

USE OF ERAM SWIM FOR NAS SYSTEM ENHANCEMENTS

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Abstract

The future of information management within the air traffic community is enhanced through sharing of flight data objects, enabled by the System Wide Information Management (SWIM) initiative. SWIM provides the backbone for sharing information throughout the national airspace (NAS), which allows new and existing applications and decision support tools to take advantage of current and consistent data on the SWIM infrastructure, for users to achieve common situational awareness, and systems to make optimum use of the airspace while maintaining safe operations. SWIM-enabling existing and evolving applications and decision support tools lowers the FAA's long-term maintenance costs by transitioning from point-to-point legacy interfaces to use of SWIM for information sharing. The SWIM initiative is aligned with the principles of Service-oriented architecture (SOA).

En Route Automation Modernization (ERAM) is operational in Salt Lake and Seattle centers and is proceeding through site deployment for the other 18 centers. One of the significant enhancements to the baseline ERAM is the addition of the first SWIM-enabled service, the Flight Information Service (FIS). The initial version of FIS provides for processing of Traffic Flow Management System (TFMS)-initiated pre-departure re-route amendments [1]. Enhancements to the initial FIS design position it for use by other consumers for an overall life cycle cost savings. The potential uses of ERAM-provided SWIM services are numerous including modernization of existing legacy interfaces (such as Host-ATM Data Distribution System - HADDS and Flight Data Input/Output - FDIO), and the addition of new users as part of development of new

applications. One potential new user, the Data Communications Air Traffic Control Facilities Notification (AFN) Accelerated Departure Clearance Service (DCL) involves several systems in achieving the end-to-end thread. FIS can accept and process updates from consumers and publish the existing ERAM flight data to authorized users, and address the specific needs of tower systems to automatically send accelerated departure clearances to aircraft. ERAM enhancements can also allow aircraft to log on as FANS aircraft, and then allow a ground station (Tower Data Link Services, TDLS) to establish controller pilot data link communication (CPDLC) sessions to exchange text from air traffic control (ATC) systems to the airplane's cockpit.

New Capabilities, Data Communications-enabled Departure Clearances

CPDLC has been in use on the oceanic system (Advanced Technologies and Oceanic Procedures - ATOP) for a number of years. Introduction of CPDLC into the En Route, Terminal, and Tower environments is planned to occur incrementally. Eventually, ATC will communicate with the aircraft via data communications from pre-departure to landing, with voice communications reserved for exceptions. The concept is that the aircraft will establish data communications before take-off, and, as it transitions from one airspace jurisdiction to another, the same session continues allowing the pilot to communicate with the controlling system throughout the duration of the flight. This concept is depicted in Figure 1.

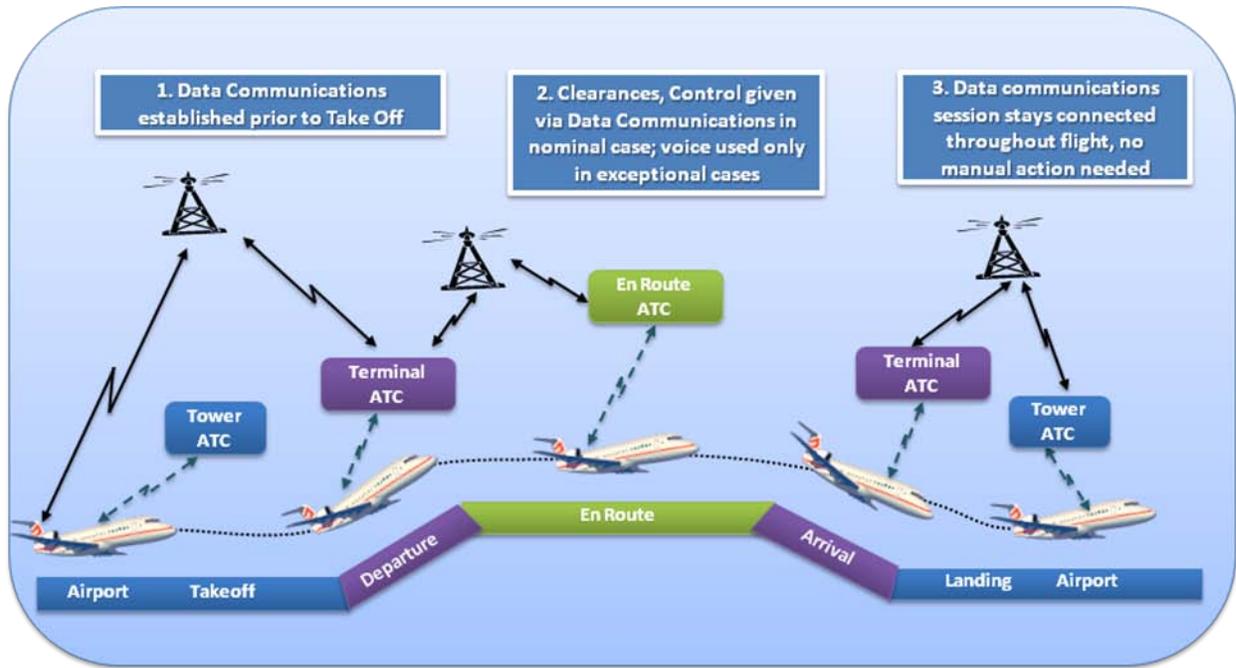


Figure 1 - Data Communications-enabled ATC Concept

The first planned phase toward this eventual end state will enable the delivery of pre-departure clearance to equipped aircraft (known as accelerated Departure Clearance, DCL) via data communications. The implementation of the end-to-end DCL thread involves several systems.

The Pilot's Perspective: Looks Simple

From the pilot's perspective, obtaining the departure clearance is initiated simply by turning on the appropriately equipped Flight Management System (FMS). When the pilot turns on the FMS, and enters the tower communication address, the logon occurs automatically in the nominal case. When ready to depart, the tower controller will initiate a CPDLC session with the aircraft, allowing the pilot to submit a data link request to the air traffic service provider (ATSP) and requests a departure clearance

message. The departure clearance is sent, the pilot acknowledges, and the pilot takes off.

Implementing Systems Do the Heavy Lifting

Let's look at the steps that could be taken by the implementing systems to achieve the simplicity perceived by the pilot, in an implementation using ERAM SWIM FIS to exchange flight data between systems involved in departure clearances. The steps can be summarized as follows: (1), the aircraft logs on to the data communications system; (2), the logon is correlated with a flight object; (3), a CPDLC session is established with the aircraft; (4), when ready to depart, the aircraft requests and receives the departure clearance. Figure 2 shows the involved systems and a high-level summary of the data exchanged between them.

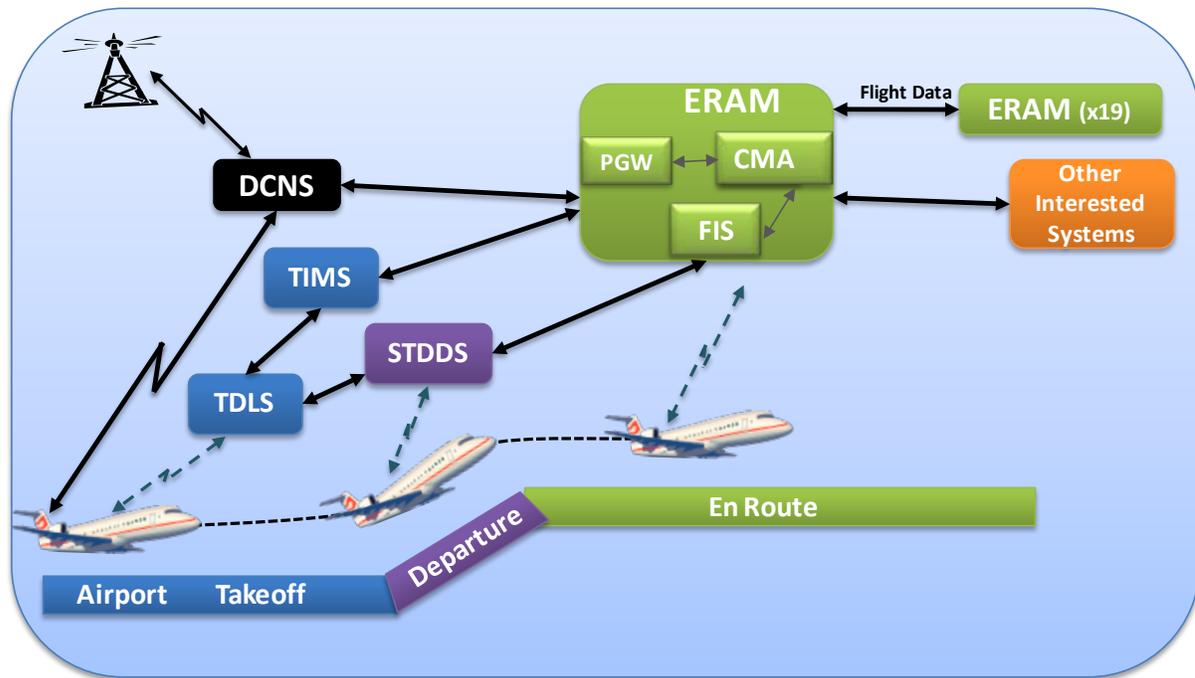


Figure 2 – Data Communications throughout Life of Flight

Some time in advance of the aircraft's impending departure, a flight plan is filed with an equipage type that allows for DCL service. At a parameter time prior to departure (flight strip print time), TDLS will display the flight to the Tower Controller. TDLS anticipates the flight requesting a departure clearance, and prepares the DCL in advance of the request, or does so based on Tower Controller action. TDLS sends a copy of the DCL to the airline operations center/flight operations center (AOC/FOC). AOC/FOC responds with the gate ID, which becomes part of the departure clearance information.

When the pilot turns on the FMS and enters the tower communication address, the logon request is sent. The logon or data link initiation capability is the method of establishing the identity and data communications capabilities of a flight requesting data communication services. The aircraft "logs on" to the system to provide the unique ID (Aircraft Registration or 24 bit address) and Flight ID for the aircraft and to indicate its available applications. Future Air Navigation System (FANS) aircraft will also provide the Aircraft Position (latitude/longitude), while Aeronautical Telecommunications Network (ATN) standards aircraft will also provide the Departure Airport and Destination Airport.

The FMS request to log on to data communications is transmitted from the FMS through the Communications Service Provider (CSP) to ERAM. Once within ERAM, Protocol Gateway (PGW) forwards the request for processing by the ERAM Context Management Application (CMA). A response is sent back to the FMS. Two events must occur successfully, in either order, before the DCL can be sent to the aircraft: a logon request from the FMS must be processed by CMA, and a session must be established between the aircraft and the Flight Object identified by the tower controller. The Flight Object, updated and published via FIS, is used as the information sharing mechanism not only between TDLS and ERAM-CMA, but any other authorized subscriber of FIS. Following both logon and session establishment processing, the FO will have the CPDLC session status and time, the current data authority, the CPDLC address and version, the correlation status. These fields were added to the ERAM Flight Object, so that FIS can be used to update and publish the information to interested subscribers, and so that the information can be passed along to downroute ERAMs along the route of flight, as a natural extension to the information already shared by ERAMs about a flight; in this manner, the Data Comm information can be maintained on behalf

of the aircraft, without the need to repeat the logon processing as data authorities change. As detailed later in this paper, enhancing the flight object with data to support TDLS makes this information available to other future users without modification. In this way, enhancements to support one flight object user provide potential value to all flight object users.

When ready, and prior to pushback from the gate, the pilot requests the departure clearance by sending a DCL Request downlink to the ATSP. The avionics transmits the request to the FAA systems in the tower [3] via Data Communication Network Service (DCNS) to PGW to Telecommunications Information Management System (TIMS) to TDLS. TDLS sends the departure clearance (including route information), and pilot acknowledges. TDLS display shows the gate information; any changes are displayed to the controller for DCL impact evaluation. Clearance revisions, if any, are sent directly to the cockpit for display to the pilot on the FMS, and are acknowledged by the pilot. FIS is used to exchange data between ground systems, including the data required by ground systems to communicate with the cockpit, but the communications between ground systems and the cockpit use CPDLC uplinks and downlinks, not FIS.

Subsequent pilot communication with the ground systems will be implemented in future phases. It would be helpful to the pilot to continue communications with the appropriate data authority, seamlessly. To that end, ground based systems can coordinate with each other, share information about the flight, and automatically establish a connection (session) between the downroute systems and the aircraft in preparation for conversing with the pilot. This communication is done via a National Single Data Authority, which will manage the CPDLC session from start to finish, providing the aircraft with the information needed as it transfers between and within centers (frequency, etc).

A Matter of Scale

The initial version of FIS, the one built to provide processing of Traffic Flow Management System (TFMS)-initiated pre-departure re-route amendments, involved only TFMS and ERAM's key site for deployment of FIS. A simple way to address naming and security was to establish a router-to-

router VPN between the two systems, include the few relevant IP addresses. With the addition of many FIS users (specifically, more than thirty SWIM Terminal Data Distribution System, STDDS instances, and a few CMA instances), naming and security cannot be solved with the same simple interim solution; the initial router-to-router solution does not scale well. Domain Name Service and Private Key Infrastructure Service were initially planned for SWIM Segment 2; having made the case that these services would be beneficial now, bringing these forward for implementation in SWIM Segment 1 merits consideration.

ERAM Enhancements Add Value to Departure Clearance

ERAM enhancements and capabilities would enable TDLS to provide the DCL capability. These come both from ERAM SWIM FIS, and from ERAM flight data processing.

Enhancements enabled by ERAM Flight Data Processing

The DCL capability requires additional data about the flight route to be sent to the aircraft, namely the full route including details about elements of the route, such as type (Automated Departure Route - ADR, Automated Departure/Arrival Route - ADAR, Standard Arrival Route - STARs, etc.) and attributes for each route element (lat/long, Fix-Radial-Distance - FRD, airport). ERAM flight data processing has this information in adaptation and adds it to the data being sent out over the interface to TDLS in support of the departure clearance.

Since the DCL capability transmits data directly to the plane's avionics, Data Comm levied requirements on the implementing systems to insure integrity of the data exchanged with the aircraft [2]. ERAM processes (including those used to develop Data Comm extensions) generally meet the intent of RTCA DO-278, AL3 based on the strength of the engineering, software, and quality processes used that have been evaluated on the ERAM program at CMMI Level 5. Gaps have been identified in the use of COTS, primarily Progress Software's FUSE, which is used in the implementation of ERAM FIS as well as by STDDS. Subsets of the Flight Object that are used in the Data Comm threads have been

identified and will be protected by use of a more stringent encoding and verification mechanism (i.e. more stringent than the 16-bit checksum in use by TCP/IP by default; a 32-bit checksum is one possibility being considered for use). It is because ERAM flight data processing meets the intent of AL3 that the few remaining gaps can be mitigated, a key ERAM advantage.

Enhancements enabled by ERAM FIS

The DCL capability requires new data to be shared between component systems, data that is not shared today. Data items include the route element categories described above, data about the Data Comm Logon, the Data Comm Session, and issued clearances. In all cases, the data are attributes of the flight. Adding such data to the flight object and distributing via FIS (between ERAM CMA, TDLS, and others) is a natural extension of FIS and examples of the intended usage of FIS and the flight object.

FIS is a well suited mechanism for flight data exchange between CMA and ERAM FDP, as well as between CMA and TDLS. CMA's purpose is to correlate Data Communications sessions with flights and with aircraft. In order to provide such correlation, CMA needs all flights in the NAS (certain data about each flight). FIS selection and filtering capabilities make it easy for CMA to get data for all flights in the NAS, but limited to just the data elements of interest, not all the data elements. FIS offers CMA the ability to establish long-running subscriptions of fine-grained control. For example, CMA performs logic processing such as matching aircraft ID and aircraft registration number (from logon data store) with exactly one FO. The matching logic for FO also requires the confirmation that the departure airport of the logon matches the flight plan's filed departure airport, that the logon is in the accepted or active state, that the flight activation state of the flight is proposed, and that there are no active flight plans (assume one per flight object) with the same registration number. Clearly, CMA has specific data needs and rather complex matching logic. Providing CMA just the data it requires avoids unnecessary transmission, processing and discarding of unnecessary data.

Returning briefly to the topic of data integrity, it is important to note that FIS's approach offers

advantages in the integrity implementation. FIS's design of publishing XML over JMS provides the ability for attributes to be used for added integrity on certain data items but not others; consumers of FIS publications can use the added integrity if their business logic requires it, or to ignore the provided attributes otherwise. Figure 3 shows an example snippet of FIS schema, for the flight state data element, here assumed to be an element requiring data integrity.

```
....  
<flight>  
    <flightState ck="FDFF2000">PENDING</flightState>  
</flight>  
....
```

Figure 3 - Example FIS Schema, showing Checksum on Protected Data

Perhaps most importantly, FIS enables the longer term DCL capability by extending the reach of flight data sharing. Once logged on, the aircraft maintains session continuity by FIS's ability to pass the logon credentials along from system to system (tower departure, terminal, en route, oceanic, international systems). FIS helps distribute the session handle to all interested parties, by adding the session handle as part of the flight data and publishing to all interested systems. In Figure 1 this is shown as the Flight Object Publish data sent to the terminal system, and tower system. Eventually this handle may be sent to other consumers of flight data, such as oceanic or international systems, enabling Data Communications to extend even further.

FIS Continuous Improvement

Examples of specific longer-term enhancements envisioned for ERAM FIS are included here, to share part of the ERAM vision for FIS. Included are a few specific examples: Regional Flight Information Service, and Delta Reconstitution of FIS Service Consumers.

Regional Flight Information Service ERAM's FIS is currently representing all the flights in a single ERAM instance there will be one instance of ERAM at each of the twenty Air Route Traffic Control Centers - ARTCCs). A consumer, such as Data Comm's CMA, having interest in all flights in the NAS, must subscribe to each of the twenty FIS

instances; as a result, CMA may receive the same flight from more than one FIS instance due to the fact that the flight is distributed to each en route center along the flight's route, i.e., more than one FIS has a copy of the flight. Introducing a higher level FIS, a Regional FIS (RFIS) would simplify the logic in many subscribing systems, by:

- Allowing the subscribers to contact the single-instance RFIS to subscribe and to send requests for creating, updating, deleting flights;
- Expecting RFIS to reduce any duplicates to a single, definitive flight instance when multiple copies exist in the NAS; and
- Expecting RFIS to send the requests for creating, updating, deleting flights to the appropriate en route center's FIS instance.

Delta Reconstitution of FIS Service Consumers

SWIM services developed to date do not support data reconstitution to facilitate subscribers' initialization or recovery from certain failures. In the case of services publishing ephemeral data (e.g., surveillance data, weather data), reconstitution may not be of interest, since current data is published within acceptable time parameters. In the case of Flight Data, reconstitution is necessary because each flight is not published frequently, or in its entirety, for subscribers to build up their flights of interest in a timely manner. ERAM FIS will reconstitute subscribers consistent with each subscriber's subscription criteria (selection of flights, filtered by fields). The entire set of flights that meet each subscriber's criteria will be provided. Due to the potential for this flight data of interest to be quite voluminous (e.g., number of flights in the thousands), reconstitution may take many minutes. Although this behavior does meet current subscribers' needs (and FIS requirements), when more stringent timing parameters will be required, optimizations will be needed (e.g., an "essential" service must recover from failures in under 10 minutes, including reconstitution of needed data, while an efficiency-critical service must do so in 60 seconds). One approach, delta reconstitution, implies that FIS, as the service provider, and subscribers, as service consumers, jointly determine what flight data subset is needed to make the subscribers' data current (complete and consistent). Then FIS sends only the

subset of data required, thereby reducing the amount of data and time to make a subscriber's data current.

FIS's Value Extends

Using the Departure Clearance example, one can see evidence of FIS's value extending to many systems. As changes are made to FIS to accommodate new capabilities such as that of Data Comm Accelerated Departure Clearances, increased data sharing becomes possible with other service consumers as well.

Interface Changes Become Easier

Today's en route system exchanges flight data using a multitude of interface control documents (ICDs), e.g., ATM IPOD ICD [5], NADIN ICD [6], Parallel ICD [4], NAM ICD [7]. To implement a change that impacts all users of flight data, for example to step up to using the ICAO4444 version intended for the year 2012, each of the ICDs must be updated appropriately, as well as updating the systems to step up to the modified ICDs. Contrast that with updating the FIS interface (available as WSDL/WSDD), making a new version of FIS available, and having each system step up to the new version of the service; the previous version of FIS would remain available until all systems migrated to using the new version, at which point the previous version of FIS can be removed from the service registry. Of course each system using flight data must still step up to a new interface, but a single, common interface can be maintained, rather than multitude ICDs; as a result, future wide-spread interface changes become easier to implement.

Changes Can Benefit All

Since FIS will be used by many NAS systems as the interface between systems, enhancements made on behalf of one system are available to all. Once the initial investment has been made (stepping up to a SWIM-based interface such as FIS), a system can make minor interface changes and receive new data. Enhancements to receiving systems are required in order to use the data (in either case) but with SWIM-based interfaces such as FIS, the user avoids incurring costly changes to both sides of the interface; a minor XML schema revision is all that's required to update the interface on both sides.

Improvements made in one system are in effect paid forward to benefit others, as depicted in Figure 4.

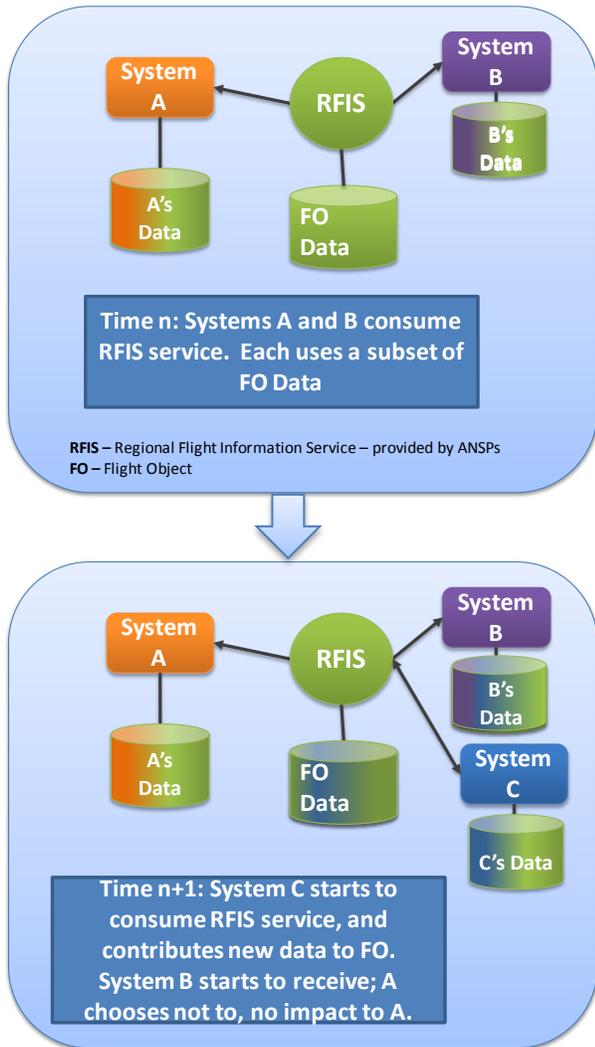


Figure 4 - RFIS's Widespread Use Provides New Benefits to Other Users

Future FIS Users

Over time, the NextGen plan is that SWIM-based interfaces replace current point to point interfaces. Along with other SWIM services, FIS will replace FDIO and HADDS interfaces. Terminal Flight Data Management (TFDM) will be one of the first new systems to use FIS. It will exchange coordinated flight plan data, trajectory projections and other derived data using FIS. Today's flight strip users will transition to become FIS users, instead of using HADDS and FDIO.

Flight Object Extensions

The FAA is undertaking a significant effort currently to identify the Flight Object; that is, to identify all the data attributes which are used to describe a flight today, by the various users of flight data. This effort reveals duplications, slight differences in use and meaning of flight data. Once completed, this analysis will result in a single NAS-wide definition of the flight object. The NAS flight object definition must be usable internationally, as FIS and SWIM-enabled interfaces extend to communicate with the international aviation community as today's interface does. To this end, the FAA and Lockheed Martin have been working on describing usage concepts and governance around the end-state FIS. Work is underway to harmonize NAS SWIM work with SESAR Flight Object definition and technologies, and to harmonize NAS and European flight data definitions. Demonstrations have shown communications between various systems within the NAS and internationally, using FIS prototypes in a lab environment.

Connecting the Dots

The initial version of FIS allowed Updates of flights for processing Traffic Flow Management System (TFMS)-initiated pre-departure re-route amendments. The enhanced FIS will allow interested systems to specify selection criteria (i.e. specifying which flights in the NAS are of interest) as well as filtering criteria (i.e. specifying the fields of each selected flight that is of interest) when establishing the subscription. FIS can be used by TDLS to subscribe to flights proposed to depart from the specified airport, to update each flight for issuing the departure clearance using CPDLC. FIS can be used by Data Comm's Context Management Application to subscribe to almost all flights¹ in the NAS.

As a result, TFMS will be able to re-route aircraft (pre-departure) automatically (without today's manual intervention of the traffic flow

¹ CMA will subscribe to receive all the data listed above for flight objects that: a. are Proposed, have a non-default tail number, and TDLS indicated logon correlation is requested, or b. are Active, have a non-default tail number, or c. have a CPDLC session established.

specialist located in each En Route center) and TDLS will be able to send the modified departure clearance to the aircraft, automatically, without voice communication between the controller and the pilot.

In future phases of Data Comm, interactions between en route ATC controllers and pilots will be CPDLC capable. This will require computer-human interface (CHI) changes in ERAM (just like DCL required CHI changes in Tower); but from the FIS perspective, data exchanges relevant to other controllers are saved in the FO and thereby passed along to all interested parties.

ERAM FIS, coupled with Lockheed Martin's engineering concept and demonstration work on SWIM-based information exchange, enable data exchanges that open up tomorrow's possibilities in air traffic control!

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