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# *Airspace Technology Demonstration 3 (ATD-3)*

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## Traffic Aware Strategic Aircrew Requests (TASAR) Technology Transfer Document Summary

Version 1.0

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## Introduction

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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 fourth of five Research Transition Products (RTPs) defined in the Applied Traffic Flow Management (ATFM) Research Transition Team (RTT) Plan. This transfer consists of NASA’s Traffic Aware Strategic Aircrew Requests (TASAR).

TASAR offers onboard automation for the purpose of advising the pilot of traffic-compatible trajectory changes that would be beneficial to the flight. TASAR is supported by the emergence of three systems: The “connected” Electronic Flight Bag (EFB), Automatic Dependent Surveillance Broadcast (ADS-B) IN, and broadband internet connectivity to the cockpit. By directly engaging the aircrew in flight optimization, TASAR empowers aircraft operators to take a much more proactive role in managing their flights. With the automation’s increased awareness of traffic and other ATC constraints, users will more often receive their desired trajectory improvements (i.e. achieve flight-specific optimization objectives) and controllers will save workload through having fewer problematic or non-approvable requests. For users that have a dispatch service, the cockpit automation will aid coordination between the dispatchers and pilots to ensure fleet requirements are met and consistent strategies are used to optimize the post-departure flights. TASAR is anticipated to save fuel, flight time, and operating costs and thereby provide immediate and pervasive benefits to the aircraft operator, as well as improving flight schedule compliance, passenger comfort, and pilot and controller workload.

Note: Document filenames in this tech transfer package include references to both the document number in this Summary and the document ID in the TASAR Bibliography (doc 3.01). For example, the TASAR Fact Sheet has a Summary document number of 1.01 and a bibliography ID of 37, so its filename is “1.01 37\_Fact Sheet\_TASAR May2015.pdf”.

## 1) Public Outreach Materials

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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. TASAR Fact Sheet (May 2015)

The TASAR factsheet gives a one-page (two-sided) summary of the TASAR concept, the TAP prototype software, and the anticipated benefits.

1.02. TASAR Poster (June 2016)

The TASAR poster shows the TAP HMI on an EFB in the TASAR Flight Trial aircraft.

1.03. TASAR Webinar (2018) [External Link]

The TASAR Webinar is an in-depth presentation of the TASAR concept, benefits, and technology. It includes a demonstration of the TAP software. It is available for viewing at the following website:

<https://www.youtube.com/watch?v=XVP91n4lyGg&feature=youtu.be>

1.04. TASAR/TAP Technology Transfer Promotional Video (2018) [External Link]

The TASAR/TAP video presents a summary of TASAR and its potential operational benefits. It is available for viewing at the following website: <https://www.youtube.com/watch?v=Xa8b2XZQu-k>

1.05. TASAR Technology Transfer Webpage (2018) [External Link]

The TASAR Technology Transfer Webpage summarizes the TASAR concept, benefits, applications, and technology. Embedded is a link to a second TASAR fact sheet developed by the Tech Transfer Office.

The page is accessible at the following website: <https://technologygateway.nasa.gov/patent/LAR-TOPS-148>

## 2) High-Level Documents

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This section contains the high-level documents that describe the TASAR Concept of Operations. Distribution outside of the U.S. Government is permitted without restrictions.

2.01. Traffic Aware Strategic Aircrew Requests (TASAR) (Ballin, Aviation 2012)

This paper presents the vision of TASAR and describes the TASAR concept of operations, its enabling automation technology which is currently under development, and NASA's plans for concept assessment and maturation.

2.02. TASAR Concept of Operations, V1.0 (NASA/CR-2013-218001; Henderson, May 2013)

The purpose of this document is to provide the detailed concept of operations for the TASAR project and describe how TASAR provides automated rerouting capabilities for flight crews.

## 3) Technical Publications

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This section describes TASAR at the technology level – including simulation or field trial results, algorithm descriptions, and data analyses. Functional requirements for TASAR 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. TASAR Bibliography (Wing, 2018)

This document provides a list of TASAR publications documenting the benefits, safety, certification, technology, testing, human factors, deployment, and project status on the development of the TASAR concept. Also listed in the bibliography are the TAP software documentation, simulation and flight trial documentation, and public outreach materials.

3.02. Conflict Detection Using Variable Four-Dimensional Uncertainty Bounds to Control Missed Alerts (Karr, GNC 2006)

This paper presents a technique for modeling uncertainty around a four-dimensional predicted trajectory and an algorithm for detecting conflicts that avoids missed alerts as long as the aircraft remain within the specified regions of uncertainty. The technique is employed in the TAP software implementation.

3.03. Pattern-Based Genetic Algorithm for Airborne Conflict Resolution (Vivona, GNC 2006)

This paper describes a strategic conflict resolution (CR) algorithm which uses a combination of pattern-based maneuvers and a genetic algorithm to resolve conflicts while maintaining conformance with traffic flow management constraints. The CR algorithm was adapted for the TASAR application as a means for producing optimized routes that avoid conflicts and is employed in the TAP software implementation.

3.04. Preliminary Benefits Assessment of Traffic Aware Strategic Aircrew Requests (TASAR) (Henderson, Aviation 2012)

This paper studies the benefits of providing aircrews with on-board decision support to generate optimized trajectory requests that are probed and cleared of known conflicts prior to issuing the request to ATC.

3.05. Costs of Limiting Route Optimization to Published Waypoints in the Traffic Aware Planner (Karr, GNC 2013)

This paper describes techniques for finding appropriate published waypoints in a maneuver pattern and a method for combining a genetic algorithm with an exhaustive search of certain types of advisory. Also included are methods to investigate the increased computation required and to estimate other costs (such as time to destination and fuel burned) that may be incurred when only published waypoints are used.

3.06. Analysis of Operational Hazards and Safety Requirements for Traffic Aware Strategic Aircrew Requests (TASAR) (NASA/CR-2013-218002; Koczko, May 2013)

This report provides the results of safety analyses performed to identify Operational Hazards and Safety Requirements for TASAR as an application that can be hosted on a Portable Electronic Device / Portable EFB. Two safety assessment methodologies were used that are compliant with the Safety Management System of the Federal Aviation Administration.

3.07. An Operational Safety and Certification Assessment of a TASAR EFB Application (Koczo, DASC 2013)

This paper presents an overview of a TASAR EFB application intended to inform the pilot of trajectory improvement opportunities while en route that result in operational benefits.

3.08. Developing an Onboard Traffic-Aware Flight Optimization Capability for Near-Term Low-Cost Implementation (Wing, Aviation 2013)

This paper discusses the approach to minimizing TASAR's cost for implementation and accelerating readiness for near-term implementation.

3.09. Traffic Aware Planner (TAP) Flight Evaluation (Maris, Aviation 2014)

This paper describes the first TASAR flight trial (Flight Trial 1 (FT-1)) conducted in a contracted Piaggio Avanti flight-test aircraft. The flight-test aircraft was modified to host the EFB, the TAP application, an ADS-B IN processor, and a satellite broadband datalink.

3.10. Annualized TASAR Benefit Estimate for Virgin America Operations (NASA/CR-2015-218786; Henderson, August 2015)

This document describes a fast-time simulation study to assess the benefits of TASAR to Virgin America. The simulation compares historical trajectories without TASAR to trajectories developed with TASAR and evaluated by controllers against their objectives.

3.11. Annualized TASAR Benefit Estimate for Alaska Airlines Operations (NASA/CR-2015-218787; Henderson, August 2015)

This document describes a fast-time simulation study to assess the benefits of TASAR to Alaska Airlines. The simulation compares historical trajectories without TASAR to trajectories developed with TASAR and evaluated by controllers against their objectives.

3.12. TASAR Certification and Operational Approval Requirements – Analyses and Results (NASA/CR-2015-218708; Koczo, May 2015)

This document analyzes and assesses the implementation requirements for certification and operational approval of TASAR. It documents results of a community survey, presents an operational hazard assessment, summarizes EFB standards adherence requirements, presents a draft certification plan, and summarizes results of a certification "dry run."

3.13. Systems Engineering Management Plan, NASA Traffic Aware Planner Integration into P-180 Airborne Test-Bed (NASA/CR-2015-218673; Maris, January 2015)

This document is an adjunct report for TASAR FT-1. It addresses the test-vehicle design, integration, and flight-testing for NASA's TAP software application.

3.14. Achieving TASAR Operational Readiness (Wing, Aviation 2015)

This paper presents status of TASAR project activities just prior to the second TASAR flight trial. It describes the project strategy for developing TASAR as a readily adoptable technology; summarizes analyses of benefits, safety, and certification; discusses TASAR technology prototyping; and summarizes human factors simulation experiments and flight-testing. Activities in preparation (at the time of publication) for airline operational trials are also summarized, including partner-airline benefits analyses, internal and external data source analyses, TAP software enhancements, and preparations for the second TASAR flight trial.

3.15. Flight test assessments of pilot workload, system usability, and situation awareness of TASAR (Burke, HFES 2016)

This paper presents results of the subjective assessments by pilots collected during the second TASAR flight trial, specifically, pilot workload, situation awareness, and system usability.

3.16. A Vision and Roadmap for Increasing User Autonomy in Flight Operations in the National Airspace (Cotton, Aviation 2016)

This paper proposes a roadmap of logical steps progressing toward increased operational autonomy for users of the NAS, beginning with NASA's TASAR concept that enables flight crews to make informed, deconflicted flight-optimization requests to air traffic control, and ending with full Airborne Trajectory Management (ABTM). The roadmap steps are related to ongoing FAA activities to clarify the economics-based transition to these technologies for operational use.

3.17. Preliminary Assessment of Operational Hazards and Safety Requirements for Airborne Trajectory Management (ABTM) Roadmap Applications (NASA/TM-2016-219176; Cotton, April 2016)

This report presents the preliminary safety assessment of the ABTM roadmap of applications. For each step in the roadmap, the incremental Operational Hazards and Safety Requirements are identified in this report for use in future formal safety assessments intended to lead to certification and operational approval of the equipment and the associated procedures.

3.18. TASAR Flight Trial 2: Assessment of Air Traffic Controller Acceptability of TASAR Requests (NASA/CR-2016-219215; Idris, June 2016)

This report from the second TASAR flight trial (FT-2) presents observations conducted at the air traffic facilities to identify and assess the main factors that affect the acceptability of pilot requests by air traffic controllers. The goal of FT-2 was to increase operational readiness of TASAR for testing onboard revenue flights with airline partners.

3.19. Deploying a Route Optimization EFB Application for Commercial Airline Operational Trials (Roscoe, DASC 2016)

This paper discusses the challenges of developing and deploying TAP software onto various EFB platforms, solutions to some of these challenges, and lessons learned to assist commercial software



developers and hardware manufacturers in their efforts to implement and extend TAP functionality in their environments.

3.20. Traffic Aware Planner for Cockpit-based Trajectory Optimization (Woods, Aviation 2016)

This paper describes the Traffic Aware Planner (TAP) software application, a cockpit-based advisory tool designed to be hosted on an Electronic Flight Bag and to enable and test the NASA concept of TASAR. The paper summarizes the system architecture, functionality, and capabilities. Developed using an iterative process, TAP's latest improvements include human-machine interface design upgrades and added functionality based on the results of human-in-the-loop simulation experiments and flight trials. Architectural improvements have been implemented to prepare the system for operational-use trials with partner commercial airlines.

3.21. Assessment of Air Traffic Controller Acceptability of Aircrew Route Change Requests (Idris, ATM 2017)

This paper summarizes observations conducted during TASAR FT-2 at the Atlanta and Jacksonville air traffic control centers to identify the main factors that affect the acceptability of aircrew requests by air traffic controllers.

3.22. Point-Mass Aircraft Trajectory Prediction Using a Hierarchical, Highly-Adaptable Software Design (Karr, Aviation 2017)

This paper describes the Behavior-Based Trajectory Prediction concept which was implemented in NASA's TAP flight-optimizing cockpit software application. This method for predicting four-dimensional trajectories of aircraft is based on taxonomic concepts developed for the description and comparison of trajectory prediction software.

3.23. Initial Implementation and Operational Use of TASAR in Alaska Airlines Flight Operations (Wing, Aviation 2018)

This paper describes activities undertaken to achieve TASAR operational status at Alaska Airlines, and it presents preliminary results of the testing leading up to initial flight operations.

#### 4) Traffic Aware Strategic Aircrew Requests Technology Artifacts

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

4.01. TASAR Systems Requirements Document, V2.0 (Carnell, 2018)

This document provides the system requirements for the development of the TASAR system. 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, 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. TAP Software Version Description, Version 15-3.11 (June 2018)

This document describes the TAP software capabilities, necessary hardware, and software, and it provides instructions for building and installing the software.

4.03. Traffic Aware Planner (TAP) Software Design Description, Version 15-3.11 (June 2018)

This document provides a high level overview of TAP's internal code organization and how the software interacts and performs the intended functions.

4.04. TAP Interface Control Document, Version 1.21 (October 2015)

This document describes the current data formats understandable by the TAP prototype software and also supports the expansion of the interfaces to accommodate a larger range of operational environments.

4.05. TAP Training Package (Burke, 2018)

4.05a. TAP Flight Manual Bulletin (draft)

4.05b. TAP Operations Procedures Manual (draft)

4.05c. TAP Computer Based Training (CBT) Module (PC version) (draft)

The TAP Training Package contains draft material for pilot training in the use of the TAP software application. Designed to effectively train pilots on TAP use, operation, and procedures, the TAP Training Package (draft, under continuing development) includes the TAP Computer Based Training (CBT) Module, the TAP Flight Manual Bulletin, and the TAP Operations Procedures Manual. The TAP CBT provides comprehensive, narrated, interactive training on the TAP Human Machine Interface (HMI) and functionality. While the TAP CBT serves as the primary means of training pilots on TAP, the Flight Manual Bulletin and Operations Procedures Manual are supplemental training materials that enhance the training experience. The TAP Flight Manual Bulletin provides additional "under the hood" details about the TAP software and describes TAP features and functions thoroughly. It provides pilots with a solid foundation to the purpose of the TAP software, including how it calculates trajectory optimizations and how the pilot can operate the various functions more effectively. The TAP Operating Procedures Handbook provides pilots with a comprehensive stand-alone reference after the pilot receives TAP CBT training.

4.06. TAP Build and Installation Instructions (June 2018)

This document describes the requirements and process to compile and install the TAP software system on a Windows or 64-bit Linux system using the source code, 3<sup>rd</sup> party software (to be independently acquired), and NASA build tools supplied in a TAP software package. An appendix presents software licensing and copyright information.

4.07. TAP Software Executable Package & Scenarios (June 2018) [Externally Delivered]

This package contains source code, executable software, and scenario definitions for the TAP v 15-3.11 prototype software. Details of the software package can be found in the TAP Software Version Description (4.02).

## 5) Simulation and Evaluation Results

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This section contains the test plans for the two TASAR human-in-the-loop (HITL) simulations and two TASAR flight trials (FT). Reports presenting the results are still in development. Selected results are included in artifacts 3.09, 3.14, 3.15, and 3.18.

5.01. TASAR HITL-1 Test Plan, V2.6 (July 2013)

The goal of HITL-1 was to assess the usability of the TAP interface in an operationally relevant context.

5.02. TASAR FT-1 Test Plan, V1.2 (July 2013)

The goal of FT-1 was to identify operational factors unique to the in-flight environment that may affect TAP functionality, data requirements, HMI, and procedures, and to use these early findings for design refinement of the TASAR application and concept.

5.03. TASAR HITL-2 Test Plan, V2.0 (August 2014)

The goal of HITL-2 was to assess a significantly redesigned HMI and associated training materials in preparation for operational trials with a partner airline.

5.04. TASAR FT-2 Test Plan, V1.0 (February 2015)

The goal of FT-2 was to increase operational readiness of TASAR for airline operational trials.