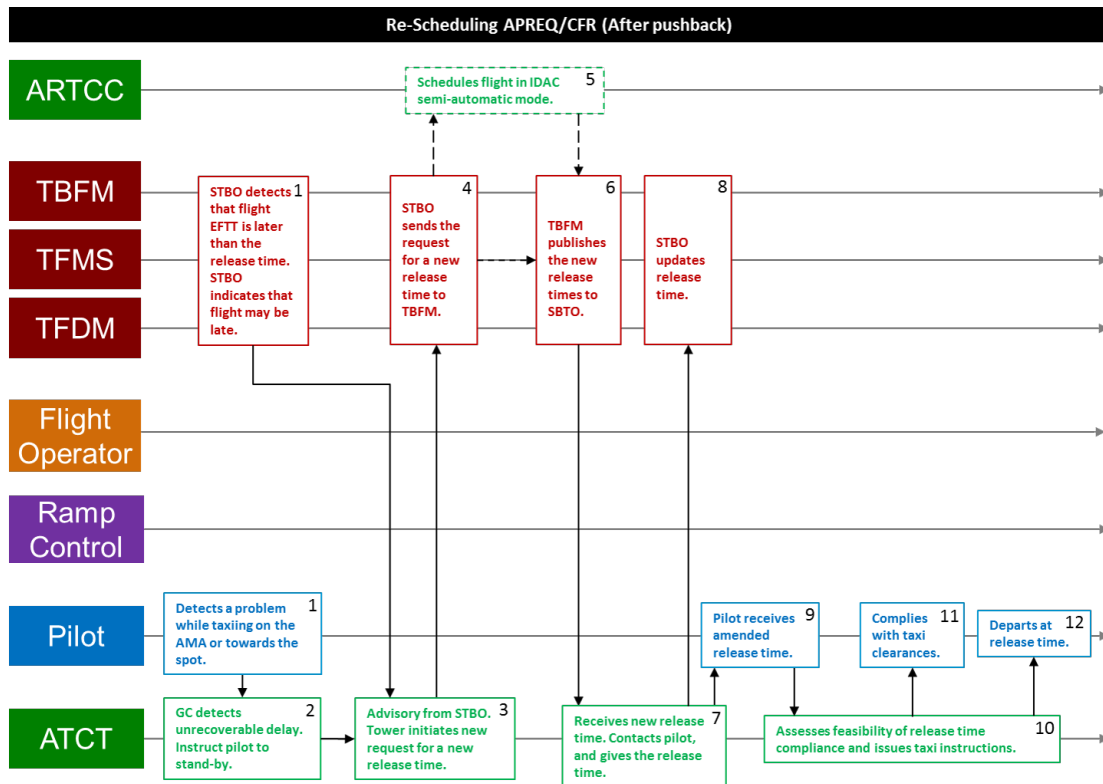


Figure 32 - This illustration shows the flow of events for APREQ/CFR re-scheduling between key stakeholders and systems for flights after pushback.

- Step 1: The detection that the flight will miss its Scheduled Departure Time can come from a) the Automation or b) the Flight Deck and the Ground Controller.
  - The Automation:** STBO monitors the flight’s EFTT and compares it with the Scheduled Departure Time. If the flight’s EFTT falls behind its release time window, the flight will be indicated as late (see explanation of the early/late indicator in section 5.3.3.2.4). If the flight has left the purview of the Ramp, the Tower does not need a new EOBT from the flight operator. However, the Tower needs to be in contact with the pilot.

- b) ***The Flight Deck and the Ground Controller:*** The pilot contacts the GC (if approaching the AMA spot or taxiing on a taxiway) or LC (if approaching the departure runway). It is important that the pilot contact GC or LC as early as is practical.
- Step 2: The GC detects that the flight is late, and assesses whether the delay can be recovered by re-sequencing the flight in the departure queue. If a recovery is not possible, the GC informs the pilot of the situation, instructs the pilot to stand-by, and asks the Tower TMC to reschedule the Scheduled Departure Time for that flight.
  - Step 3: In this case, the call to reschedule is made by the Tower TMC. The rescheduling of the Scheduled Departure Time is handled electronically through STBO.
  - Step 4-6: These steps are similar to the Tower's response to an unacceptable Scheduled Departure Time given by the Center in the nominal APREQ/CFR process (see Step 6 in section 5.3.3.2.3). The Tower looks for a new release time and submits it to the Center. The Requested Takeoff Time needs to be at least the same as the EFTT, or later.
  - Step 7-8: Once the Tower accepts the new Scheduled Departure Time, STBO updates the sequence of aircraft. The Tower then needs to inform the pilot of the amended release time.
  - Step 9-12: These steps are similar to the nominal APREQ/CFR steps. The GC issues instructions to the pilot, controls the flight, and hands it to the LC. The LC then clears the flight for departure.

#### **5.6.7 Use Case 7: Departure Runway Change due to Departure Fix Closure**

This case represents the situation when a flight's departure runway is changed due to the closure of a departure fix. After the PDC has been issued to the flight, if flights are being rerouted to a new departure fix, CDRs are used to update the flight plan. For this use case, the departure fix closure is identified at the time of pushback. The tactical surface metering is also on, and Ramp Control is following the advisories. The steps for changing the departure runway due to a departure fix closure are shown in Figure 33, and described below.

- Step 1: The TRACON notifies the Tower about the local event (e.g., departure fix closure). The departure fix closure and the CDR fix for rerouting the affected flights are entered into the STBO Client.
- Step 2: The tactical surface scheduler re-computes/updates the TTOT, TMAT, and TOBT for the affected flight.
- Step 3: The Ramp receives notification on the RTC/RMTC about the departure fix closure.
- Step 4-5: These steps are the same as steps 4-5 as described in Use Case 1: Tactical surface metering for non-TMI flights in section 5.6.1.
- Step 6: After the pilot calls for pushback, the ramp controller tells the pilot that the departure fix is closed and instructs the pilot to contact CD for a new route, if available, or to stand-by, if no route is available.
- Step 7: The pilot contacts CD and is given a new route.

- Step 8: Once the advisory reaches the end of the hold time, the ramp controller clears the aircraft for pushback.
- Step 9-12: These steps are the same as steps 7-10, as described in section 5.6.1.

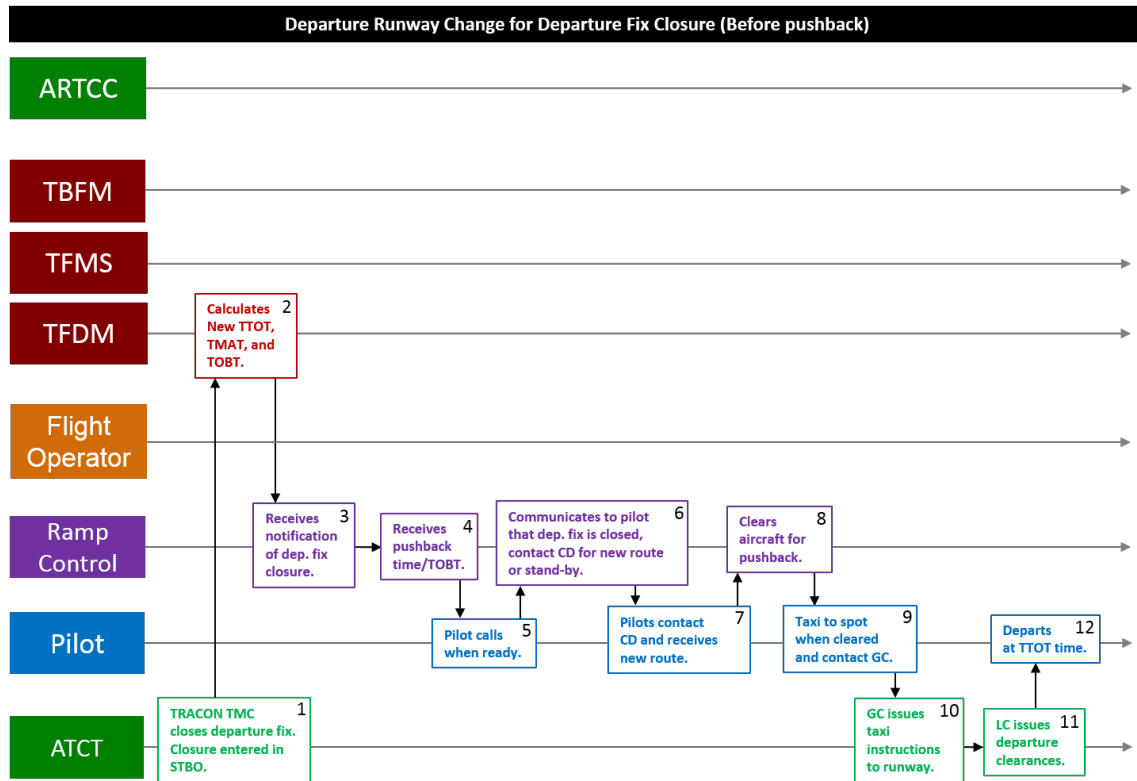


Figure 33 - This illustration shows the flow of events for changing a flight's departure runway due to a departure fix closure.

## 6 Potential Impacts

The following section discusses both the operational and organizational impacts due to implementation of the IADS system. Also, impacts during development of the system are explained.

### 6.1 Operational Impacts

In the Phase 1 Baseline IADS Demonstration, the most significant changes to current operations are due to:

- the data exchange and integration between the Tower and the Ramp
- the automated coordination of APREQ/CFR procedures
- the tactical surface metering procedures for Ramp Control
- the use of TFDM EFD

These operational changes impact the procedures of the Tower personnel (i.e., the TMC, CD, GC, and LC), the Center TMC, Ramp Control, and the pilots.

- The new APREQ/CFR procedure proposed by the IADS system allows for automated coordination between the surface and the en route systems. Phone calls for coordinating APREQ/CFR release times will be no longer needed for many flights scheduled between the CLT Tower and the ZDC TMCs.
- Ramp Control will be notified via the automation about APREQ/CFR restrictions, and release times of affected aircraft will be automatically displayed on the RTC/RMTC. The pilot also receives the release time (wheels up time) from the Tower CD via a verbal communication.
- Tower controllers will no longer use paper flight progress strips to control surface traffic. The GC and the LC will hand off flights electronically to the next position, and it will no longer be necessary to scan flight strips.
- The Tower TMC will use the STBO Client to update the runway utilization intent, the runway assignment, any departure fix closures, and the TMI restrictions, as necessary. This information will be automatically sent to the Ramp, and Ramp Control will receive notifications on their display (i.e., RTC/RMTC).
- The ramp controller will be using pushback advisories displayed on the RTC for releasing departure aircraft from the gate when surface metering is on. The pushback advisory indicates either immediate pushback or gate-hold with a hold time. Target Movement Area entry Times (TMATs) are provided to the ramp controllers.
- The Ramp Manager will use the RMTC to turn on/off the surface metering, and communicate with the Tower digitally for information concerning runway utilization intent, departure fix closures, and TMI restrictions. The Ramp Manager's decisions made through the RMTC are shared with the ramp controllers. The Ramp Manager will also use the RMTC to edit the priority flights list.
- Flight operators who will be participating in the Phase 1 demonstration will be responsible for providing the EOBTs of their flights to the IADS system through the SWIM interface or through a direct flight operator data feed to the IADS system.



## 6.2 Organizational Impacts

Organizational impacts include participation of the IADS system users in training prior to and during the Phase 1 ATD-2 demonstration. Each system user organization will be required to allocate resources to participate in personnel training on the new procedures required by the IADS system. The training requirements include:

- Training on the request and scheduling of APREQ/CFR flights will be required. The bulk of the training required for this procedure will be for the Tower TMCs, who will be the primary users of the STBO Client for APREQ/CFR procedures. Training for the Center TMCs will be primarily focused on use of the enhanced TBFM/IDAC capability and the STBO Client.
- Training for the ramp controllers is required for the use of the RTC, including pushback advisories and APREQ/CFR procedures. Training for the Ramp Managers is required on the utilities of the RMTC, including surface metering, managing the Priority Flight list, and enhancing the coordination with the Tower through electronic data exchange and integration.
- Training of users/research observers on the DRM user interface will be required. The DRM capability will be exercised in a predictive mode, providing predictions on demand/capacity imbalances and recommending DMPs. The users/research observers participating in the evaluation will provide feedback on the DRM-generated predictions.
- Training for the pilots of participating flight operators will also be required. There will be a potential change in the procedure for coordinating an APREQ/CFR restriction among the Tower, Ramp, and flight deck. The pilot will receive the gate-hold/push advisory from the Ramp when the release time is electronically transmitted from the Tower to the Ramp.

In addition to user training, the IADS system users will be participating in shadow evaluation sessions at designated facilities in CLT during the development of the IADS system. The users will also participate in HITLs held in the simulation facilities located at NASA Ames Research Center. These activities will provide the users with opportunities to evaluate the system and provide feedback, which will be used for system enhancement.

There is a potential impact of delayed pushback times due to departure gate holding advised by the surface metering, which may affect flight operator on-time ratings and individual pilot performance ratings which use the D0 metric. However, this is not expected to vary significantly from today's CLT Ramp operations, due to the current departure sequencing procedure exercised by Ramp Control.

## 7 Summary

The concept of use of the Phase 1 capability of the IADS system to be demonstrated at CLT in 2017 was presented. A discussion of the operational shortfalls of current CLT airport and airspace operations was presented, followed by the benefit mechanisms and concept elements of the proposed Phase 1 IADS system. User interactions with the tactical surface metering capabilities were described in detail, along with sample use cases. Use cases were also used to illustrate the step-by-step APREQ/CFR procedures of the tactical departure scheduling capability.

The Phase 1 Baseline IADS capabilities of the ATD-2 sub-project consists 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 traffic streams via accurate predictions of takeoff times and automated coordination between the Airport Traffic Control Tower (ATCT, or Tower) and the Air Route Traffic Control Center (ARTCC, or Center)
- Improvements in departure surface demand predictions in Time Based Flow Management (TBFM)
- A prototype Electronic Flight Data (EFD) system provided by the FAA via the Terminal Flight Data Manager (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 an on-screen dashboard displaying pertinent analytics in real-time

Components of the IADS system will be deployed at the CLT Tower, the Washington Center, the CLT AAL Ramp, the AAL IOC, and the CLT Airport Operations.

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, reduced workload for the Tower and Center operations via 3T electronic data sharing and automation assisted coordination of flights, and increased situational awareness and reduced workload for the airline Ramp Control personnel via pushback advisories and the use of the RTC and RMTC.

Upon successful demonstration of the Phase 1 Baseline IADS capability, Phase 2 and Phase 3 demonstrations of the matured IADS traffic management capability will be conducted in 2018 and 2019, respectively. At the end of each phase of the demonstrations, NASA will transfer the ATD-2 sub-project technology to the FAA and industry partners.

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## Appendix A: IADS Operational Environment

Figure 34 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.

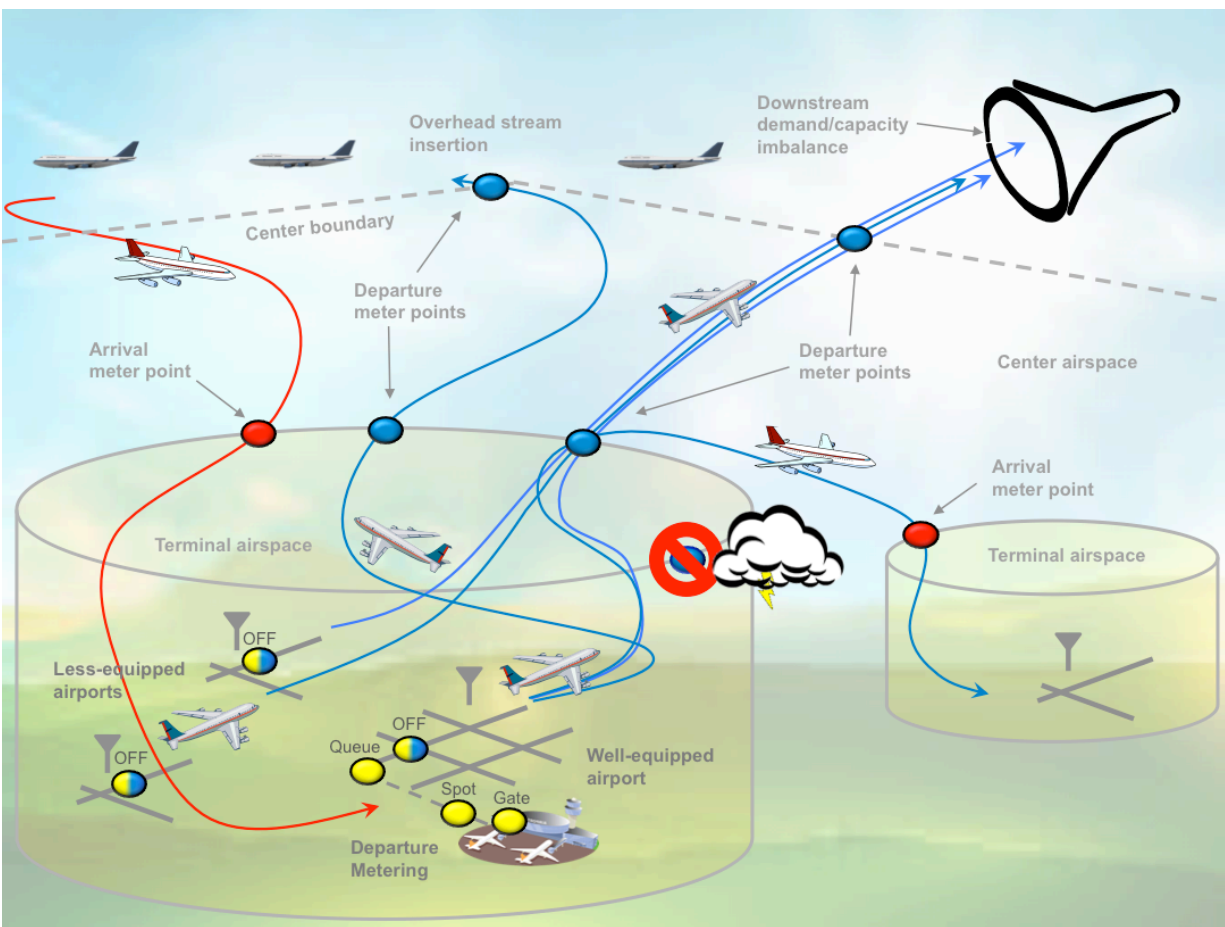


Figure 34 - A simplified view of the ATD-2 sub-project operational environment for the Phase 1 Baseline IADS Demonstration illustrates a variety of surface and airspace control points, plus impacts due to weather and downstream demand/capacity imbalances.

Note that Figure 34 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 active movement area, 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 airline Ramp towers and FAA Towers (e.g., electronic flight strips) than their less-equipped counterparts.

Figure 34 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 34 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 34 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 35, 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 35. The gold stars on the schedule denote schedule commitments that NASA has made to their Field Demonstration

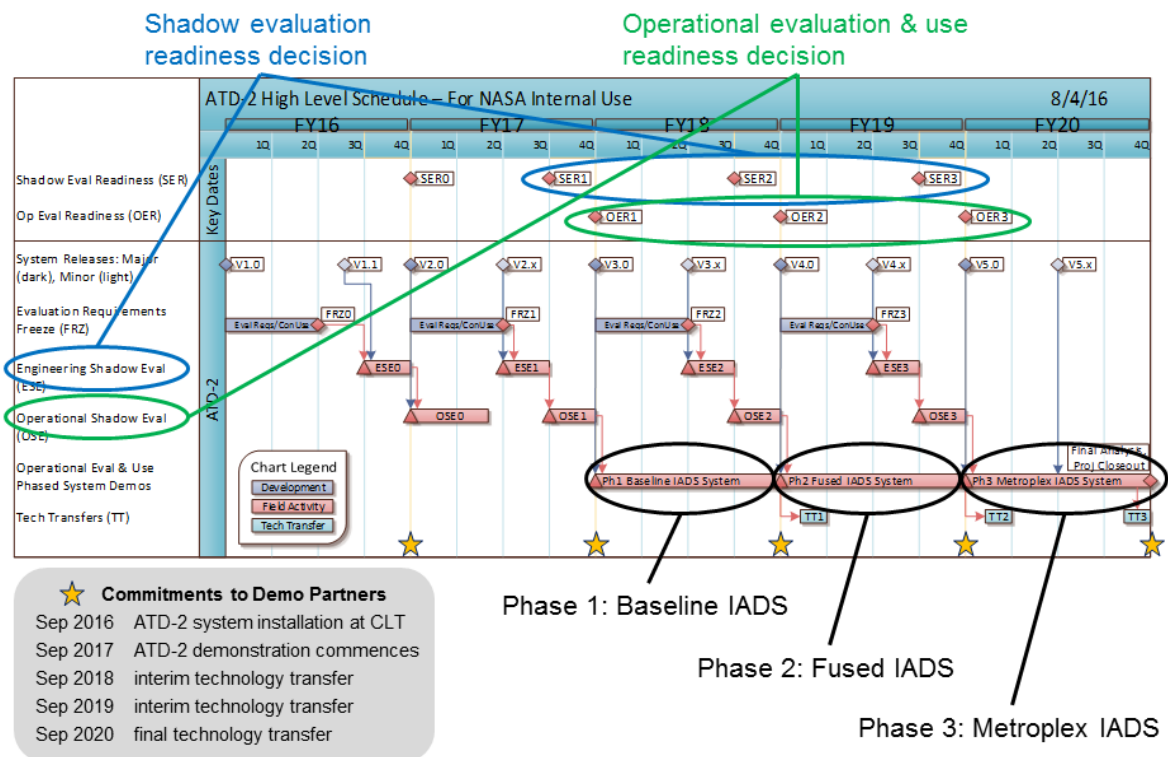


Figure 35 - The ATD-2 sub-project employs a field demonstration strategy built upon three distinct phases, each representing an increased system capability.

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 36. 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.



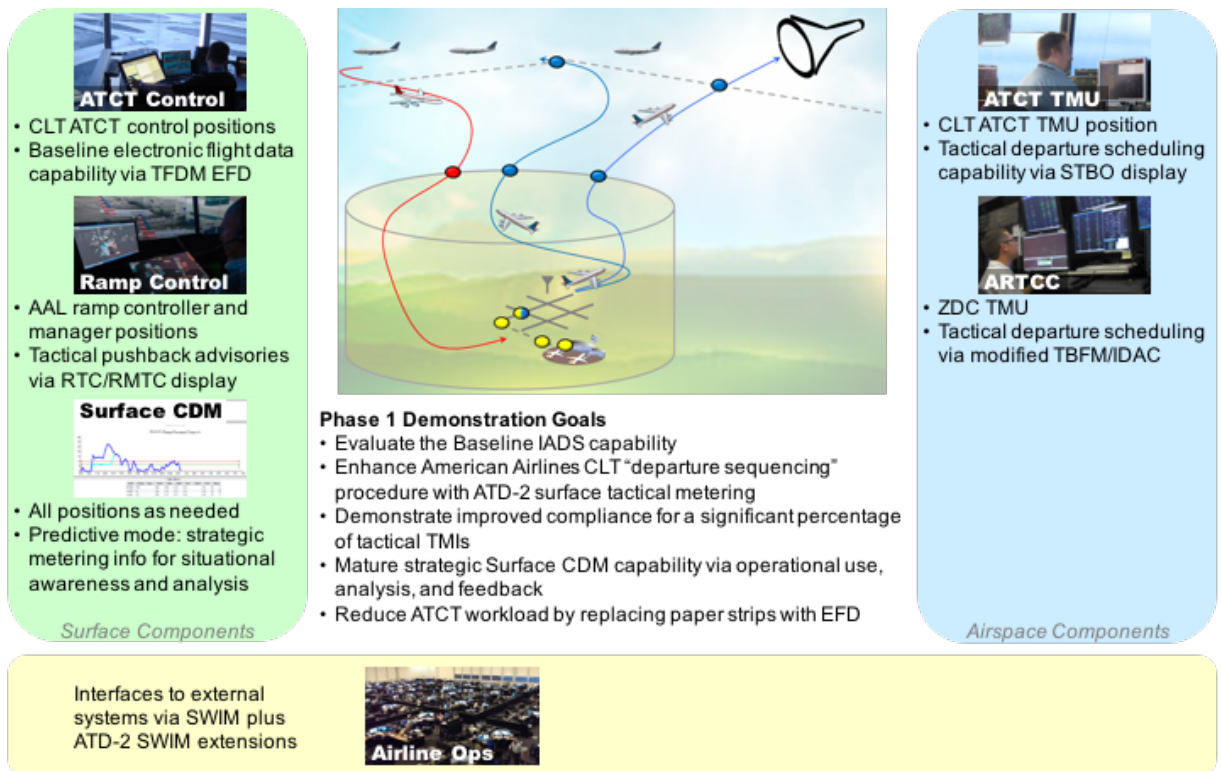


Figure 36 - This operational overview of the IADS system highlights both the participants at various facilities and the system improvements for the Phase 1 Baseline IADS Demonstration.

## 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 37. 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.

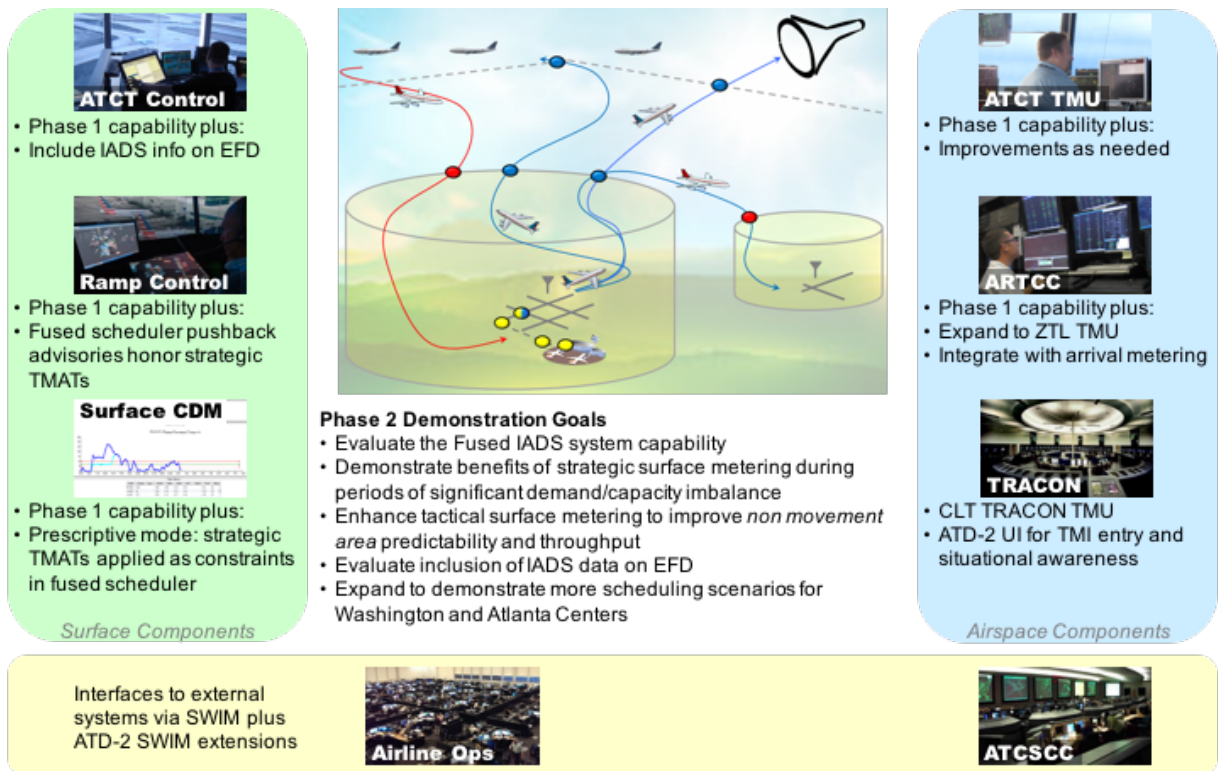


Figure 37 - This enhanced operational overview of the IADS system highlights both the participants at various facilities and the system improvements for the Phase 2 Fused IADS Demonstration.

### 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 38. 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.

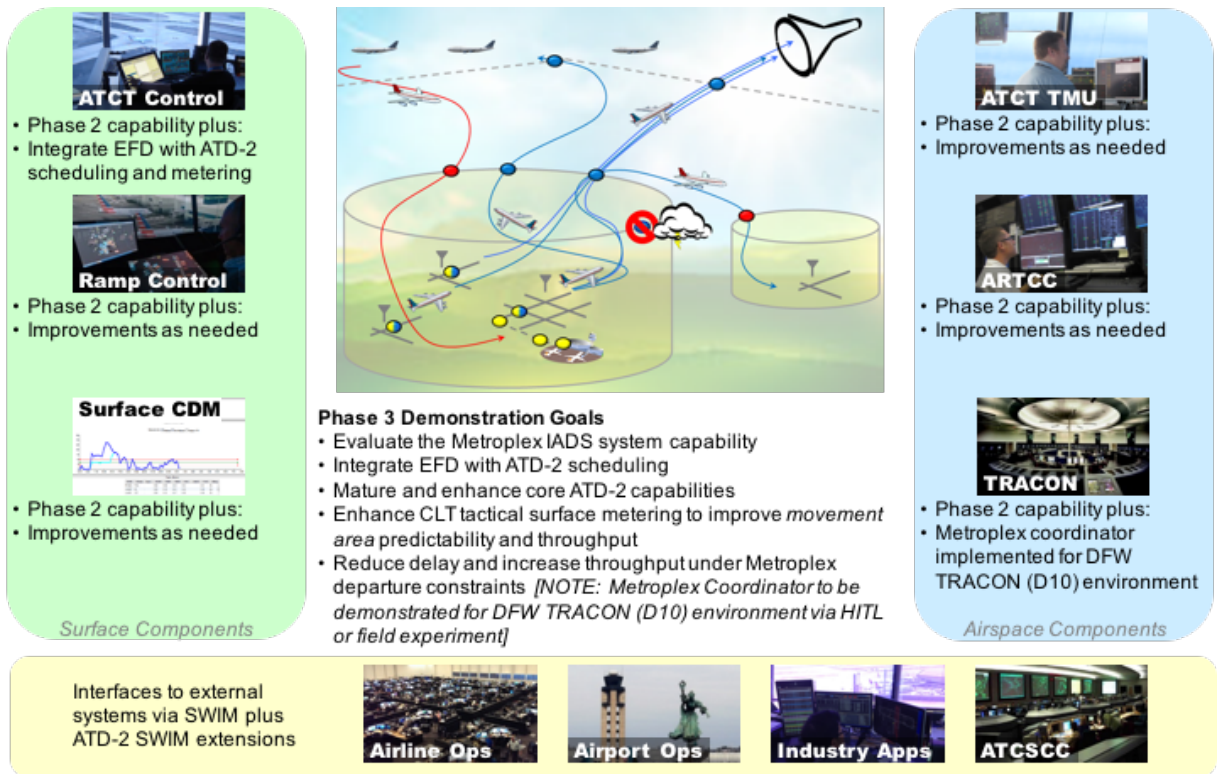


Figure 38 - This full operational overview of the IADS system highlights both the participants at various facilities and the system improvements for the Phase 3 Metroplex IADS Demonstration.

## Appendix C: Acronyms

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

<b>Acronym</b>	<b>Term</b>
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
CDM	Collaborative Decision Making

<b>Acronym</b>	<b>Term</b>
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
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
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 System
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
ETMS	Enhanced Traffic Management System
ETOT	Estimated Takeoff Time
EWR	Newark Liberty International Airport
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FCA	Flow Constraint Area
FCFS	First-Come, First-Served
FDIO	Flight Data Input/Output
FEA	Flow Evaluation Area

<b>Acronym</b>	<b>Term</b>
FFC	Future Flight Central
FID	Final Investment Decision
FIXM	Flight Information Exchange Model
FLM	Front Line Manager
FMC	Flight Management Connector
FO	Flight Operator
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
MRA	Metrics, Reporting & Analysis (DRM component)
N-value	Target number of flights in queue
N90	New York TRACON
NAC	NextGen Advisory Committee (FAA)

<b>Acronym</b>	<b>Term</b>
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 TFM Data 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
RTC	Ramp Traffic Console
RTT	Ramp Transit Time
RTT	Research Transition Team
SIAP	Standard Instrument Approach Procedure

<b>Acronym</b>	<b>Term</b>
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
TQET	Target Queue Entry Time
TRACON	Terminal RADAR Approach Control
TS	Trajectory Synthesizer
TSAS	Terminal Sequencing and Spacing (formerly TSS)



<b>Acronym</b>	<b>Term</b>
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