Airspace Technology Demonstration 3 (ATD-3)

Multi-Flight Common Route (MFCR)

Technology Transfer Document Summary

Version 2.0

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Revision History

Rev	Date	Sections Affected	Description of Change	Author
1.0	12/11/2017	All	Original	KSheth MAmer EWang
2.0	06/22/2018	1 Public Outreach Materials 2 High-Level Documents	Changed to external links for ATD-3 videos Added NASA TM version of MFCR ConOps	EWang

Table of Contents

Introduction

Airspace Technology Demonstration – 3 (ATD-3) is part of NASA's Airspace Operations and Safety Program (AOSP) – specifically, its Airspace Technology Demonstrations (ATD) Project. ATD-3 is a multi-year research and development effort which proposes to develop and demonstrate automation technologies and operating concepts that enable air navigation service providers and airspace users to continuously assess weather, winds, traffic, and other information to identify, evaluate, and implement workable opportunities for flight plan route corrections that can result in significant flight time and fuel savings in en route airspace. In order to ensure that the products of this tech-transfer are relevant and useful, NASA has created strong partnerships with the FAA and key industry stakeholders.

This summary document and accompanying technology artifacts satisfy the second of three Research Transition Products (RTPs) defined in the Applied Traffic Flow Management (ATFM) Research Transition Team (RTT) Plan. The original transfer, completed in December 2017, consisted of NASA's Multi-Flight Common Route (MFCR) research for efficient route corrections for en-route weather avoidance. This transfer updates the Concept of Operations document to a publicly-available NASA Technical Memorandum. Blue highlighting indicates the newly modified deliverables.

The MFCR concept builds on the experience of the legacy Dynamic Weather Routes (DWR) and focuses on a better balance of potential savings with ATC acceptability, common route corrections options for multiple flights on similar routings, and better use of existing and/or modern automation for communication and coordination of route change options. All of these capabilities are expected to improve system performance significantly in terms of actual delay-reducing clearances issued to multiple flights. Common routes for groups of flights are better suited for use by FAA traffic managers and could result in more savings with less operator workload compared to routes for individual flights. Decision support tools (DSTs) that find a better balance between potential delay reduction and Air Traffic Control (ATC) acceptability could improve the overall delay reduction achievable in actual air traffic operations.

1) Public Outreach Materials

This section contains high-level descriptions and multi-media products appropriate for the general public. Distribution outside of the U.S. Government is permitted without restrictions.

1.01. ATD-3 Fact Sheet (April 2017)

The ATD-3 factsheet describes NASA's concept for improving efficiency and throughput in the en-route and arrival phases of flight through the integration of ground- and flight-deck based technologies, including MFCR. The factsheet is publicly available on the NASA Ames Aviation System Division webpage: (http://www.aviationsystemsdivision.arc.nasa.gov/research/strategic/atd3.shtml).

1.02. ATD-3 Integrated Concept Animation V1.1 (May 2017) [External Link]

This animation illustrates the current operational challenge of convective weather and the goals of the ground and flight-deck tools that comprise the ATD-3 integrated concept. The 5-minute animation, geared for technical audiences, is available for viewing at the NASA Ames Aviation System Division webpage: https://www.aviationsystems.arc.nasa.gov/research/strategic/atd3.shtml.

1.03. ATD-3 Integrated Concept Animation V1.2 (October 2017) [External Link]

This animation provides a high-level overview of the ATD-3 integrated concept. The 2-minute animation for broader audiences is available for viewing at the NASA Ames Aviation System Division webpage: https://www.aviationsystems.arc.nasa.gov/research/strategic/atd3.shtml.

2) High-Level Documents

This section describes MFCR at the Concept of Operations level. Distribution outside of the U.S. Government is permitted without restrictions.

2.01. Multi-Flight Common Route (MFCR) Concept of Operations Synopsis, Version 1.0 (NASA/TM–2018–219714)

MFCR leverages existing weather, airspace, and traffic data, as well as improvements in navigation, surveillance, communication, and digital information technologies, to build on existing ATM automation and address some of the shortcomings associated with strategic traffic flow management initiatives and weather forecasting uncertainties. These capabilities provide significant potential benefits in the form of time, fuel, and cost savings. The concept of operations described in this document describes MFCR functionality as delivered by NASA to the FAA in December 2017, including a list of potential enhancements that may be included when the system is fielded.

2.02 ATD-3 Measures of Performance (MOP) Specifications Document, Version 1.0 (SHarrison, May 2017)

The measures of performance described in this document are derived from the ATD-3 Objectives and quantitatively characterize the system performance. These specifications will be used to assess the outcomes of each ATD-3 activity, including human-in-the-loop simulations, fast-time simulations, flight tests, operational flight trials, and field demonstrations. They are recognized by the Sub-Project Manager, Technical Leads, and Principal Investigators (PIs) as valid system-level representations of ATD-3 system performance.

3) Technical Publications

This section describes MFCR at the technology level – including simulation or field trial results, algorithm descriptions, and data analyses. Functional requirements for MFCR are based on the ATD-3 technical

publications found here. The papers are ordered by date to show the progression. Distribution outside of the U.S. Government is permitted without restrictions.

3.01. Assessment of National Airspace System Airborne Rerouting Tool (KSheth, ATM2015)

This paper presents an assessment of a National Airspace System airborne rerouting tool. The tool implements NASA's Dynamic Weather Routes concept for wind-corrected flying-time savings during convective weather activity. A description of the system, as applicable to the entire United States airspace is provided, and results are presented demonstrating benefits of such a system from various Centers' and airlines' perspectives.

3.02. Analysis of Multi-Flight Common Routes for Traffic Flow Management (KSheth, Aviation2016)

This paper presents an approach for creating common weather avoidance reroutes for multiple flights and the associated benefits analysis, which is an extension of the single flight advisories generated using the Dynamic Weather Routes (DWR) concept. These multiple flight advisories are implemented in the National Airspace System (NAS) Constraint Evaluation and Notification Tool (NASCENT), a nation-wide simulation environment to generate time- and fuel-saving alternate routes for flights during severe weather events. The results indicate that many opportunities exist where individual flight routes can be clustered to fly along a common route to save a significant amount of time and fuel, and potentially reducing the amount of coordination needed.

3.03. Subject Matter Expert Evaluation of Multi-Flight Common Route Advisories (KBilimoria, Aviation2017)

This paper documents the results of a preliminary subject matter expert evaluation of MFCR. The simulation investigated the need for human-automation teaming to design weather re-routes for delay recovery.

4) Multi-Flight Common Route Technology Artifacts

This section contains the MFCR functional requirements and internal documentation related to development of the MFCR prototype implementation. Distribution outside of the U.S. Government is permitted without restrictions.

4.01. ATD-3 MFCR Functional and Performance Requirements Document, Rev 2.0 (MAmer, November 2017)

This document provides the functional and performance requirements for the development of the MFCR simulation systems and products. The requirements provided in this document are maintained in NASA's ATD-3 CORE™ model-based systems engineering database. Each requirement includes a hierarchical number, permanent project unique identifier (PUID), requirement title, rationale, and verification method. It defines the system conditions and requirements to allow the capabilities to function properly to produce benefits.

4.02. Optimized Common Route Assignment for Multiple Flights During Severe Weather (ATAC, September 29, 2017)

The ATAC NRA Team, consisting of ATAC Corporation (ATAC), AvMet Applications Inc. (AvMet) and Cognitive Systems Engineering (CSE), submitted this document in support of the NASA NRA project titled "Optimized Common Route Assignment for Multiple Flights During Severe Weather," (Contract Number: NNA16BE50C). This report includes the ATAC Team's estimates of the benefits and costs of implementing NASA-developed weather rerouting decision aids on a nationwide scale.

4.03. ATD-3 Multi-Flight Common Route User Guide (November 2017)

The MFCR User Manual is designed to assist users who have varying degrees of acquaintance with the MFCR system. The first two sections, Motivation: Understanding MFCR's approach and Weather and MFCR, should be of special value to users who desire a broad overview of MFCR before plunging into the details. Users who already have a basic understanding of MFCR may wish to skip the first two sections and jump directly to the last four. The major sections of this manual are as follows: Motivation — Understanding MFCR's approach, Weather and MFCR, Detailed functional description of the MFCR GUI, Invalid flight plan routes, User Interactions with the MFCR GUI, and Modifying an MFCR Trial Plan.

4.04. ATD-3 MFCR Version Description Document (AClymer, October 2017)

This document describes the MFCR software developed, evaluated, and verified through the MFCR HITL conducted in September 2017.

4.05. ATD-3 MFCR FAA Software Installation Instructions (AClymer, October 2017)

This document contains instructions for installing the MFCR software executable package (4.06) and for running the included HITL scenarios.

4.06. ATD-3 Multi-Flight Common Routes (MFCR) Software Executable Package & Scenarios (November 2017)

This package contains source code, executable software, and scenario definitions for the MFCR functionality. Details of the software package can be found in the Version Description Document (4.04). This software can be referenced in NASA's version control system using the following labels:

- Version name: facet-MFCR-HITL-20171017-cc5cef7730a-nascent-linux.tar.gz
- Version date: 10/17/2017
- Commit ID: cc5cef7730a
- git tag: MFCR_FAA

5) Simulation and Evaluation Results

This section contains the in-depth summaries of MFCR human-in-the-loop simulations and evaluations.

5.01. Executive Summary: Human-in-the-Loop (HITL) Evaluation of Multi-Flight Common Routes (MFCR) (KBilimoria, October 2017)

A HITL evaluation of the MFCR tool was conducted in the Air Traffic Control Laboratory at NASA Ames, Sep 26 – 28, 2017. Four SMEs, all current FAA employees with extensive air traffic operations experience, evaluated the MFCR tool and its concept of use. This document's objective is to provide a brief summary of the evaluation soon after it was completed; it includes: a synopsis of the test outcome and preliminary results.

5.02. MFCR HITL Outbrief (KBilimoria, November 2017)

A HITL evaluation of the MFCR tool was conducted in the Air Traffic Control Laboratory at NASA Ames during 26-28 September 2017. The objective of this outbrief is to provide a detailed description of how the HITL was conducted as well as the results; it includes: the test outcome and the Measures of Performance (MOP) results.

5.03. MFCR HITL Verification and Validation Report (MAmer, November 2017)

The Multi-Flight Common Routes (MFCR) software verification of Airspace Technology Demonstration – 3 (ATD-3) requirements was completed for requirements selected per the ATD-3 Simulation Requirements Verification Matrix (RVM). The verification of these requirements using the ATD-3 MFCR test procedures is documented in this report, which contains the results (PASS/FAIL) and supporting comments by the MFCR Systems Engineer.

5.04. MFCR HITL Requirements Verification Matrix (MAmer, November 2017)

The verification of MFCR requirements using the ATD-3 MFCR test procedures is summarized in this document, which contains the results (PASS/FAIL) and supporting comments by the MFCR Systems Engineer.