Preliminary Observations About Providing Problem Resolution Advisories to Air Traffic Controllers

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Abstract

This paper reports on research being conducted by The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) into providing a set of problem resolution advisories to air traffic controllers. The goal of this research is to assist the controller in the generation of strategic resolution maneuvers in complex, heavy traffic situations, and consequently facilitate an efficient, strategic mode of Air Traffic Control (ATC) in these situations. These capabilities are currently being developed as an extension to the User Request Evaluation Tool (URET) prototype, and build on the URET capabilities to support a strategic mode of ATC operation. The primary focus of this research is termed Problem Analysis, Resolution and Ranking (PARR), which provides a ranked set of resolution maneuvers for aircraft-to-aircraft, aircraft-to-airspace, and metering problems. Resolutions are generated in a range of dimensions and directions, and support is provided for the rapid evaluation and implementation of the results. Additional efforts involve the generation of automatically probed sets of altitude, direct-to-downstream fix, and speed maneuvers to enhance the existing URET menu displays. A graphical display is also being developed to assist the controller in the evaluation of the altitude probe results. This paper describes these resolution capabilities, presents data from real world scenarios, and discusses the results of initial laboratory analyses.

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1 Introduction

This paper reports on research into providing a set of problem resolution advisories to air traffic controllers, to assist in the generation of strategic resolution maneuvers in complex, heavy traffic situations. These capabilities are currently being developed as an extension to the User Request Evaluation Tool (URET) prototype, and build on the URET capabilities to support a strategic mode of ATC operation. This continued evolution towards a strategic mode of operations is expected to yield significant system benefits as outlined in Section 2.

1.1 Background

To meet user demands and to accommodate growth in traffic, the FAA and National Airspace System (NAS) users have embarked on an initiative known as Free Flight. Free Flight improves flexibility of flight, while maintaining or increasing NAS safety. To implement Free Flight, the FAA has been developing concepts, defining architectures, and developing the decision support capabilities needed to support the concepts.

A first step of this Free Flight effort came in 1994, when the FAA and the aviation community set out to redefine the vision for the evolution of the NAS. In January 1995, the "Report of the RTCA Board of Directors' Select Committee on Free Flight" was published as a result of this collaboration. A major thrust of this new joint vision was to increase user flexibility and move away from use of a rigid route structure, without compromise of safety. This report also included a number of recommendations for making progress toward this goal, one of them being the immediate implementation of a conflict probe capability for use by controllers.

Following the above recommendation, the FAA and CAASD installed the first version of the URET prototype in the Indianapolis Air Route Traffic Control Center (ARTCC) in January 1996. Following the successful deployment to Indianapolis, the URET prototype was installed in the adjoining Memphis ARTCC. The use of URET in these two centers has increased over time, so that now URET is used in daily operations at nearly all sectors 22 hours per day, 7 days per week. Additional information on the utilization of URET is given in [1].

Following the initial Free Flight recommendations, a specific concept for the next step in Free Flight has been formulated for the 2005 time frame [2-4]. This concept includes the provision of enhanced problem resolution support tools to assist the en route sector controller team in handling the more complex traffic patterns that can result from a less structured environment.

1.2 URET Overview

URET processes real-time flight plan and track data from the 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 instrument flight rules (IFR) flights. URET also adapts itself 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. Each trajectory is continuously compared against incoming aircraft track data, and is recalculated if the aircraft is determined to be outside of lateral, longitudinal, and/or vertical conformance bounds that are calculated as part of the trajectory generation process.

URET uses the predicted trajectories and a probability distribution analysis to detect potential aircraft problems up to twenty minutes into the future, and to alert the appropriate sector. Alerts are color coded as to severity and type, with airspace alerts coded blue, and aircraft alerts coded yellow or red. Along with a probability distribution analysis, a yellow alert occurs if the conformance bounds between two aircraft are predicted to lose ATC separation. A red alert indicates a higher severity, and is presented if a yellow alert condition exists, and the predicted aircraft-to-aircraft horizontal separation (without conformance bounds) also falls below the ATC separation minimum.

Trajectory generation and conflict detection are also the basis for the system'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. This "what if" checking provides better capabilities for handling pilot requests.

URET has a controller interface that includes both textual and graphic information. The text-based Plans Display and Aircraft List manage the presentation of flight data (call-sign, route, altitude, etc.), Trial Plans, and conflict information for the sector. Clearance language is also generated for Trial Plans. The Graphic Plan Display (cf. Figure 1) provides a graphical capability to view aircraft routes and altitudes, predicted conflicts, and results of Trial Plan resolutions, which are color coded to reflect the conflict status of the plan.

Additional overview material on URET may be found in [1], [5], and [6].

1.2.1 Observations Regarding URET Trial Planning

Observations regarding the use of the URET Trial Planning capabilities are as follows:

<u>During busy operations, the sector team often becomes more focused on tactical operations</u> – Less time is available for strategic ATC, and finding conflict-free Trial Plans becomes more difficult due to increased density of aircraft. A resolution capability that can immediately provide a conflict-free Trial Plan will clearly help to facilitate a strategic mode of operation during busy operations.

<u>The need for automated coordination of proposed control actions</u> – If controllers are to deal with conflicts more strategically, they will have to coordinate more often with other sectors. URET has a sector-to-sector coordination capability that has undergone evaluation and refinement, and it is expected to be placed in daily use in the second half of 2000. However, the extent to which this capability facilitates strategic operations may be limited during

busy periods, unless the Trial Plans being coordinated are conflict-free: any Trial Plans offered for coordination that are not conflict-free may require additional analysis by the receiving controller, and thus more difficult to approve during busy conditions. A resolution function will help support the more efficient application of an automated coordination function during busy periods.

Preference for minimal keystroke and trackball actions – An analysis of the controller keystroke and trackball actions showed that controllers had a strong preference for creating those Trial Plans that required the fewest keyboard/trackball actions. Use of a resolution capability will allow the controller to generate more complex and effective Trial Plans, while still requiring only minimal keyboard/trackball actions.

1.3 Problem Resolution Enhancements

The primary URET problem resolution enhancement described in this paper is the Problem Analysis, Resolution and Ranking (PARR) function. PARR provides a set of problem resolution advisories to air traffic controllers in the form of URET Trial Plans, to assist in the generation of strategic problem resolutions in complex traffic situations. PARR was initially developed with extensive controller laboratory evaluations in the late 1980s and early 1990s as part of the AERA (Automated En Route ATC) Automated Problem Resolution (APR) program [7-9]. It has been further refined since incorporation into a laboratory version of URET in 1998.

Additional efforts involve the generation of automatically probed sets of altitude, direct-to-downstream fix, and speed maneuvers, so that the controller can rapidly assess the conflict status of each of these maneuvers without having to manually check each element of the set for conflicts. The results of the probed set of altitude maneuvers are also being used in the development of a vertical profile display; this display is designed to enhance situational awareness, and to assist in the evaluation of PARR and other vertical maneuver options.

2 Anticipated Benefits

It is expected that the proposed resolution enhancements will make significant contributions to the attainment of the key ATC system goals: safe, orderly, expeditious air traffic flow, and increased controller productivity. These contributions are summarized below:

Enhanced safety – The expected increase in the use of airspace creates the potential for a higher number of conflict situations, and the relaxation of ATC restrictions will lead to more complex traffic patterns. The resolution enhancements will increase safety by providing tools with which controllers can obtain an improved, strategic situational understanding, and more easily implement strategic, problem-free resolutions. Strategic, problem-free resolutions will improve safety because of increased time for decision-making, coordination, and confirmation that the resolution maneuver is actually being flown.

Controller workload reduction – Controller workload will be reduced since the automation will provide assistance in the conflict resolution process, by suggesting specific resolutions, by indicating successful and failed resolution dimensions/directions, and by providing enhanced visualization tools for situational understanding. Finally, the resolution enhancements will reduce downstream controller workload, as strategic, conflict-free resolutions will be less likely to cause downstream conflicts than the more tactical resolutions employed today.

Increased user benefits – The reduction in controller workload described above will enable the accommodation of greater numbers of aircraft operating in less structured airspace. This workload reduction will also allow more time for controllers to address requests from the airspace users. The rapid assessment of these requests will be facilitated by the tools for enhanced situational understanding.

Improved probe accuracy due to more complete resolution entry to the automation – In today's system, some resolution maneuvers are not entered into the automation, due to difficulty in estimating future maneuver transition points (e.g., resumption of a step climb maneuver), and the entry of these transitions into the automation. The resolution enhancements will facilitate the automated entry of this information, thus improving the probe's model of aircraft intent. The improved intent modeling will, in turn, lead to a direct improvement in probe accuracy.

Resolution efficiency – Strategic resolutions are more efficient in that relatively small perturbations to the aircraft route can often resolve the conflict if started early enough. Additionally, the automation can compute efficient maneuver parameters using detailed aircraft performance and atmospheric data.

In consideration of the above benefits, a cost/benefits study done for the Advanced Automation System [10] estimated the incremental benefits for a full, automated conflict resolution capability (AERA 2) to be $2.5 billion in constant 1988 dollars ($3.5 billion in 2000 dollars), for a 20-year life cycle span.

3 Problem Analysis, Resolution and Ranking

PARR provides a set of ranked problem resolution advisories to the controller in the form of URET Trial Plans. Current development of PARR is focused on the resolution of aircraft-to-aircraft and aircraft-to-airspace problems as described in Sections 3.1 – 3.4 below. The extension of PARR to develop conflict-free resolutions to metering problems is described in Section 3.5. Plans to enhance PARR for additional problem types (e.g., for hazardous weather avoidance) are outlined in Section 6.

3.1 Overview

For the resolution of aircraft-to-aircraft and aircraft-to-airspace problems, PARR may be initiated either for an aircraft with one or more of these problems, or for a specific aircraft-to-aircraft problem. If initiated for an aircraft, only resolutions which maneuver that aircraft will be generated. If initiated for a problem, a set of resolutions for each of the two involved aircraft will be generated (any given resolution will maneuver only one aircraft).

For a given aircraft to be maneuvered, PARR will search for conflict-free trajectories to resolve all problems with that aircraft (within URET's twenty-minute lookahead horizon) in an ATC acceptable manner, without introducing new problems. The search process examines each of the following five dimensions/directions, thus yielding up to five resolutions for that aircraft: (a) above the conflict, (b) below the conflict, (c) left of route, (d) right of route, and (e) an increase or decrease in speed. If PARR is initiated for a specified aircraft-to-aircraft problem, then up to five resolutions for each of the two involved aircraft may be generated.

Each PARR resolution is a complete Trial Plan, i.e., it returns the maneuvered aircraft to its original route, destination, or transition. All maneuvers are within the operational performance envelope of the maneuvered aircraft (typically less than the achievable performance limits of the aircraft). The operational performance envelope includes parameters for the maximum turn angles permitted in the Route Change maneuvers. All turn angles and speed changes are built and displayed in appropriate magnitude increments (e.g., five-degree increments for turns and ten-knot increments for speeds).

Typically, one of the PARR resolutions would be selected and implemented by the controller. Alternatively, the controller may use the resolution set to estimate which maneuver dimensions/directions (e.g., a left turn vs. a climb) are good or are not good candidates for further inspection. Finally, the number of successful resolutions available may be used by the controller as an ongoing indicator of when maneuver options are becoming limited, and positive action should be taken to resolve the conflict.

PARR will generate vertical maneuvers that go above and below the original conflict. For above-maneuver shapes – increase altitude, extend climb, early climb, early extend climb, and step late descent – the aircraft passes above the original conflict region. For below-maneuver shapes – decrease altitude, step early descent, and step climb – the aircraft passes below the original conflict region.

PARR will generate lateral maneuvers that initially deviate left and right of the route. The maneuver end point will always be a Very High Frequency Omni-directional Range (VOR) navaid or the arrival airport. The maneuver may have one maneuver leg (e.g., a direct to VOR maneuver) if such a maneuver is possible and resolves all of the problems. More typically, the maneuver will have two maneuver legs, with initial turn angle being the minimum necessary to resolve the conflict.

PARR will generate longitudinal resolutions that speed up or slow down the aircraft, depending on which change has the smallest deviation from the currently planned speed. The time to return to this speed is also given.

In the event that no resolutions are generated, the controller is notified that no resolutions are available. This can occur if there is no conflict that starts greater than a parameter time in the future (currently 40 seconds), or PARR has determined that any resolution would exceed the operational performance envelope of the aircraft.

After the set of resolutions has been generated, they are categorized according to the color code of any alerts they may have, in the following order from most to least preferred:

> No alerts > blue (airspace) alert(s) only > yellow (but no red) alert(s) > red alert(s)

Within a given alert status category, the resolution ranking is determined by a numerically weighted combination of factors. The following are the main factors that influence ranking:

1. The start time of any resolution alerts.
2. The maneuver dimension and direction.
3. The maneuvering status of the aircraft.
4. The sector of control.
5. The Time of Arrival (TOA) impact.
6. The number of flight levels changed.
7. The time at an interim altitude.

8. The magnitude and duration of a speed change.

Figure 1 illustrates a PARR resolution for COM615, a climbing aircraft involved in a complex set of problems: two red conflicts (with EWW381 MES3509) and one yellow conflict (with SWA436). In this case, PARR generated three conflict-free resolutions: a direct to the OBK VOR (highest ranked, and illustrated in Figure 1), a left turn vector before proceeding to the MSN VOR, and a step-climb maneuver. The Resolution List in this figure lists all generated resolutions, and is described below.

3.2 Computer Human Interface (CHI)

Because PARR is an enhancement to the URET capabilities, the PARR CHI is being designed to be compatible and consistent with the URET CHI. The objective of the PARR CHI design is to provide the controller with easy access to the PARR resolutions while integrating PARR seamlessly into the existing URET system. The current PARR CHI described below is undergoing modification to improve this integration.

When initiating PARR for a specified aircraft, the Aircraft ID is first selected from the URET Aircraft List, Graphic Plan Display, or Plans Display. When initiating PARR for a specified problem, that problem is first selected either by selecting the Alert Indicator in the URET Aircraft List or Graphic Plan Display, or from the problem information presented in the Plans Display. After selection of the aircraft, PARR is initiated by selection of a "Resolve" button that has been added to the Aircraft List, Graphic Plan Display, and Plans Display.

A summary of the PARR results is presented in the Resolution List This display was designed to provide a compact, readily interpretable overview of the PARR resolutions. In order to improve the integration with the URET CHI, ongoing work is aimed at incorporating features of the Resolution List within the URET Plans Display, and presentation of the PARR results in this display.

Details of the current Resolution List are presented in Figure 2. The icon buttons along the top of the Resolution List window provide access to common URET and PARR specific functions with a minimum of trackball movement and button action. This allows the controller quick access to perform tasks such as sending PARR amendments to the FAA Host Computer System, coordinating resolutions with other sectors, opening, closing, and recentering the Graphic Plan Display, viewing the Vertical Profile of the altitude resolutions, regenerating the set of resolutions, and exiting the Resolution List.

Below the icon buttons, information for the maneuvered aircraft and the set of resolutions for that aircraft are presented. Each resolution entry is color coded according to alert status, and contains the resolution rank number, the clearance in an abbreviated format, the URET Trial Plan ID number (e.g., ".T2"), and a list of any conflicts that resolution may have. The controller may select a resolution entry using the trackball or may step up and down the resolutions using the keyboard or the up/down arrow icon.

The clearance language, which does not assume any particular aircraft equipage, is in terms of heading changes, VORs, VOR radials, altitudes and speeds. An option also exists to generate point-to-point clearance language, which may contain latitude/longitude points and VOR fix/radial/distances, and assumes an RNAV equipped aircraft. The clearance language on the Resolution List is abbreviated as described in Table 1.

Standard Form	Abbreviated Form
turn left	←
turn right	→
deg	^{0}
fly present heading	fph
at HHMMZ(ΔMM) . . .	[ΔMM. . .]

Table 1. Abbreviated Clearance Language

An example of the standard clearance language is:

fly present heading, at 1230Z(6) turn left 30 deg SGF

In abbreviated form this becomes:

fph [6: ← 30^0 SGF]

Preliminary observations by controllers have found the abbreviated clearance language useful in conveying the intent of each resolution in the set in a concise manner, and allowing the controller to quickly find the resolution in a desired dimension and direction.

The Highest Ranked Resolution is automatically selected and posted to the Plans Display. If the Graphic Plan Display is open, the selected resolution is also displayed as illustrated in Figure 1. Other resolutions may be selected as described above, with exactly one resolution being selected at any given time. Once the resolution is selected, it may be coordinated or implemented the same as any other URET Trial Plan.

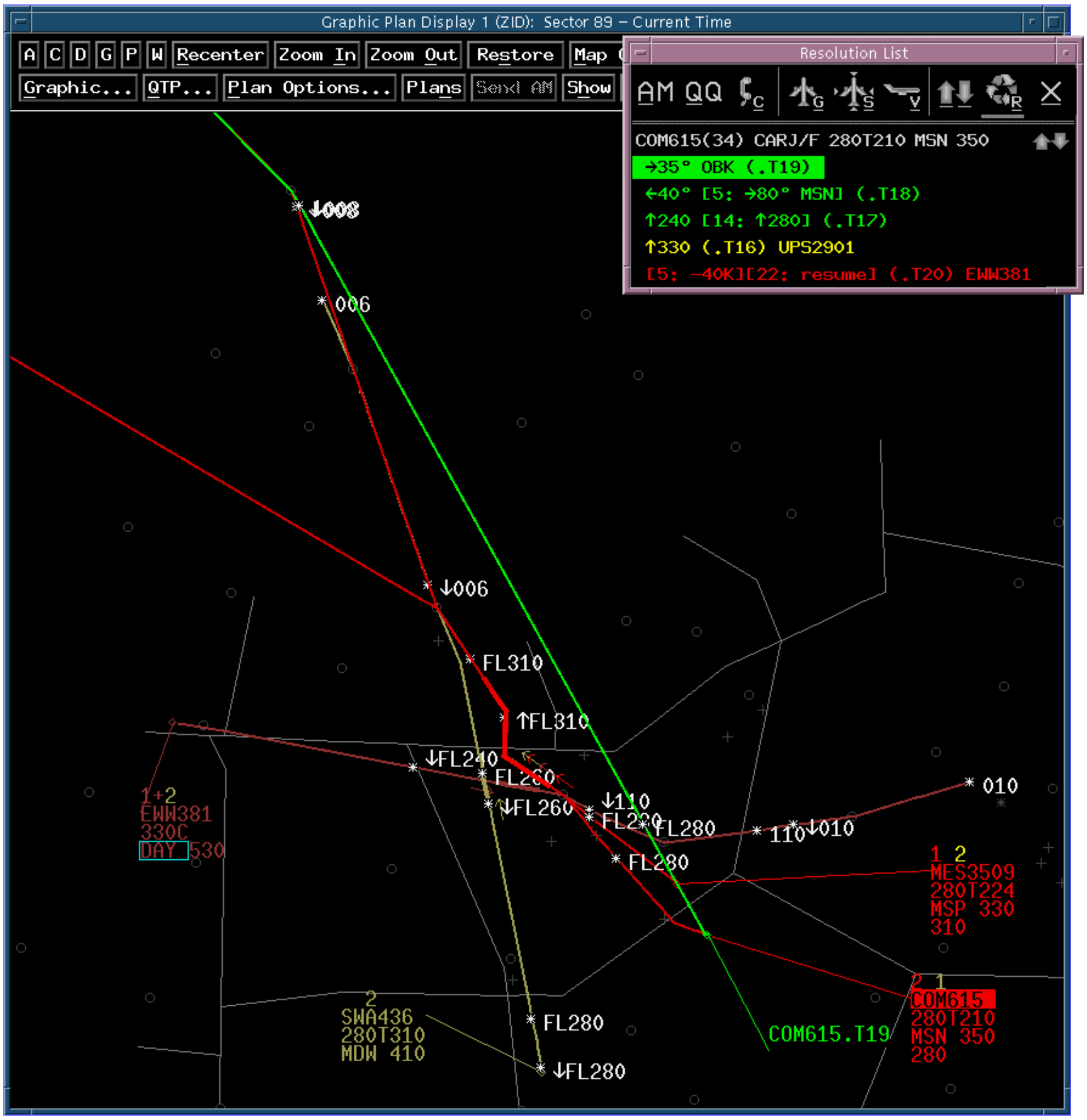

Figure 1. Graphic Display of PARR Resolutions

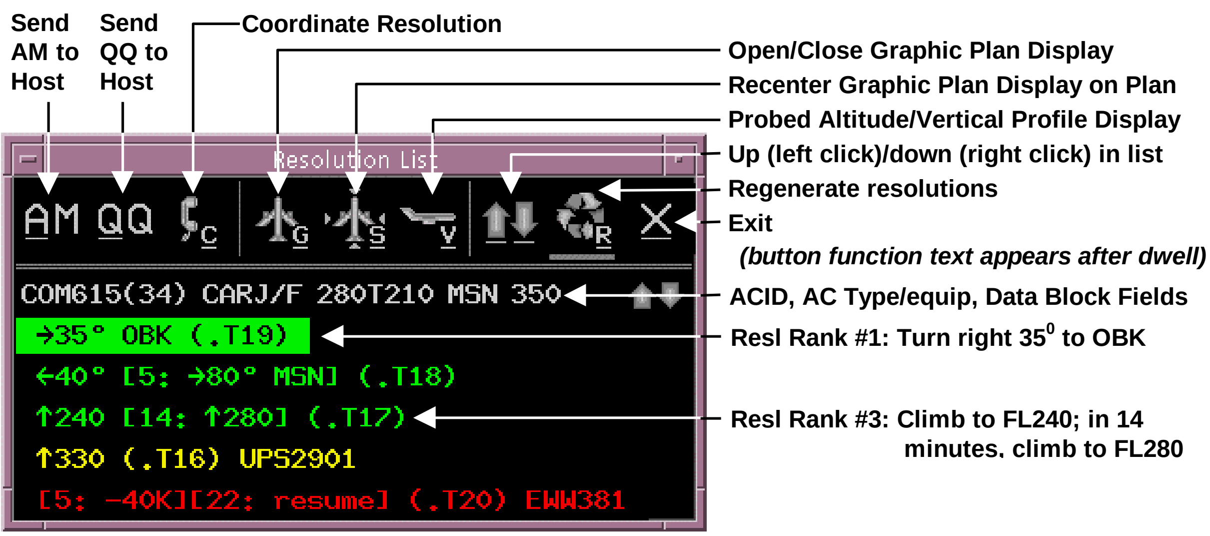

Figure 2. PARR Resolution List

3.3 Resolution Generation Statistics

To help test PARR and to quantify its results, an automated test program was created. A recorded scenario of 3.75 hours of real-world data from Indianapolis Center (date: 04-17-98) was run in URET. The test program scanned the URET database at predetermined intervals looking for conflicts that were deemed non-tactical (> 3 min start time). If a non-tactical conflict was found, PARR was executed on the conflict and the results of the PARR execution (number of resolutions with red, yellow, blue, and green color code) were collected and tabulated; in this run, PARR was executed 715 times.

The results from this analysis, shown in Table 2, must be regarded as strictly preliminary. They suggest that in over 95% of non-tactical conflict situations PARR is able to construct at least one conflict-free resolution. In those cases where there was no conflict-free resolution, a preliminary examination indicates that a significant factor is the buffer added to model the uncertainty in the resolution maneuver start time. This expanded buffer can conflict with neighboring aircraft traveling in a parallel direction, making any conflict-free resolution (with the added buffers) impossible. In these cases, PARR will maneuver the subject aircraft in a manner to increase the separation with the aircraft it is currently in conflict with.

Indianapolis Center: Non-Tactical Conflicts	
Resolution Color Coding:	
Green (no conflicts)	72%
Blue (≥ airspace conflict only)	5%
Yellow (≥ 1 yellow aircraft conflict; 0 red)	12%
Red (≥ 1 red aircraft conflict)	11%
Total	100%
Resolution Sets with ≥ 1 green resolution	96%

Table 2: Resolution Count Summaries

3.4 Laboratory Observations

Preliminary laboratory observations with several active controllers familiar with URET include the following:

- PARR reduces workload by reducing the need for additional downstream maneuvers.
- PARR reduces the number of aircraft maneuvers, which results in fuel, distance, and time savings.
- PARR is easier than manual Trial Planning.
- PARR showed that, when a relatively severe maneuver was necessary, that less severe maneuvers did not work.
- As a D-side only tool, PARR was suited for mid and long-range problems in the en route domain, but not short-term tactical problems; the solution of these latter problems was considered an R-side function.
- Ranking needs to consider WAFDOF (Wrong Altitude For Direction of Flight), current and future altitude restrictions, and aircraft navigational equipage (for lateral maneuvers); these modifications are currently in progress.

3.5 Extension to Time-Based Metering

PARR has been enhanced to generate conflict-free maneuvers that meet a specified Meter Fix Time (MFT). In this case, PARR is initiated for an aircraft that is being metered, but is not currently predicted to meet the MFT. The procedures for implementing and displaying the metering resolution are similar to those for the aircraft-to-aircraft and aircraft-to-airspace resolution capabilities described above. Initiation of PARR to generate maneuvers that meet the MFT is done via the metering list, as illustrated in Figure 3.

Once initiated for a metering entry, PARR will search for maneuvers that meet the MFT with a trajectory that is free of conflicts with non-metered aircraft, and with metered aircraft that are predicted to meet their metering times. This search could also be readily extended to resolve conflicts with metered aircraft that are not predicted to meet their metering time. However, this is not currently done due to the expectation that these latter aircraft will be subsequently maneuvered to meet their assigned MFT, and that resolutions which attempt to avoid these (to be modified) aircraft trajectories are generally not desirable. The presence of any such predicted conflicts is included as a ranking factor.

If delay to meet a MFT is required, the PARR resolution will first reduce the aircraft's speed to an acceptable minimum (for fuel efficiency, and to reduce the size of vector maneuvers), and then add lateral delay as needed. Where applicable, lateral maneuvers for both left and right of route will be generated. As a future enhancement, options for the use of cruise altitude changes for speed control will also be presented, and hold maneuvers will be generated for delays greater than a parameter amount.

In the event an earlier arrival time is required, the route will be shortened when possible, with a speed increase added as necessary to meet the meter time.

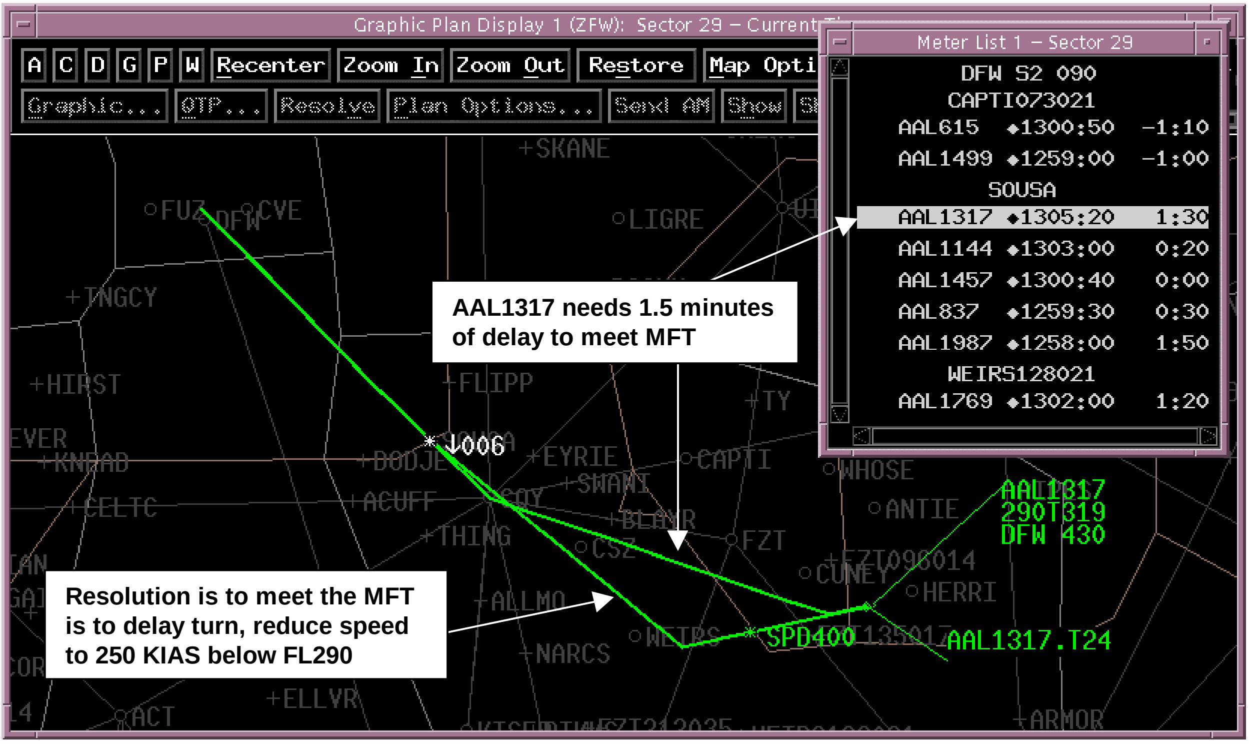

Figure 3. PARR Metering Application

An example of PARR metering resolutions is shown in Figure 3. In this figure, AAL1317 is being metered into the DFW TRACON. PARR creates a conflict-free resolution that causes the aircraft to arrive at the Meter Fix (SOUSA) within a parameter time of the assigned MFT.

4 Conflict-Probed Menu Entries

The URET FFP1 system provides menus to facilitate the entry of new assigned altitude and speeds, and route modifications including direct-to-downstream fix maneuvers. Each menu contains a set of respective altitudes, speeds, and fixes. The selection of one of these entries creates a corresponding Trial Plan that is posted to the Plans Display, and the menu is removed.

A candidate post-FFP1 enhancement is to color-code a range of menu entries (those most frequently used) with the alert status of the corresponding Trial Plan. For example, a menu entry for a maneuver direct to a fix listed in the URET Route Menu (cf. Section 4.2) would be coded red if the Trial Plan to that fix has at least one conflict that is coded as red. To accomplish this, Trial Plans are created and probed after controller initiation to display the menu, and prior to the menu display. Since only the color of the menu entries is affected and no new displays are required, the probed menus appear to be an excellent initial step for an enhanced problem resolution capability for URET.

Details of the probed altitude and route menus are discussed below, as are further enhancements to these menus. Efforts are also underway for a Probed Speed Menu.

4.1 Probed Altitude Menu

Controllers at several FAA en route facilities have requested that entries in an altitude menu be probed for conflicts prior to display, and such a probed altitude menu has been demonstrated in [11]. This capability has been implemented in the URET laboratory prototype, and preliminary controller evaluation indicates that this is indeed an effective way of conveying probe information for new assigned altitudes.

In the URET Altitude Menu, up to 21 altitudes are displayed, as shown in Figure 4. The set of probed altitudes is a subset of this range, and is based on values likely to be chosen by the controller. This range is determined using the aircraft's flight phase, current altitude, and assigned cruise altitude as described below. Trial plans are generated only within the performance limits of the aircraft.

For a Current Plan in the departure phase of flight, Trial Plans are generated for three cruise altitudes above and seven cruise altitudes below the Current Plan Top of Climb altitude. For a Current Plan in the en route phase of flight, Trial Plans are generated for a maximum of five altitudes above and below the Current Plan cruise altitude.

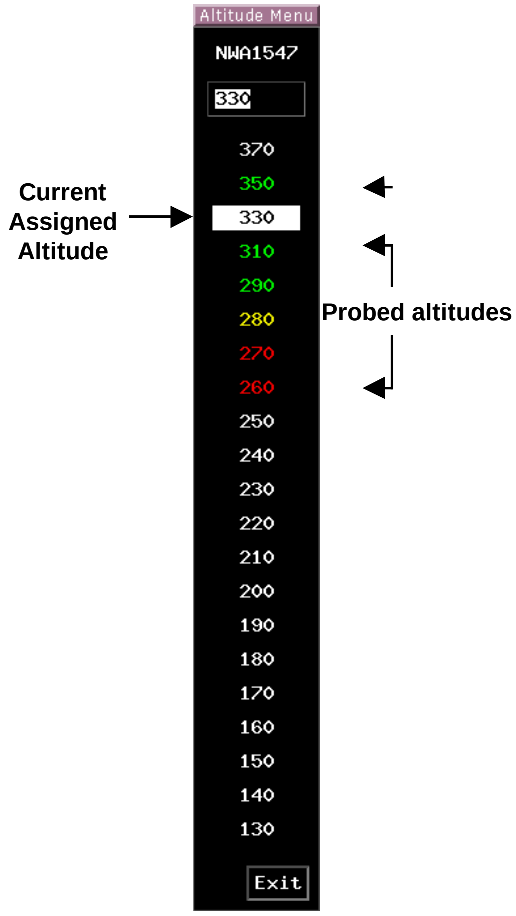

Figure 4. Probed Altitude Menu

For a Current Plan in the arrival phase of flight (defined to be a parameter time prior to the currently predicted top of descent), Trial Plans are generated for up to ten altitudes above the destination airport.

4.2 Probed Route Menu

The Probed Route Menu is illustrated in Figure 5. It consists of URET Route Menu, with color-coded entries for each direct-to-downstream fix entry. As with the probed altitude menu, preliminary discussions with controllers have indicated that this is an effective way of conveying probe information for direct-to-downstream fix maneuvers.

4.3 Probed Menu Enhancements

Research is underway to facilitate the evaluation of the problem results presented in the probed menus, e.g., to determine the number of conflicts for a particular Trial Plan, the conflict start, involved aircraft, and the conflict geometry. This issue is closely related to the evaluation and implementation of the set of resolutions generated by PARR as described in Section 3.2, except that the clearance associated with the each of the probed menu entries may be inferred directly from the menu entry (e.g., to proceed direct to the specified downstream fix). The functions available in the Resolution List, e.g., for

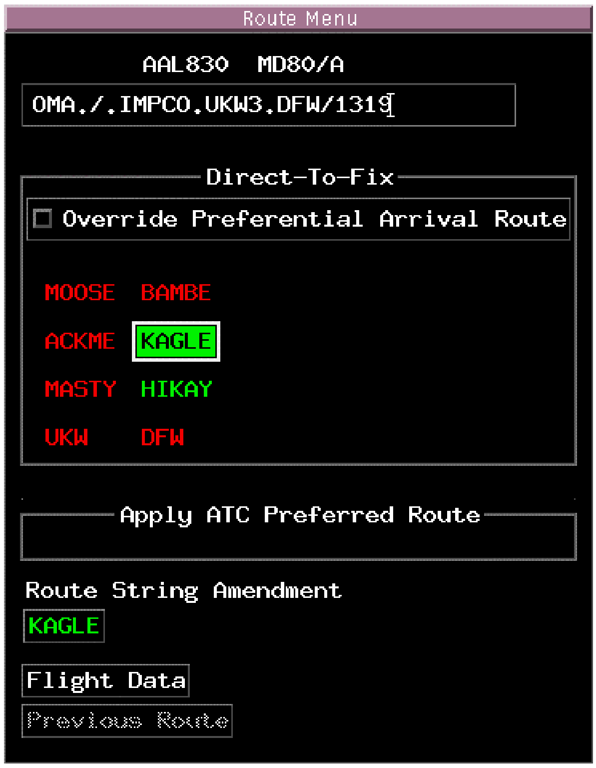

Figure 5. Probed Route Menu

Trial Plan display, implementation, and regeneration are directly applicable to the evaluation of the probed menu entries.

An enhanced version of the Probed Altitude Menu is displayed in the left panel of Figure 6. With this menu, PARR altitude resolutions are also generated if there is at least one problem with the Current Plan, and corresponding button icons are presented for the selection and display of these resolutions. A vertical display of the menu entries may also be obtained as described in Section 5. The remaining button icon functions follow those described in Section 3.2 for the Resolution List, with the up/down icon now stepping up and down in altitude. If a Trial Plan corresponding to a selected altitude has not been created, then a new set of Trial Plans is generated that include this altitude. Since this menu may remain open as the controller proceeds with the evaluation process, all Trial Plans (including the PARR resolutions) are regenerated every parameter number of seconds (currently, every thirty seconds).

5 Vertical Profile Display

A Vertical Profile Display is being developed to provide a visualization aid in the vertical dimension, for the evaluation of different vertical maneuver options. The operational benefits of this display will be assessed as development proceeds.

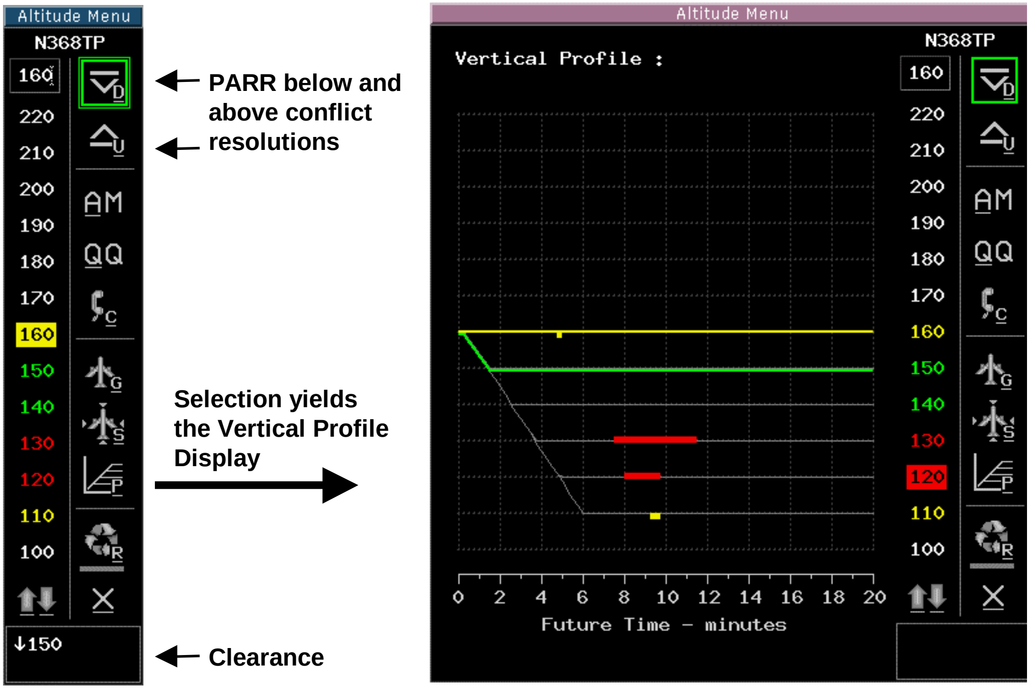

Figure 6. Enhanced Probed Altitude Menu with Vertical Profile Display

Figure 7. Trial Plan and Conflicting Aircraft Vertical Profile Display

As illustrated in Figure 6, the Vertical Profile Display is initiated from the enhanced Probed Altitude Menu. It uses the Trial Plan trajectory and conflict information generated for this menu, and provides a vertical vs. time view of this data and the aircraft's Current Plan. As illustrated in the left panel of Figure 7, the controller may select an altitude or resolution for additional conflict information display. Cursor dwell on the ID of a conflict aircraft causes the vertical trajectory of that aircraft to be displayed, as shown in the right panel of this figure.

When the Current Plan has at least one conflict, vertical PARR resolutions for this Current Plan are also generated and displayed. It is anticipated that this display will assist the controller in understanding the resolution rationale, e.g., why a particular level-off altitude, or time to resume climb, was chosen.

6 Next Steps

Near-term activities are focusing on continuation of laboratory evaluations, with focus on the PARR aircraft-to-aircraft and aircraft-to-airspace resolution capabilities, and the conflict-probe menu entries described in Section 4. The evaluators will be active FAA controllers who have access to URET in daily operational use. A number of issues will be addressed during evaluations, including the following:

1. The Concept of Use for each resolution enhancement, and the plan for transitioning to this Concept of Use from current URET operations in a phased, operationally acceptable manner.
2. The overall acceptability of the integrated URET/PARR CHI, clearance representation, and resolution ranking.
3. The ability to generate operationally acceptable resolutions, particularly in complex and/or heavy traffic.
4. Implementation of resolutions with future maneuver actions.
5. Impact on controller workload.
6. Training requirements.
7. Roles and responsibilities of Sector Team members, and coordination with other sectors.

Additional technical issues that will be addressed are:

1. Algorithmic accuracy of the PARR resolution capability.
2. The definition of metrics and measurement techniques for benefits assessment.

Following completion of the laboratory evaluations, further evaluations will be conducted at FAA field facilities as necessary to fully resolve any remaining operational and technical issues.

In addition, a Research Management Plan is being developed by the FAA and MITRE/CAASD to lay out an evolution of problem resolution capabilities that will build on those described in this paper. Planned steps in this evolution include problem detection and resolution aids for severe weather situations; integration with Traffic Management flow constraints; the use of air/ground data link; and integration into a common en route Sector Team CHI.

7 Conclusion

Research is being conducted to provide a set of problem resolution advisories to air traffic controllers, to assist in the generation of strategic resolution maneuvers in complex traffic situations. These capabilities are currently being developed as an extension to the User Request Evaluation Tool (URET) prototype, and build on the URET capabilities to support a strategic mode of ATC operation. This continued evolution towards strategic operations utilizing problem resolution support is reflected in the Free Flight concept for the 2005 time frame [2-4]. Laboratory analyses to date indicate these capabilities are capable of being implemented as an enhancement to the URET Free Flight Phase 1 system, and can yield significant benefits to both the controller and the airspace user.

8 References

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