INITIAL EVALUATION OF URET ENHANCEMENTS TO SUPPORT TFM FLOW INITIATIVES, SEVERE WEATHER AVOIDANCE AND CPDLC

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Abstract

The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) and the Federal Aviation Administration (FAA) are currently developing a set of enhancements to the User Request Evaluation Tool (URET) conflict probe. These enhancements are designed to further the support provided by URET for strategic Air Traffic Control, by extending the URET analysis and detection capabilities to new types of problems (e.g., severe weather), and facilitating the delivery of clearances using data link communications.

The URET enhancements described in this paper provide support for the implementation of Traffic Flow Management (TFM) Flow Initiatives, severe weather avoidance, and assistance in clearance delivery using the FAA's Controller Pilot Data Link Communications capability. The URET problem detection capabilities are enhanced to indicate where controller action may need to be taken to implement a Miles in Trail Flow Initiative, or assist with severe weather avoidance. Analysis capabilities for these situations are provided by enhanced URET displays and Trial Planning capabilities.

This paper provides a description of these enhancements as currently implemented in the CAASD En Route Research Prototype, their Concept of Use, and the methodology and results of initial laboratory evaluations.

Introduction

To meet user demands and to accommodate growth in traffic, the Federal Aviation Administration (FAA) and National Airspace System (NAS) users have embarked on an initiative known as Free Flight. Free Flight provides users with as much flexibility of flight as possible, while maintaining or increasing NAS safety and predictability. To implement Free Flight, the FAA has been developing and refining concepts, defining architectures, and developing the decision support capabilities needed to support the Free Flight concepts. The FAA, assisted by The MITRE Corporation's Center for Advanced Aviation System Development (CAASD), has also been working with industry representatives to develop the NAS Operational Evolution Plan [1] that further integrates and aligns the FAA's objectives and plans with those of the aviation industry.

The FAA is implementing Free Flight with an incremental development strategy. In the first step (Free Flight Phase 1, or FFP1), a set of existing core capabilities was deployed to a limited number of sites. One of these capabilities is the User Request Evaluation Tool (URET), which provides the en route Sector Team with automated conflict detection and Trial Planning capabilities, and a set of tools to assist in the management of flight data. A prototype version of URET was developed by CAASD and deployed to the Indianapolis Air Route Traffic Control Center (ARTCC) in 1996 and to the Memphis ARTCC in 1997. This prototype was used for over 1.4 million sector-hours to develop and validate requirements for the production version of URET, which was installed at those sites in January 2002. URET has now been deployed to 6 ARTCCs as part of FFP1, and will be deployed to the remaining 14 ARTCCs as part of Free Flight Phase 2 (FFP2).

Evidence from the ongoing usage of URET is that it supports a shift away from tactical operations based on radar data towards strategic Air Traffic Control (ATC) planning based on flight plans and associated trajectories. The benefits provided by this shift include less frequent and/or less severe maneuvers to resolve conflicts, more time for negotiation between controllers and pilots to develop clearances that meet the objectives of both, accommodation of pilot requests and user-preferred routing resulting in the reduction of delays and user operating costs, and the relaxation of many of the altitude and speed restrictions currently in place [2 - 3].

The following Free Flight enhancements are expected to provide further support for a shift toward strategic ATC planning, as reflected by FAA and industry consensus in [4 - 7]:

- The addition of tools to the FFP1 baseline to further assist the controller in the detection, analysis, and resolution of a variety of problems involving aircraft, Special Use Airspace (SUA) and severe weather areas, and TFM Flow Initiatives.
- The integration of these resolution tools with data link and other decision support capabilities into a system that is common to both the Radar (R) and Radar Associate (RA) positions, and allows access to the full range of tactical and strategic information at each position.

This set of problem detection, analysis and resolution support capabilities is termed Problem Analysis, Resolution and Ranking (PARR). As with URET, the initial development of the PARR capabilities was conducted in the late 1980s and early 1990s by CAASD and the FAA as part of the AERA (Automated En Route ATC) program [8 - 10]. PARR is being designed as a series of incremental enhancements to URET, and has been designated as priority research for FFP2. The first PARR enhancement provides support for the quick assessment of alternatives such as direct routings, altitudes and speeds using the existing URET conflict probe functionality and displays [11 - 13].

A subsequent step in PARR expands the problem detection and analysis capabilities provided by URET to include support for the implementation of Traffic Flow Management (TFM) Flow Initiatives (FIs) and severe weather avoidance. The URET problem detection capabilities are enhanced to indicate where controller action may need to be taken to implement a Miles in Trail (MIT) FI, or assist with severe weather avoidance. Analysis capabilities for these situations are provided by enhanced URET displays and Trial Planning capabilities. The capability to data link the PARR resolutions are provided by the integration of the FAA's Controller Pilot Data Link Communications (CPDLC) capability with URET.

This paper provides a description of these URET enhancements to support TFM MIT FIs, severe weather avoidance and CPDLC. Each enhancement (as currently implemented in the CAASD En Route Research Prototype) is described in turn, along with an overview Concept of Use. Following these descriptions, the results of an initial laboratory evaluation of each capability is presented.

Because PARR is a URET enhancement and utilizes many of the URET capabilities, an overview of URET is provided in the following subsection. Further details on URET may be found in [14].

URET Overview

URET processes real-time flight plan and aircraft track data from the NAS Host computer. These data are combined with site adaptation, key aircraft performance parameters, and winds and temperatures from the National Weather Service in order to build four-dimensional flight profiles, or trajectories, for pre-departure, inbound, and active flights. URET also adapts its trajectories to the observed behavior of 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. URET uses these predicted trajectories to continuously detect potential aircraft separation violations for Instrument Flight Rules flights up to twenty minutes into the future. These trajectories are also used to determine which sector should automatically receive notification of an alert and presentation of flight data.

In addition to their application of modeling the currently planned actions of aircraft, trajectories are the basis for URET's Trial Planning capability. Trial Planning allows the controller to check a desired flight plan amendment for potential conflicts before a clearance is issued. A two-way interface allows the controller to enter the Trial Plan as a Host flight plan amendment with the click of a button.

The URET capabilities include a controller interface for both textual and graphical information. The Aircraft List is the primary URET display, and provides flight data and alert information for all aircraft that are currently in the sector, or predicted to be in the sector in the next 20 minutes. Additional textual and graphical information may be quickly accessed from the Aircraft List. For example, selection of an alert indicator presents a graphical depiction of the involved aircraft and conflict regions on the Graphic Plan Display (GPD). Trial Plans may also be viewed graphically on the GPD, or the corresponding clearance language and Host Amendment text viewed on the Plans Display. Color coding of Current Plans and Trial Plans is used to reflect the conflict status of each plan.

TFM MIT Flow Initiatives

MIT FIs are commonly used to modulate air traffic flow into congested areas such as busy sectors and arrival streams [15]. They are conveyed to controllers verbally by Operational Supervisors or via General Information messages, and are defined for a group of aircraft using criteria such as time of applicability, arrival airport and a boundary crossed. The controller must determine if a given aircraft meets these criteria; if so, the MIT constraint is applied as a minimum spacing between two aircraft when crossing a defined fix or boundary. For example, an MIT FI might be defined for all aircraft crossing the Indianapolis (ZID) and Cleveland (ZOB) ARTCC border between for the hours of 1100Z – 1200Z daily, with a destination of CVG via the fix TIGRR; an example constraint in this case is a minimum of 20 MIT spacing at the ZID-ZOB border.

In spite of their widespread use, MIT FIs can be difficult to implement for two reasons. First, the controller must identify the aircraft that are subject to the MIT FI. This can be particularly difficult when the controller has to apply multiple MIT FIs for different streams of aircraft. Additionally, if the MIT constraint boundary is in a downstream sector, the controller may be unaware of the preceding aircraft to which the MIT distance should be referenced.

A second reason that MIT FIs can be difficult to implement is the workload in estimating the sequence and spacing at the constraint boundary between aircraft with different aircraft performance characteristics, speeds, routes and/or altitudes. Such difficulty extends to the determination of appropriate maneuvers to implement the required spacing.

Due to these difficulties, the errors in realized MIT spacing can be large [16]. This can lead to overcompensation, in which the required minimum MIT spacing is increased due to the uncertainty in obtained spacing – which may, in turn, cause additional (upstream) MIT constraints to be applied.

This section describes URET enhancements designed to assist the controller with MIT identification and prediction, by identifying which aircraft are subject an MIT FI, and by providing predicted spacing and sequence information. Further details on these enhancements may be found in [17]. An overview of a Concept of Use for these capabilities is also provided; additional details are given in [18]. An overview of related research by NASA is presented in [15].

URET Enhancements to Support MIT FI Implementation

As with other PARR enhancements to URET [11, 12], the capabilities to support the implementation of MIT FIs were designed to integrate closely with the existing URET displays. In this approach, the Aircraft List remains the primary URET display, with selectable indicators (termed MIT Indicators) added to denote MIT applicability for an aircraft. These indicators are presented in a column next the URET Alert Indicators, as illustrated in Figure 1. Selection of these indicators provides further graphical and textual MIT information.

When a specific MIT FI has been selected by the controller (either by selection from a list of MIT FIs, or from selection of an MIT Indicator), the MIT Indicator provides the sequence number of the aircraft at the MIT constraint boundary. Sequence numbers are modified only due to a trajectory remodeling of currently sequenced aircraft (e.g., for a flight plan amendment) or a new aircraft is added in sequence (e.g., due to a departure).

Graphical Display of MIT Information

As noted above, the URET GPD provides a graphical depiction of selected conflicts, including the involved aircraft and conflict regions. Analogous capabilities have been developed to provide a graphical depiction of the aircraft involved in the MIT FI, along with the spacing and sequence information for each aircraft. Aircraft routes may also be displayed, as illustrated in Figure 2. All aircraft involved in the MIT constraint in the display area are shown, including those aircraft not listed on the Aircraft List (e.g., aircraft that do not enter the sector). Sequence and spacing information for each aircraft is provided in the fourth and fifth lines of the URET data block: the fourth line provides the sequence number (surrounded by a box), followed by the predicted MIT, and the fifth line shows the route distance and time to the MIT constraint. The MIT graphical display is accessed from the Aircraft List MIT Indicators in the same manner as the graphical conflict display is accessed from the adjacent Alert Indicators.

List Display of MIT Information

In addition to the graphical MIT display, URET has been enhanced to provide aircraft MIT information in a concise textual list, ordered by the predicted aircraft sequence. This list is termed the "MIT List," and is illustrated in the right portion of Figure 2. It contains the same spacing and sequence information as contained in the URET data blocks, along with the Computer/Flight ID of the aircraft, and the current aircraft speed and type.

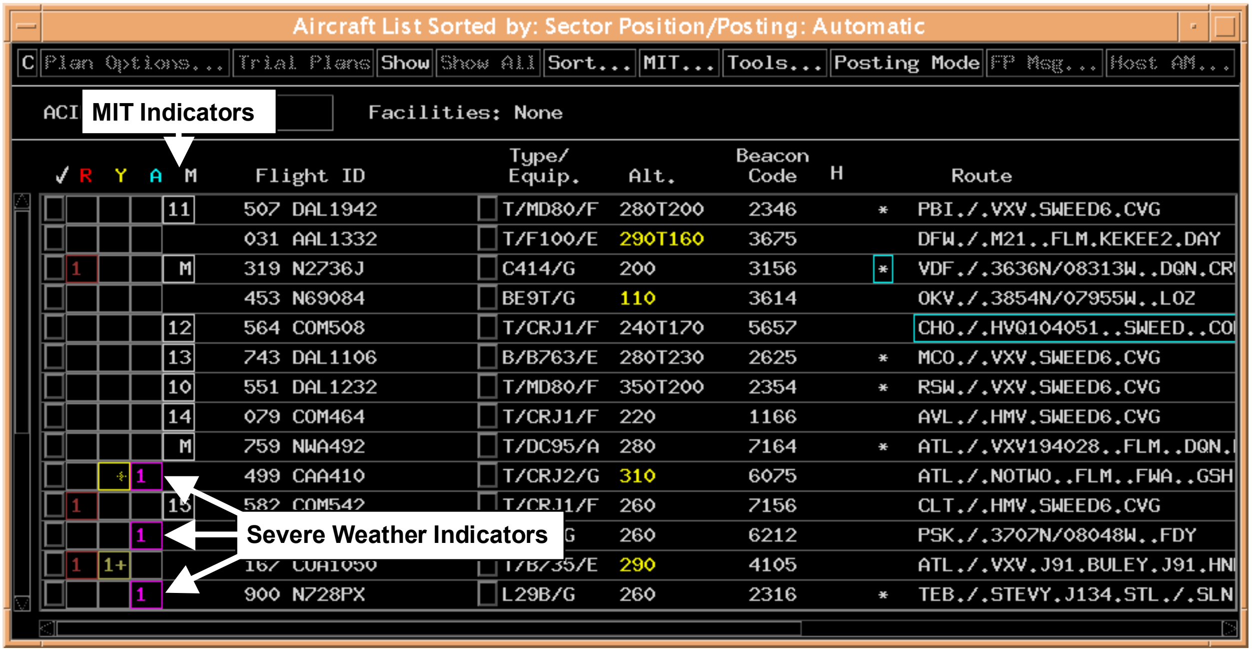

Figure 1. MIT and Severe Weather Indicators on the URET Aircraft List

Concept of Use

The Concept of Use for the URET MIT capabilities is very similar to that for the URET aircraft-to-aircraft and aircraft-to-SUA conflict probe capabilities. The Aircraft List remains the primary URET display, and the controller scan of this list now includes the MIT Indicators. The controller selects an MIT FI of interest, and views the sequence numbers to determine which aircraft are subject to the MIT restriction as well as the number and order of aircraft in the MIT stream. The controller also

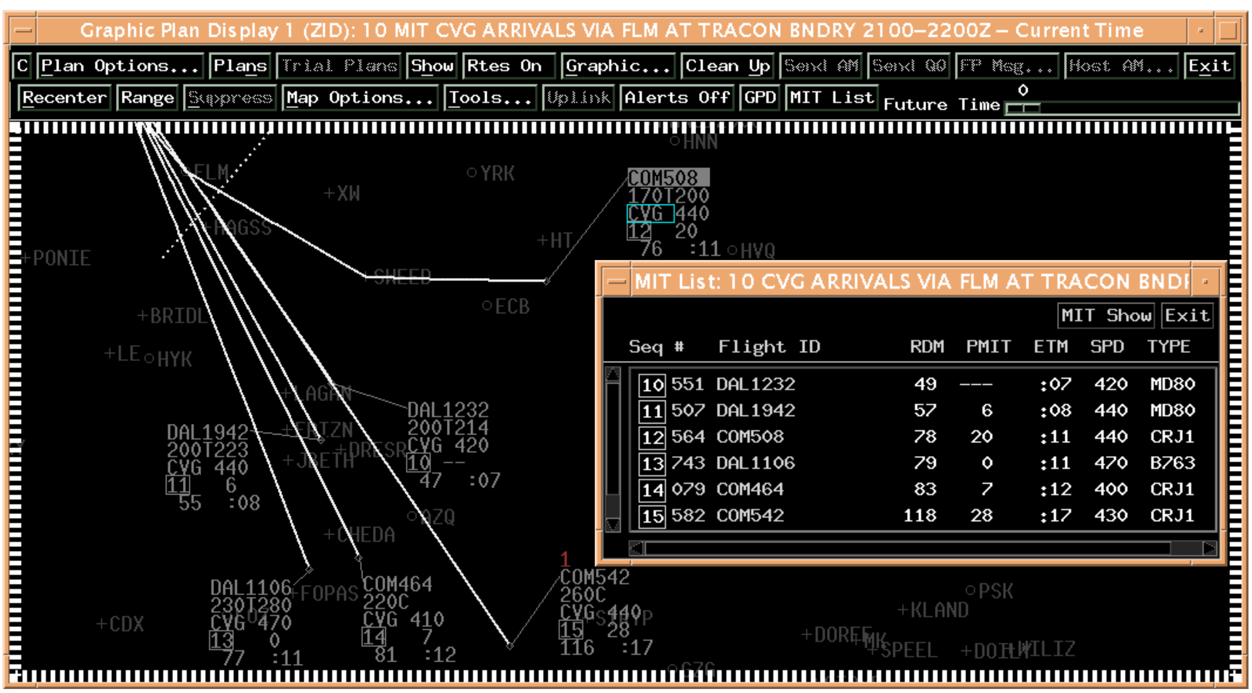

Figure 2. Graphical MIT Display and MIT List

looks for gaps in the sequence to determine where aircraft from other sectors fit into the MIT stream.

If further information is desired, the controller displays the MIT stream on the graphic display and MIT List. The controller scans the predicted MIT values on these displays to determine if there are predicted spacing problems. If any predicted MIT values are significantly less than the required spacing, the controller uses the displayed MIT information to determine the best course of action.

Severe Weather Avoidance

Severe weather is a major cause of delay in the NAS today [19], with en route aircraft consistently avoiding areas of severe weather [20]. Although pilots are responsible for this avoidance, controllers typically assist pilots whenever requested. Currently, controllers have few tools available to assist pilots in severe weather avoidance, and often rely on pilot reports (PIREPS) for severe weather-related information [21].

This section describes URET enhancements designed to support the controller in severe weather situations, by displaying areas of current and forecast severe weather, and identifying aircraft that are in, or predicted to enter, these areas. Further details on these enhancements may be found in [17]. An overview of a Concept of Use is also presented; additional details are given in [21].

The sector capabilities for support in severe weather situations are designed to complement the TFM capabilities for managing the reduction in capacity associated with large areas of severe weather. This reduction in capacity may require rerouting of aircraft [18, 19, 22]. Currently, these reroutes must be entered manually at the sector; work is underway to transmit them electronically from TFM to URET, providing automatic notification to the controller and eliminating the need for manual reroute entry [19, 23].

Severe Weather Problem Prediction

The prediction of severe weather problems is performed using the National Weather Service's National Convective Weather Forecast (NCWF) product [24]. This product is updated every 5 minutes, and utilizes NEXRAD (NEXt generation weather RADar) radar and lightning data. It defines detection "polygons" of current severe convective weather with polygonal lateral bounds, a maximum altitude, and a 1-hour extrapolation forecast.

The NCWF is currently used for TFM severe weather reroute applications across multiple sectors and centers [19, 22], using forecasts of 1 – 2 hours. It normally has a minimum lateral polygonal area of 520 km^2; for the smaller scale, sector application in URET, this minimum has been reduced to 50 km^2. Accuracy of the current NCWF product is addressed in [24]; research for improved products tuned to smaller scale, shorter-term applications such as URET is described in [25, 26]. These products will assessed for use in URET as they become available, along with additional products that address other types of severe weather, e.g., icing.

Severe weather polygons are defined in URET by using the NCWF detection and extrapolation forecast, to obtain polygons at 0, 10, 20, 30 and 40 minute projections. Assuming each polygon is active and stationary ±5 minutes between its projection time, URET Current Plans are probed for penetrations of active polygons for 0 – 20 minutes in the future; Trial Plans are probed for an additional 20 minutes [21].

URET Display Enhancements

As with the URET enhancements described above to support the implementation of MIT FIs, the display modifications to support severe weather avoidance were designed to integrate closely with the existing URET displays. The Aircraft List remains the primary URET display, with selectable indicators added to note predicted problems with areas of severe weather. Since both the severe weather and SUA problem indicators denote airspace problems, they share the same space on the Aircraft List and are color-coded as illustrated in Figure 1. SUA alerts take precedence over severe weather notification whenever an aircraft has an SUA and severe weather problem simultaneously.

Selection of a severe weather indicator for an aircraft provides a graphical display (on the GPD) of the aircraft trajectory and severe weather areas involved in the problem as illustrated in Figure 3. All polygons representing severe weather areas can be displayed, and the controller may graphically create a Trial Plan around these weather polygons using trackball input. NEXRAD data (matching that on the R Controller's display) can also be displayed on the GPD. Textual severe weather problem information is available on the URET Plans Display as illustrated in Figure 4.

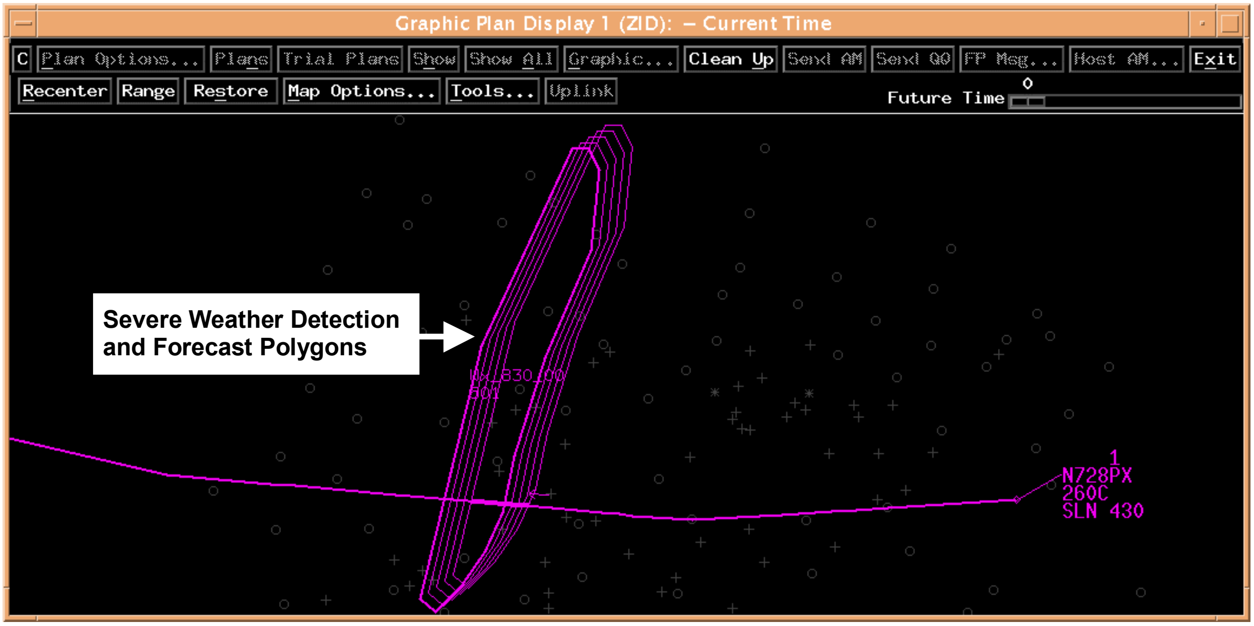

Figure 3. Graphical Display of a Severe Weather Problem

Figure 4. Textual Display of a Severe Weather Problem

Concept of Use

As with the MIT FI enhancements described above, the Concept of Use for the URET severe weather capabilities is very similar to that for the URET aircraft-to-aircraft and aircraft-to-SUA conflict probe capabilities. The Aircraft List remains the primary URET display, and the controller scan of this list now includes the severe weather indicators. When severe weather notification is displayed, the controller can view the problem on the GPD, along with all severe weather polygons and/or NEXRAD data if desired.

Pilot requests regarding severe weather avoidance may be handled as follows:

- If a pilot requests a specific reroute to avoid severe weather, the controller uses the URET Trial Planning capability to determine if the requested reroute is problem-free. If so, the controller issues the reroute and enters the appropriate amendment into the Host computer through URET.
- If the pilot requests support in determining a weather avoidance maneuver, the controller may use the severe weather display to create a Graphic Trial Plan around the severe weather. If conflict-free, the flight plan is amended and the appropriate maneuver is relayed to the pilot as a reroute (using data link if available), or as heading changes as required. The controller may also use the severe weather display and Trial Planning capabilities to determine if the aircraft can climb over the severe weather area in a conflict-free manner.
- If the pilot requests additional weather information, such as direction, speed or maximum altitude of the severe weather

area, the controller uses the severe weather polygon and NEXRAD displays on the GPD to provide assistance.

When an aircraft-to-aircraft or aircraft-to-SUA problem is displayed on the Aircraft List, the controller uses the URET Trial Planning capabilities to resolve the predicted problem. If a Trial Plan has a severe weather problem associated with it, the controller may modify this Plan to avoid the severe weather areas, particularly if the aircraft has previously requested a deviation for weather.

All of the enhancements for severe weather avoidance are designed to assist controllers with current responsibilities by providing more information, and are not intended to shift the responsibility for severe weather avoidance to controllers.

URET/CPDLC Integration

Over the past several years, the FAA has collaborated with industry stakeholders to design and build CPDLC services to supplement the current voice communication system. The first step in CPDLC, termed Build 1, is in daily use at the Miami ARTCC. It provides four information services: Transfer of Communication, Initial Contact, Altimeter Settings, and Menu Text. The FAA plans to deliver an expansion of service types to include support for the assignment of speeds, headings, altitudes and route clearances in an enhancement to the FAA's En Route Automation Modernization (eRAM) program. The research described in this paper addresses the integration of these expanded services with URET. Concepts for the integration of additional capabilities such as the downlink of pilot requests are also discussed.

URET Display Enhancements

As with the URET enhancements to support TFM MIT FIs and severe weather avoidance, the enhancements to support CPDLC were designed to integrate closely with the existing URET displays. As illustrated in Figure 5, the Aircraft List remains the primary URET display, with a column of indicators added to denote if an aircraft has a CPDLC Session Established within the Center (open triangle), an aircraft is eligible for CPDLC data communications from the sector (closed triangle), or a message transaction is in process (up arrow). Selection of this latter indicator provides message content and status on the URET Plans Display.

The URET capability to enter a Trial Plan as a Host flight plan amendment has been extended by adding an "Uplink" button to the URET Trial Planning menus, the GPD, and the Plans Display. This button initiates both the amendment and CPDLC uplink with a single action; the "Host AM" button remains available when the clearance is to be delivered via voice. Message status information on a clearance uplinked using URET is presented in the Plans Display. Following a successful clearance uplink, the Uplink indicator is removed from the Aircraft List and the Amendment Plan is removed from the Plans Display after a parameter time.

Further details on these enhancements may be found in [17].

Concept of Use

Figure 5 also presents an overview of the Concept of Use for the URET enhancements to support CPDLC. This concept is very similar to that for the existing URET Trial Planning and Host amendment capabilities, supplemented by an automatic uplink to the aircraft after completion of the Host amendment.

When the sector is staffed by more than one controller, each Sector Team member agrees upon communications responsibility when they begin working a sector. Typically, procedures would stipulate that time-critical messages continue to be communicated using voice communications while strategic clearances such as aircraft reroutes would be data linked using the integrated URET/CPDLC capabilities.

The URET Controller scans the Aircraft List for URET alerts and eligibility to exchange CPDLC messages with the aircraft involved in the alert. In response to a URET alert, the controller uses the URET and PARR capabilities to create a Trial Plan that resolves the predicted conflict. When the sector is staffed by more than one controller, the Sector Team members discuss the potential resolution. Once agreed upon, the URET controller selects the Trial Plan and uses the integrated uplink capability ("Uplink" button). The Trial Plan is sent to the Host as an Amendment Message. After the Host accepts and converts the Amendment Message, the clearance is automatically uplinked to the pilot in a CPDLC message and an indication that the message has been uplinked is provided on the integrated CHI. After a response is received from the pilot, the CPDLC message status is updated to reflect the status change.

Additional details on this Concept of Use are given in [27].

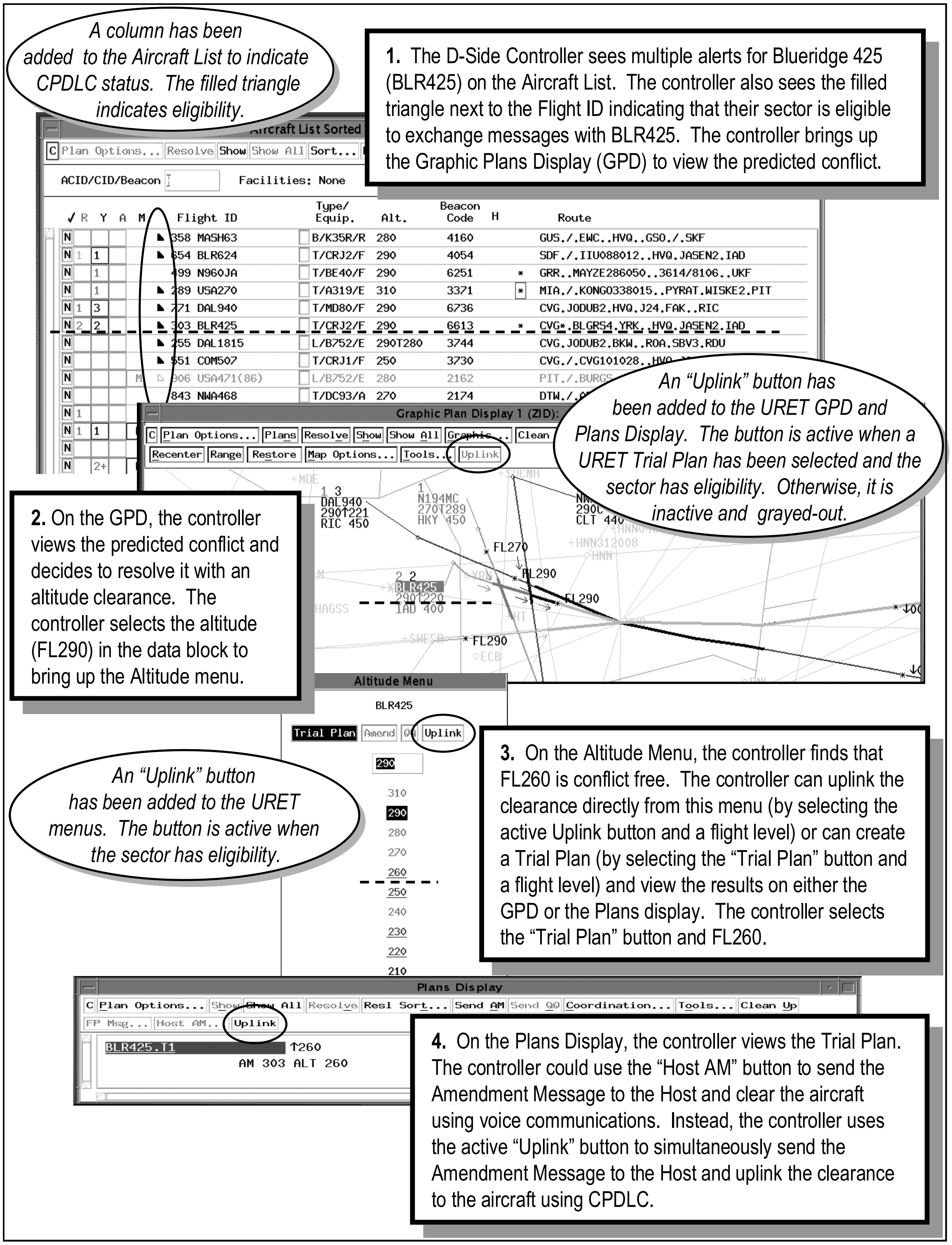

Figure 5. URET/CPDLC CHI and Concept of Use

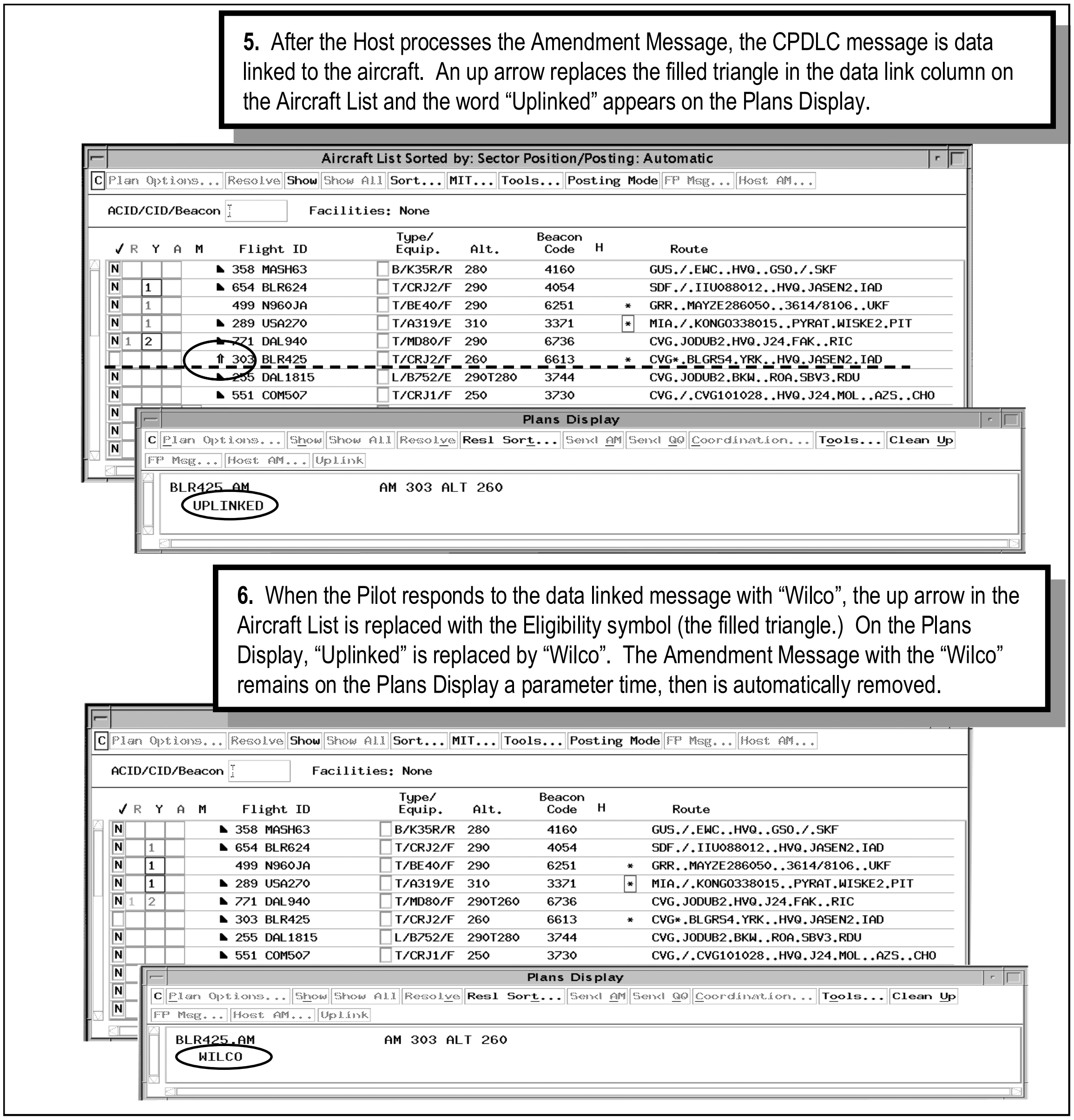

Figure 5. URET/CPDLC CHI and Concept of Use (concluded)

Concepts for Additional Capabilities

Additional concepts being examined for URET/CPDLC integration include the following.

Assistance with Procedural Clearances. To support accurate trajectory modeling, altitude and speed restrictions are adapted in URET and applied when generating the trajectory model. If not part of a published arrival or departure route definition; such restrictions must currently be verbally cleared to the aircraft. Similarly, URET models the Host preferential routes which are not part of the original flight plan; such route modifications must also be verbally cleared to the aircraft. In this concept, URET reduces controller workload by automatically formatting and displaying these procedural clearances to the controller, so that they can be uplinked with a single action using the integrated CHI.

Downlink of Pilot Requests. In this concept, the CPDLC downlink request for a flight plan modification (e.g., a new assigned altitude) triggers the creation of a Trial Plan for the proposed amendment. This Trial Plan is then automatically probed for conflicts and the results displayed to the controller. As with the clearance delivery process described above, this request may be approved with a single action using the integrated CHI. If problems are found with the request, the controller can use the URET and PARR capabilities to examine alternative actions, or submit the request for periodic rechecking to determine when it becomes problem free [9, 29].

Downlink of User Preferences. When an aircraft must be maneuvered for separation or flow problems, a number of problem-free maneuvers in different dimensions and directions are often possible. However, these maneuvers may not be equally preferable to the airspace user due to differences in time, fuel, and preferred altitude impact. In this concept, these preferences are initially filed in an enhanced flight plan, with updates (e.g., as Pilot Requests) from the aircraft via CPDLC downlink as the flight proceeds. The controller can then view these preferences in planning maneuvers for an aircraft, and PARR incorporates them when constructing resolutions. Additionally, the controller is notified when a user preference can be granted due to the lifting of a previous restriction [9, 29].

Downlink of Aircraft Intent. In URET, the trajectory altitude and speed profiles must be estimated based on observed and adapted aircraft performance characteristics, and the flight plan speed and altitude. In this concept, these profile estimates are improved through the downlink of intended altitude and speed profiles, e.g., planned Mach/IAS climb and descent speeds, top of climb and descent points, and cruise speed. With this data, trajectory and conflict probe accuracy can be improved, particularly in the vertical dimension for transitioning aircraft. This, in turn, will support improved airspace utilization.

Evaluation Overview

Operational evaluations were held April and July 2002 in the CAASD laboratories with (respectively) 5 and 6 former Certified Professional Controllers. Both evaluations were held over the course of three days, and also included evaluations of URET enhancements to support the electronic distribution of TFM reroutes to the sector [30].

For each capability, the evaluation included the following:

- An introductory training briefing including a description of the functionality, CHI, Concept of Use and evaluation focus areas.
- A set of facilitated hands-on exercises to demonstrate the functionality and CHI.
- Hands-on practice and evaluation at individual workstations.
- A group discussion using a questionnaire as a guide.

The evaluation of each capability focused on the following:

- Operational acceptability and usefulness of the Concept of Use.
- Operational acceptability of the functionality and CHI to support the Concept of Use.
- Potential benefits for controllers, airspace users and overall traffic flow.

The evaluation scenario used recorded ZID data from Sept. 7, 2001, with selected MIT restrictions obtained from ZID Traffic Management Logs. The evaluation platform was the CAASD En Route Research Prototype; which contains the full set of URET prototype and initial PARR capabilities as described in [11 - 13]. Details of the evaluation components and questionnaires are available in [30].

Evaluation Results

MIT FI Implementation

The evaluation results indicated that the URET enhancements to support MIT FIs are operationally acceptable and useful, and could provide benefits for controllers, airspace users and overall traffic flow. Potential controller benefits that were cited included the following:

- Reduced workload for identifying aircraft that are subject to MIT FIs, due to the MIT Indicators on the Aircraft List. MIT Indicators are particularly helpful in situations where multiple FIs affect one sector.
- Easier identification if action is needed to implement or maintain spacing, due to spacing and sequence information on the MIT List and GPD, as well as the graphical display of MIT streams on the GPD.
- Easier determination of the manner and magnitude of a required action for spacing, due to spacing and sequence information on the MIT List and GPD, as well as the graphical display of MIT streams.
- Improved coordination with other sectors to implement spacing, due to the common URET displays with MIT information across sectors.

- The ability to determine when spacing is insufficient, even when aircraft are not in a single stream.

Participants suggested that URET enhancements to support MIT FIs would offer the following benefits for airspace users and overall traffic flow:

- Reduced errors in identifying which aircraft are subject to the MIT FI, due to the MIT Indicators on the Aircraft List.
- Less severe, more strategic maneuvers for spacing, that will also support increased capacity in sectors where streams must be merged and spaced.
- A reduction in "passback" MIT constraints, to the extent that extensive coordination between sectors is not required. For example, 40 MIT "passback" constraints on each of two merging streams (designed to support a 20 MIT constraint after merging) might be unnecessary due to the added capability to see all aircraft involved in the merging streams.
- The predicted MIT calculations accurately take into account different aircraft speeds; this reduces the need to place aircraft in-trail, thus facilitating direct routing and the elimination of inefficient speed-matching of aircraft.

The evaluation participants indicated that the MIT Indicators (including sequence numbers) are displayed in an effective way. They also indicated that the stability level of the MIT spacing and sequence values is operationally acceptable.

The evaluation participants suggested several modifications to the Concept of Use and functional capabilities. Specifically, participants pointed out that according to the concept, controllers scan the predicted spacing values for insufficient spacing whenever an MIT Indicator is displayed. However, there is no stimulus prompting controllers to re-examine the predicted spacing values if they change. Consequently, participants indicated that automatic notification of insufficient spacing is necessary, and would provide controllers with an indication of when the predicted spacing values should be examined. Automatic notification would also eliminate unnecessary monitoring of MIT displays in cases where spacing is sufficient.

The addition of Trial Planning capabilities for MIT spacing was also discussed. Generally the participants agreed that providing spacing results in Trial Plans would be a useful enhancement, as otherwise controllers are not notified when a spacing maneuver will result in a sequence change. This is an important issue as sequence swapping can result in significant predicted MIT changes for other aircraft in the stream. The provision of spacing results in Trial Plans will be examined at the next evaluation.

Severe Weather Avoidance

Participants indicated that the URET enhancements to support severe weather avoidance are operationally acceptable and could provide benefits for controllers, airspace users and overall traffic flow. Specifically, they indicated that it is operationally acceptable and useful to provide severe weather notification for Current Plans and Trial Plans. Generally, the participants agreed that the severe weather look-ahead times implemented for Current and Trial Plans (20 and 40 minutes, respectively) are appropriate.

Participants agreed that providing notification for penetration of severe weather that is classified as Level 3 and above is appropriate, and providing polygons at 10 minute increments is useful for depicting polygon speed and direction. Participants said that the severe weather polygon and NEXRAD displays are useful and do not provide redundant information. Some participants suggested severe weather notification should not share space with SUA alerts on the Aircraft List. This issue will be revisited at the next evaluation.

The participants cited the following potential controller benefits from the URET enhancements for severe weather avoidance:

- Current Plan severe weather notification leads to enhanced situational awareness allowing controllers to anticipate pilot requests for weather-related reroutes: Anticipation of pilot requests allows controllers more time to formulate solutions for those requests.
- Severe weather displays assist with creating routes that do not penetrate severe weather, decreasing subsequent pilot requests for reroutes due to weather.
- In some cases (e.g., when leading aircraft have requested reroutes for weather), severe weather notification on the Aircraft List allows controllers to deal with severe weather situations in a more timely way rather than waiting until pilot requests are received before taking action.

- Less negotiation with pilots to navigate aircraft through severe weather areas.
- The display of NEXRAD data to the RA Controller allows them to collaborate more effectively with the R Controller, as the same data information is available to both.

Participants suggested that URET enhancements for severe weather avoidance would offer the following benefits for airspace users and overall traffic flow:

- Severe weather displays in conjunction with Graphic Trial Planning allow controllers to generate more effective and efficient routes for navigating around severe weather.
- Severe weather notification in Trial Plans warns controllers when route changes send aircraft into severe weather, decreasing the likelihood that aircraft will receive routes that encounter severe weather.
- Severe weather displays used in conjunction with Graphic Trial Planning allow controllers to enter vector maneuvers into the Host, improving the quality of URET trajectories and increasing the likelihood that aircraft will receive the most efficient routes possible in severe weather situations.
- Severe weather displays allow controllers to provide useful weather information when requested by pilots.
- A more system-wide perspective of severe weather situations is available to the controller leading to more strategic decision making.

The participants noted that the above benefits were based on the assumption that the accuracy of the severe weather detection and prediction was operationally acceptable, with appropriate buffers applied to account for predictive uncertainty. Measurements of this accuracy using metrics similar to those developed for the URET aircraft-to-aircraft conflict probe [31] and buffer determination are ongoing.

URET/CPDLC Integration

Participants indicated that the URET enhancements to support CPDLC are operationally acceptable and could provide benefits for controllers, airspace users and overall traffic flow. Specific controller benefits that were cited included the following:

- Reduced workload for the Sector Team by allowing routine clearances to be issued through URET (i.e., less switching back and forth between separate CPDLC and URET displays).
- Reduced controller workload for issuing TFM reroutes that are displayed as Trial Plans.
- Reduced controller workload for issuing Trial Plans (e.g., when Graphic Trial Plans are created to avoid severe weather areas) and PARR resolutions.
- Flexible task sharing by allowing RA Controllers to issue clearances.

Participants suggested that URET/CPDLC integration would offer the following benefits for airspace users and overall traffic flow:

- Improved accuracy of communications.
- Increased use of more efficient route clearances utilizing an aircraft's RNAV capabilities; such clearances might be created using PARR or Graphic Trial Planning, and would not constrain the aircraft to fly over named fixes for ease of voice clearance.
- Increased use of efficient, strategic lateral maneuvers that do not disturb the cruise altitude of the aircraft, as RA Controllers can easily issue such clearances using the integrated URET/CPDLC capabilities.

The evaluation team also had specific comments on the design, including the following:

- Message status information should be added to the data block on the GPD to support situational awareness.
- A response of "Standby" should be posted in a way that alerts the controller to this message status, as the controller may need to react to the possibility that the response could be delayed for some minutes.
- Since Host flight plan amendments are processed and accepted before the clearance is data linked to the aircraft, it may be necessary to change the flight plan back to its previous state (using a new Host amendment) in the event of an "Unable" response. Existing URET support for revision back to the previous route should be extended to support revision back to the previous assigned altitude.

Conclusions

The April 2002 and July 2002 evaluation results were highly favorable. Specifically, participants indicated that the Concept of Use, functionality and CHI for the URET enhancements for to support MIT FIs, severe weather avoidance and CPDLC are operationally acceptable and useful. Future evaluations will refine the Concept of Use for each capability, examine intra- and inter-sector coordination issues, and address enhancements such as problem detection for MIT FI constraints, improved Trial Planning support, and downlink of pilot requests.

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Keywords

URET, PARR, CPDLC, Data Link, En Route, Conflict Probe, Problem Resolution, Decision Support, Traffic Flow Management, Severe Weather

Biography

Daniel Kirk received his Ph.D. degree from the University of Michigan in 1985. He joined The MITRE Corporation in 1988, where his work has included the development of problem resolution algorithms and requirements for the Automated En Route ATC (AERA) 2 project, and various aspects of the User Request Evaluation Tool (URET) project. Dr. Kirk is currently a Principal Engineer and task lead for the development of the PARR problem resolution algorithms and their assessment.

Richard Bolczak received his masters degree from Northeastern University and his bachelors degree in Engineering from General Motors Institute. He joined The MITRE Corporation in 1981. He has over twenty years of work experience in transportation engineering and communications. He is currently a Lead Engineer responsible for the development and evaluation of an integrated URET/CPDLC capability at CAASD.