Near-Term Terminal Area Automation for Arrival Coordination

Jeffrey Shepley
The MITRE Corporation
McLean, Virginia, United States of America
jshepley@mitre.org

***Abstract*—As the Federal Aviation Administration (FAA) increasingly implements Area Navigation (RNAV) and Required Navigation Performance (RNP) procedures during the transition to the Next Generation Air Transportation System (NextGen), air traffic control (ATC) operational facilities expect to improve the predictability of arrival operations. Sponsored by the FAA, The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) explored methods for retaining this predictability for merging traffic. This paper focuses on a near-term solution which leverages RNAV and RNP procedures to improve predictability of merging arrival operations in the terminal area. CAASD, in coordination with ATC specialists from FAA operational facilities, has developed the concept for a near-term automation capability which calculates the distance of aircraft to a merge point along an RNAV or RNP procedure and conveys this information via an indicator on the terminal controller workstation. The relative position information facilitates early decision making by controllers, which reduces reliance on vectors, thereby maintaining the predictability of the operation. To further develop the concept and define its functional and interface requirements, CAASD developed a research prototype. Using this prototype, CAASD has conducted Human-In-The-Loop (HITL) simulations with ATC specialists. These simulations led to a version of the prototype for which the FAA has requested and CAASD has developed a plan for a field evaluation.**

Keywords- CRDA; Terminal Merging; Relative Position; RPI; Situation Awareness; Spacing; Traffic Management Coordinator; Controller Workload

I. Introduction

With the increasing implementation of terminal Area Navigation (RNAV) and Required Navigation Performance (RNP) arrival procedures, operational benefits include reduced required voice communication, improved situational awareness, reduced flying time and distance, improved predictability, and increased throughput. However, to achieve these benefits, the aircraft must remain on the planned RNAV or RNP routes. This is a change in paradigm from the current practice of regularly vectoring aircraft to achieve the proper sequencing and spacing in the terminal area [1]. Complicating the matter are merge points within the terminal area, which exist because most airports have more arrival flows than runways to accommodate them; therefore traffic streams must converge. Terminal approach controllers must actively manage traffic near these merge points to ensure appropriate spacing of flights. This need is fulfilled today through manual techniques that become very tactical and lead to high workload in busy traffic periods. Even with existing Time-Based Metering (TBM) capabilities and the splitting out of terminal controller positions, controllers often cannot achieve proper spacing of merging traffic using speed control alone and must vector flights off of the RNAV or RNP procedures to produce the desired spacing thereby reducing the key benefits of RNAV and RNP (Figure 1).

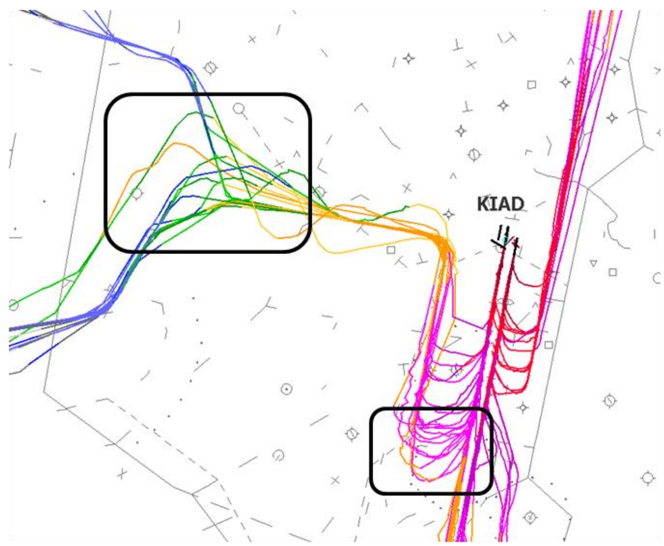

Figure 1. Vectors for Arrival Spacing at Dulles International Airport (RNAV Environment)

II. Background

The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) explored a variety of solutions to the merge problem across a range of implementation time frames [1]. Those that could be achieved in the near-term time frame are characterized by leveraging current aircraft equipage and the ability to utilize existing surveillance data. Use of existing surveillance data is more appropriate for the near term because current aircraft equipage would not be sufficient for flight deck based spacing solutions (e.g., utilizing Automatic Dependent Surveillance-Broadcast [ADS-B]) at most airports.

The following section describes why the terminal area merge coordination activity is difficult for controllers using existing tools.

A. *Terminal Area Merge Coordination*

Terminal area controllers can easily manage the spacing of in-trail aircraft because the distance between the aircraft can be quickly estimated with sufficient precision using a visual scan of the radar returns of the two aircraft. By having a precise measurement of the two aircraft's current spacing, the control inputs needed to achieve the desired spacing are relatively basic.

In order to determine the clearances needed to achieve the desired spacing for merging aircraft, the controller must estimate the flight path distance of each aircraft to the merge point (taking into account the geometry of the RNAV or RNP path). The controller then compares these two estimated distances in order to determine the relative position of one aircraft to the other with respect to the merge point. The relative position estimation is then used much like in-trail spacing to determine which clearances to issue to each aircraft; however, since this is only a rough estimation, and since each aircraft is flying along a separate flow subject to different winds, these estimates must be regularly recalculated by the controller as the aircraft near the merge. The original clearances may have to be revised to account for their imprecision. Alternatively, the controller may choose to forgo issuing early clearances, instead relying on the use of vectors as the aircraft approach the merge when their relative positions are easier to estimate; however, this reduces the predictability of the operation. Ideally, the controller would use speed control to retain the predictability of the RNAV operations[1].

Often the inability of controllers to fully utilize speed clearances results from a difficulty in visualizing the relative distances of aircraft from a merge point on converging paths. Existing tools and controller capabilities are not precise enough to ensure the optimal use of speed clearances. These tools include range rings[2], the MinSep tool, the Predicted Track Line (PTL) tool, the Terminal Proximity Alert (TPA), as well as mental devices, such as memorizing tie points in the airspace or conducting mental velocity-distance-time calculations. All suffer from the same major setback; none produces a precise estimate of the distances of aircraft to the merge point along an RNAV or RNP arrival path, much less provide a visualization of the relative positions of these aircraft in relation to that merge point. Yet, this distance is precisely the information that the controller is trying to assess with the existing (inadequate) tools and mental tasks.

The next section describes the lessons learned as a result of CAASD's efforts to find an appropriate near-term tool or concept to aid controllers in merge coordination.

B. *Review of Near-Term Solutions Lessons Learned*

Since the early 1990's the Converging Runway Display Aid[3] (CRDA) has been available in the terminal automation to aid controllers with coordination of arrivals to converging runways [2]. It has been used successfully for arrival operations at Norfolk (KORF), Memphis (KMEM), Philadelphia (KPHL), Pittsburgh (KPIT), and Lambert-St. Louis (KSTL) international airports among other airports. Success has included increased VFR arrival throughput of 28% at KPHL and up to 15% at KMEM. A similar capability has been implemented by NAV CANADA, which claims runway efficiency benefits of up to 25% depending on runway configuration and weather conditions [3]. Anecdotally, it has also been suggested by NAV CANADA that CRDA applications at Calgary Airport (CYYC) have allowed the airport to avoid the need to construct an additional runway for the past 10 years.

Since not all converging flow inefficiencies involve converging runways, CAASD identified an opportunity for expanded use of relative position visualization in the terminal area. From CAASD laboratory experience and observation of actual operational environments, controllers have commented that they are not able to use relative position indicator targets if these indicators do not perform in a predictable manner. That is, the indicator targets on the controller's display must exhibit dynamics similar to a real aircraft. This means that from radar scan to radar scan the indicator target should produce a continuous track with the distance between the successive indicator targets representative of the speed of the aircraft creating the indicator target. CAASD, in coordination with subject matter experts (SMEs) from FAA operational facilities, determined most applications of CRDA in the terminal area would not produce suitable indicator target dynamics on routes with non-collinear waypoints [4]. The limitations can be summarized as follows:

- *CRDA projects "ghosts" in reference to one line segment at a time*[4]. This limitation means that CRDA cannot include a calculation of distance through a turn (Figure 2). It also means that a CRDA implementation for a route with non-collinear waypoints must be defined with a reference line and a qualification region for each non-collinear section of the route. This is complicated by the second limitation below.

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1 In certain circumstances speed control alone is not sufficient to solve a merge problem; however, even in this case accurate relative position information can be used to increase the precision of vectoring, to reduce inefficient vectors that produce extra spacing and can reduce throughput.

2 Range rings are circular markings which controllers can bring up on the radar display to judge straight-line relative distances to a point in space. For any two aircraft selected by the controller, the MinSep tool displays the point of closest approach for the two aircraft assuming that they continue in a straight path at their current speeds. The PTL tool displays a straight line in the direction of the aircraft, whose lengths is based on the current speed of the aircraft and a user-defined "look ahead time". The TPA is similar to PTL except that the line is projected at a user-defined distance.

3 CRDA is a visualization capability for relative position information of converging tracks exists in modern FAA terminal automation platforms, including the Common Automated Radar Tracking System (CARTS) and the Standard Terminal Automation Replacement System (STARS).

4 In CRDA applications, the term "ghost" is typically used to refer to the indicator produced on the controller's display, which indicates the relative position of an actual aircraft target along a converging path.

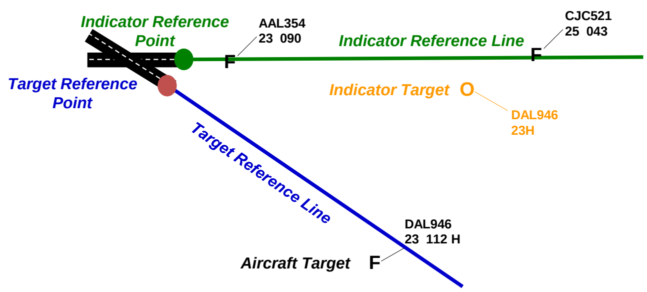

Figure 2. CRDA Single Line Segment Limitation [5]

- *CRDA qualification regions as currently implemented in the U.S. are limited to trapezoidal shapes*[5]. As such, gaps and overlaps in coverage exist through turn segments when multiple CRDA applications are used in succession. In the current CRDA implementation, when there is a gap or overlap, no ghost target is displayed (Figure 3)[6].

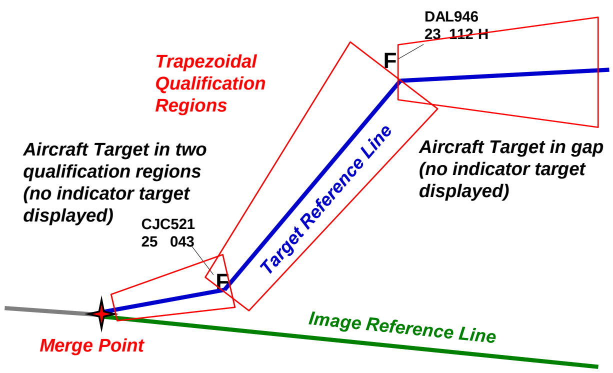

Figure 3. CRDA Trapezoidal Qualification Region Limitation [5]

These limitations result in unsuitable ghost dynamics for most multi-segmented RNAV or RNP procedure applications; controllers would not be able to effectively use the CRDA ghosts for many of these applications.

Driven by the increasing implementation of multi-segmented RNAV and RNP procedures, CAASD began exploring ways to extend the relative position visualization concept beyond single segment applications, so that it could be used in the more generalized terminal environment. Fortunately, newer terminal automation has been widely deployed across the National Airspace System (NAS), which has increased support for advanced algorithms (a limiting factor when CRDA was developed in 1990). CAASD developed more advanced algorithms, leveraging the newer terminal automation, to address the unrealistic indicator target dynamics for non-collinear applications [4]. The advanced algorithms enabled:

- Indicator target projection in reference to a non-collinear route (Figure 4).
- Accounting for a nominal turn anticipation path through route segment transitions (Figure 4).

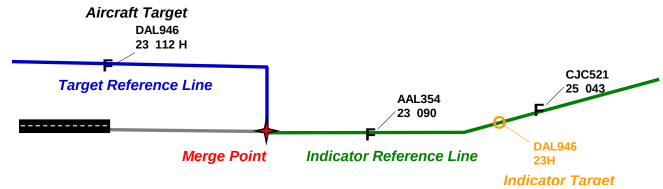

Figure 4. Indicator Target Accounting for Turn Anticipation Through a Route Segment Transition [5]

- Polygonal qualification regions which eliminate gaps and overlaps in coverage through turn segments (Figure 5).

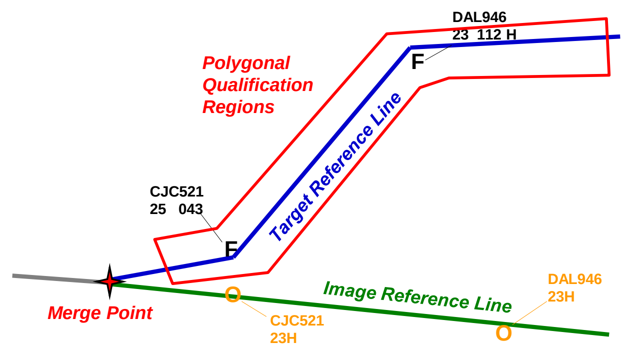

Figure 5. Polygonal Qualification Region Eliminates Gaps and Overlaps in Coverage [5]

III. CONCEPT EXPLORATION

The FAA sponsored CAASD to conduct exploration into extending use of image projection in the terminal area. There were three goals for this research:

- Determine functional requirements for terminal use of relative position information.
- Determine applicability of relative position information for other ATC operational facility positions and uses.
- Conduct a preliminary benefits assessment of the use of relative position information.

The following sections describe the concept exploration apparatuses and activities undertaken by CAASD to meet these three research goals.

A. *Research Prototype*

To determine which features would be required for relative position visualization, CAASD produced a research prototype of the advanced imaging algorithms with the same user interface as the existing CRDA capability[7]. This research prototype, called Relative Position Indicator (RPI), is a passive

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[5] The NAV CANADA version of CRDA does not have this limitation because it was implemented later when computational constraints were not as restrictive.

[6] Even if a ghost is projected from a route with collinear waypoints, if the image route is non-collinear, the reference line should still be defined by a qualification region for each route segment in the image route, and the ghost image will jump when the aircraft transitions between these qualification regions.

[7] The STARS implementation of CRDA was used to emulate the user interface.

tool that displays projected indicator targets to help controllers visualize the relative position of converging aircraft. The tool does not provide active advisories. RPI only requires route structure and adaptation data as well as a real-time surveillance feed[8].

In the early stages, RPI was shown to SMEs from FAA ATC operational facilities to obtain feedback on the interface. However, the primary source used to identify required capabilities was feedback from a series of Human-In-The-Loop (HITL) evaluations with SMEs [5]. Figure 6 summarizes the iterative process used to gather and develop user requirements for RPI.

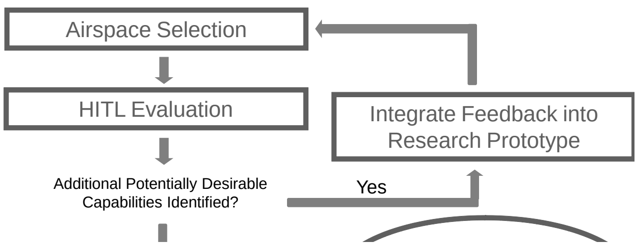

Figure 6. Functional Requirements Gathering Process[5]

B. Airspace Selection

The airspaces selected for evaluation were chosen to include a range of facility sizes and airspace complexities. Within the size and complexity category, individual facilities were chosen based on the availability of the facility to participate (for site visits)[9] or the availability of expertise to help design the scenarios (for evaluation in the CAASD Air Traffic Management [ATM] Laboratory). Each airspace had at least one terminal merge and a merge on final approach in order to explore a broad range of potential RPI applications (Figure 7).

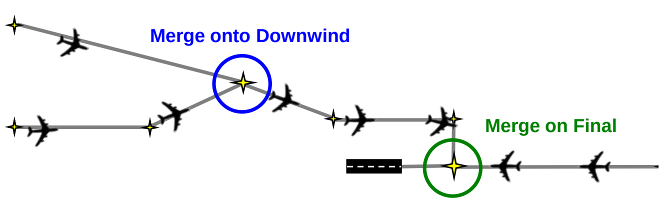

Figure 7. Facility Selection Criteria: Merge Classification [5]

These evaluations have included:

- April 2007 – An evaluation of West Palm Beach Terminal Radar Approach Control (TRACON) facility (PBI) conducted at CAASD. PBI is a mid-sized TRACON with both a terminal merge and a merge on final approach.

[8] RPI will likely use the aircraft position as defined in the radar automation's track table (the position in which an aircraft target is displayed on the Terminal Controller Workstation [TCW]), as opposed to using the raw surveillance feed.

[9] Site evaluations were conducted using CAASD's research platform, described in Section III, Subsection C.

- June 2007 – An evaluation of PBI conducted at PBI.
- July 2007 – An evaluation of Las Vegas TRACON (L30) conducted at L30, specifically McCarran International Airport (KLAS). KLAS is among the top 35 busiest airports in the NAS, and has both terminal and final approach merges.
- August 2007 – An evaluation of L30 conducted at CAASD, specifically KLAS.
- November 2007 – An evaluation of Northern California TRACON (NCT) at NCT, specifically San Francisco International Airport (KSFO). KSFO is also a top 35 airport, which has both terminal and final approach merges. In addition, RPI was used during this simulation to help make runway balancing decisions for aircraft arriving from the north.
- February 2008 – An evaluation of Potomac TRACON (PCT) at CAASD, specifically Dulles International Airport (KIAD). Another top 35 airport, the KIAD evaluation focused on both terminal and final approach merges. The terminal merge at KIAD is notable for its multi-segmented path to the merge along the SHNON arrival which makes it difficult to estimate the relative positions of merging flights.

C. Simulation Environment

The evaluations were conducted using a research platform that emulates CARTS/STARS radar scope displays and allows participants to interact with simulated aircraft targets in much the same way as controllers interact with real traffic. The radar displays were rendered on large monitors similar in size and resolution to the FAA's Terminal Controller Workstation (TCW) displays for evaluations conducted at the CAASD ATM Laboratory. During site visit evaluations, due to transportation constraints, smaller monitors were used, ranging in size from 15"-19". The participants interacted with the research platform using their preference of a trackball or a mouse, and a QWERTY keyboard[10] (Figure 8).

The simulation environment included several pseudo-pilots tasked with managing a list of aircraft and responding to controller communications for aircraft in that list. The pseudo-pilots also entered aircraft instructions issued by the controller participants into the simulation software.

[10] ARTS/STARS do not include a QWERTY keyboard. However, from regular home and office computer use, participants were familiar with the QWERTY keyboard, so it had minimal impact on the results of the simulation. The appropriate mapping of inputs to RPI functionality on ARTS/STARS keyboards requires additional research.

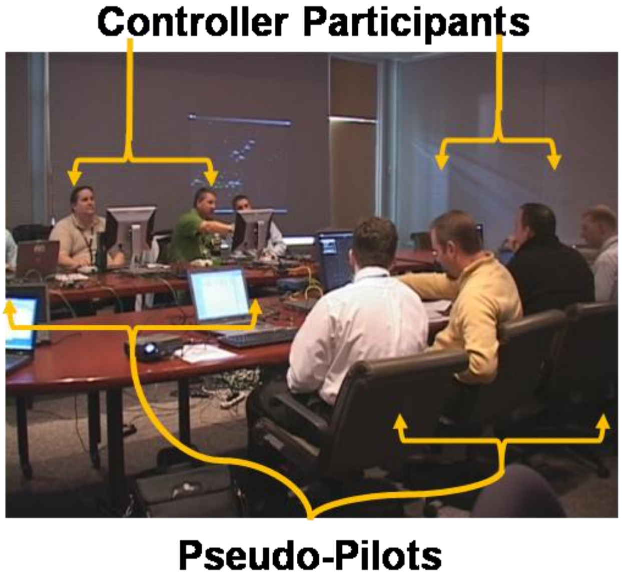

Figure 8. HITL Simulation Set-up

D. Participants

The participants generally had 15 or more years of experience in ATC, generally as line controllers and often with experience as ATC Supervisors or Traffic Management Coordinators (TMC). Evaluation sessions held at ATC facilities involved one or more ATC Supervisors from that facility. Sessions conducted at CAASD involved a team of seven terminal ATC Supervisors and TMCs from TRACON facilities across the NAS, including, Atlanta Large TRACON (A80), Dallas TRACON (D10), Houston TRACON (I90), L30, NCT, Phoenix TRACON (PHX), and Southern California TRACON (SCT).

E. Site Adapted Scenarios

Traffic scenarios were based on actual facility operations to provide a realistic context in which participants could evaluate RPI. When conducting evaluations at an ATC facility, this method allowed participants to focus on evaluating RPI, since they were already familiar with the airspace and operational requirements of the scenario.

For evaluation sessions at ATC facilities, facility participants were consulted to help identify specific applications of RPI to evaluate. Facility contacts were also consulted to help design the evaluation sessions conducted at CAASD.

F. Conduct of Evaluations

Before conducting simulations, the participants were oriented with the simulation environment, details about the airspace, and other operational conditions being simulated during the scenario. Several practice scenarios were conducted with each set of participants to acquaint them with the simulation environment, the simulated operations, and the functions of RPI. As appropriate, the RPI applications and user interface settings were adapted after these training scenarios to suit the preferences of the participants.

For each facility, several RPI applications were simulated to give the participants several perspectives on how the tool could be applied to the operation. These variations included applying RPI to other merge geometries in the airspace and switching reference and image paths to project indicator targets onto other flows. Scenarios with position combinations (that is, one controller working two areas of control responsibility) were also conducted to see if RPI could be used to help a single controller work additional traffic. The scenarios typically ran for 30 minutes to one hour. After each scenario, the participants were debriefed to capture feedback on how they used RPI and any suggestions for changes to the user interface or additional functions.

G. Integrating Feedback

After each evaluation, participants' feedback was used to modify the RPI research prototype. For example, mirror image projection was first suggested by participants from A80, adjusting indicator target color by application was proposed during the PBI evaluation, and dynamic offsetting was first proposed during the LAS evaluation[11]. Inconsistent feedback across participants was weighed against the objectives of the automation. For example, to fulfill the near-term implementation objective of enhanced merging and spacing, suggestions for some advanced capabilities were deferred to concepts for mid-term or far-term automation enhancements.

In the first evaluation, the research prototype had the user interface capabilities available in the CRDA computer-human interface. However, as feedback was used to add new capabilities to the research prototype, the updated prototype was used in subsequent evaluations. This iterative process continued until feedback on RPI's capabilities was generally positive and consistent across a range of participants.

IV. Results

The evaluations produced three types of results, each of which will be discussed in this section:

- Additional functional requirements for terminal use of relative position information.
- Additional applications of RPI for the TRACON TMC position[12].
- Inputs into a preliminary benefits assessment of the use of RPI.

A. Requirements Identified for Terminal Applications[13]

The results in this section represent the requirements that were identified considering the evaluations described above. Of note is that the requirement set which came out of the evaluations was similar across diverse airspace and participant

[11] See results section for details on each capability.

[12] The TMC position at a TRACON is responsible for making traffic decisions such as the use of miles-in-trail initiatives, runway and fix load balancing, and sector acceptance rates. These judgments are based on the number and complexity of traffic expected to enter the TRACON.

[13] For more details on the requirements identified in this section, refer to reference 5.

sets. An evaluation group that was involved throughout the requirements development process, and which saw several iterations of the simulated research prototype, was generally agreeable to the requirements listed in this section. Any disagreement was largely a matter of whether some functions were necessary, not that they would be detrimental to the overall system [14]. These disagreements abated if these functions were labeled optional—allowing for a tailored approach to each application and for each controller.

This section describes the baseline user interface leveraged from the FAA's implementation of CRDA. It then details what changes to this baseline are recommended for the terminal capability, based on the HITL evaluations.

The proposed user interface for RPI, to include how the indicator targets are displayed and interfaced with, shares many characteristics with the CRDA implementation in CARTS/STARS [6, 7]. A sample of these shared user interface features includes:

- The indicator target's position symbol is an alphanumeric character adapted to the route pair configuration for which the indicator target is generated. Separate position symbols can be adapted for "stagger" and "tie" modes.
- A leader line extends from the indicator target's position symbol to the data block.
- The brightness of the indicator targets can be adjusted.
- Individual indicator targets can be displayed and suppressed.
- The full and partial indicator target data block states can be displayed (Figure 9).

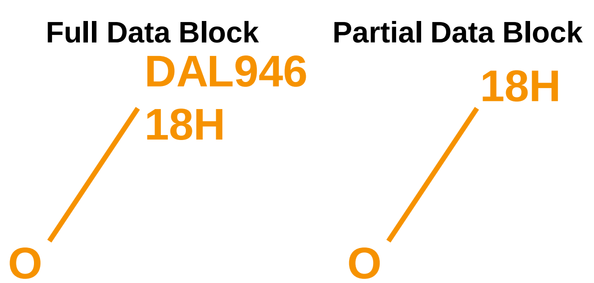

Figure 9. STARS Indicator Target Data Block States[5]

Throughout the HITL evaluations it became apparent that several user interface requirements would have to be altered from the baseline. These requirements are:

- *Support Toggling Between Partial and Full Data Block States*. RPI shall permit toggling indicator target data blocks between partial and full states for all indicator targets in a specified application. In the baseline, each data block must be toggled individually, which adds to controller workload.
- *Support Indicator Target Coloring by Application*. RPI shall permit indicator targets for each merging application to be adapted to display in independent colors to distinguish between the indicator targets of multiple applications being displayed at the same time. Unlike runways, a route may merge with more than one other route; the baseline does not support color coding by application[15].

Expanding to segmented paths introduces more complex merge geometries which do not exist in converging runway operations. In addition to conventional image projection, RPI is designed to meet the following requirement:

- *Mirror Image Projection*. RPI shall permit adapted applications in which aircraft targets to the right of the target reference line will project a indicator target offset to the left of the image reference line, and vice versa (Figure 10).

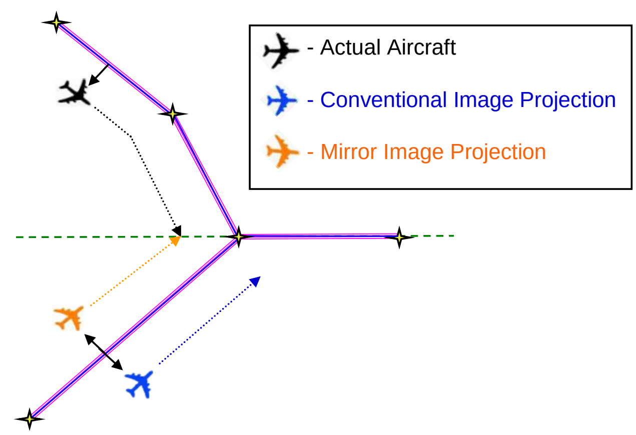

Figure 10. Mirror Image Indicator Target Projection [5]

Depending on the merge configuration it can be useful for the aircraft to be represented as a mirror image of the conventional projection. For example, in Figure 10 the actual aircraft target is offset to the right of the target reference line and is therefore on the "outside" of the turn onto the common segment of the merging flows. The mirror image projection provides an intuitive depiction of this situation (while the conventional image shows the indicator target on the "inside" of the turn).

The merge on final approach can change during normal operations, especially with a downwind/straight-in configuration. This issue can cause the indicator targets to provide little benefit. The following requirement allows RPI to continue to provide valuable information during dynamic merge operations:

- *Dynamic Offsetting.* RPI shall permit the controller to longitudinally offset the indicator target images on the

[14] Some participants, for example, felt that they were already skilled enough at merging that they may not use all the RPI capabilities being proposed. Making these features optional would allow less experienced controllers to benefit from their use without requiring all controllers to use them.

[15] The ARTS 3A system, on which the FAA originally implemented CRDA, only supported green. When CRDA was implemented into STARS, the same functionality was used for the sake of commonality across platforms.

controller’s own display, in real time, by a specified distance (Figure 11). Only one indicator target will be displayed for each aircraft at any given time.

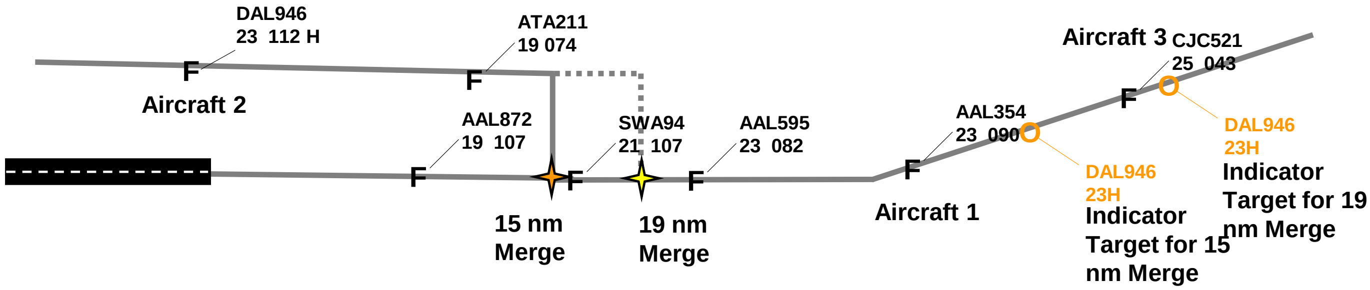

Figure 11. Dynamic Offsetting (Showing Two Options) [5]

B. Identification of Traffic Management Applications[16]

HITL participants with a TMC background suggested that RPI could be applied to their tasks as well.

The TMC at a TRACON makes traffic decisions utilizing information about the number and position of aircraft which will fly through the facility’s airspace. The TMC’s decisions affect controller workload and the efficiency of the operation. Use of miles-in-trail initiatives, runway and fix load balancing, and sector acceptance rates are often determined based on sector counts and traffic complexity. In many cases complexity is difficult to assess without a clear visualization of the relative position of merging traffic. The TMC also has difficulty assessing this information for the same reasons as those stated for controllers (in II. Background).

One of the responsibilities of the TMC is to ensure proper runway load balancing. The TMC often has two or more runway assignment options for arriving aircraft and must determine which runway flow the aircraft should join. The TMC could utilize relative position information to identify which flow better accommodates the aircraft. The resulting merges would require less controller intervention and lead to reduced aircraft delay.

Figure 12 depicts the visualization of the problem, enabled by RPI, which makes the optimal runway assignment clear to the TMC. In this case, the TMC projects indicator targets for the arrival traffic from the northwest flow onto both the northeast and the southwest flows to determine that the southwest flow will better accommodate Aircraft 1 from the northwest. Depending on the facility, the TMC may enter the runway assignment directly into the CARTS/STARS automation, or coordinate the assignment verbally with the affected TRACON radar controller or supervisor[17].

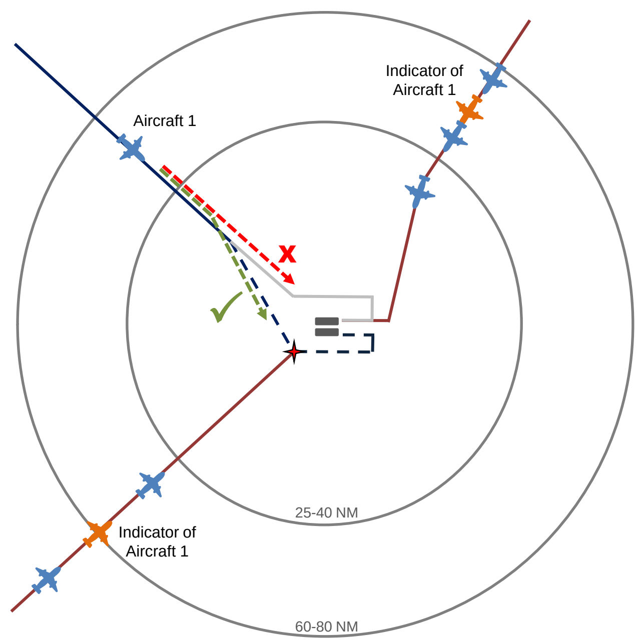

Figure 12. Runway Assignment Decision with RPI [8]
An indicator target is placed on two flows to determine which flow better accommodates Aircraft 1.

Keeping an aircraft in a holding pattern is undesirable for many reasons including placing additional workload on the controller, as well as increased fuel consumption for the aircraft. RPI can be used to project indicators of aircraft from a converging flow on to the flow with the holding pattern, helping the TMC decide when to safely and efficiently take the aircraft out of holding (Figure 13).

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[16] For more details on TMC applications of RPI indentified in this section, refer to reference 8.

[17] It should be noted that the Traffic Management Advisor (TMA) system helps with runway load balancing; however, in the near-to-mid term, there remains a tactical element involved in runway decision making which RPI can address (see figure 12).

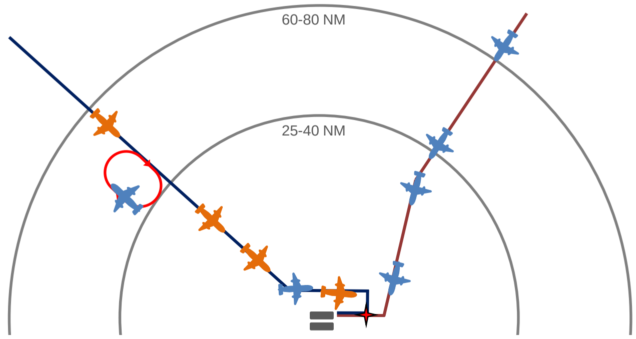

Figure 13. Taking Aircraft out of Holding with RPI [8]
Indicator targets are displayed on a flow with holding aircraft to determine slots for removing aircraft from the holding pattern.

When a certain degree of leeway exists in the exact timing of a runway configuration change, the TMC is responsible for identifying the last aircraft to land in the current configuration. RPI can be used by the TMC to help decide which aircraft should be the final one to land in the current configuration, and subsequently, how to flow aircraft to the new configuration. RPI helps the TMC identify slack in the arrival demand where the configuration switch will cause the least disturbance to the arrival flows (Figure 14)[18].

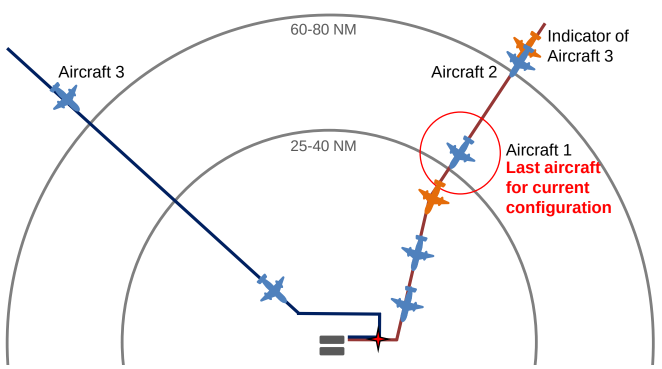

Figure 14. Coordinating Configuration Change with RPI [8]
Indicator targets are used to determine a slack in demand after Aircraft 1, indicating a potentially good time to make the runway configuration change.

Once the final aircraft is chosen, the TMC can change RPI applications to help aid the merge coordination for the new configuration. Notice in Figure 15 that, based on the indicator of Aircraft 3, Aircraft 2 is now farther from the new merge point onto final approach than Aircraft 3.

[18] If the radar data does not indicate slack in demand, the TMC will typically look to the TSD with Enhanced Traffic Management System (ETMS) or the Traffic Management Advisor Planview Graphical User Interface (TMA PGUI) to make a preliminary last aircraft decision. In this case, RPI could be used to monitor the decision made using ETMS and, if necessary, update this decision as the relevant aircraft approach the TRACON boundary and are associated with the facility's radar.

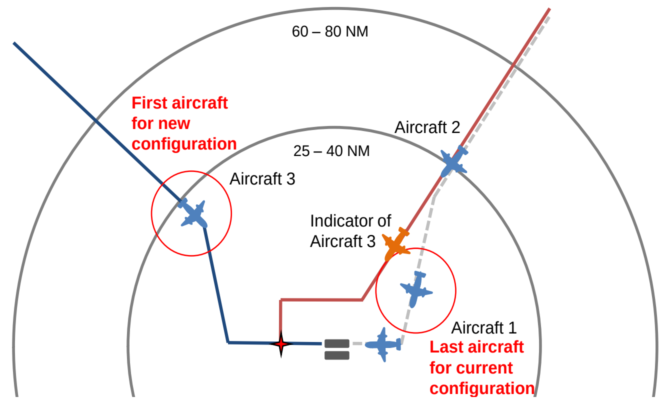

Figure 15. Coordinating for New Configuration with RPI [8]
A new RPI application can be used to project indicator targets for the new runway configuration.

C. *Preliminary Benefits Analysis*[19]

The HITL evaluations provided inputs into a benefits analysis of RPI usage at the top 35 airports in the NAS. The analysis considered the results observed in the HITL evaluations and proposed a methodology for estimating the operator benefits from using RPI at these airports. This was based specifically upon observations that RPI use in HITL simulations led to shorter downwind extension [10].

Throughout the day the length of the downwind extends and contracts based on operational conditions. During periods of light traffic, there are fewer merge conflicts on final approach, which allows controllers to turn in downwind traffic sooner and reduces the need for delay vectoring of straight-in traffic. However, there is a limit to how close an aircraft can turn into the airport during normal operating hours, due to airspace constraints and the vertical descent profiles that these necessitate. Therefore, delay is defined as flight time greater than the minimum for the current operational conditions. The nominal flight track of flights throughout the day for a particular configuration was used to estimate the delay value for this preliminary benefits analysis.

The basis of the analysis was identifying inefficient delay vectors at merge points, which added track length to the nominal path, at the airports evaluated (an example is shown in Figure 16). This track length was converted into average flight time delay.

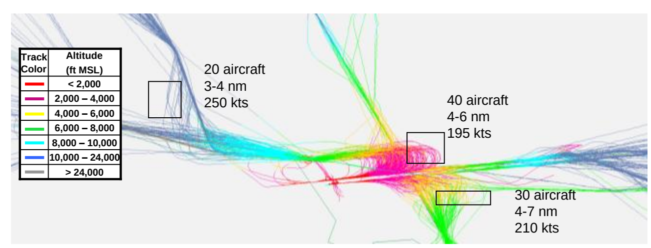

Figure 16. Example Delay Estimation for Los Angeles International (LAX) Arrivals [9]

[19] For more details on benefits indentified in this section, refer to reference 9.

Using the airline industries published direct operating cost[20], these delays were converted to dollars. The resulting annualized estimate for all 35 airports totaled approximately $100 million.

V. Conclusion

RPI is a mature concept that is being evaluated by the FAA for implementation in the near term[21]. As the FAA evolves the concepts of TBM and improves the accuracy of delivery to the meter fix, RPI as a controller tool is thought to complement the FAA's TBM TMA capability to deliver the "right" number of aircraft to the terminal area (to match the terminal's arrival capacity) by providing a controller tool that helps the terminal controllers to fine-tune the spacing of the aircraft at merge points internal to the terminal area (including the runways). However, RPI as a TMC tool might have some overlap with the functionality of future TBM applications, for instance, in planning and balancing flows between different runways. However, RPI as a TMC tool might still supplement the TMA information to suggest other decisions such as when to take aircraft out of holding or how to best coordinate aircraft during a runway configuration change. These are the areas that will require more concept development and evaluation to fully understand the extent to which RPI could be used for traffic management decision-making in the terminal environment, versus relying on TBM TMA as the sole source for supporting traffic management arrival decision-making.

The interaction between RPI and TMA could be studied in a limited set of field evaluations. A field evaluation would aid understanding of conditions that are difficult to simulate in the laboratory, such as the interaction between TMCs and air traffic controllers, and exposure to a broad range of operational conditions. In addition, data collected during the field evaluation could help refine the benefits estimates already conducted. As RPI moves toward implementation, the lessons learned during field evaluations may provide useful insight into optimizing the configuration of adaptation data. So while not necessary to make the implementation decision, field evaluations may be considered an effective activity on the path toward implementation.

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Author Biography

Jeffrey P. Shepley is a Senior Simulation Modeling Engineer with The MITRE Corporation's Center for Advanced Aviation System Development (CAASD). He has a Bachelor of Science degree in systems engineering from The University of Virginia (2006) and is a Master of Science degree candidate in systems engineering at the Johns Hopkins University.

He has worked on RPI concept refinement, requirements validation, and benefits analysis for two years. His other work with CAASD has included human-in-the-loop evaluations of RNAV implementation for ATC facilities across the NAS and requirements validation for ground-based automation for assisting air traffic controllers to detect pilot deviations.

Disclaimer

[20] The direct operating cost at the time of the report $65.80 per block minute (from 2006). The fuel cost at the time averaged $2.00 per gallon. The direct operating cost reported for 2008 was $72.13 per block minute [11].

[21] For example, RPI is being considered as part of the Terminal RNAV Operational Assessment Request (OAR) submitted to the Terminal Requirements Board for validation in August 2008.