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Abstract: The purpose of this document is to analyze the impact of Remotely Operated Aircraft (ROA) operations on current and planned Air Traffic Control (ATC) automation systems in the En Route, Terminal, and Traffic Flow Management domains. The operational aspects of ROA flight, while similar, are not entirely identical to their manned counterparts and may not have been considered within the time-horizons of the automation tools. This analysis was performed to determine if flight characteristics of ROAs would be compatible with current and future NAS automation tools.

Improvements to existing systems / processes are recommended that would give Air Traffic Controllers an indication that a particular aircraft is an ROA and modifications to IFR flight plan processing algorithms and / or designation of airspace where an ROA will be operating for long periods of time.

Status:

SEIT-Approved

Limitations on use:
This document is a work in process and has not yet been reviewed and approved as an Access 5 position or submitted to FAA as Access 5-suppored recommendations.

Remotely Operated Aircraft (ROA) Impact on the National Airspace System (NAS) Work Package

Automation Impacts of ROA's in the NAS

The following document was prepared by a collaborative team through the noted work package. This was a funded effort under the Access 5 Project.

EXECUTIVE SUMMARY

This is an analysis of the impact of Remotely Operated Aircraft (ROA) operations on current and planned, during the next decade, Air Traffic Control (ATC) automation systems in the En Route, Terminal, and Traffic Flow Management domains.

The operational aspects of ROA flight, while similar, are not entirely identical to their manned counterparts and may not have been considered within the time-horizons of the automation tools. This analysis was performed to determine if flight characteristics of ROAs would be compatible with current and future NAS automation tools.

The following systems, categorized by areas of consideration, were evaluated in this analysis:

En Route

- Host Computer System (HCS)
- User Request Evaluation Tool (URET)
- En Route Automation Modernization System (ERAM)
- Display System Replacement (DSR)
- Center Terminal Radar Approach Control Automation System (CTAS)
- Direct Access Radar Channel (DARC)

Terminal

- Automated Radar Terminal System (ARTS (II, IIE, Microearts))
- Standard Terminal Automation Replacement System (STARS)

Traffic Flow Management

- Enhanced Traffic Management System (ETMS)

This analysis determined that with minor modifications to URET, all other systems, current and planned, in the air traffic environment will perform normally with the introduction of ROAs in the NAS.

Improvements to existing systems / processes are recommended that would give Air Traffic Controllers an indication that a particular aircraft is an ROA and modifications to IFR flight plan processing algorithms and / or designation of airspace where an ROA will be operating for long periods of time.

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TABLE OF CONTENTS

TABLE OF FIGURES

The following document was prepared by a collaborative team through the noted work package. This was a funded effort under the Access 5 Project.

1.0 Introduction

This is an analysis of the impact of Remotely Operated Aircraft (ROA) operations on current Air Traffic control (ATC) Automation systems and planned ATC automation systems during the next decade in the En Route, Terminal, and Traffic Flow Management Domains.

1.1 Background

Access 5 is a national project sponsored by the National Aeronautics and Space Administration (NASA), with participation by the Federal Aviation Administration (FAA), Department of Defense (DoD), and industry, to introduce civil High Altitude, Long Endurance (HALE) ROA to routine flight in the NAS. Access 5 commenced in May 2004 and is slated to run for five or more years.

The goal of Access 5 is to assist in the development of policies and procedures, demonstrate the enabling technologies, and identify infrastructure to promote a robust civil market for HALE ROA. Access 5 will address ROA airworthiness certification, flight operations, and crew certification. Project efforts will also include the development of appropriate standards, working where appropriate, through existing national standards groups. The project products are policy and procedure recommendations on ROA system airworthiness certification, ROA flight operations, ROA pilot certification, and appropriate standards. The project will identify mature technologies in several areas, including conflict avoidance and communications, and will also provide recommendations on maintenance for continued airworthiness, currency for pilots, and guidelines/processes for safe operation.

Access 5 plans call for integrating HALE ROA into the NAS through a four-step process:

Step 1: Routine operations of HALE ROA above Flight Level (FL) 400 (40,000 feet) with restrictions

Step 2: Routine operations above FL180 (18,000 feet) with restrictions

Step 3: Routine operations above FL180 and access to ROA designated airports with emergency landings in restricted areas

Step 4: Routine operations above FL180 and access to ROA designated airports, including emergency landings (i.e., true "file-and-fly")

1.2 Automation Impact of ROA's in the NAS

It was deemed necessary to evaluate the current and future NAS automation tools to determine the impact of adding a new class of air-vehicle, the ROA, into the NAS. The operational aspects of ROA flight, while similar, are not entirely identical to their manned counterparts and may not have been considered within the time-horizons of the automation tools. An analysis was performed to determine if flight characteristics of ROAs would be compatible with current and future NAS automation tools.

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Areas of consideration:

En Route

Terminal

Traffic Flow Management

Automation Associated with Each Area see (figure 1):

En Route: Host, DSR, URET, CTAS, ERAM, DARC

Terminal: ARTS (II, IIE, Microearts), STARS

Traffic Flow Management: ETMS

1.3 En Route Automation Systems

En route automation systems considered include Host, DSR, URET, CTAS, ERAM, and DARC. Host, DSR, and ERAM provide flight data, surveillance and track data processing and provide the display of surveillance, weather, and map information used by the en route air traffic controller. Direct Access Radar channel (DARC) provides the enroute controller a backup system that processes surveillance and track data only, with a limited set of functionality that the primary system provides. URET provides a medium term conflict probe capability, aircraft-to-aircraft and aircraft-to-airspace, and the ability to display and manipulate flight data electronically. ERAM is designed to replace Host, DSR, URET and the DARC automation systems. CTAS provides metering information to the air traffic controller.

Assuming a filed Instrument Flight Rules (IFR) flight plan, surveillance data such as transponder returns, and VHF/UHF remote pilot/controller communications, there is very little constraint upon en route automation systems when dealing with Remotely Operated Aircraft (ROA). The automation systems would not be able to distinguish between an ROA and any other IFR aircraft operating in the NAS, except for the aircraft type, as filed in the flight plan.

The main driver of data in the en route automation domain is flight and track data processed by the Host and ERAM systems. This flight and track data is then used by the URET and CTAS systems. The URET and CTAS automation systems will process data from an ROA flight identically as any other IFR flight. As long as the flight data, flight data updates, and track information is received, the URET and CTAS systems will perform normally. Interestingly, a minor modification to URET will be required for some ROA operations. It was determined that, for example, a slow moving ROA with a headwind greater than the filed TAS would pose a problem for the URET trajectory modeler. If, when building a trajectory, the predicted groundspeed is calculated to be less

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than zero, the trajectory modeler is terminated and no trajectory is built. This is actually common when low speed High Altitude Long Endurance (HALE) aircraft climb through the jet stream to operating altitudes. A modification to the URET algorithms will be implemented in the 2006 timeframe.

1.4 Terminal Automation Systems

Terminal automation systems considered include ARTS (II, IIE, Microearts), and STARS. These terminal automation systems provide the surveillance and track data processing and the display of surveillance, weather, and map information used by the terminal air traffic controller.

Assuming a filed IFR flight plan, surveillance data such as transponder returns, and VHF/UHF remote pilot/controller communications, there is little constraint upon terminal automation systems when dealing with ROAs. The automation systems would not be able to distinguish between an ROA and any other IFR aircraft operating in the NAS, except for the aircraft type, as filed in the flight plan.

Terminal automation systems, ARTS and STARS both process flight data and track data. When an IFR flight plan is filed, the terminal automation is supplied flight data by the appropriate Host or ERAM en route automation system. Flight data for an ROA flight would be identical to all other IFR flight data being exchanged between the en route and terminal automation systems. All automation functions such as tracking, short term conflict alert, and minimum safe altitude warning would function for the ROA flight in the same manner as any other IFR flight. An ROA may require flight solely within terminal airspace and without an IFR flight plan being filed, such as for a local test flight. Terminal automation systems will allow this as the controller can start a track and the automation will pair the track data with the beacon return. This function will be no different for an ROA as with any pop-up flight.

Flight data for the air traffic controllers is presented in the form of a terminal flight strip. These are formatted for proposed flights, over flights, and arrival flights. These flight strips are supplied by the associated en route Host or ERAM system and will be no different for an ROA flight as with any other IFR flight.

1.5 Traffic Flow Management Systems

ETMS is the system used by Traffic Management Specialists to predict, on national and local scales, traffic surges, gaps, and volume based on current and anticipated airborne aircraft. Traffic Management Specialists evaluate the projected flow of traffic into airports and sectors, and then implement the least restrictive action necessary to ensure that traffic demand does not exceed system capacity. Monitor Alert, a part of ETMS, analyzes traffic demand for all airports, sectors, and airborne reporting fixes in the continental United States, and then automatically displays an alert when demand is predicted to exceed capacity in a particular area.

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Assuming a filed IFR flight plan and surveillance track data such as supplied by the en route automation systems, there is little constraint upon traffic flow management systems when dealing with ROAs. The ETMS receives flight plan data and active track data for all IFR flights in the NAS. Each En Route Center automation system sends the ETMS updated tracking information for each flight on a 3 minute update interval. The ETMS also receives updated flight plan information whenever the flight plan is modified, for example, when an altitude or route is modified. The ETMS automation system would not be able to distinguish between an ROA and any other IFR aircraft operating in the NAS, except for the aircraft type, as filed in the flight plan.

The Air Traffic Control domains considered, En route, Terminal, and Traffic Flow Management, along with their associated automation systems (see figure 2) work as a completely integrated system, with continuous passage of flight and surveillance data on a 24/7 basis. The introduction of ROAs into the Air Traffic environment pose no insurmountable challenge to the various automation systems currently in existence or planned within the next decade.

It is perceived that air traffic controllers will want an indication that a particular aircraft is an ROA. This could be accomplished in all the automation systems in a similar way, highlighting of the data block, for example. This highlighting could be based on aircraft type, as filed in the IFR flight plan.

1.6 Flight Plan Latency

Concern has been expressed that some ROA missions may exceed the flight plan lifespan of existing and future automation systems. For example, a typical flight today in the NAS, that departs from Los Angeles and flies to New York, has a flight plan lifespan of 2-4 hours. An ROA, on the other hand, depending on its particular mission, may need a flight plan lifespan of 2-7 days. In other words, its mission may require it to depart, proceed to its target or research area, loiter or fly a particular pattern which may last for several days, then proceed to its destination. The question then arises if the existing and planned automation systems will support this type of flight plan.

After an IFR flight plan is filed, it ultimately resides in the database within the ARTCC that contains its departure point. The flight plan exists in this database as a proposed or inactive flight. Flight data is then presented to the controller, in either paper, or electronic form, an adapted number of minutes, typically 30 prior to the proposed departure time which is contained in the flight plan. This proposed flight plan will remain in the database of the ARTCC for an adapted number of minutes after the proposed departure time, typically equating to 2-4 hours, and will then be removed automatically. If the flight has not departed within this adapted time and the operator has not updated the proposed departure time, the flight plan will be removed and the pilot or operator is required to file a new flight plan and the sequence of events is repeated. This paradigm for proposed flight plans is also valid for ROA flight plans.

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When a flight departs, the flight plan becomes active either through a manual entry by the controller or automatically through the terminal/enroute automation systems. Once airborne, the flight and flight data typically exist in the terminal automation system for 15-30 minutes. The airspace surrounding an airport is typically small and the flight is assumed to proceed outbound, either into the en route environment, or into another (adjacent) approach control. This flight data is then purged automatically from the terminal automation system an adapted number of minutes after transfer of control to the en route facility or adjacent approach control. It is important to note that, in the case of an IFR flight plan, the flight data for the approach control is maintained and supplied by the host ARTCC. The flight data supplied by the host ARTCC is of 2 types. First, the flight data needed by the controller such as route information, type and equipment, beacon code, etc. is supplied via an interface to the En Route Host Computer System and is used to print flight progress strips. The flight data needed by the terminal automation system, on the other hand, contains different information and is supplied via the NAS/ARTS interface.

The lifespan for a flight plan of an active flight is directly related to the aircraft speed, and the distance to be traveled within a single facility. Take the example of the LAX-JFK commercial turbojet flight. The inactive flight plan exists in the Los Angeles ARTCC and will populate the Southern California Tracon automation system at an adapted time before the proposed departure time. Flight progress strips are also printed at the Tracon, Tower, and first en route sector, at the adapted time. Note, for URET enroute facilities, the flight data also populates the appropriate departure list. When this flight departs, the flight data changes from inactive to active, and ultimately, the SOCAL Tracon works the aircraft to a point that it transfers control to Los Angeles Center. The terminal automation system then purges the flight data an adapted number of minutes after this transfer of ownership. This would happen, approximately, within 30 minutes after departure. Los Angeles Center will then work the aircraft, sector to sector, until transferring control to Albuquerque Center. It is roughly 370 NM to the Albuquerque boundary and the flight time for a turbojet would be approximately 40-45 minutes. Approximately 20-30 minutes prior to transfer of control to Albuquerque, the Los Angeles Center automation would send flight data to the Albuquerque Center computer. The Los Angeles Center flight data would then be purged in another 20 minutes. Albuquerque then transfers control to Kansas City, who, in turn transfers to Indianapolis, etc.

The longest flight plan lifespan in this example would be that of Kansas City Center where the flight would exist in the Kansas City automation for approximately 2 hours. If the aircraft in this example were a single engine Cessna (with very large fuel tanks), rather than a multi engine turbojet, the lifespan in the Kansas city Automation would be increased to approximately 9 hours.

Typically, flight plans in the NAS are assumed to have a duration of less than 24 hours. Commercial and General Aviation aircraft do not currently have the endurance to exceed

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a 24 hour period. Military however, with refueling capability, can remain airborne for this length of time. They accomplish this through the use of filed delays at a specific fix (limited to 3 hours) or, more typically, will file a flight plan to a Military Operations Area (MOA), cancel the active flight plan upon arrival, and use a new flight plan when they are ready to depart the MOA.

Consider now, an ROA based in Wichita Kansas, for example. Suppose its mission is to fly from Wichita to Garden City at an altitude of FL450, park or orbit for 3 days, and then return. Further, assume its filed TAS is 75 kts. Would existing and planned infrastructure allow such a flight plan to be filed and would the infrastructure process an active flight of this duration? This example is considering, for simplicity, the entire flight to be within the Kansas City ARTCC.

The first constraint deals with the filed route of flight. There is a current limitation of 48 route elements that may be filed in a single flight plan. If this flight were to file point-to-point, such as Latitude/Longitude to Latitude/Longitude, there can be no more than 48 occurrences. Depending on the mission and particular pattern to be flown, it may be possible, if not practical, to be filed. A second, and more limiting constraint, are the time estimates over each fix in the route of flight. Current en route automation systems decompose the route of flight into a series of fixes, and associate an estimated time over each fix, called a coordination time. The system cannot process a coordination time in excess of 24 hours in the future due to its inability to associate a day with the time.

A third constrain is the maximum delay time that may be filed at a particular fix. Currently, a delay at a fix may not exceed 22 hours in duration.

Options:

1. Modify en route flight plan processing algorithms to allow for long duration flight plans.
2. Modify en route flight plan processing algorithms to allow for long duration delays at a fix.
3. Define Special Use Airspace (SUA) or Special Activity Airspace (SAA) for long duration loitering or maneuvering. This would be similar to a military operation where a flight plan would terminate at the airspace (or at a fix close to or within the airspace). The flight would transition to a second (proposed) flight plan upon mission completion and would then be cleared by Air Traffic Control to depart the SAA based on the new flight plan.

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1.7 Automation System Descriptions

The Display System Replacement (DSR) provides continuous real-time, automated support to air traffic controllers for the display of surveillance, flight data and other critical control information. This information is processed by the Host and Oceanic Computer System Replacement (HOCSR) and the Enhanced Direct Access Radar Channel (EDARC) subsystems. The DSR provides controller workstations, displays, and input/output devices and a communications infrastructure to connect the DSR with external processing elements of the en route ATC automation system.

The Host Computer System (HCS) receives and processes surveillance reports, and flight plan information. The HCS sends search/beacon target, track and flight data, surveillance and alphanumeric weather information, time data, traffic management advisories and lists to the (Display System Replacement) DSR. The HCS associates surveillance-derived tracking information with flight-planning information. The DSR sends requests for flight data, flight data updates, and track control messages to the HCS. HCS-generated display orders are translated for use within the DSR workstation. While radar data processing is distributed among the terminal and En Route computer resources, the HCS performs virtually all of the flight data processing for its entire geographical area of responsibility. Every tower (ATCT) and terminal radar approach control (TRACON) relies exclusively on its parent HCS for flight data.

The User Request Evaluation Tool (URET) provides conflict probe capabilities to the data controller display in the Air Route Traffic Control Centers (ARTCC) facilities. URET combines real-time flight plan and radar track data with site adaptation, aircraft performance characteristics, and winds and temperatures aloft to construct four dimensional flight profiles, or trajectories, for pre-departure and active flights. For active flights, it also adapts itself to the observed behavior of the aircraft, dynamically adjusting predicted speeds, climb rates, and descent rates based on the performance of each individual flight as it is tracked through en route airspace, all to maintain aircraft trajectories to get the best possible prediction of future aircraft positions. URET uses its predicted trajectories to continuously detect potential aircraft conflicts up to 20 minutes into the future and to provide strategic notification to the appropriate sector. URET enables controllers to "look ahead" for potential conflicts through "what if" trial planning of possible flight path amendments. It enables controllers to accommodate user-preferred, off-airway routing to enable aircraft to fly more efficient routes, which reduce time and fuel consumption.

Center Terminal Radar Approach Control Automation System Build 1 (CTAS Build 1) includes Traffic Management Unit (TMU) capabilities (timelines, load graphs, automated miles-in-trail, and the situation display) and single center metering using miles-in-trail or time-based scheduling and meter lists on en route displays.

The En Route Automation Modernization System (ERAM System) will replace the existing diverse but functionally unequal primary and backup channels (Host and DARC)

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with redundant, functionally equivalent primary and backup channels. The new primary and backup channels achieve identical full functionality by using highly reliable fault tolerant processing elements running identical software. A tertiary system with diverse software, and physical and electronic isolation from the ERAM primary and back-up systems, will be maintained as fall back until the functionality, reliability, and availability of ERAM is demonstrated in the field. A training subsystem with functionality identical to the operational system will permit training to be conducted in parallel with operations.

The Automated Radar Terminal System - Model IIE (ARTS IIE) provides radar data processing (RDP) and decision support tools to the controller in the terminal environment. Utilized at low to medium-size Terminal Radar Control (TRACONs) Facilities the ARTS IIE is capable of receiving input from up to 2 sensors, can process up to 256 tracks simultaneously, and support up to 22 displays. The ARTS IIE implements the Common ARTS software for improved performance maintenance efficiency. The radar data processing (RDP) software provides automated surveillance tracking and display processing. Included in the ARTS IIE software are decision support tools such as Minimum Safe Altitude Warning (MSAW), Conflict Alert (CA), Mode C intruder alert, Converging Runway Display Aid (CRDA), and Controller Automation Spacing Aid (CASA).

The Automated Radar Terminal System - Model IIA (ARTS IIA) provides radar data processing (RDP) and decision support tools to the controller in the terminal environment. Utilized at small Terminal Radar Approach Controls (TRACONs), ARTS IIA is capable of receiving input from one sensors, can process up to 256 tracks simultaneously and support up to 11 displays. The radar data processing (RDP) software provides automated surveillance tracking and display processing. Included in the ARTS IIA software are the decision support tools, minimum safe altitude warning (MSAW) and conflict alert, (CA).

The Automated Radar Terminal System - Model IIIA (ARTS IIIA) provides radar data processing (RDP) and decision support tools to the controller in the terminal environment. Utilized at larger airports, ARTS IIIA is capable of receiving input from up to three sensors, can process up to 900 tracks simultaneously and support up to 36 displays. The RDP software provides automated surveillance tracking and display processing. Included in the ARTS IIIA software are decision support tools such as Minimum Safe Altitude Warning (MSAW), Conflict Alert (CA), Mode C intruder alert, Converging Runway Display Aid (CRDA), Final Monitor Aid (FMA), and controller automation spacing aid.

The Automated Radar Terminal System - Model IIIE (ARTS IIIE) consists of the hardware platform and software required providing radar data processing (RDP) and decision support tools to the controller in the terminal environment. The ARTS IIIE is used at consolidated Terminal Radar Approach Control (TRACON) facilities. The Common ARTS program provided an ARTS IIIE capable of receiving input from up to 15 sensors, the ability to process up to 10,000 tracks simultaneously, and support up to

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223 displays. The RDP software provides automated surveillance tracking and display processing including mosaic display of radar data. Included in the ARTS IIIE software are decision support tools such as Minimum Safe Altitude Warning (MSAW), Conflict Alert (CA), Mode C intruder alert, Converging Runway Display Aid (CRDA), Final Monitor Aid (FMA), and controller automation spacing aid.

The Microprocessor-En Route Automated Radar Tracking System (Micro-EARTS) is a radar processing system implemented with Commercial Off-the-Shelf (COTS) equipment, for use in both En Route and Terminal environments. It provides single sensor and a mosaic display of traffic and weather using long- and short-range radars. At Anchorage, Alaska, Micro-EARTS also provides Automatic Dependent Surveillance-Broadcast (ADS-B) surveillance and display. Micro-EARTS interfaces with multiple types of displays, including Display System Replacement (DSR), Digital Bright Radar Indicator Tower Equipment (DBRITE), and the flat panel tower controller displays.

The Enhanced Traffic Management System (ETMS) application is at the heart of the Traffic Flow Management (TFM) system, and through it flows the network of all TFM interfaces. ETMS at the Command Center deals with the strategic flow of air traffic at the national level. ETMS at remote facilities is used for local airspace management within the local facility's own area of responsibility. To facilitate coordination between the Traffic Management Coordinators (TMC) at remote Traffic Management Units (TMUs) and the Traffic Management Specialists (TMS) at the Air Traffic Control System Command Center (ARTSCC), each local ETMS may also view the national composite picture of traffic for which the Command Center has responsibility. ETMS enables TMS and TMC personnel to track and predict traffic flows, analyze effects of ground delays or weather delays, evaluate alternative routing strategies, and plan traffic flow patterns.

The Direct Access Radar Channel (DARC) provides a back-up processing path to provide surveillance data to the displays in the event of a primary channel (Host Computer System (HCS) failure. The DARC path is a physically, logically and electrically separate processing path (with diverse hardware and software) from the primary Host Computer System (HCS) Radar Data Processing (RDP) paths. Thus DARC provides a tertiary path, to keep radar data on the controller's displays, should both HCS RDP paths be disabled for any reason. The DARC provides radar data processing, very limited flight data processing, but with significantly less functionality than the HCS. Basically, DARC serves as a lifeboat should both HCS processing paths become disabled.

The Standard Terminal Automation Replacement System (STARS) processes primary and secondary radar information to acquire and track data points to display aircraft position for controllers. STARS provides safety tools such as, conflict alert (CA), Mode C intruder (MCI), final monitoring aid (FMA), Minimum Safe Altitude Warning (MSAW), Converging Runway Display Aid (CARDA), and Controller Automated Spacing Aid (CASA). Also, STARS provides the capability to implement the following enhancements: improved radar processing, Global Positioning System (GPS) compatibility, adaptive routing, Center Terminal Radar Approach Control (TRACON)

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Automation System (CTAS), data link implementation, improved weather display, and better utilization of traffic management information.

1.8 Glossary

ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal System
CTAS	Center Tracon Automation System
DARC	Direct Access Radar Channel
DSR	Display system Replacement
ERAM	En Route Automation Modernization
ETMS	Enhanced Traffic Management System
HALE	High Altitude Long Endurance
IFR	Instrument Flight Rules
MOA	Military Operations Area
NAS	National Airspace System
ROA	Remotely Operated Aircraft
SAA	Special Activity Airspace
SUA	Special Use Airspace
STARS	Standard Terminal Automation Replacement System
TAS	True Air Speed
TRACON	Terminal Radar Approach Control
UHF	Ultra High Frequency
URET	User Request Evaluation Tool
VHF	Very High Frequency

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Figure 1 NAS Automation Flow

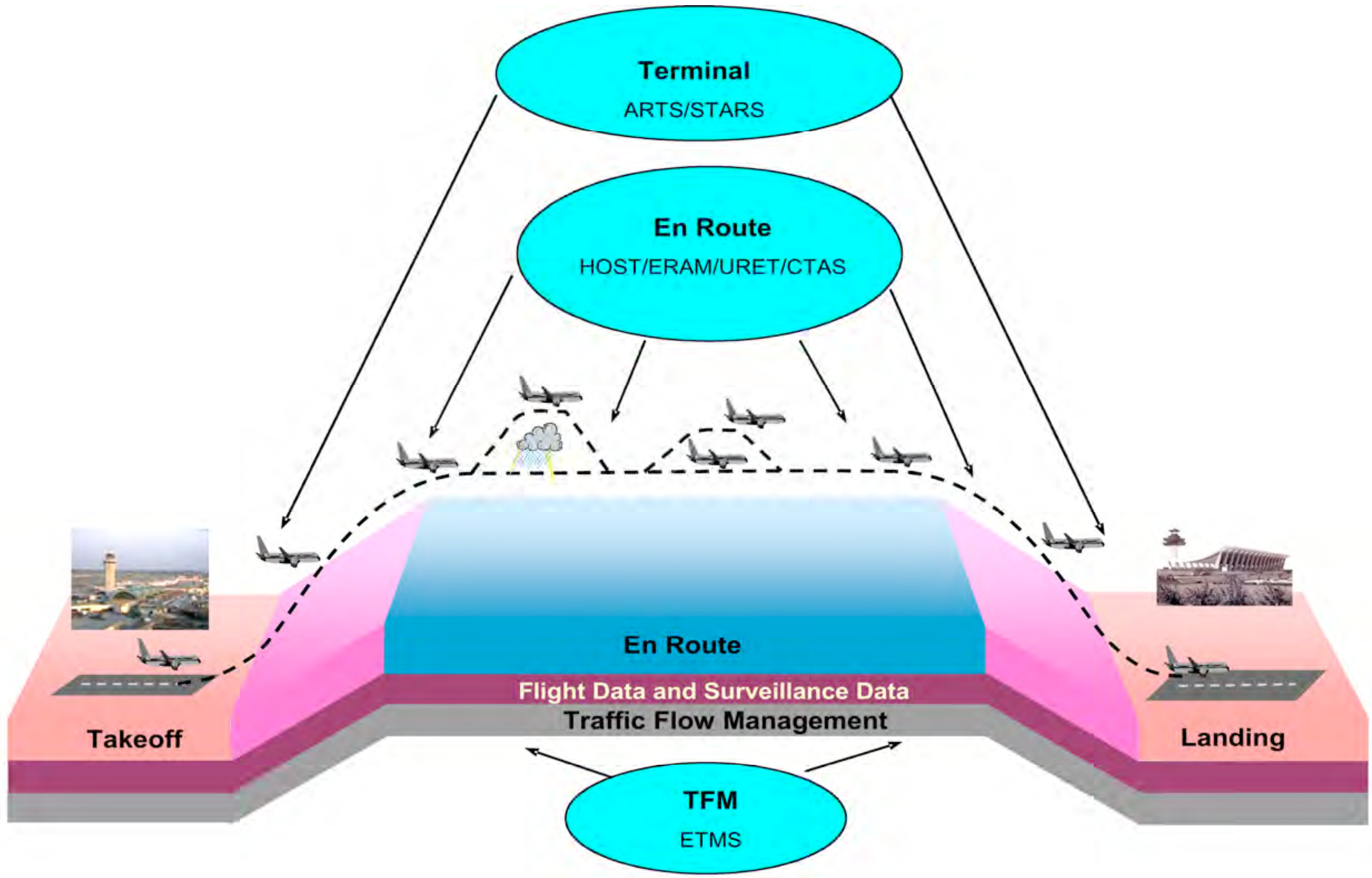

Figure1

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Figure 2 NAS Automation Connectivity

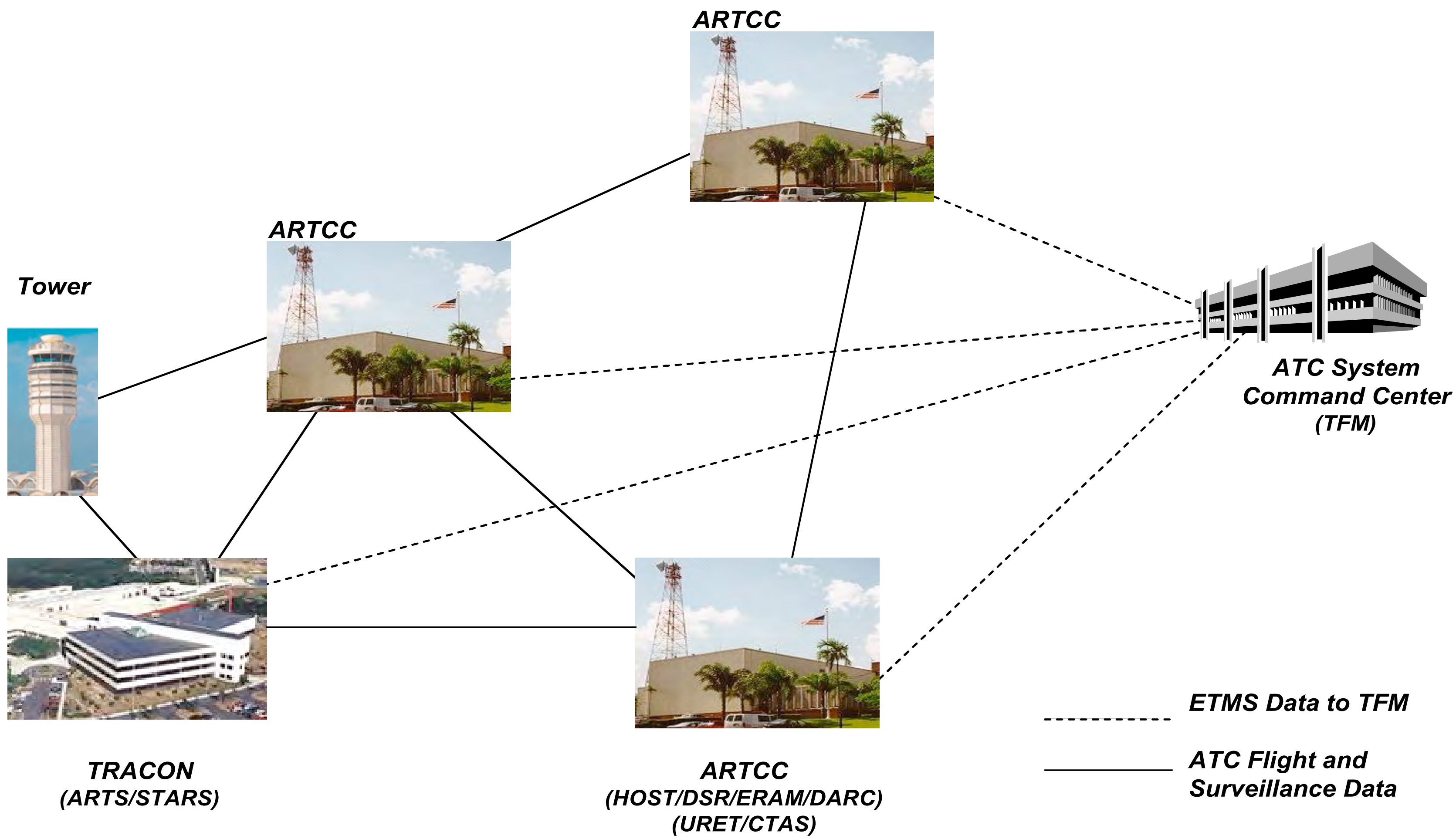

Figure 2

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