Airspace Technology Demonstration 2 (ATD-2)

Integrated Arrival/ Departure/Surface (IADS) System Demonstration

Technology Transfer Document Summary (ReadMe)

Version 3 - Final Phase 3 Metroplex IADS

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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 final delivery of 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.

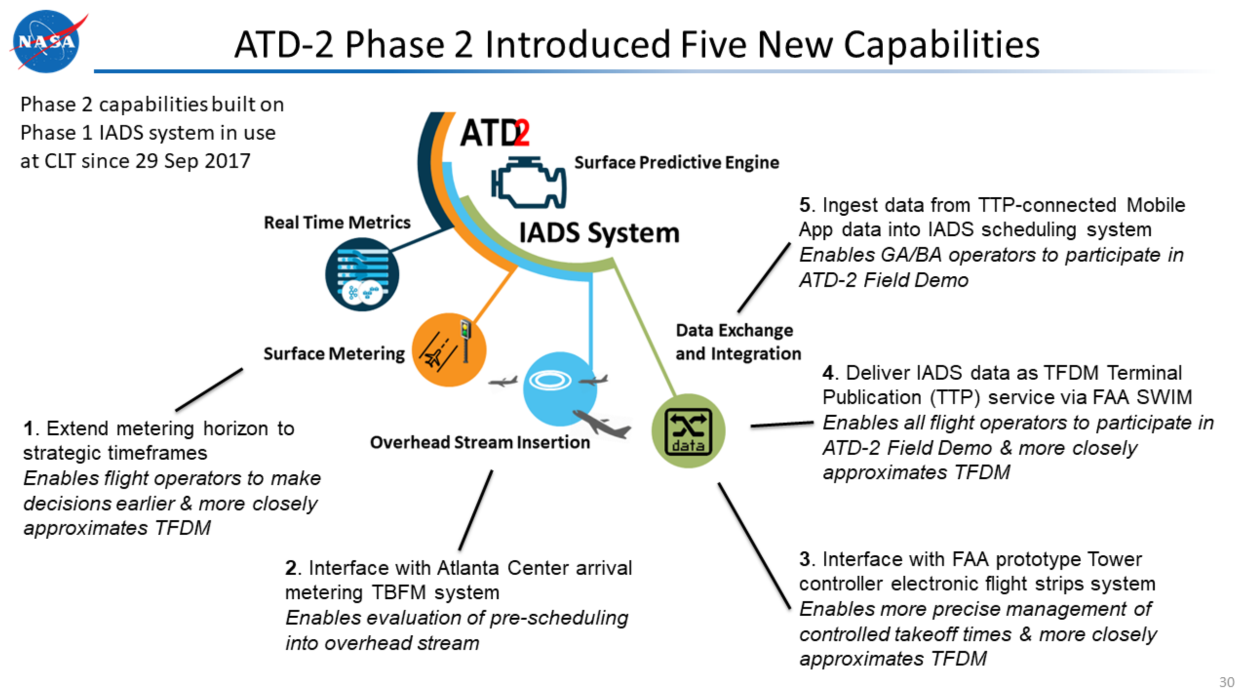

Figure: New Capabilities Introduced by Phase 2 Fused IADS System

The Phase 3 Metroplex IADS system provided additional capabilities for a multi-airport demonstration in the North Texas terminal environment including Dallas/Fort Worth International Airport (DFW) and Dallas Love Field Airport (DAL). “Stormy 20” was originally scheduled for April to August 2020, but the COVID-19 pandemic significantly impacted data collection due to the dramatic reduction in traffic volume as well as the reduction in operational flight operator and ATC resources. Given the significant in-kind investments made by Field Demo Partners and the strong interest expressed by the broader airline community in collecting operational data associated with this body of work, NASA leadership directed the ATD Project to extend ATD-2 through FY21. The “Stormy 21” Operational Evaluation commenced April 2021 and concluded in September 2021. “Stormy 21” achieved the goal of the extension to enable data collection, analysis, and stakeholder engagement to deliver meaningful ATD-2 Phase 3 results to NASA stakeholders. New Phase 3 functionality included:

- Trajectory Option Set (TOS) Service – flight operator submitting requests to reroute flights on pre-coded departure routes
- Scheduling to the Terminal Boundary – multi-airport scheduling via the DFW Terminal Radar Approach Control (D10 TRACON)
- Traffic Management Initiative (TMI) Propagation – restrictions entered by the Fort Worth Air Route Traffic Control Center (ZFW ARTCC) propagated via the National Traffic Management Log (NTML)

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://aviationsystems.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 cumulative set of capabilities delivered in all phases of ATD-2 research. This final tech transfer package is the 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 Final Phase 3 README (September 2021)

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 Final Phase 3 Docs List (September 2021)

(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 2021)

(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://aviationsystems.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://aviationsystems.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://aviationsystems.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://aviationsystems.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.

1.1-08. Airspace Technology Demonstration 2 (ATD-2) Concept of Use (ConUse) Addendum for Phase 3 (SWilson, July 2020)

This presentation serves as an addendum to the ATD-2 ConUse from Phases 1 and 2 and describes the concept of use for the ATD-2 Phase 3 IADS system and quantitative benefits assessment.

1.2 Project Documents

1.2-01. ATD-2 Glossary, V4.0 (LMorgan-Ruszkowski, May 2021)

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 September 2018 - August 2019, v6 (FAA, September 2019)
1.2-05. ATD-2 FAA/NASA Coordinated Activities, Compilation September 2019 - July 2020 (FAA, July 2020)
1.2-08. ATD-2 FAA/NASA Coordinated Activities, Compilation July 2020- August 2021 (FAA, September 2021)

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 IADS Systems Specification - Core STBO Capabilities (Phase 2) (TNgo, July 2020)
1.2-06. ATD-2 IADS Systems Specification - Metroplex & TOS Concepts (Phase 3), Version 2 (TNgo, September 2021)

These documents summarize the IADS system capabilities developed in Phases 2 and 3. They also serve as the Requirements Verification Matrix (RVM) deliverables for the ATD-2 project.

1.2-07. ATD-2 Phase 3 System Requirements (TNgo, July 2020)

This document contains the system requirements for the IADS data elements and functional capabilities developed during ATD-2 Phase 3.

2. Phase 1, 2, 3 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 (August 2020)

This document serves as a user manual for the ATD-2 Surface Trajectory-Based Operations (STBO) Client (version 5.11) utilized by Air Traffic Control in the Tower. It describes the elements of the STBO Client interface and provides step-by-step instructions for using the tool. STBO Client functionality includes the display of live flight information, management of traffic restrictions, and prediction of expected traffic demand. The STBO Client is a component of the NASA Airspace Technology Demonstration 2 (ATD 2) sub-project.

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 (August 2020)

This document serves as a user manual for the ATD-2 Ramp Traffic Console (RTC) (version 5.11) utilized by the Ramp Control Tower. It describes the elements of the RTC interface and provides step-by-step instructions for using the tool. This document also provides instructions for use of the Ramp Manager Traffic Console (RMTC) for Ramp Manager functions, such as managing the priority flight list and setting the ramp status.

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 (August 2020)

This document serves as a user manual for the ATD-2 Web-Based Surface Metering Display (SMD) (version 5.11). It describes the elements of the SMD interface and provides step-by-step instructions for using the tool. The SMD can be used to select the type of metering, set specific metering parameters, and set excess queue time variables. Feedback can also be submitted through the site. The SMD is a component of the NASA Airspace Technology Demonstration 2 (ATD-2) sub-project.

2.1-19. ATD-2 Metroplex Planner User Manual (September 2021)

This document serves as a user manual for the ATD-2 Metroplex Planner (version 6.1.2) for use by the Air Route Traffic Control Center (ARTCC), Terminal Radar Approach Control (TRACON), airport Air Traffic Control Towers, and airline Flight Operators. It describes the elements of the Metroplex Planner interface and provides step-by-step instructions for using the tool. In addition to live flight information, traffic management information, and demand/delay predictions, the Metroplex Planner supports Trajectory Option Set (TOS) rerouting. The Metroplex Planner is a component of the NASA Airspace Technology Demonstration 2 (ATD-2) sub-project.

ATD-2 Phase 3 Training Videos [External Links]

These videos have been produced for remote training on ATD-2 Phase 3 capabilities for field demo partners in the North Texas area. Participants include Air Traffic Controllers (ATC) at Dallas-Fort Worth International Airport (DFW) and Dallas Love Field (DAL) and flight operators (FO). The videos have been designed to explain specific functions of the ATD-2 system and are tailored to the specific user group. The videos can be utilized both as an on the spot training resource by active, operational personnel or in a more formal training environment.

2.1-20. ATD-2 Phase 3 Training Video: Stormy 2020 Overview (DBakowski, May 2020)

- https://youtu.be/OglE7LWl1Rs

2.1-21. ATD-2 Phase 3 Training Video (FO): How To Start ATD2 (DBakowski, May 2020)

- (AAL) https://youtu.be/cMkIZgjyOwQ
- (SWA) https://youtu.be/miL19w57-1s

2.1-22. ATD-2 Phase 3 Training Video (FO): How to Submit a TOS (DBakowski, May 2020)

- (AAL) https://youtu.be/faj1Dl2S_vc
- (SWA) https://youtu.be/whnZBpwfMms

2.1-23. ATD-2 Phase 3 Training Video (FO): How to Use Settings (DBakowski, June 2020)

- https://youtu.be/3k8BMNJMoRY

2.1-24. ATD-2 Phase 3 Training Video (All): How to Set Up the Map (DBakowski, June 2020)

- https://youtu.be/28Wlods8JS0

2.1-25. ATD-2 Phase 3 Training Video (All): How to Use the Map (DBakowski, June 2020)

- https://youtu.be/1ulqpp8HSpc

2.1-26. ATD-2 Phase 3 Training Video (All): How To Read a Timeline (DBakowski, June 2020)

- https://youtu.be/amDrnyJfcxw

2.1-27. ATD-2 Phase 3 Training Video (All): How to Filter a Timeline (DBakowski, June 2020)

- https://youtu.be/u2KAr7ZJeIc

2.1-28. ATD-2 Phase 3 Training Video (All): How to Use Taxi List and Departure Fix Table (DBakowski, June 2020)

- https://youtu.be/jmD7moFN0s8

2.1-29. ATD-2 Phase 3 Training Video (ATC): How to Use Runway Utilization and Configuration (DBakowski, June 2020)

- https://youtu.be/vvMHvkTb7hc

2.1-30. ATD-2 Phase 3 Training Video (ATC): How to Use the TOS Operation Tab (DBakowski, June 2020)

- https://youtu.be/tfv4TocisvU

2.1-31. ATD-2 Phase 3 Training Video (All): How to Use CDR List (DBakowski, June 2020)

- https://youtu.be/2M_Znt7G6ZQ

2.1-32. ATD-2 Phase 3 Training Video (All): How to Change Timeline Settings (DBakowski, June 2020)

- https://youtu.be/SjBjrAwdIS0

2.1-33. ATD-2 Phase 3 Training Video (ATC): How to Close a Taxiway (DBakowski, June 2020)

- https://youtu.be/a8eQllD1yus

2.1-34. ATD-2 Phase 3 Training Video (All): Delay Values on the Timeline (DBakowski, July 2020)

- https://youtu.be/mVWhUdTL03M

2.1-45. ATD-2 Phase 3 Training Video (AAL, ENY, ATC): IN Delay Metrics: Filed route, TOS route, and IN Delay Savings (DBakowski, February 2021)

- https://youtu.be/Aisrpwlay4g

2.1-46. ATD-2 Phase 3 Training Video (SWA): IN Delay Metrics: Filed route, TOS route, and IN Delay Savings (DBakowski, February 2021)

- https://youtu.be/RNt9iT48qq4

ATD-2 Phase 3 Training Slides

2.1-35. ATD-2 Phase 3 Training Slides (AAL): Timeline (DBakowski, June 2020)
2.1-36. ATD-2 Phase 3 Training Slides (SWA): Timeline (DBakowski, June 2020)
2.1-37. ATD-2 Phase 3 Training Slides (ATC): Timeline (DAL Tower) (DBakowski, June 2020)
2.1-38. ATD-2 Phase 3 Training Slides (AAL): Metroplex Planner CDR List (DBakowski, June 2020)
2.1-39. ATD-2 Phase 3 Training Slides (SWA): Metroplex Planner CDR List (DBakowski, June 2020)
2.1-40. ATD-2 Phase 3 Training Slides (AAL): How to Submit a TOS (DBakowski, June 2020)
2.1-41. ATD-2 Phase 3 Training Slides (SWA): How to Submit a TOS (DBakowski, June 2020)
2.1-42. ATD-2 Phase 3 Training Slides (ATC): How to Approve a TOS (DAL Tower) (DBakowski, June 2020)
2.1-43. ATD-2 Phase 3 Training Slides (ATC): TOS Operation & DCC Advisory Tabs (ZFW) (DBakowski, June 2020)
2.1-47. ATD-2 Phase 3 Training Slides (ATC): How to Approve a TOS in ATD-2 (ZFW) (GJuro, March 2021)

2.1-48. ATD-2 Phase 3 Training Slides (All): New TOS Approval Mode (DBakowski, March 2021)
2.1-49. ATD-2 Phase 3 Training Slides (All): New Scratch Pad Features (DBakowski, March 2021)

The Phase 3 training slides accompany the training videos and provide examples on how to use the ATD-2 Phase 3 capabilities for field demo partners in the North Texas area. The slides have been tailored for ATC at DAL Tower, ATC at ZFW Center, American Airlines (AAL), Southwest Airlines (SWA), and Envoy Airlines (ENY). The slides and videos are also available on all the ATD-2 Phase 3 operational systems via a menu option.

2.1-44. ATD-2 Software Version V5.x Releases and Notes, Version 2 (CFreedman, September 2021)

This document summarizes the 5.x series of ATD-2 software releases to Charlotte-Douglas International Airport (CLT) and/or Dallas-Fort Worth International Airport (DFW) in support of the ATD-2 Phase 2 and Phase 3 field demonstrations.

2.1-50. ATD-2 Software Version V6.x Releases and Notes (CFreedman, September 2021)

This document summarizes the 6.x series of ATD-2 software releases to Dallas-Fort Worth International Airport (DFW) in support of the ATD-2 Phase 3 field demonstration.

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 (August 2020)

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 artifacts 2.3-00 to 2.3.10 in this section were 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

An additional artifact (2.3-11) contains ATD-2 contributions presented at the SWIFT SWIM Industry Collaboration Workshop #10 in May 2020.

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

2.3-11. Development & Analytics Focus Group, SWIFT 10 Update (Erin Cobbett, May 2020)

This presentation contains updates from the Development and Analytics Focus Group for the SWIFT SWIM Industry Collaboration Workshop #10. Contributions from the NASA ATD-2 team are included in these slides.

2.4 Machine Learning Predictive Services Technology

Artifacts in this section describe the Machine Learning (ML) services developed under the ATD-2 subproject as reference implementations and released by NASA as Open Source software on github. The

ML services serve as examples for industry partners and future NASA projects developing digital air traffic data services from publicly available FAA SWIM data feeds. The top-level NASA ML airport data services github is here: https://github.com/nasa/ML-airport-data-services.

2.4-01. ATD-2 IADS Machine Learning Services - Airport Configuration Prediction Model (SKhater, August 2021)

Github: https://github.com/nasa/ML-airport-configuration

Airport configuration selection is a complex decision-making process that involves several operational and human factors. This ML model predicts a set of airport configurations at a given airport, and up to 6 hours ahead. There are separate trained models for each airport, and the model to query must correspond to the airport whose configuration is to be predicted.

2.4-02. ATD-2 IADS Machine Learning Services - Arrival Runway Model (AChurchill, August 2021)

Github: https://github.com/nasa/ML-airport-arrival-runway

Assigning flights to runways at an airport is a critical function that influences all aspects of airport operations and performance. This model predicts the specific runway on which a flight will land, beginning several hours before that landing is expected to occur. Separate models are trained for each airport.

2.4-03. ATD-2 IADS Machine Learning Services - Departure Runway Model (AChurchill, August 2021)

Github: https://github.com/nasa/ML-airport-departure-runway

Assigning flights to runways at an airport is a critical function that influences all aspects of airport operations and performance. This model predicts the specific runway on which a flight will depart, beginning several hours before that takeoff is expected to occur. Separate models are trained for each airport.

2.4-04. ATD-2 IADS Machine Learning Services - Estimated ON Model (DWesely, August 2021)

Github: https://github.com/nasa/ML-airport-estimated-ON

Aircraft landing times and predictions thereof are of interest to many stakeholders and for many reasons. The aim of the EON model service is to use machine learning (ML) to better predict the landing time of a flight than physics-based approaches (i.e. best SWIM ETA).

2.4-05. ATD-2 IADS Machine Learning Services - Impeded and Unimpeded Taxi In Time Prediction Models (SKhater, August 2021)

Github: https://github.com/nasa/ML-airport-taxi-in

Accurate taxi time prediction is required for enabling efficient gate-in time prediction as well as any surface congestion based on long taxi in time. The ITIM model predicts the impeded duration of taxi time between the arrival landing, or "on" time, and the “in” time at the arrival stand. Unimpeded taxi time prediction is required for enabling prediction of gate conflict at landing, as well as prediction of banks based on unimpeded taxi-in time (this may alert controllers that arrivals will need to be impeded).

2.4-06. ATD-2 IADS Machine Learning Services - Impeded and Unimpeded Taxi Out Time Prediction Models (AAmblard, August 2021)

Github: https://github.com/nasa/ML-airport-taxi-out

The Impeded Taxi Out model predicts the transit time of aircraft on the surface from pushback to spot crossing and take-off while considering surface traffic. The Unimpeded Taxi Out time prediction service is predicting the transit time of aircraft while unimpeded on the surface from pushback to spot crossing and take-off. Unimpeded Taxi Out Time estimates are essential quantities for a scheduler to build an efficient schedule, allowing aircraft with lower unimpeded taxi-out time (i.e. that could reach the runway faster) to be put first.

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

3.1-29. Shadow Evaluation of the ATD-2 Phase 3 Trajectory Option Set Reroute Capability in the North Texas Metroplex (WCoupe, ATM Seminar 2021)

This paper presents results of NASA’s Airspace Technology Demonstration 2 Phase 3 Trajectory Option Set reroute capability designed to resolve a demand capacity imbalance along the terminal airspace boundary. We focus on Candidate flights generated during the Stormy 2020 Shadow Evaluation which was the result of using the system to passively collect predictions for each flight at the OUT event. Benefit metrics associated with the predictions are defined for the individual rerouted flight and also the system-wide savings. Candidate flights are grouped into three distinct use cases and the benefit mechanism is explained for each use case along with illustrative data. Analysis of the different use cases shed light on the underlying causes of the reroute opportunities.

3.1-30. Real-time Unimpeded Taxi Out Machine Learning Service (AAmblard, Aviation2021)

This paper describes a study on the estimation of the unimpeded taxi out time using Machine Learning (ML) tools and proposes an implementation that can be used to make real-time predictions at any airport in the National Airspace System. Kedro, an open-source pipeline framework, is used to develop the model definition and training. Models are stored in scikit-learn containers on an MLFlow server where they can be retrieved and served to make predictions in the live system. These open source frameworks provide common structures between ML services, allow for easier maintenance and updates, and overall deliver an easier CI/CD (Continuous Integration/Continuous Deployment) process.

3.1-31. Analysis of Impacts of Terminal Restrictions on Departures in D10 TRACON (DBhadoria, Aviation2021)

This paper uses the ATD-2 terminal restriction data collected in the D10 (Dallas-Fort Worth) TRACON to quantify the impact of restrictions on the demand, analyze the relation between terminal restrictions and departure taxi time on airport surface, and establish relationships between restrictions and surface delay. We found that the restrictions on departure flights have a direct adverse effect on departure excess taxi time on the airport surface.

3.1-32. Predicting Arrival and Departure Assignments with Machine Learning (AChurchill, Aviation2021)

This paper describes our efforts training machine learning (ML) models to predict both departure and arrival runway assignments using an entirely data-driven approach. This approach is compared to existing rule-based approaches developed in previous research using input from Subject Matter Experts. The models have features derived from various FAA data feeds, and leverage multiple machine learning algorithms. Results for models trained for nine major U.S. airports are described and compared to one another across various important dimensions. Particular attention was paid to developing a repeatable framework for training these models so the approach could be scaled to other airports, and to developing models that are useful in a real-time environment.

3.1-33. A Recursive Multi-step Machine Learning Approach for Airport Configuration Prediction (SKhater, Aviation2021)

This paper proposes a novel recursive multi-step machine learning (ML) approach to predict airport configuration. The multi-step approach guarantees stability of the predicted configuration by taking as input the configuration predicted at the previous time step. The features of the proposed model include weather data, future arrival and departure counts and current configuration. We show the predictive performance of the proposed model for six major US airports, including CLT, DFW, JFK, EWR, LGA, and DAL.

3.1-34. A Machine Learning Approach to Predict Aircraft Landing Times using Mediated Predictions from Existing Systems (DWesely, Aviation2021)

This paper describes a novel approach for predicting the landing time of airborne flights in real-time operations. The landing time is predicted by using mediation rules to select from among physics-based predictions already available in real time in the FAA SWIM system data feeds. A machine learning model is built and trained to predict the error in the mediated prediction, using features describing the current state of an airborne flight. Initial results based on five months of data at six large airports demonstrate that incorporating a machine learning model on top of the mediated physics-based prediction can lead to substantial additional improvements in prediction quality.

3.1-35. NASA ATD-2 Trajectory Option Sets Prototype Capability for Rerouting Departures In Metroplex Airspace (EChevalley, DASC2020)

This paper describes NASA's ATD-2 Phase 3 prototype capability that is being tested in the North Texas region through summer 2021. For the first time, a shared Decision Support Tool (DST) provides opportunities for participating Flight Operators (FOs) and Air Traffic Controllers (ATCs) to coordinate using a Trajectory Option Set (TOS). When the metroplex airspace is impacted by demand/capacity imbalances, TOS enables departure flights to be rerouted to alternative departure routes with less surface delay.

3.1-36. ATD-2 Phase 3 Scheduling in a Metroplex Environment Incorporating Trajectory Option Sets (WCoupe, DASC2020)

This paper describes the ATD-2 Phase 3 scheduling algorithm enabling the coordinated scheduling and describes the interaction between airports within the Metroplex and the terminal boundary. We describe the metrics developed to inform flight operators about reroute opportunities and discuss the potential benefits to the rerouted flight and the system wide aggregate benefits of a single reroute.

3.1-37. Predicting Gate Conflicts at Charlotte Douglas International Airport Using NASA ATD-2 Fused Data Sources (WCoupe, DASC2020)

For non-safety critical applications, there is opportunity for third party service providers to offer near real-time data-driven prediction services powered by FAA SWIM data similar to the ATD-2 IADS system. This paper investigates the gate conflict prediction problem as a concrete use case which could help drive efficiencies. We model gate conflicts as a regression problem and describe the iterative process of model building, model validation, and evaluation used to assess the efficacy of our approach. We quantify our predictive accuracy and identify paths for improvement. Through this iterative process we hope to evolve our models and methods to a near real-time prediction service.

3.1-38. Impact of ATD-2 Tools on Human Factor Metrics at Charlotte Douglas International Airport (BParke, DASC2020)

ATD-2 decision support tools introduced at CLT have shown impressive reductions in fuel consumption and CO_2 emissions. Questions have remained on 1) human factors impact of these new ATD-2 tools and surface metering and 2) the users' perceptions of how these tools affect operations. This paper describes the survey results from multiple types of users on their workload and situational awareness when the using or not using the ATD-2 tools during daily operations.

3.1-39. Strategic Surface Metering at Charlotte Douglas International Airport (IRobeson, DASC2020)

This paper describes the strategic metering capabilities of the ATD-2 Phase 2 IADS system and the operational results from CLT.

3.1-40. Investigating Effects of Controlled Flights through Fast-Time Simulation (ZZhu, DASC2020)

This paper evaluates the impacts of controlled flights on airport performance and assesses the ATD-2 benefits of pushback hold advisories for both controlled and non-controlled flights using fast-time simulation for Charlotte Douglas International Airport.

3.1-26. Objective Measurement Assessment of Departure Advisories for Ramp Controllers from a Human-In-The-Loop Simulation (HLee, AVIATION2020)

In April/May 2019, NASA conducted a human-in-the-loop (HITL) simulation with ramp and tower controllers with experience at Dallas/Fort Worth International Airport (DFW). The purpose of this HITL was to evaluate the impacts of various surface metering goals in ramp operations at DFW and test new features of the ATD-2 ramp controller decision support tools. This paper evaluates the quantitative metrics from the simulation results related to airport performance and surface metering given various departure scheduling advisories for ramp controllers.

3.1-27. Human Factors Impact of Different Ramp Controller Scheduling Advisories for ATD-2 Surface Metering in a Human-in-the-Loop Simulation (BParke, AVIATION2020)

This paper examines whether the ATD-2 surface metering advisories – successfully used in the on-going field demonstration at Charlotte Douglas International Airport (CLT) – are effective at a different airport, Dallas/Fort Worth International Airport (DFW), and how the advisories affect Ramp Controller workload and situation awareness. The human-in-the-loop (HITL) simulation was conducted in 2019 and utilized NASA Ames Research Center's Future Flight Central, an airport simulator with a full-scale 360-degree view, to show simulated airport operations at DFW in real-time to Ramp Controllers with DFW operational experience.

3.1-28. Impact of General Aviation Operations on Airport Performance Through Fast-Time Simulations at Charlotte Douglas International Airport (ZZhu, AVIATION2020)

The ATD-2 IADS system features new capabilities of data exchange and integration, collaborative surface metering and scheduling, which has demonstrated operational benefits of reducing delay time and fuel consumption. General Aviation flights, however, are not currently included in the surface metering programs because of their different operational procedures and lack of reliable predictability in departure time. Thus, their impact on the system performance is not well understood. This paper presents a study of the impact of General Aviation traffic at CLT using fast-time simulations.

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 CO_2 emission reduction were achieved during the period with a total of 944 hours of engine run time reduction. The amount of CO_2 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

This section contains the cumulative set of simulation results and benefits descriptions from ATD-2 research. **Documents are listed newest to oldest in this section.**

Final Phase 3 Metroplex IADS System

4.11. ATD-2 Phase 3 Benefits Mechanism, v4 (DBhadoria, August 2021)

The benefits discussed in this document are for Phase 3 benefits at the North Texas metroplex terminal airspace. ATD-2 Phase 3 builds upon Phases 1 and 2 by extending the capabilities to a Metroplex environment where multiple airports are interacting and competing for resources at the terminal boundary. This document describes the metrics used to inform the flight operators, Air Traffic Control

(ATC) tower, FAA, and even broader aviation community about opportunities to reroute aircraft and the metrics used to assess the performance of the ATD-2 Phase 3 system including benefits. This document provides definitions and detailed calculation methods of identified Phase 3 benefit metrics such as OFF Delay Savings, IN Delay Savings, and Aggregate System-Wide Savings. This document also describes the mechanism to translate delay savings metrics into fuel and emissions savings.

Initial Phase 3 Metroplex IADS System

4.10. ATD-2 Benefits Mechanism, v1 (DBhadoria, May 2020)

This document describes the ATD-2 benefits mechanism used to assess the ATD-2 Phases 1 and 2 IADS capabilities and field evaluation conducted at CLT since September 2017. The ATD-2 benefits mechanism mainly consists of surface metering and overhead stream insertion. This document provides detailed calculation methods of major benefit metrics, such as fuel savings, gas emissions savings, and engine runtime reduction, which can be obtained through surface metering, gate hold of Approval Request (APREQ) flights prior to pushback, and the renegotiation of release time while taxiing.

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 each Phase of the field evaluation period. This section contains the most relevant of those activities.

5.01. ATD-2 Remote Webinars (October 2019) [External Link]

The ATD-2 team hosted a series of online webinars during ATD-2 Phase 1 and 2. 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://aviationsystems.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 TFDM TTP Prototype and Mobile App Use Case (July 12, 2018)
- Recap of Industry Formulation Input Received on Future Planning (October 17, 2019)

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)
5.17. ATD-2 IADS System Initial Phase 3 Informal Tech Transfers - Completed (August 2020)
5.18. ATD-2 IADS System Final Phase 3 Informal Tech Transfers - Completed (September 2021)

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.aviationsystems.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)

5.06. ATD-2 Phase 3 Stormy 19 Review, v3 (EChevalley, October 2019)

This presentation to ATD-2 field demo partners at the conclusion of the Stormy 19 season includes the Trajectory Option Sets (TOS) process, key functionality enhancements completed for Stormy 19, and potential future capabilities for the ATD-2 system.

5.07. ATD-2 CDM CAT NTML Lessons Learned (RStaudenmeier, October 2019)

This presentation conveys lessons learned about data, data sources, and NTML related changes that were required to enable TMI information for the ATD-2 field demonstration.

5.08. Surface Meets TOS Update & Potential Future Work (ACapps, October 2019)

This briefing for the Surface CDM (Collaborative Decision Making) Team (SCT) & Flow Evaluation Team (FET) discussed the foundational data/information quality needs to enable a collaborative TOS concept that includes surface. The primary goal of this briefing was on soliciting broad feedback from the operator community. This discusses the importance of the Earliest Off Block Time (EOBT) as a predictor for improving NAS demand predictions as well as possible areas where SCT/FET could contribute to uses of Trajectory Option Sets in future FAA systems.

5.09. ATD-2 Update for the National Customer Forum (NCF) (ACapps, February 2020)

This briefing for the National Customer Forum (NCF) includes an update on ATD-2 CLT benefits, lessons learned from the integration of surface and TBFM automatic scheduling, a high level overview of planned work for 'Stormy 20', project status overview, summary of recent capabilities, and topics for on-going collaboration with ATD-2.

5.10. Long Term Integration and Implementation of ATD-2 Phase 3 Capabilities (PSmith, February 2020)

This presentation for the Surface CDM (Collaborative Decision Making) Team (SCT) & Flow Evaluation Team (FET) includes review of recommendations from an earlier SCT/FET meeting, support of operator workflows, and software integration in operational systems. The briefing also identifies incorporating ATD-2 Phase 3 capabilities into the workflows.

5.11. System-Wide Benefit Metrics (WCoupe, February 2020)

This presentation for the Surface CDM (Collaborative Decision Making) Team (SCT) & Flow Evaluation Team (FET) discusses goals for real-time metrics, new fields available in the ATD-2 System for displaying metrics to users, and analyses on delay prediction accuracy and delay savings. This includes information on aggregate delay savings that can be used by operators to better understand the savings to their fleet from a single TOS decision.

5.12. Required Filtering to Optimize Use of TOS (EChevalley, February 2020)

This presentation for the Surface CDM (Collaborative Decision Making) Team (SCT) & Flow Evaluation Team (FET) includes lessons learned from Stormy 19, an overview of how terminal restrictions are handled by the ATD-2 system, and additional Trajectory Option Sets (TOS) route filtering capabilities planned for Stormy 20.

5.13. Examples of Machine Learning with TBFM Data, SWIM Industry/FAA Team (SWIFT) Briefing (ACapps, February 2020)

This briefing provides an example of how machine learning can be applied to large aviation data problems, using TBFM SWIM data elements and data analytics lessons learned from ATD-2 as well as an industry standard workflow to address these problems.

5.14. ATD-2 Stormy 20 Kickoff, Rev 3 (GJuro, March 2020)

This presentation includes Stormy 20 objectives, operational plans, training, metrics, and demonstrations of new Phase 3 features.

5.15. Compilation of Answers from Selected ATD - 2 Industry Workshop Questions on SWIM (March 2020)

This document contains a subset of questions on SWIM submitted at the 2019 ATD-2 Industry Workshop along with answers compiled from ATD-2 team members.

5.16. ATD2 Phase 3 Overview, Rev 4 (GJuro, May 2020)

This presentation for the National Customer Forum includes an overview of ATD-2 Phase 3 with a focus on the collaborative Trajectory Option Sets (TOS) capabilities that are being demonstrated in ATD-2 work.

5.19. ATD Technical Interchange Meeting (TIM) Presentations (September 2021) [External Link]

The ATD TIM was held on September 22-23, 2021 as an online event hosted by the NASA Aeronautics Research Institute (NARI). It featured presentations and panel discussions that highlighted the contributions of the ATD-1, ATD-2, and ATD-3 demonstration activities to NextGen. The TIM focused on how the FAA and Industry are utilizing the knowledge and technology developed and delivered under ATD.

All presentations from the workshop, including recordings of the panels and sessions, are available here: https://nari.arc.nasa.gov/atd2021tim

In total, there are 7 presentations and about 12 hours of recorded content from the TIM. The topics presented are listed below.

- ATD Project Overview
- ATD-1 / Trajectory Based Operations (TBO)
- ATD-2 / Single-Airport Integrated Arrival Departure Surface (IADS)
- ATD-2 / Multi-Airport Integrated Arrival Departure Surface (IADS)
- ATD-2 / Digital Services
- ATD-3 / Traffic Aware Strategic Aircrew Requests (TASAR)
- ATD-3 / Dynamic Routes for Arrivals in Weather (DRAW) and Multi-Flight Common Route (MFCR)