

Airspace Technology Demonstration 2 (ATD-2)

*Integrated Arrival/ Departure/Surface (IADS)
System Demonstration*

*Technology Transfer Document Summary
(ReadMe)*

Version 2 - Phase 2 Fused IADS

ATD2-2019-TN73465

*Alan Capps, Shawn A. Engelland, Jane Thipphavong, Andrew Ging, Yoon C. Jung
NASA Ames Research Center, Moffett Field, CA*

*Easter M. Wang, Henry M. Sielski, Tyler T. Ngo
Universities Space Research Association (USRA) - NASA Academic Mission Services (NAMS)
NASA Ames Research Center, Moffett Field, CA*

*Louise K. Morgan-Ruszkowski
KBRWyle/Parallel Innovations
NASA Ames Research Center, Moffett Field, CA*

*Ehsan Talebi
Millennium Engineering & Integration Company
NASA Ames Research Center, Moffett Field, CA*

September 2019

Table of Contents

Introduction.....	3
Overview.....	3
Technology Transfer Process and Organization	4
1. High-Level and Project Documents	5
1.1 High-Level Documents and Videos	5
1.2 Project Documents	6
2. Phase 1 and 2 Knowledge and Technology Artifacts.....	7
2.1 IADS System.....	7
2.2 TFDM Terminal Publication (TTP)	9
2.3 SWIM and Fuser Technology	9
3. Technical Publications	11
3.1 Publications	11
3.2 NASA Research Announcement (NRA) Reports and Briefings	16
4. Evaluation Results.....	18
5. Informal Technology Transfers	20

Introduction

Overview

Airspace Technology Demonstration – 2 (ATD-2) is part of NASA's Airspace Technology Demonstrations (ATD) Project under its Airspace Operations and Safety Program (AOSP). ATD-2 is a multi-year research and development effort to improve the predictability and operational efficiency of the air traffic system in metroplex environments while maintaining or improving throughput by enhancing and integrating arrival, departure, and surface prediction, scheduling, and management systems. In order to ensure that the products of this knowledge and technology transfer are relevant and useful, NASA has created strong partnerships with the FAA and industry stakeholders.

This summary document and accompanying artifacts satisfy the second of three research transition products (RTPs) defined in the IADS research transition team (RTT) plan.

During the ATD-2 Phase 1 demonstration, the following capabilities were developed and deployed to the Charlotte International Airport (CLT) air traffic control facilities, including Tower and Ramp, as well as Washington Air Route Traffic Control Center (ARTCC) for field evaluation (end of September 2017 – September 2018):

- Data Exchange and Integration which provides the foundational data sharing among FAA and the Operator community
- Overhead Stream Scheduling that leverages operator-provided earliest off block times (EOBTs) along with highly accurate trajectory-based taxi time estimates to schedule into the overhead stream, and communicate the corresponding release times to all users
- Tactical Surface Metering which leverages concepts consistent with Surface Collaborative Decision Making (Surface CDM) and Terminal Flight Data Manager (TFDM) metering while allowing the latest inputs (like pilot call in, or lack of EOBT) to be factored into the surface metering plan
- Real-time Dashboard and post operations data products that make use of the highly instrumented data that becomes available from the surface system and its many data sources

The Phase 2 Fused IADS system provided substantial updates to Phase 1 Baseline IADS Demonstration capability. Improvements were made to the IADS modeler and tactical surface scheduling, collaborative surface metering, tactical departure scheduling for overhead stream insertion, Electronic Flight Data (EFD) via integration with the FAA Advanced Electronic Flight System (AEFS), RTC/RMTC, and departure trajectories. New capabilities included:

- A TFDM SWIM prototype feed that enabled delivery of IADS data via the TFDM Terminal Publication (TTP) service of the FAA's SWIM system
- Fusion of strategic and tactical surface scheduling and metering

- Integration and ingestion of data from TTP-connected Mobile App for General Aviation (GA) flights
- Expansion of airspace deployments to include adjacent Center automation, in particular interface with the Atlanta Center (ZTL) arrival metering TBFM system to evaluate pre-scheduling of flights
- Improvements in Data Analysis and System Health (DASH) monitoring and updates

Field evaluation of Phase 2 IADS capabilities commenced in September 2018 and continued through the end of September 2019.

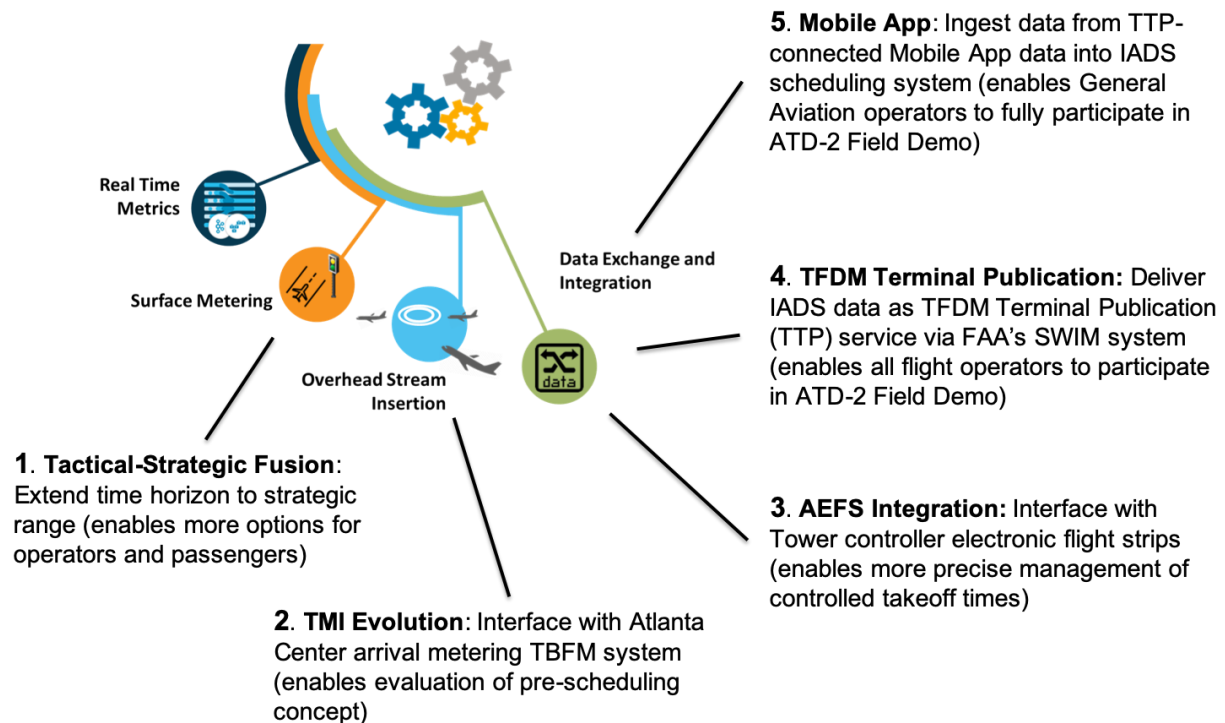


Figure: New Capabilities Introduced by Phase 2 Fused IADS System

Blue highlighting indicates the new or modified deliverables. Distribution of these materials outside of the U.S. Government is permitted without restrictions.

Technology Transfer Process and Organization

The tech transfer artifacts listed in this document can be accessed via the following NASA website:

<https://aviationsystemsdivision.arc.nasa.gov/publications/atd2/tech-transfers/>

The transfer of NASA's ATD-2 technology is planned as a series of incremental deliveries of research and development products. This package describes the capabilities of both Phase 1 and Phase 2.

Subsequent tech transfers will add products to the collective ATD-2 tech transfer package in such a manner that the final tech transfer package is complete documentation of the entire lifecycle of ATD-2.

This tech transfer package is organized with this README document as the starting point for both web and USB deliveries. The Docs List is an additional starting point for USB or zip file deliveries only.

[ATD-2 Tech Transfer Phase 2 README \(September 2019\)](#)

This README lists the artifacts contained in this delivery with brief summaries of their contents, which are intended to help recipients understand what is available.

[ATD-2 Tech Transfer Phase 2 Docs List \(September 2019\)](#)

(USB or zip file delivery only) The Docs List provides a simple way to access the individual documents. Click on a document name in the Docs List, and the specified document will open in a separate window. The Docs List remains open in its original window.

[Document Search \(September 2019\)](#)

(USB or zip file delivery only) Double-click on the DocSearchIndex.pdx file to open the “Search” dialog. Enter the search criteria, choose any other filters to narrow the search, and select “Search”. All documents that match the search criteria will be listed in the dialog. Just click on the desired item to open the document.

1. High-Level and Project Documents

This section contains the high-level documents that describe the ATD-2 Concept of Operations and internal project documents that describe preliminary requirements and benefits of the ATD-2 technologies.

1.1 High-Level Documents and Videos

1.1-01. [ATD-2 Fact Sheet \(Apr 2019\)](#) [External Link]

The ATD-2 factsheet describes NASA’s IADS concept and the associated technologies that will demonstrate the benefits of an IADS traffic management system for complex terminal environments. The factsheet is publicly available on the NASA Ames Aviation System Division webpage: https://www.aviationsystemsdivision.arc.nasa.gov/research/atd2/ATD2_FS-2019-04-03-ARC_Final.pdf.

1.1-02. [New NASA Field Demo Tests Software to Reduce Airport Delays \(December 2017\)](#) [External Link]

This 2-minute NASA video introduces the ATD-2 Phase 1 field demonstration at Charlotte-Douglas International Airport (CLT). The video is geared for public audiences and available for viewing at the

NASA Ames Aviation System Division webpage:

<https://www.aviationsystemsdivision.arc.nasa.gov/research/atd2/index.shtml>.

1.1-03. NASA Field Demo to Reduce Ground Delays Begins (November 2017) [External Link]

This 9-minute NASA video describes the ATD-2 CLT field demonstration in more detail and includes interviews with NASA management and partners from the FAA, National Air Traffic Controllers Association (NATCA), and American Airlines. The video is geared for public audiences and available for viewing at the NASA Ames Aviation System Division webpage:

<https://www.aviationsystemsdivision.arc.nasa.gov/research/atd2/index.shtml>.

1.1-04. ATD-2 Concept Animation V2.1 (April 2018) [External Link]

This animation provides a high-level overview of the ATD-2 integrated concept. The 4-minute animation for public audiences is available for viewing at the NASA Ames Aviation System Division webpage:

<https://www.aviationsystemsdivision.arc.nasa.gov/research/atd2/index.shtml>.

1.1-05. NASA/TM-2018-219770 Airspace Technology Demonstration 2 (ATD-2) Phase 1 Concept of Use (ConUse) (YJung, February 2018)

The ATD-2 ConUse document provides an overview of the IADS concept and detailed descriptions of how each group of users will interact with the proposed system. Specifically, this document focuses on the conceptual elements for the ATD-2 Phase 1 Baseline IADS Demonstration at CLT.

1.1-06. NASA/TM-2019-73286 Airspace Technology Demonstration 2 (ATD-2) Phase 2 Technology Description Document (TDD) (ETalebi, September 2019)

This Technology Description Document (TDD) provides an overview of the ATD-2 IADS technology from Phase 1 Baseline, which began demonstration in 2017, and Phase 2 Fused, which began demonstration in September 2018 - both at CLT. This TDD is intended to be a companion document for the ATD-2 ConUse document.

1.1-07. Airspace Technology Demonstration 2 (ATD-2) Concept of Use (ConUse) Addendum for Phase 2 (YJung, September 2019)

This presentation serves as an addendum to the ATD-2 Phase 1 ConUse and describes the concept of use for the ATD-2 Phase 2 IADS system and quantitative benefits assessment.

1.2 Project Documents

1.2-01. ATD-2 Glossary, V2.0 (September 2019)

The Glossary contains descriptions of terms and acronyms found in several ATD-2 IADS documents. The purpose is to provide a common understanding of the terms for anyone interested in ATD-2.

1.2-02. [ATD-2 FAA/NASA Coordinated Activities, Compilation FY16-18](#) (FAA, September 2018)

1.2-03. [ATD-2 FAA/NASA Coordinated Activities, Compilation Sep 2018 - Aug 2019, v6](#) (FAA, September 2019)

These documents give an overview of the coordinated activities between NASA and the FAA in support of ATD-2. It is a compilation of monthly status reports generated by FAA ANG.

1.2-04. [ATD-2 Systems Specification - Phase 2](#) (TNgo, September 2019)

This document summarizes the IADS system capabilities developed in Phase 2. It also serves as the Requirements Verification Matrix (RVM) deliverable for the ATD-2 project.

2. Phase 1 and 2 Knowledge and Technology Artifacts

This section contains documents on the development of the ATD-2 IADS System prototype and its related technologies.

2.1 IADS System

The IADS System is comprised of multiple components: Surface Trajectory Based Operations (STBO), Ramp Manager Traffic Console (RMTC)/Ramp Traffic Console (RTC), Schedulers, and Integrated Departure/Arrival Capability (IDAC)-like capability for electronic negotiation of departure release times.

2.1-01. [STBO Client User Manual](#) (September 2019)

The STBO Client manual was updated to include new functionality for ATD-2 Phase 2. It describes how to use the ATD-2 Air Traffic Control Tower tools.

2.1-02. [Quick Reference Guide STBO Client V2.0](#) (September 2018)

2.1-03. [ATC Tower and Terminal Radar Approach Control \(TRACON\) Training V1.0](#) (September 2017)

These STBO Client training materials were used during ATD-2 Phase 1 starting in September 2017 and describe how to use the ATD-2 Air Traffic Control Tower tools.

2.1-04. [RTC/RMTC User Manual](#) (September 2019)

The RTC/RMTC manual was updated to include new functionality for ATD-2 Phase 2. It describes how to use the ATD-2 ramp tools.

2.1-05. [Quick Reference Guide RTC V2.0](#) (September 2018)

2.1-06. [American Airlines CLT Ramp Training RTC/RMTC V1.0](#) (September 2017)

These RTC/RMTC training materials were used during ATD-2 Phase 1 starting in September 2017 and describe how to use the ATD-2 ramp tools.

2.1-07. [STBO Client Observer Mode User Manual V1.0](#) (September 2017)

2.1-08. [Quick Reference Guide STBO Client Observer Mode V1.1](#) (July 2018)

These STBO Client Observer Mode training materials were used during ATD-2 Phase 1 starting in September 2017. Observer Mode allows the user to view, but not make data entries on, the STBO Client display.

2.1-09. [RTC/RMTC Observer Mode User Manual V1.0](#) (September 2017)

This RTC/RMTC Observer Mode training material was used during ATD-2 Phase 1 starting in September 2017. Observer Mode allows the user to view, but not make data entries on, the RTC/RMTC display.

2.1-10. [What-If System User Manual V1.0](#) (August 2017)

This What-If System training material was used during ATD-2 Phase 1 starting in September 2017. The What-If System is meant to be a “sandbox” to be able to view the potential impact of system wide changes on the tower side (STBO Client) and metering decisions on the ramp side (RMTC) without actually making changes to the system.

2.1-11. [ATD-2 Washington Center \(ZDC\) Training](#) (September 2017)

2.1-12. [TBFM IDAC Procedure to Disable NASA Connection with CLT STBO Electronic Requests for Release Times](#) (September 2017)

These training materials for Washington Center controllers were used during ATD-2 Phase 1 starting in September 2017.

2.1-13. [ATD-2 Phase 1 New Features Training](#) (August 2018)

This document is a compilation of training materials from multiple New Feature releases during ATD-2 Phase 1 since the initial release in September 2017.

2.1-14. [ATD-2 V3.0.x Releases and Notes Overview](#) (MEshow, August 2018)

2.1-15. [ATD-2 V3.1.x Releases and Notes Overview](#) (CFreedman, August 2018)

These documents summarize the ATD-2 software releases during ATD-2 Phase 1 since the initial release in September 2017.

2.1-16. [ATD-2 RTC and RMTC Version 4.4 Updates](#) (DBakowski, May 2019)

This presentation was used during Phase 2 ramp controller training on the new scheduling capabilities deployed in V4.4.

2.1-17. [ATD-2 V4.x Releases and Notes Overview](#) (CFreedman, September 2019)

This document summarizes the ATD-2 software releases during ATD-2 Phase 2.

2.1-18. [ATD-2 Web-Based Surface Metering Display \(SMD\) User Manual, V4.6.0 \(September 2019\)](#)

This document describes the elements of the full SMD interface and provides explanations for how to interact with the SMD. It provides instructions for selecting the type of metering, entering specific metering parameters, and setting excess queue time variables. There are instructions for submitting system feedback and bug reports as well.

2.2 TFDM Terminal Publication (TTP)

The TTP functionality produces and consumes Surface System Wide Information Management (SWIM) data as a surrogate for TFDM Build 2. It provides TTP data to industry via SWIM for CLT and Dallas-Fort Worth (DFW) airports in 2018-2019. TTP data is leveraged to satisfy the needs of mobile app users, cargo areas, gate agents, pilots, and others. The ATD-2 goal for TTP is to incentivize early on-ramping to TTP data feed.

The Phase 1 tech transfer in September 2018 contained initial ATD-2 TTP Messages implementation documents (2.2-01 to 2.2-05) from NASA and draft TFDM TTP Service documents (2.2-06 to 2.2-11) from Leidos Civil - Transportation and Financial Solutions. These documents are now obsolete and have been removed from the tech transfer package.

2.2-12. [NASA TFDM Terminal Publication \(NASA TTP\) Service Profile and Documents \(September 2019\)](#)

This document summarizes the 14 updated NASA TTP Messages implementation documents and Leidos TFDM TTP specifications located on the FAA NAS Service Registry and Repository (NSRR) site. An NSRR account can be requested on the initial login page.

NASA TTP NSRR Profile: <https://nsrr.faa.gov/services/nasa-ttp/profile>

NASA TTP NSRR Documentation: <https://nsrr.faa.gov/services/nasa-ttp/documents>

2.3 SWIM and Fuser Technology

The Fuser is ATD-2's solution to managing the multiple data feeds available from SWIM. The Fuser provides services for data parsing, flight matching, and data fusion. The content in this section was presented in the ATD-2 and TFDM Special Session of the SWIM Industry-FAA Team (SWIFT) meeting in May 2019. SWIFT is an FAA forum that offers a collaborative environment for outreach activities related to FAA information services shared via SWIM. These presentations are also available on the SWIFT website:

https://www.faa.gov/air_traffic/technology/swim/swift/media/SWIFT%20Meeting%20Presentation%206%20Day%202%205_22_19.pdf

2.3-00. [ATD-2 Perspective: SWIFT Day 2 Introduction \(ACapps, May 2019\)](#)

This presentation describes the manner in which the ATD-2 began consuming data from SWIM and gradually built new services to satisfy in its mission. This lessons learned from this work indicate that

additional data-rich services will be required in the future. This also led to the development of data pre-processing and mediation services that are now of much interest to the community. The presentation mentions some of the barriers to progress that exist for those seeking to use SWIM flight data, and NASA's desire to share its lessons learned with the aviation community.

2.3-01. [Learning To SWIM with ATD-2](#) (SGorman, May 2019)

This presentation describes how ATD-2 accesses, consumes, and parses the various data feeds available from SWIM.

2.3-02. [Fuser Why Everyone Should Have One](#) (SGorman, May 2019)

This presentation gives a high-level overview of the ATD-2 Fuser as one solution to the challenges of effectively utilizing SWIM data.

2.3-03. [Fuser Deeper Dive \(Mediation & Use Cases\)](#) (SGorman, May 2019)

This presentation describes details of flight matching and processing in the Fuser and provides some specific challenges and solutions.

2.3-04. [Fuser Database](#) (SGorman, May 2019)

This presentation covers the Fuser databases, naming conventions, and examples of how the databases have been used to support ATD-2.

2.3-05. [Turning SWIM Data into Consistent Reports for Analysts and Users](#) (AChurchill, May 2019)

ATD-2 relies on, and generates, huge amounts of data. However, this raw data needs to be collected and converted into useful information for operational analysis. In this presentation, we describe the efforts undertaken on the ATD-2 project to generate various reports to support project analysis and user needs.

2.3-06. [Accuracy Comparison of Various Landing Time Prediction Sources](#) (AChurchill, May 2019)

This presentation describes on-going work to quantify accuracy of different sources of landing time predictions as actual arrival event approaches.

2.3-07. [Analysis of APREQ Flights at CLT](#) (WCoupe, May 2019)

This presentation describes on-going work to quantify impact of IADS Phase 1 & 2 capabilities on APREQ flights at CLT.

2.3-08. [Predictive Analytics for ATD-2](#) (WCoupe, May 2019)

This presentation describes on-going work to leverage high quality data and predictive analytics to improve understanding and performance of IADS system.

2.3-09. [TFDM Terminal Publication Service \(TTP\)](#) (SGorman, May 2019)

This presentation covers the ATD-2 prototype of the TFDM Terminal Publication (TTP) feed with information on what's in it, how to access it, and how to work with it.

2.3-10. [ATD-2 Fuser and Data Mapping Documentation Website](#) (SGorman, Mar 2019) [External Link]

These documents provide high-level and detailed descriptions of how the Fuser works, diagrams of the ATD-2 system with a focus on the Fuser, details on the data sources used by the Fuser, and mappings of the source data into a common object by the Fuser. The documentation is available through this website:

https://aviationsystems.arc.nasa.gov/atd2-industry-workshop/fuser/ATD-2-Industry-Workshop-Documentation-Outline_81565170.html

3. Technical Publications

These documents describe the IADS System at the technology level – including simulation or evaluation results, algorithm descriptions, and data analyses. **Publications are listed newest to oldest**, followed by NASA Research Announcement (NRA) presentations and reports. These documents cover topics related specifically to IADS concepts and technologies

3.1 Publications

3.1-20. [Fast-Time Simulation for Evaluating the Impact of Estimated Flight Ready Time Uncertainty on Surface Metering](#) (HLee, DASC2019)

This paper describes the development of a linear regression model to model the Earliest Off-Block Time (EOBT) uncertainty distribution over time based on actual EOBT data collected at Charlotte airport. The EOBT model is integrated with a tactical surface scheduler and a fast-time simulation tool. To evaluate the impact of the EOBT accuracy on airport surface operations, fast-time simulations are implemented for selected traffic scenarios under different levels of modelled EOBT accuracy. The simulation results show that the EOBT uncertainty affects several performance metrics related to the surface metering, such as gate hold, taxi time reduction, and target takeoff time predictability, which in turn influences ATD-2's scheduler performance.

3.1-21. [Alternatives for Scheduling Departures for Efficient surface Metering in ATD-2: Exploration in Human-in-the-Loop Simulation](#) (BParke, AHFE2019)

This paper describes a Human-in-the-Loop (HITL) simulation conducted to explore the impacts of various surface metering goals on operations and Ramp Controllers at Charlotte Douglas International Airport (CLT). Three conditions were compared: (1) Baseline, with no surface metering, (2) instructions to meet advisory times at the gate only, and (3) instructions to meet advisory times at the gate as well as the

times at the scheduled taxiway spot, where aircraft are delivered to Air Traffic Control (ATC). Results of the HITL are summarized as well.

3.1-22. Scheduling Improvements Following the Phase 1 Field Evaluation of the ATD-2 Integrated Arrival, Departure, and Surface Concept (WCoupe, ATMSeminar2019)

This paper describes how data from the Phase 1 field evaluation helped identify scheduler improvements and guided the implementation of refinements. The improvements in the IADS scheduler described in this paper are incorporated into the IADS Phase 2 scheduler enabling strategic Surface Metering Programs and will be evaluated during the field evaluation.

3.1-23. Field Evaluation of the Baseline Integrated Arrival, Departure, Surface Capabilities at Charlotte Douglas International Airport (YJung, ATMSeminar2019)

This paper describes the Phase 1 Baseline IADS capabilities and field evaluation conducted at CLT from September 2017 for a year. From the analysis of operations data, it is estimated that 538,915 kilograms of fuel savings and 1,659 metric tons of CO2 emission reduction were achieved during the period with a total of 944 hours of engine run time reduction. The amount of CO2 savings is estimated as equivalent to planting 42,560 urban trees. The results have also shown that the surface metering had no negative impact on on-time arrival performance of both outbound and inbound flights.

3.1-24. Electronic Departure Approval Requests in ATD-2 Daily Operations (TCallantine, AIAA2019)

This paper presents a review of Approval Request (APREQ) operations and compliance data from daily electronic APREQ negotiations over fourteen months beginning in January 2018. It describes APREQ compliance improvements observed as the electronic negotiation process has matured and discusses contributing factors, including renegotiation of departure release times.

3.1-25. Prediction of Pushback Times and Ramp Taxi Times for Departures at Charlotte Airport (HLee, AIAA2019)

When optimizing the takeoff sequence and schedule for departures at busy airports, it is important to accurately predict the taxi times from gate to runway because those are used to calculate the earliest possible takeoff times. The recent deployment of the integrated arrival, departure, and surface traffic management system at Charlotte airport by NASA enables more accurate flight data in the airport surface operations to be obtained. Taking advantage of this system, actual pushback times and ramp taxi times from historical flight data at this airport are analyzed. Based on the analysis, a simple, data-driven prediction model is introduced for estimating pushback times and ramp transit times of individual departure flights.

3.1-01. Simulation-based Benefits and Costs Assessment of NASA’s Airspace Technology Demonstration-2 (ASaraf, DASC2018)

This paper estimates the benefits and costs for an integrated arrival, departure, surface traffic management technology currently under operational evaluation at Charlotte Douglas International Airport. ATD-2 benefits were projected using high-fidelity fast-time simulations of current-day operations (including modeling of current-day operational shortfalls) and future ATD-2 operations (including the modeling of associated ATD-2 benefit mechanisms). Costs were compared against National Airspace System (NAS)-wide benefits, and a projected return on investment was calculated.

3.1-02. Operational Impact of the Baseline Integrated Arrival, Departure, and Surface System Field Demonstration (SSharma, DASC2018)

This paper describes the baseline IADS system that was deployed at the end of 2017 and is continuing to run as part of the ATD-2 demonstration taking place at CLT. The primary areas of deployment and system use are in the CLT Air Traffic Control Tower, CLT TRACON, CLT American Airlines ramp tower, Washington Center facility, and American Airlines Integration Operations Center (IOC). In addition to describing the functions and capabilities that are part of the baseline IADS system, this paper also provides metrics regarding operational use as well as initial benefits metrics.

3.1-03. Evolution of Electronic Approval-Request Procedures at Charlotte Douglas International Airport (LStevens, DASC2018)

This research examines new electronic APREQ coordination enabled by the NASA ATD-2 system and compares it to the call-for-release method of coordination. Data suggest that both the average tactical delay and compliance with the electronically coordinated departure times did not differ significantly from departure times coordinated using call-for-release.

3.1-04. Flight Deck Implications for the Implementation of an Integrated Arrival, Departure, and Surface (IADS) Traffic Management System (DBakowski, AHFE2018)

This briefing summarizes research into the impact of the ATD-2 IADS System for commercial and general aviation (GA) pilots at CLT. It discusses training and procedures needed for pilots to support and benefit from ATD-2. The IADS System allows sharing information among all operators who are responsible for managing traffic to support efficient operations. One concept for facilitating information sharing to the flight deck, Mobile Application for GA Pilots (Mobile App), is also discussed.

3.1-05. Impact of Data Exchange provided by ATD-2 Tools at Charlotte Douglas International Airport (BParke, AHFE2018)

This paper describes the new tools provided by the ATD-2 IADS System to deliver new data exchange elements to CLT air traffic facilities. Feedback was collected from TRACON, ATC Tower, and Ramp Tower controllers and managers through surveys designed to elicit human factors input. Results were positive

with controller workload unaffected by ATD-2 tool use and situational awareness improved in the Tower and Ramp.

3.1-06. Tactical Surface Metering Procedures and Information Needs for Charlotte Douglas International Airport (SVerma, AHFE2018)

This paper focuses on the procedures and information requirements associated with the tactical surface metering tool used in the CLT ramp control tower. This tool was first calibrated in Human-In-the-Loop simulations and was further developed through use in the operational world. This paper describes the collaborative procedures that the users exercised in their respective operational worlds to enable surface metering and how several metrics were used to improve the metering algorithm.

3.1-07. A Data Driven Analysis of a Tactical Surface Scheduler (WCoupe, ATIO2018)

This paper provides a data-driven analysis of the runway demand capacity balancing and measures the accuracy of schedules that are generated while running in a live operational environment at CLT. We found that using minimum-time wake vortex separation constraints to define runway capacity resulted in scheduling departure operations at a slightly higher rate than the runway was operating, and we discovered a surprising relationship between the runway rate and the accuracy of the schedules.

3.1-08. Field Testing of Vision-Based Surveillance System for Ramp Area Operations (HLu, ATIO2018)

The objective of this research is to develop a Vision-BAsed Surveillance System (VBASS) for ramp areas in airports. We installed six cameras at CLT and demonstrated that VBASS is capable of tracking aircraft under different lighting conditions in real time using the streaming videos obtained from the CLT cameras.

3.1-09. Benefit Assessment of Integrating Arrival, Departure, and Surface Operations with ATD-2 (ASaraf, DASC2017)

This paper describes the results of modeling, simulation and data analysis work performed in order to develop reliable estimates of the benefits of NASA's ATD-2 concept on a nationwide scale based on high-fidelity, realistic models of ATD-2 performance at selected airport sites. It also identifies current-day operational shortfalls and relevant ATD-2 benefit mechanisms at NAS-wide airports.

3.1-10. Evaluation of Approval Request/Call for Release Coordination Procedures for Charlotte Douglas International Airport (LStevens, DASC2017)

This paper focuses on the Approval Request (APREQ) procedures developed for the ATD-2 project between the Air Traffic Control (ATC) Tower at Charlotte Douglas International Airport and Washington Center. In March 2017, NASA conducted a Human-in-the-Loop (HITL) simulation to evaluate the operational procedures and information requirements for the APREQ procedures in the ATD-2 IADS

system between ATC Tower and Center. The findings from the HITL are used to compare ATD-2 APREQ procedures with information about current day APREQ procedures.

3.1-11. Evaluation of a Tactical Surface Metering Tool for Charlotte Douglas International Airport via Human-in-the-Loop Simulation (SVerma, DASC2017)

This paper focuses on the calibration and the effectiveness of the ATD-2 tactical surface metering tool using various metrics from the Human-in-the-Loop (HITL) simulation conducted at NASA in March 2017. Key performance metrics include gate hold times from pushback advisories, taxi-in/out times, runway throughput, and departure queue size. Subjective metrics presented include workload, situational awareness, and acceptability of the metering tool and its calibration.

3.1-12. Assessing Tactical Scheduling Options for Time-Based Surface Metering (SZelinski, DASC2017)

This paper presents a parametric analysis of the most recent tactical scheduler design for NASA's ATD-2 sub-project. The tactical scheduler design is implemented in a fast-time simulation model of CLT using NASA's Surface Operations Simulator and Scheduler. A key parameter of the advisory generation function is the taxi time delay buffer used when calculating target gate pushback times from runway schedule. The results show an improvement in tactical scheduler performance.

3.1-13. Real Time Metrics and Analysis of Integrated Arrival, Departure, and Surface Operations (SSharma, ATIO2017)

This paper provides background on the ATD-2 concept and motivation for developing a real time Dashboard tool. It describes the architecture and implementation of the tool in an operational setting along with the method for documenting requirements collected from the intended users. It also illustrates the approach in producing real time metrics and analysis with a set of anticipated uses and implications of implementing it in an operational environment.

3.1-14. Benefit Opportunities for Integrated Surface and Airspace Departure Scheduling (RCoppenbarger, DASC2016)

This paper describes the concept and benefit mechanisms aimed at improving flight efficiency and predictability while maintaining or improving operational throughput. The potential impact of the technology is studied and discussed through a quantitative analysis of relevant shortfalls at CLT, the site identified for initial deployment and demonstration in 2017.

3.1-15. Comparison of Different Control Schemes for Strategic Departure Metering (HIdris, DASC2016)

This paper presents a simulation-based analysis of the departure metering process, which delays the release of flights into the airport movement area while balancing the two competing objectives of maintaining large enough queues at the airport resources to maximize throughput and absorbing excess delays at the gates or in ramp areas to save on fuel consumption, emissions, and passenger discomfort.

Three metering strategies are compared under deterministic, demand uncertainty conditions, uncertainties of flight transit time and runway service rate.

3.1-16. Departure Queue Prediction for Strategic and Tactical Surface Scheduler Integration (SZelinski, DASC2016)

This study analyzes strategic surface scheduler predictability to facilitate future integration with tactical scheduling. Strategic queue predictions and target gate pushback times to achieve a desired queue length are compared between fast time simulations of CLT surface operations with and without tactical scheduling. It shows that use of variable departure rates as a strategic scheduler input will substantially improve queue predictions over static departure rates.

3.1-17. Queue Buffer Sizing for Efficient and Robust Integrated Departure Scheduling (HIdris, ATIO2016)

Integrated schedules of arrival, departure and surface operations need to maintain a certain level of robustness in order to accommodate uncertainties stemming from the operations and the environment. In this paper, a method based on identifying throughput saturation using analysis of historical data is used for determining the appropriate size of queue and delay buffers in order to achieve such robustness applied to departures at CLT.

3.1-18. Taxi-Out Time Prediction for Departures at Charlotte Airport Using Machine Learning Techniques (HLee, ATIO2016)

Predicting the taxi-out times of departures accurately is important for improving airport efficiency and takeoff time predictability. In this paper, machine learning techniques were applied to actual traffic data from CLT for taxi-out time predictions in order to determine the most accurate techniques. Operational complexity and uncertainties that make it difficult to predict the taxi times accurately are also discussed.

3.1-19. Miles-in-Trail Requirements Relaxation: A Key Benefit mechanism of Integrated Arrival Departure Surface Traffic Management (ASaraf, ATIO2016)

This paper studies the impact of departure miles-in-trail (MIT) restrictions on ATD-2 operations using fast time simulations, demonstrating that maintaining MIT restrictions at current-day levels while ATD-2 is in operation may impede the full realization of the benefits from ATD-2. It also demonstrates that relaxing MITs when ATD-2 scheduling is active would save around 1-3% total departure delay while retaining a high level of taxi and airborne delay savings over current-day operations, and maintaining a level of safety commensurate with current-day operations.

3.2 NASA Research Announcement (NRA) Reports and Briefings

3.2-01. Benefit and Cost Assessment of Integrating Arrivals, Departures, and Surface Operations with ATD-2 NASA NRA Final Report, 30 March 2018, NNA16BD87C (ATAC)

3.2-02. Benefit and Cost Assessment of Integrating Arrival, Departure, and Surface Operations with ATD-2 NRA Final Briefing, 30 March 2018, NNA16BD87C (ATAC)

This NRA report and briefing describe the findings and conclusions from the research performed for computing the benefits and costs of implementing the ATD-2 IADS technologies on a nationwide scale. These materials also provide descriptions of the simulation models and technical approaches developed in support of this work.

3.2-03. Distributed Schemes for Integrated Arrival/Departure/Surface Scheduling: Second Year Final Report, NNA14AB46C (Engility, Oct 2016)

3.2-04. Distributed Schemes for Integrated Arrival/Departure/Surface Scheduling: NRA Year Two Final Briefing, NNA14AB46C (Engility, Oct 2016)

3.2-05. Miles-in-Trail Restrictions Relaxation: A Key Benefit Mechanism of Integrated Arrival Departure Surface Traffic Management Briefing, NNA14AB46C (ATAC, Oct 2016)

The objective of the NRA is to investigate and develop integrated scheduling solutions for arrival, departure and surface operations. The option year report and briefings summarize simulation-based analyses of the departure metering process to investigate strategic queue management strategies and their robustness to uncertainty, assess the impact of delaying departures at their gates on blocking the arrivals destined for the same gates, and evaluate the effects and benefits of relaxing current-day MIT constraints when ATD-2 is in operation.

3.2-06. Development of Methods of Increasing Terminal Flexibility and Control Authority Option Year 1 Final Report, Ver1, 30 September 2016, NNA14AC42C (Architecture Technology Corporation (ATCorp))

3.2-07. Development of Methods of Increasing Terminal Flexibility and Control Authority Option Year 1 Final Presentation, Ver1, 30 September 2016, NNA14AC42C (ATCorp)

3.2-08. Final Report for "Methods of Increasing Terminal Airspace Flexibility and Control Authority", Ver1, 29 October 2015, NNA14AC42C (ATCorp)

3.2-09. Base Year Final Presentation NASA CTD-Subtopic 1 NRA: Methods of Increasing Terminal Airspace Flexibility and Control Authority, Ver1, 21 October 2015, NNA14AC42C (ATCorp)

The focus of the NRA contract is to develop a What-if Analysis Tool for planning Departure Management Programs (DMP) at airports. These reports and briefings summarize the work conducted throughout the base and option years, with a focus on use case specification for the what-if analysis capability and the implementation of the What-if Analysis Tool and its application to traffic and weather scenarios at Charlotte Douglas International Airport (CLT).

3.2-10. Distributed Schemes for Integrated Arrival Departure Surface (IADS) Scheduling NRA Year 1 Final Briefing, 21 October 2015, NNA14AB46C (Engility)

3.2-11. Distributed Schemes for Integrated Arrival/Departure/Surface Scheduling Arrival and Departure Interactions at Five Major Airport / Metroplex Environments, 9 January 2015, NNA14AB46C (Engility)

3.2-12. [Distributed Schemes for Integrated Arrival/Departure/Surface Scheduling Literature Review of Past and Current Approaches to Integrating Arrival Departure and Surface Scheduling, 1 December 2014, NNA14AB46C \(Engility\)](#)

The objective of the NRA is to investigate and develop integrated scheduling solutions for arrival, departure and surface operations. The base year reports and briefing summarize the research completed to identify and model real-world Arrival-Departure-Surface interaction cases, develop concepts and architectures for distributed scheduling, implement the concepts in high fidelity fast-time simulation platform, and conduct performance analysis of the concepts.

4. Evaluation Results

Documents are listed newest to oldest in this section.

Phase 2 Fused IADS System

This section contains the in-depth summaries of Phase 2 IADS System evaluation activities, including human-in-the-loop simulations.

4.08. [Assessment of Ramp Times 4 \(ART-4\) Human-in-the-Loop \(HITL\) Simulation - Final Results \(YJung, September 2019\)](#)

Airspace Technology Demonstration 2 (ATD-2) sub-project conducted a Human-in-the-Loop (HITL) simulation in April 2019 to assess Dallas/Fort-Worth International Airport (DFW) Ramp Controllers ability to deliver aircraft to the spot within the compliance window (+/- 5 min) under various metering conditions.

4.09. [Assessment of Ramp Times 2 \(ART-2\) Human-in-the-Loop \(HITL\) Simulation - Final Results \(LStevens, March 2019\)](#)

Airspace Technology Demonstration 2 (ATD-2) sub-project conducted a human-in-the-loop (HITL) simulation in June 2018 to assess various strategies for CLT Ramp controllers to deliver aircraft to the spot within the compliance window (+/- 5 min).

Phase 1 Baseline IADS System

This section contains the in-depth summaries of Phase 1 IADS System evaluation activities, including stakeholder shadow sessions and human-in-the-loop simulations.

4.01. [ATD-2 Phase 1 Evaluations \(SSharma, September 2018\)](#)

The ATD-2 Shadow Sessions allowed the ATD-2 team to interact with many users during software design and development. They allowed the ATD-2 team to gain a detailed understanding of what was

important to different sets of users, and to better understand what each group needs to perform their job. The shadow sessions introduced the ATD-2 user interfaces, the software and data transfer planning, and the important components and interactions of the system. This allowed the ATD-2 team to gain constructive user feedback and interaction while the system was still being developed, thus leading to a better research product and experience once engineering evaluations began. Documentation included meeting notes, presentations, some pictures, and some audio recordings.

4.02. On-Time Performance ASPM Non-Parametric Statistical Analysis (TKozon, August 2018)

The purpose of this analysis is to provide a data-driven examination of two selected flight metrics, i.e., (1) total taxi-out time and (2) actual off time minus scheduled off block time. More specifically, Aviation System Performance Metrics (ASPM) data were analyzed to determine any possible differences in CLT departure flights on these two metrics when comparing pre-IADS against post-IADS metering operations.

4.03. Taxi Time Comparison Before and After Surface Metering Using ASPM Data (HLee, April 2018)

In this taxi time analysis, the ASPM data before and after surface metering were compared to see the effects of surface metering on taxi-out/in times. Results show that the surface metering from ATD-2 technologies did no harm in taxi-out times at CLT.

4.04. Effects of EOBT Accuracy on the On-Time Performance (HLee, March 2018)

This analysis shows the effects of Earliest Off-Block Time (EOBT) accuracy on the on-time performance metrics, such as A0 and A14 of outbound flights, and Target Takeoff Time (TTOT) compliance.

4.05. ATD-2 Phase 1 Go Live Discussion (SSharma, Sep 2017)

This presentation describes the agile micro-phases used for rolling out Phase 1 capabilities.

4.06. Tactical Surface Tool for Ramp (TSTR) HITL Results (SVerma, August 2016)

This briefing summarizes the TSTR simulation. The objectives of the HITL include evaluation of the ramp controller tools, Ramp Traffic Console (RTC) and Ramp Manager Traffic Console (RMTC), and evaluation of transition procedures between ATD-2 advisory and non-advisory modes.

4.07. Charlotte – En route Departure Capability (EDC) Evaluation & Demonstration (CEED) Human-In-The-Loop Results Outbrief (EChevalley, March 2016)

This briefing summarizes the CEED simulation. The objectives of the HITL include the assessment of current Traffic Management Initiatives on CLT departure flows and control operations and the impact of compliance with ATD-2 advised departure release times.

5. Informal Technology Transfers

ATD-2 has engaged in multiple informal knowledge transfer events during the Phase 1 evaluation period. This section contains the most relevant of those activities.

5.01. [ATD-2 Remote Webinars](#) (July 2018) [External Link]

The ATD-2 team hosted a series of online webinars during ATD-2 Phase 1. The goals of the webinars are to: 1) keep the broad group of ATD-2 stakeholders informed of progress in an inexpensive and unobtrusive manner; 2) demonstrate actual system capability and lessons learned (vs documents/plans); 3) take input from stakeholders to improve the ATD-2 system, processes and/or outreach; and 4) identify areas where more detailed discussion is desired/warranted. Past webinars can be viewed and the schedule for future sessions is available here:

<https://www.aviationsystemsdivision.arc.nasa.gov/research/atd2/remote-demos/index.shtml>

- Tactical Surface Metering (September 21, 2017)
- Ramp Traffic Tools, Capabilities, Best Practices (October 12, 2017)
- General Briefing, Field “go-live” status update (November 9, 2017)
- Real-time Dashboard, Post Ops, Current Reports, Data Analysis (December 14, 2017)
- Latest IADS Capabilities (March 14, 2018)
- Surface Metering - Initial Analysis, Impact, and Evolution (March 21, 2018)
- Understand and Process ATC Restrictions in the NAS - Part 1 (April 25, 2018)
- Understand and Process ATC Restrictions in the NAS – Part 2 (May 23, 2018)
- ATD-2 Data Sharing via TFDN TTP Prototype and Mobile App Use Case (July 12, 2018)

5.02. [ATD-2 IADS System Phase 1 Informal Tech Transfers - Completed](#) (August 2018)

5.03. [ATD-2 IADS System Phase 2 Informal Tech Transfers - Completed](#) (September 2019)

Informal tech transfers have occurred periodically during the ATD-2 project. Most occurred in the form of an email conversation or a presentation/remote outreach demo being given. These informal transfers are documented in order to track and refer back to them.

5.04. [ATD-2 Update for TBFM/TFDM Ops Teams](#) (ACapps, Jun 2019)

This presentation was developed to update the TBFM/TFDM operational teams on ATD-2 Phase 2 progress and Phase 3 plans. It includes top-level compliance data and APREQ delay data, processes for data exchange between ATD-2 and TBFM and surface metering, and potential benefits of EOBTs.

5.05. [ATD-2 Industry Workshop Presentations](#) (September 2019) [External Link]

The ATD-2 Industry Workshop was held on September 4-5, 2019 in Dallas, TX, to bring industry partners together with NASA researchers and FAA future system implementers. The objectives included:

- Transfer to NAS users the lessons learned from the implementation of NASA's ATD-2 project
- Identify emerging needs for tools, services and platforms for the aviation market
- Provide a deeper understanding of the transformational potential of the future surface system
- Enable industry operators to meet upcoming TFDM requirements for their organization while achieving benefits

All presentations from the workshop, including recordings of the panels and sessions, are available here: <https://www.aviationsystemsdivision.arc.nasa.gov/atd2-industry-workshop/presentations.html>

In total, there are 25 presentations and over 12 hours of recorded content from the workshop from 3 panel discussions and 21 breakout sessions. The topics presented are listed below.

Panels:

- Preparing for the Transition to TFDM and a Data-Driven NAS. Perspectives from Industry and FAA leaders.
- Discuss early results of ongoing evaluation of Trajectory Options Set (TOS) with Surface for Metroplex departures
- Opportunity for formulation input into NASA's future aviation plans (with NASA ATD and ATM-X projects)

Breakout Sessions:

- 'Fuser in the cloud' overview and latest updates/needs
- Future Surface Decision Support Overview (with ATD-2 demo)
- SWIM-Fused data products used by ATD-2 analysts for quantifying NAS performance and benefits (part 1)
- Latest strategic surface metering system and progress status in CLT (extending freeze horizon)
- Understanding TMIs in the NAS (Part 1)
- SWIM-Fused data products used by ATD-2 analysts for quantifying NAS performance and benefits (part 2)
- Opportunities for Mobile Applications in the 3T environment
- Evolving operational roles (ATC and Operator) with TFDM in the 3T environment
- Benefits of Pre-scheduling into the overhead stream with EOBTs (analytical focus)
- New TFDM Terminal Publication (TTP) SWIM data, how to sign up and how to benefit from it
- Pre-scheduling with EOBTs, its benefits and complexities (operationally focused)
- Benefits of surface departure metering while 'doing no harm' to other operational metrics
- Industry/FAA future needs/ expectations for the implementation of TFDM into the NAS
- Understanding TMIs in the NAS (Part 2)
- Simulation and modeling used in surface analysis (2 presentations)
- Substituting flights in TFDM with SWIM

- Analytical evidence of surface compliance leading to more efficient overhead stream scheduling
- Ramp Traffic Console Capabilities and Use in Operational Environment (part 1)
- Benefits of good EOBTs to Surface Metering
- Metroplex TOS Departures, initial results and next steps input
- Ramp Traffic Console Capabilities and Use in Operational Environment (part 2)