Established on Required Navigation Performance (EoR) (RNP): Human Factors Implementation Guidance for Air Traffic Control Facilities within the National Airspace System.

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16. ABSTRACT

The Federal Aviation Administration (FAA) NextGen Human Factors Division commissioned this research to identify and share lessons learned from air traffic control facilities that were "early adopters" of Established on Required Navigation Performance (EoR) (RNP) procedures. Based on a review of relevant concept validation documentation and research literature and 38 interviews with personnel at Seattle and Denver Terminal Radar Control (TRACON) facilities, a suite of guidance materials was developed to support air traffic control facilities with EoR implementation. The materials included: a) a pair of hybrid process charts/checklists covering the Plan & Design and Implement/Sustain stages of an EoR implementation, b) an Air Traffic Control facility communication toolkit to support EoR implementation, and c) an Air Traffic Controller's EoR Journey Map describing some typical air traffic controller responses to the introduction of EoR. In developing these materials, consideration was given to a set of design principles informed by user-centered design and design thinking approaches, as well as by change management considerations. These materials were validated during a third site visit to Houston Terminal Radar Control facility, where twenty interviews were conducted with operational personnel, including Certified Professional Controllers. As well as providing feedback and suggested revisions to these materials, the site visit also allowed the researchers to collate human factors data on an EoR implementation within a dual and triple runway configuration. The results from Phase II of this work include a suite of materials that air traffic control facilities can adapt to support their own EoR implementation projects, as well as additional insights into how best to support controllers through transitions and changes associated with the introduction of new technology, new procedures, and increased automation.

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A NOTE ON INTERVIEW DATA

All interviews reported here were conducted in a non-attribution context, meaning that the interview data reported is not directly attributable to a specific individual. To provide greater assurance of non-attribution, the interviews were not recorded. Hence, the interviewee responses provided in this document are of necessity described and/or summarized based on interview notes. In accordance with good practice when using qualitative data, information extracted from interview notes has been placed in quotation marks to clearly differentiate it from the body of the text. While every effort was taken to capture views and opinions accurately, and to represent them fairly within this report, the responses shared may not be verbatim quotations. The views and opinions expressed in this document are not necessarily those of the NextGen Human Factors Division, the Federal Aviation Administration, or the United States Government.

1. INTRODUCTION

1.1. Scope of work

The Federal Aviation Administration's (FAA) NextGen Human Factors Division commissioned Architecture Technology Corporation to conduct an applied research project to identify human factors best practices and share lessons learned in the operationalizing of a Performance Based Navigation (PBN) concept known as "Established on Required Navigation Performance" (EoR). EoR utilizes Required Navigation Performance (RNP) procedures within a terminal environment and is intended to assist air traffic control facilities in bringing the advantages of PBN into their arrival and approach operations. EoR currently utilizes Required Navigation Performance Authorization Required[1] (RNP-AR) procedures for clearing a suitably equipped aircraft with an appropriately authorized crew onto a pre-defined approach to an airport, without requiring either 1,000 feet vertical or 3 miles radar separation from aircraft established on other approved simultaneous instrument approaches to parallel runways. Currently, the RNP-AR approaches used for EoR operations within the NAS have considered an aircraft established on its approach while still downwind of the airport, prior to turning inbound and aligning with the extended runway center line for landing.

Introducing a new procedure or concept into an air traffic operation requires consideration of the "human factors" associated with the change, in the widest sense of term. Human factors is a discipline which focuses on the multiple perspectives of varying end users and attempts to integrate these "user" concerns into the wider system and organizational context. Within the context of PBN, the end users of the "Established on Required Navigation Performance" concept might include air traffic controllers, front line managers, operational managers, and air traffic managers, as well as safety, quality assurance and training departments. A comprehensive human factors approach may also extend to considering the impact on airlines, including pilots, airline operations and planning personnel. While the current work focuses primarily on the operational air traffic impacts of implementing PBN, it is inevitable that there will be some overlap with flight deck and airline considerations.

The project was conducted in two stages. Stage I involved a literature review along with visits to two "early adopter sites" (Seattle and Denver Terminal Radar Approach Control facilities, or TRACONs) to interview facility personnel about their experiences of implementing EoR. It also involved conducting interviews with airline representatives from some operators flying into these airports. That stage of the work was documented in a report which analyzed the gap between planned implementation strategies and best practices, highlighting lessons learned from the actual experience of facilities in implementing EoR operations (Thomas, Serrato & Kirby, 2018). Stage II of the project involved the development of a suite of human factors implementation guidance materials based on user-centered design principles and the emerging discipline of "design thinking",

[1] There are plans to extend EoR operations to other forms of RNP approaches, including RNAV (GPS) and Advanced RNP (A-RNP). The current project considers only RNP-AR approaches, since these were the approaches used for EoR at the "early adopter" sites in Seattle, Denver and Houston. Different types of RNP approaches may introduce different human factors considerations, depending on the context of use and the intended application.

along with the validation of those materials via a Subject Matter Expert (SME) workshop and a third site visit to Houston TRACON. That work is documented in this report.

This document is the final report of the project, providing details of Stage II of the research. This report also provides implementation guidance which addresses the lessons learned from the use of RNP-AR procedures for EoR operations within widely spaced, dependent, and dual and triple simultaneous approach configurations. As EoR becomes more widely used within the National Airspace System (NAS), this guidance may benefit from further refinement as new types of EoR operations in additional configurations are considered for design and implementation within the NAS.

1.2. Background

PBN is an advanced form of navigation that specifies a precise flight path. Rather than certifying specific systems (including sensor equipment, procedures and crew requirements), PBN protocols specify the navigational performance that is required to permit proposed operations in the defined airspace. PBN protocols may include requirements in terms of the navigational system's accuracy, integrity, availability, continuity and functionality. There are approximately 9,000 PBN procedures within the NAS, including departures, routes, arrivals and approaches; a Required Navigation Performance (RNP) level is specified for each. RNP is expressed as a value that represents a performance tolerance in nautical miles from the intended position to the actual position of an aircraft - the lower the number, the higher the performance standard required.

"Established on Required Navigation Performance" (EoR) refers to RNP instrument approach procedures that are designed to guide aircraft established on initial paths that are not aligned with the landing runway to a straight-in final, without requiring either 1,000 feet vertical or 3 miles radar separation from aircraft established on other approved simultaneous instrument approaches to parallel runways. For example, a common type of approach used within EoR operations considers that an aircraft is established on its approach while still downwind of the airport, prior to turning inbound and aligning with the extended runway center line for landing. The downwind leg and the inbound turn-to-final are incorporated within the pre-defined procedure. The design of this type of approach means that aircraft can turn to final sooner than they would on a vectored approach, and they do not need to receive air traffic control instructions to make the turn. These approaches reduce flight time, flight distance and approach variability, as shown in Figure 1.

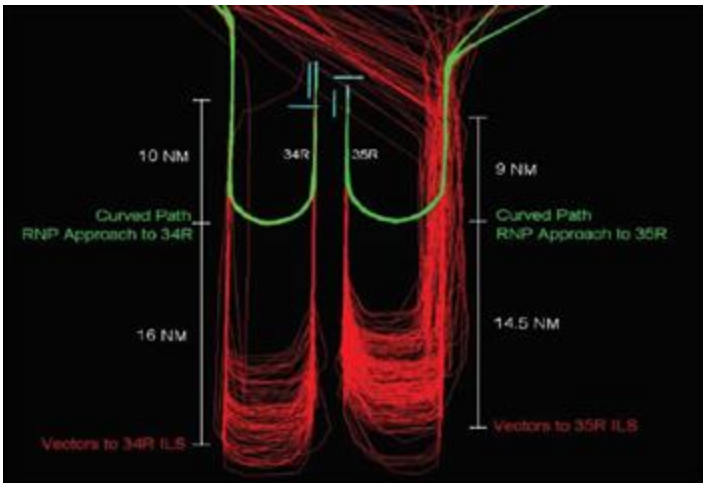

Figure 1: EoR operations (green) provide a shorter final approach for equipped aircraft at Denver International Airport. Source: FAA, 2016a, p. 19.

Currently, only RNP "Authorization Required" approaches are used for EoR operations within the NAS. These RNP approaches require prior authorization to fly, including aircraft authorization and specific flight crew training. RNP-AR approaches have been used within EoR operations under a range of simultaneous approach configurations within the NAS:

- **Simultaneous dependent approaches ("staggered"):**
  Where runway centerlines for dependent approaches are between 2,500 and 9,000 feet apart, simultaneous approaches require that the aircraft are staggered to maintain diagonal separation - in other words, approaches to one runway are *dependent* on approaches to the other runway. RNP-AR approaches used within EoR operations have been implemented at Seattle-Tacoma International Airport and Seattle TRACON (S46) was an "early adopter" site included in this research.

- **Simultaneous independent approaches ("widely spaced"):**
  Simultaneous approaches to independent widely spaced runways can be used when the runway centerlines are separated by more than 9,000 feet. This type of simultaneous approach does not require the use of No-Transgression Zones (NTZs) or final monitoring. Denver International Airport runs a widely spaced operation on its "outboard" runways; RNP-AR approaches used within EoR operations have been implemented and Denver TRACON (D01) was included in this project as an "early adopter" site.

- **Simultaneous Independent Approaches ("duals and triples"):**
  Duals and triples are a type of independent approach where two or three parallel runway centerlines are separated by a distance within the range of 3,000 to 9,200 feet. Because of the proximity of runway centerlines, a No-Transgression Zone (NTZ) at least 2,000 feet wide is mandated between runways and an air traffic controller must monitor the aircraft on the radar scope during the final approach (the "final monitor controller"). George Bush Intercontinental Airport at Houston runs EoR within a duals and triples configuration; Houston TRACON (I90) was included in this project to support validation of the "early adopter" findings.

1.3. Human centered implementation of EoR

It was evident from the Stage I literature review that most of the publicly available research on PBN addresses flight deck human factors; few studies were identified that focused on human factors issues associated with PBN from the perspective of operational air traffic control (Thomas, Serrato & Kirby, 2018). As expected, since EoR is a new operational concept, there was no academic research available on this specific application of PBN. However, EoR concept validation and safety studies commissioned or conducted by the Federal Aviation Administration were available, and these were reviewed and discussed within the Stage I report. Since the aim of the work was to identify gaps in the human factors knowledge base and identify "lessons learned" from the "early adopter" facilities, site visits were also undertaken to Seattle and Houston TRACONs, to interview personnel and learn more about the implementation of EoR from the perspective of operational air traffic control.

Interviews were conducted at Seattle and Denver TRACONs with a total of 38 personnel, including Certified Professional Controllers (CPCs), training and quality assurance support staff, operational managers (including Front Line Managers and Operational Managers), and automation technicians and engineers (see Thomas, Serrato & Kirby, 2018). For CPCs, interview questions focused on the operational aspects of EoR, including sequencing techniques, controlling tips and hints, and decision making while conducting EoR operations. For support specialists, managers, and automation specialists, questions focused on activities undertaken at facilities to prepare for the implementation of EoR. At both TRACONs, the interview protocol and questions were agreed in advance with the relevant NATCA representative. The interviews at Seattle and Denver provided rich insights into the experience of implementing EoR at each facility, and the results help demonstrate how human factors considerations are a critical component of the change management process in supporting the transition to trajectory-based operations.

Successful implementation of EoR at any facility is ultimately dependent on CPCs deciding to assign and clear aircraft for the RNP approaches. Without CPCs consistently assigning and clearing the approaches, overall adoption and utilization rates at the facility will remain low, and the potential benefits of PBN will not be fully realized. The focus of the data analysis was therefore to identify the success factors that would increase the probability that a CPC would assign and/or clear an aircraft for an RNP approach within EoR operations, when it is appropriate to do so. Based on this "human-centered" research question, analysis of the Seattle and Denver interview data identified several factors that could be regarded as influencing the success of an EoR implementation. These were broadly classified into the categories shown in Figure 2.

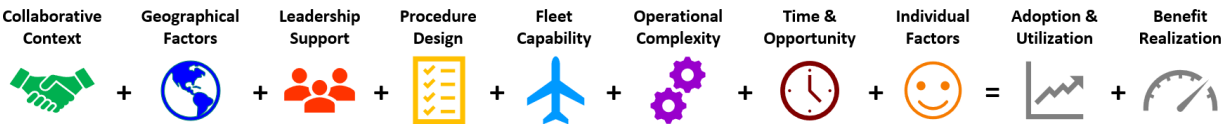

Figure 2: EoR success factors for EoR adoption, utilization and benefit realization

Figure 2 provides a descriptive framework of "success factors" for EoR implementation. Not all of these may be "human factors" in the purest sense of the term, but all are factors that influence controller acceptance of EoR operations. Each category may be described as follows:

- **Collaborative context:** this refers to collaboration between all stakeholders, including air traffic controllers at towers and TRACONs, pilots, as well as airlines and airport authorities. Strong working relationships lead to stronger solutions and greater "buy-in" from stakeholders.
- **Geographical factors:** Required Navigation Performance (RNP) procedures are often a solution to geographical challenges, such as noise in residential areas, mountainous terrain, nearby airfields, and so on. Successful procedure design requires all such factors and possible solutions be considered, including airport limitations (such as runway use and runway availability) as well as local terrain and possible interactions (e.g. having other airports within the vicinity).
- **Leadership support:** successful implementations require leadership support, meaning that leaders provide the time and resources necessary to reach successful procedures design solutions, and to plan a managed and progressive implementation. This includes ongoing reinforcement, including encouraging air traffic controllers and pilots to use the new procedure.
- **Procedure design:** successful procedures tend to be win-win solutions, meaning that there is something in the design of value to every stakeholder. Ideally, the smallest operator would see a gain from implementation at an airport as well as the dominant carrier (although it may not be the same type of gain or benefit).
- **Fleet capability:** there is likely to be a mixed fleet with varying RNP capabilities at most TRACONs and airports. The most successful early implementations were those that found ways to support controllers by mitigating a mixed fleet, such as by segregating the RNP operation to a different runway or using procedures in visual conditions only – at least initially - until both air traffic controllers and pilots become more comfortable with the change.
- **Operational complexity:** every air traffic control facility has a unique combination of factors that drive complexity, including the traffic volume and mix, and the operational tempo. Successful implementation requires considering the operational context at each facility, since a "one-size-fits-all" approach is unlikely to be successful.
- **Time and opportunity:** air traffic controllers need time to figure out how to integrate a new procedure into their repertoire of controlling techniques. If air traffic controllers are working at maximum capacity levels, they will find it a challenge to try something new. Successful implementations are those that find ways to support controllers with integrating new procedures into their own controlling style, through training, simulation or exposure during low traffic and/or low complexity periods.
- **Individual factors:** there are also subjective factors that play a role in whether a new procedure will be widely used. Some pilots and air traffic controllers are very open to trying new things, while others tend to prefer tried and tested techniques. Workload, motivation, confidence and the level of training are all factors that influence an individual's decision to try a new procedure.

Air traffic controllers are a key determinant of whether EoR operations will be widely adopted at any given facility, since successful implementation requires that air traffic controllers choose to assign and clear eligible aircraft when they deem it to be appropriate. Understanding how controllers integrate EoR operations into their existing controlling practices, and the operational and organizational factors that enhance or hinder that process, is critical to maximizing air traffic controller acceptance and adoption of EoR operations procedures and realizing the potential benefits of PBN.

1.4. Development of human factors implementation guidance materials

The primary focus of this research was to identify key human factors issues associated with increasing the adoption and utilization of RNP approaches. High rates of adoption and utilization are required for the maximum benefits of PBN to be realized[2]. The interviews at Seattle and Denver TRACON allowed some of the key "enablers" and "blockers" at these early adopter sites to be identified, so that the lessons learned could be shared with other air traffic control facilities. The specific requirement of Stage II was to develop human factors implementation guidance that could be used to share lessons learned and best practices with operational air traffic facilities, and to include within the development process the validation of draft materials at a third operational facility.

In developing human factors implementation guidance materials from the interview data, consideration was given to a set of design principles. These design principles assisted with making decisions about the content, structure, and format of the guidance materials. The design principles considered the context in which the implementation guidance would be used, as well as the different intended audience groups. The design principles were informed by user-centered design and design thinking approaches, as well as by change management considerations. The following design principles were followed wherever possible throughout the development and refinement of the human factors implementation guidance materials:

1. Aim to summarize key research findings in a manner which might best appeal to air traffic control specialists and other facility personnel by removing technical and academic human factors references and using operational terms, real-world examples, controller quotations and user anecdotes where possible;
2. Aim to provide appealing and engaging graphic resource materials that communicate key information related to EoR implementation in a logical and easy to understand manner, and to support these materials with external/additional information only where necessary;
3. Aim to represent information visually wherever possible, using icons, graphics and color coding to communicate clearly to different audience groups, allowing users to identify the most salient information for their role, and to navigate easily across and between the suite of materials;
4. Aim to answer "what's in it for me" questions for CPCs (since they are the "front-end" of the transition to trajectory-based operations inherent within EoR), and provide tips, hints and strategies that help controllers to see that this transition will be a unique journey for every controller, although there may be some common experiences;
5. Aim to cross-reference materials to any relevant FAA policies and processes, so that regulatory material, job orders/processes, procedural details and technical data are not repeated within the guidance and the materials remain "self-contained" as far as possible;
6. Aim to provide the FAA with "close-to-final-version" samples of materials likely to be effective in communicating with facilities about transitioning to an EoR operation, so that these can be edited and tailored for different facilities and are not provided as a "one-size-fits-all" solution;
7. Aim to communicate that the use of the implementation guidance is optional and not mandated; and that collaboration between facility management and NATCA representatives will determine the best approach to EoR implementation at any one facility;

[2] As already noted, the current project considers only EoR operations utilizing RNP-AR approaches.

8. Aim to acknowledge throughout the materials that CPCs themselves have the expertise within their own airspace, and that their professional judgement is to be respected and supported in making decisions about whether EoR is appropriate in any specific situation.

Based on these principles and the information derived from the Stage I interviews, an initial suite of materials was developed via an iterative process employing human factors, user-centered design and visual communication methods. The initial suite of implementation guidance materials included four main graphic resources, each aimed at a different audience and with slightly different intended purposes. This allowed each resource to be designed for specific intended users, as follows:

Phase 1 Human Centered EoR Implementation Process: Plan and Design
This graphic resource is a hybrid process chart and checklist, detailing some of the key activities that could be undertaken by facility managers and the NATCA facility representative (FACREP) to increase the likelihood of a successful EoR implementation. The Phase 1 process chart focuses on the planning and design elements of the project lifecycle and is geared towards foundational and preparatory activities. It includes some project planning and change management elements, where these were highlighted as relevant within the early adopter research. The resource provides suggested activities for the Air Traffic Manager (ATM), NATCA FACREP, Operational Manager (OM), Training Departments, Front Line Managers (FLMs), and Airspace & Procedures personnel (including managers and/or specialists). This graphic is not aimed at CPCs directly, but at the main management and bargaining unit roles within the facility supporting CPCs in making the transition to EoR operations. Text on the process chart emphasizes the foundational requirement of collaboration in order to achieve a successful implementation. Chart boxes are colored green to match relevant cards in the Air Traffic Control (ATC) Facility Toolkit for EoR Implementation.

Phase 2 Human Centered EoR Implementation Process: Implement and Sustain
This graphic resource is a hybrid process chart and checklist, detailing some of the key activities that could be undertaken by facility managers and the NATCA facility representative (FACREP) to increase the likelihood of a successful EoR implementation. The Phase 2 process chart focuses on implementation and sustainment elements of an EoR project. activities. It includes some project planning and change management elements, where these were highlighted as relevant within the early adopter research. The resource provides suggested activities for the ATM, NATCA FACREP, OM, Training Departments, FLMs, and Airspace & Procedures personnel (including managers and/or specialists). This graphic is not aimed at CPCs directly, but at the main management and bargaining unit roles within the facility who support CPCs in making the transition to EoR operations. Text on the process chart emphasizes the foundational requirement of collaboration in order to achieve a successful implementation. Chart boxes are colored blue to match relevant cards in the ATC Facility Toolkit for EoR Implementation.

ATC Facility Toolkit for EoR Implementation

This graphic resource is a deck of index-sized cards, including one cover card and a range of content cards. The content cards summarize key lessons learned and take-aways from the early adopter research in a portable and engaging format. Rather than requiring facility personnel to read a full research report, the cards aim to provide accessible and actionable hints and tips to support EoR implementation projects at facilities. Although all cards would be of some interest to most people within an air traffic control facility, the deck also provides an indication of which roles in a facility would find each card most useful, via the use of colored icons. Cards within this deck are color coded to indicate when the information might be most relevant or helpful to facilities:

- Purple cards contain information likely to be relevant throughout both Phases 1 and 2 of an EoR implementation project.
- Green cards contain information likely to be most relevant in Phase 1 of an EoR implementation project (per the Phase 1 Plan and Design Process Chart).
- Blue cards contain information likely to be most relevant in Phase 2 of an EoR implementation project (per the Phase 2 Implement and Sustain Process Chart).

Air Traffic Controller's EoR Journey Map

This resource is a journey map that explains some of the typical controller reactions to EoR procedures as they were introduced at the "early adopter" sites. The reactions and experiences included are essentially as described in the early adopter research, although these have been represented in the context of a change management journey and simplified for the purposes of the graphic. While the experience of every air traffic controller will be unique, the journey map illustrates some typical responses reported by controllers in becoming comfortable and confident in using EoR. The journey map also suggests some facility management actions that would support controllers through the transition, to increase the probability that a greater proportion of CPCs will eventually begin using EoR.

1.5. Validation approach

The initial suite of draft implementation materials was validated at a workshop held in Washington DC in March 2019. The initial versions were printed and laminated, before being reviewed by a group of Subject Matter Experts including:

- A PBN specialist with EoR experience, both as an airspace and procedures manager at a TRACON and as an implementation mentor for facilities adopting EoR operations. This attendee also had operational experience as an air traffic controller, including certifications at both air traffic control towers and approach radar control facilities;
- A human factors specialist familiar with the people aspects of introducing higher levels of automation and associated procedures and the human factors aspects of change management;
- A research consultant with experience in the engineering aspects of EoR, and with experience in managing phased implementations of new technology in an oceanic context;
- An operational air traffic controller with experience in facility implementation of EoR, who also had experience with supporting the air traffic controller bargaining unit with EoR, and who held a pilot's license;

- An engineer with experience in mentoring facilities through the EoR implementation process, and with a significant understanding of the programmatic challenges of introducing new technologies and new procedures into air traffic control facilities.

Based on the feedback obtained from the above workshop, the materials were further refined and adjusted, so that they were ready for further validation with operational staff at the third site visit.

2. METHOD

2.1. Aims of the Houston TRACON site visit

Stage II of this research required that the draft implementation guidance be validated at a third operational air traffic control facility. The facility selected for the validation site visit was Houston TRACON (I90), which was the third facility within the NAS to implement EoR operations with RNP-AR approaches. The EoR operation was deployed at Houston Intercontinental Airport in a duals and triples configuration. This was potentially different from the EoR implementations at Seattle and Denver, representing an opportunity to learn more about this type of implementation, as well as an opportunity to validate the draft human factors implementation guidance materials. Hence, there were two major aims for the site visit to Houston TRACON:

a) To explore I90's experience in implementing EoR within a duals and triples configuration, and to identify lessons learned from a human factors perspective;
b) To obtain feedback on the draft human factors implementation guidance from staff who had experience in implementing EoR operationally within air traffic control.

2.2. Conduct of the Houston TRACON site visit

A site briefing was provided to the facility team in advance, including the ATM and the NATCA Facility Representative. The briefing provided an opportunity for the facility team to review the requested interviewee list and sample interview questions and make suggestions for additions and improvements. Since all visits to an operational facility are dependent on operational demands and constraints, the facility was advised that the research team would be flexible to accommodate operational shift patterns as necessary. The facility team was also advised that interview data would remain non-attributable as far as possible, with personal identifiers removed from reported data.

A research team of two human factors specialists visited Houston TRACON May 28-30, 2019. On arrival at the facility, the research team was offered a tour of the operational floor, although it was not possible to view EoR operations or spend time monitoring a CPC. The NATCA NextGen representative (a former I90 controller) and the current NATCA FacRep provided an overview of the airspace and the complexities of the TRACON operation.

Interviews were conducted in an interview room near the operations floor. CPCs were made available for around twenty minutes to half an hour, by agreement with the FLM; non-operational staff were generally available for longer periods of time. All interviews followed the protocol that had been agreed upon in advance, with questions focused on the areas of interest. While it was acknowledged ahead of time that the relevant topics and questions would likely vary according to who was being interviewed, the researchers sought information related to the following topics:

- EoR planning and implementation (facility preparation);
- EoR impact on workload, controlling style and practices;
- Automation, trust and confidence;
- Operational challenges and benefits of EoR (likely to be facility specific);
- Training considerations (either expected or emergent);
- Supervision/management considerations and leadership support;
- Feedback on draft implementation guidance materials and suggested changes;
- Suggestions for best practical use of the implementation guidance materials;
- Lessons learned and suggestions for improvement with regards to EoR implementation.

For CPCs, background questions included how long they had been a controller, whether they had been a controller at other facilities (FAA or otherwise), which positions they currently worked, and whether they had experience of delivering on-the-job training at Houston TRACON. Because of the time constraints with each interviewee, and particularly with operational air traffic controllers, each interviewee was asked to provide feedback on one or two elements of the human factors implementation guidance, such as a process chart and/or a toolkit card.

2.3. Houston TRACON interviewees

Over the three-day period of the site visit, a total of twenty interviews were conducted with personnel from across the I90 operation and the local Operational Support Facility (OSF). These included interviews with:

- Eleven current CPCs;
- The NATCA NextGen representative (a former I90 controller);
- The current NATCA facility representative;
- The airspace & procedures support manager, who held a key role in the initial implementation of EoR approaches at Houston;
- Two front line supervisors, one of whom was also a support specialist in training;
- An airspace and procedures support specialist;
- A training specialist who helped to develop the initial EoR training at Houston;
- The training manager who also works as a quality assurance and control specialist;
- An OSF engineer who held a key role in developing the Converging Runway Display Aid (CRDA) adaptation for Houston TRACON.

One human factors specialist led all interviews, with the second specialist taking notes, and all interviews were conducted in the presence of the NATCA National NextGen Rep (also a former Houston TRACON CPC). Care was taken to note background data for each interviewee and the element(s) of the implementation guidance that they were asked to review and provide feedback on.

3. RESULTS & DISCUSSION

3.1. Structure of this section

The Houston site visit resulted in the conduct of twenty interviews; the focus here is on analysis of the interview data and discussion of the results. There were two main aims of the Houston site visit:

a) To explore I90's experience in implementing EoR within a duals and triples configuration, and to identify lessons learned from a human factors perspective;
b) To obtain feedback on the draft human factors implementation guidance from staff who have experience in implementing EoR operationally within air traffic control.

To address the first aim, it was decided to analyze the Houston interview data using the same framework developed and used to describe the success factors emerging from the Seattle and Denver interviews (Thomas, Serrato & Kirby, 2018), and shown again in Figure 3.

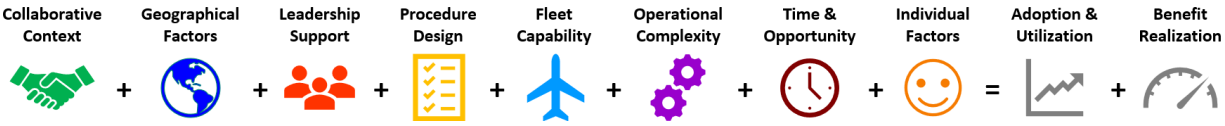

Figure 3: EoR success factors for EoR adoption, utilization and benefit realization

Following this discussion, the results section summarizes some of the key feedback on the implementation guidance. The aim is not to provide detail of editorial comments, but to summarize the feedback obtained by material/resource type, and to provide some suggestions for the best practical use of these materials from the perspective of management and staff at an operational air traffic control facility. Quotes from interview notes are also provided as illustrative examples.

3.2. EoR success factors in dual and triple simultaneous approaches

a. Collaborative context

As with the data obtained from interviews at Seattle and Denver, the collaborative context was also mentioned as being associated with successful implementation at Houston. This success factor is associated with having strong working relationships between various facility stakeholders, including management and the bargaining unit, as well as the facility having collaborative relationships – or at least the means to start building them – with external stakeholders. External stakeholders might include air traffic controllers at the airport air traffic control tower and the operational support facility (OSF), as well as airline or other operator contacts, airport representatives, local resident groups and other parties with an interest in the operation.

One quotation from someone involved with the EoR implementation at Houston spoke to the collaboration required between the bargaining unit and the facility management, as well as the collaboration needed between facilities and with airlines:

> *"It took five or six months from the kick-off meeting to the time we flew it. The SOP changes, so you need to collaborate with the local union reps on the local stuff… There are requirements that say for your SOPs, if this is where you want to put it, does it make sense to the workforce? We also had to work with the tower for LOA changes in order to do it, and the tower has to do the same collaboration with their groups – looking at impact and adverse effects…then when that's all said and done, we do an SRMP safety panel to look at it from another set of ideas, and bring in others who aren't part of the building process to poke holes and propose scenarios. And the technical pilots get with their union reps too." (MGR304)*

This sentiment was echoed in several interviews and did not simply refer to collaboration with the bargaining unit and with airline personnel. One participant commented on the collaboration between OSF staff at different facilities in helping with the CRDA tool used to support controller decision making for EoR at Houston. The sharing of experiences between adaptation specialists has been a significant factor in the expansion of the use of CRDA for RNP-AR approaches at several facilities. In addition, the importance of engaging stakeholders and ensuring that operator requests are considered was also highlighted in the following quotation:

> *"The airline… wanted to create an agreement that let them turn and descend at a certain point – earlier than the others – but that point wasn't in our airspace. If we don't build it the way they want it, they won't use it. But if you don't create it, then they can't use it either…."* (CPC318)

In the instance discussed in this interview, it was not possible for the facility to accommodate the request from the operator; nevertheless, the quotation highlights the necessity of dialogue and a willingness to consider stakeholder perspectives.

b. Geographical factors

Compatible with the results from Seattle and Denver, interviewees at Houston TRACON also discussed geographical factors impacting on facility use of EoR approaches. The factors raised within this category at Houston did not include the residential noise restrictions discussed at Seattle. Although there are noise abatement procedures at Houston, they were not cited within the context of EoR operations. Similarly, the proximity of mountains (cited at Denver) was not a factor evident within the data from interviews at Houston. The geographical factors mentioned at Houston TRACON included the interactions with another local airport (David Wayne Hooks Memorial Airport) and restrictions which were based on runway use and location.

Regarding the runways, the interview data suggested that having additional RNP-AR approaches approved for use within the EoR operation would enable them to be used more frequently, particularly regarding runway 08L:

> *"Originally it was on 26R to come down quicker on the downwind, and 8L wasn't as much of a benefit because of Hooks. Now that duals and triples on simultaneous are allowed, if we had the*

EoR for 8L it would save half the flying miles – the difference between flying the EoR on 26R versus the ILS is about a 32-mile saving." (CPC317)

"We use them as often as we can, as often as we can as long as we're landing that runway and the equipage meets the requirements. But, the runways we have them to are the two least desired runways. If we had them on the other outboard runways our numbers would triple." (CPC302)

The interaction with traffic from another airport in the vicinity was a factor at Houston, as was also the case at Seattle:

"Compared to say, Chicago and Atlanta, how congested is this airspace? Compatible with Chicago, we have two major airports. Yes, they do more volume, but for us the congestion is because the two airports are in close proximity, which adds to the complexity." (MGR304)

Geographical factors are clearly a consideration in procedure design; they also impact the way that RNP-AR procedures are used by controllers within the EoR operation.

c. Leadership support

At both Seattle and Denver TRACONs, interviewees discussed the importance of leadership support in achieving a successful implementation of EoR operations (Thomas, Serrato & Kirby, 2018). This group of success factors includes the multiple ways that leaders provide the time and resources necessary to reach successful procedure design solutions and plan a managed and progressive implementation. This category includes ongoing reinforcement, including encouraging air traffic controllers and pilots to use the new procedure. Leadership support was also cited at Houston as being a driver of EoR use. Sometimes this was positive – one of the FLMs interviewed also worked within training and said:

"The hard part is the group of folks reluctant to do it…. it's up to the supervisor to help promote that." (MGR306)

Conversely, there was also the view that support from FLMs was not the appropriate level of leadership support, since without having operational experience their ability to influence CPCs was limited:

"Supervisors don't necessarily know or have worked the actual procedures that they are advising on. Supervisors didn't plug in… they didn't try to understand the operational mix and making it happen… You have to provide ongoing training and coaching – but some controllers don't respect the supervisors and their encouragement because they haven't done it… Support is important to feel appreciated and supported, but it would be more credible if it was coming from a SME or team lead." (CPC309)

Anecdotally, the issue of supervisor credibility is often described as an element of operational culture in air traffic control. It can be very difficult for a supervisor to gain respect and influence without first having become certified and experienced on the positions they supervise. In many cases, leadership encouragement to try something new may be provided by a more experienced controller, or someone whose controlling techniques and style are well respected on the operations floor. Another quotation from Houston supports this idea, suggesting that support, encouragement or "peer pressure" from colleagues might be a more powerful influence on whether a controller would decide to try the EoR approaches:

"I think there were some people that were afraid of it which made them timid, so they didn't want to do it. Some used the EoRs through peer pressure, or hearing others saying 'it's not so bad'…" (CPC309)

As experts, controllers tend to trust their own professional judgement and experience above the judgement and experience of others, since they are responsible for the aircraft in their own airspace. The exceptions tend to be where another controller is very highly experienced and/or has gained a reputation for expertise with a specific type of event or operational challenge.

d. Procedure design

There was less concern reported at Houston regarding the design of the RNP-AR procedures, compared to the interview data obtained at Seattle and Denver. At both of those "early adopter" facilities, there was a greater level of discussion about the procedures that were approved for use within the EoR operation, and how they were designed. At Houston, the interview data did not focus so much on the procedure design process; most of the feedback was associated with the way that the procedures were flown. As at Denver, there were reports that pilots had "hand-flown" the RNP-AR approaches:

"There's a disconnect between the creators at the FAA HQ, and controllers, and pilots and users. We need more honesty and transparency. The airline pilots shouldn't have been hand flying the Yankee[3] procedures - how did that happen? Joint training would be helpful - every pilot in the NAS should spend time in an air traffic control facility." (CPC316)

Controller reports of pilots "hand-flying" cannot be corroborated retrospectively with actual flight data; however, there are at least two possible explanations for controllers reporting that pilots sometimes "hand-fly" these approaches. The approach plates for RNP-AR approaches generally require that these procedures are flown with Autopilot (AP) or Flight Director (FD). AP means that that the aircraft is being flown by the on-board systems; this generally allows for a smoother and more accurate flight trajectory than can be achieved by human manipulation. FD means that the pilots are flying the aircraft with "flight director" guidance on the primary flight displays; there is variation both within and between pilots in their ability to smoothly and closely follow the flight director guidance. Hence, it is possible that appearance of "hand-flying" on the radar may occur even where pilots are following the published guidance and flying the procedure with FD. A second possibility for controllers reporting "hand-flying" is that the pilots are attempting to hand-fly (without FD) a disconnect between two route segments. For example, disconnects sometimes occur between arrival and approach routes. It can take several minutes for pilots to link these segments manually on the Flight Management System (FMS), so the disconnected portion may be hand-flown without FD guidance. Either way, the perception among controllers that a part of the approach is being "hand-flown" impacts their trust and confidence that the aircraft will remain on the pre-defined approach procedure.

[3] The RNP-AR approaches used at Houston are known within the facility as "RNP Yankees" or "Yankees". At Seattle, these are known as "Mikes" and at Denver as "Zulus" These terms are based on the approach plate labels; the lack of consistent terminology for referring to these approaches may become a wider issue as EoR operations are deployed more widely across the National Airspace System.

This is an area where the different terminology between air traffic and control and the flight deck potentially could create a barrier of understanding. Air traffic controllers typically refer to the RNP-AR approaches used within EoR operations by the approach plate label – informally the Yankee, Mike or Zulu, or more formally referring to the RNAV Yankee, RNAV Mike or RNAV Zulu. Sometimes controllers will offer pilots "the curved approach", but they do not generally use the term "EoR". It may support EoR implementation at air traffic control facilities to request that pilots fly RNP-AR approaches within EoR operations using only AP. However, the challenge for airlines and operators is that pilots do not know when a specific RNP-AR approach is being assigned and cleared within an EoR operation.

Another issue identified at Houston that falls within the broad category of "procedure design" was associated with the speeds listed on the approach charts. Some controllers questioned whether a specific charted speed was useful, or whether a maximum speed would be more useful (so long as they also considered aircraft performance characteristics):

> *"We have a 210 max charted speed on ours, but that's it…. I don't feel the need to have a charted speed, a maximum speed is good – we can always go slower. Why wouldn't I slow the guy way out from the airport to 170 if that speed allows me to give him that arc with half the distance and less speed? Slow them down and it will work all day long."* (CPC 318)

Providing a maximum speed allows air traffic controllers to use speed control proactively to manage a sequence, particularly with regards to managing compression (Thomas, Serrato & Kirby, 2018).

The final procedure design issue evident within the Houston data was the way that aircraft converge at associated fixes on parallel runways at the same altitude. This type of operation relies on RNAV capabilities functioning as planned, to ensure that the aircraft on the RNP approach under EoR operations maintains separation. Although the safety analyses associated with EoR operations concluded that this met the target level of safety for collision risk (Walls et al, 2016), qualitatively these operations feel unusual or even uncomfortable for controllers:

> *"Aircraft are converging at the exact same altitude which is not what controllers are used to doing. What if the pilots miss the arc, what are the mitigation steps? They're turning and descending too – that makes it more difficult."* (CPC308)

> *"People are nervous with the altitudes. If they were staggered a little bit at least with the adjacent runways it would help - or adjust them so the altitudes aren't the same. Some of the blunders that we've seen, if we'd had a staggered approach, we'd have had an extra few seconds to respond and correct."* (CPC310)

Controllers spend their professional lives identifying and addressing opportunities where aircraft that are intended to remain separated might get too close; it is understandable that this reported issue may be associated with a reluctance to use EoR operations until the technology has been proven to the satisfaction of individual controllers.

e. Fleet capability

Fleet capability was identified as a key concern at both Seattle and Denver TRACONs. Houston also raised this as a concern, since controllers are sequencing aircraft on conventional and RNP approaches. Managing this mix is analogous to "mode-switching", in that controllers need to adeptly switch their expectations, decisions and actions between aircraft to manage a mixed sequence. This is likely to remain an issue until conventional approaches become "the exception". Until then, successful implementation of EoR operations requires careful planning to support controllers in mitigating the workload changes associated with switching between conventional and RNP approaches.

> *"Well, with a different fleet mix, with mixed abilities, and different winds, it changes it all. If all of the equipped aircraft could line up it would be great…."* (CPC316)

While fleet capability will likely remain an issue unless non-RNP equipped aircraft become a minority proportion of the fleet at any given facility, this is not always regarded by controllers as a negative factor; some controllers relish the challenge this provides:

> *"Here we have a blend of traffic, so it is different. If all we did was EoRs, it wouldn't be very fun. It would be very easy, and I wouldn't feel like I'm earning my money - that eliminates the whole point of me being there. The challenge of the variety is enjoyable."* (CPCP308)

Controllers at Houston also acknowledged that this issue is probably specific to each operation and each facility, since it depends on the routes and the way that these are worked:

> *"Blending – we don't blend fast and slow – we don't really do that here. I can see that being an issue at other airports though."* (CPC318)

The queue-jumping perception that was mentioned at Denver TRACON was also mentioned at Houston TRACON. This relates to perceptions of fairness in that some controllers may view the RNP approach to be taking something of a "short-cut" through a planned sequence:

> *"I tell the feeder to give anyone capable of the RNAV the approach, and I'll take it. In the beginning, slowing aircraft on the downwind for it was something I had to learn, and then also to extend the guy in front a little further for that RNAV Y aircraft. It took some getting used to. But the #1 isn't really the #1 in the line, the RNAVs come in as part of that sequence. What's 20-24 miles for one aircraft if you're getting two RNAVs in before he comes back, and he had to head out 20 miles anyway?"* (CPC315)

Controllers generally pride themselves on delivering a fair and professional service as well as a safe and expeditious one. It is perhaps not surprising that a perception of RNAV aircraft "queue-jumping" may be associated with a reluctance to use RNP-AR approaches within EoR operations. At Denver, controllers who used RNP-AR within EoR operations had devised their own term for this, saying that they "cartwheeled" an RNAV equipped aircraft into an available slot within the planned sequence, rather than breaking or significantly altering a planned line-up (Thomas, Serrato & Kirby, 2018).

f. Operational complexity

Operational complexity refers to the factors that make each air traffic control facility unique: this could include quirks of airspace design, the traffic complexity, mix or volume, or the operational tempo. Every air traffic control facility has a unique combination of factors that drive complexity, and each controller experiences operational complexity in different ways. While often associated with subjective workload, operational complexity and controller workload are not synonymous. A successful implementation of EoR requires that the project be tailored to each operational context: a "one-size-fits-all" approach is not likely to be successful.

> *"Here we have a lot of wind at different altitudes that creates a lot of different situations. The downwind here can speed up and then it slows them on the turn in."* (CPC302)

As at Denver TRACON, proactive speed control was reported as one of the key methods for managing compression to support increased use of EoR approaches:

> *"As the final controller, you manage the speeds of the EoR and the RF leg. You can slow them down to whatever you need to do to make it work all the way to the Final Approach Fix, 5 miles from the runway. So, it's very good to learn as the final controller what you have to do to deal with the wind, compression, and the higher than standard Final Approach speeds…."* (CPC318)

Speed control is essentially the only tool available to air traffic controllers when managing an RNP-AR approach within an EoR operation. Controllers are unable to vector the aircraft because it is on a pre-defined approach path, and they also are unable to change the altitude if the aircraft is to remain on the RNP-AR procedure. Proactive speed control is key:

> *"I tell the feeder, give me any RNAV capable aircraft, assign it and I will decide if I'm going to issue it. I know how many miles I need – I look out farther on my range than other controllers because I want to see them. In order to make these approaches work, you have to get them slowed down reference the straight-in – reducing their speed sooner than published if I can save twenty or thirty miles in flight distance it is small price to pay…"* (CPC318)

At Houston, another source of complexity was the need to use Final Monitor controllers to monitor the no-transgression zone. A couple of quotations illustrate the operational perspective on Final Monitors with regards to EoR operations:

> *"They join at the same altitude at the same point which makes your job as a monitor more stressful. It's everything you're taught not to do - and we're watching it happen. If there's a monitor position – be ready and proactive to prevent a midair on the final. You can't just assume it will work."* (CPC319)

> *"I don't like it being the Final Monitors job to fix it and take evasive action. Where do you go, what do you do? You're relying on someone on the other side of the room to make the decision. I don't think we need final monitors - period. If these approaches are deemed safe by the FAA to be run in that configuration, why do I need to switch the guy on the downwind to the tower frequency for a guy that is pointed away from the airport?"* (CPC316)

The first quotation illustrates that the having aircraft converge on fixes to parallel runways at the same altitude may be a source of stress for the Final Monitor controller; this issue intersects with the procedure design points discussed in an earlier section of this report.

g. Time and opportunity

In any change initiative, having insufficient time and opportunity to try something new is considered a potential barrier to success. As with Denver TRACON, controllers at Houston reported using EoR when they had been given the time and opportunity to become comfortable with this type of operation. One of the factors includes within this category is having a phased and gradual implementation approach:

> *"It was implemented well here. We started with widely spaced parallels in visual conditions only. Then the whole facility had training on it, we got people back in the labs, we trained the ghost targets…"* (CPC312)

A gradual or progressive introduction allows controllers to become comfortable with the EoR operation in less demanding operational conditions. For example, RNP-AR approaches may initially be made available for EoR operations in visual conditions only, during off-peak traffic periods, or on a dedicated runway. These factors are context-dependent, and so the degree to which a phased implementation can be achieved, and how to achieve it, will vary for each facility.

Another important driver of a successful implementation is the use of an adaptation to CRDA, since this enables controllers to identify potential opportunities to use RNP-AR as they are on position. At Houston, there was a local adaptation to the CRDA led by an engineer at the Operational Support Facility (OSF), as there had been at Denver. The engineer responsible for leading the I90 adaptation had benefited from the lessons learned at Denver, and it is known that there had been some dialogue between facilities to share experiences and lessons learned. This is also evidenced by the engineer's discussion of how he accomplished the adaptation:

> *"You have to find out from the facility - how far back do you want to start the ghost? We said originally 40 miles out on final. I have to build the boxes out 40 miles, and then get the boxes out on the actual, and they all have to mirror each other. So, if I have 5 boxes on the actual approach and then 5 on the ghost approach, they have to reflect each other. They have to meet-up exactly as it moves from one box to the other – it has to be perfect. If it isn't, you lose the target, or you duplicate the target."* (OSF311)

Communicating with other facilities is known to be an effective way to share lessons learned on specific design and adaptation solutions (e.g. Spencer, Smith, Durham & Evans, 2015). However, there were some initial hiccups reported with the CRDA adaptation at I90, and some questions about how controllers could best remember the keystrokes to turn CRDA on and off:

> *"It would show on one runway and then jump to another runway… but since then, it has been pretty accurate. We start picking up the ghost target 30 or 35 miles out."* (CPC312)

> *"Use of the ghost targets has helped considerably and helped the transitions… Why can't it just be turned on all the time? It should also be on the feeder's scopes as well…. And if you need to learn the keystrokes for enabling the ghost targets - know it."* (CPC307)

At Denver TRACON, macros were programed to allow CRDA to be turned on and off from the TMU with every runway change. The Denver OSF was co-located with the TRACON, which meant that collating and actioning controller feedback was easier than at Houston. Nevertheless, reports from Houston acknowledged the value of using CRDA based on the innovation developed by Denver OSF, and appreciated the positive impact that the CRDA adaptation had on the EoR implementation at the facility:

> *"If you don't have CRDA – no ghost targets – that is crazy. It is inefficient to do it that way. Make sure you have CRDA available for RNP at your facility. We would not have rolled out RNPs here without CRDA. That would have been a showstopper." (CPC312)*

The data from Houston supports the earlier findings of this research that CRDA is a valuable decision support tool (Thomas, Serrato & Kirby 2018). The adaption created initially at Denver to support their EoR operation has been shown to assist terminal controllers at other facilities in making decisions about whether and how an RNAV approach can be integrated into their planned sequence. To capitalize on this, there may be ways to improve communication and lesson learning between engineers at Operational Support Facilities who assist facilities with EoR implementations.

h. Individual differences

This category refers to individual differences between controllers that may influence the uptake of EoR, including factors such as teamwork, experience and confidence. Some controllers are more open to trying new techniques, while others prefer to continue with tried and tested methods. Trust in automation is known to be a key consideration when experts are asked to adopt a new technology (for example, Lee & See, 2004). However, this is by no means the only factor, and a range of individual differences were evident within the interview data from Houston TRACON.

The following quotation gives a flavor of the teamwork considerations that influence controllers within EoR operations:

> *"I solicit them as the feeder for the final controller… I'm a big proponent of giving the final controller a lot of options. If the final controller can't do it – then fine, but if he wants to do it and has a slot for that airplane and I don't do it, the final controller has to scramble, solicit the pilot, reload, brief, and approve. They can always fall back on the ILS – if they don't get the RNP, they're going for a ride. For any pilot that is wishy washy, I tell them it will save you 25 miles plus."* (CPC318)

With feeder controllers assigning RNP-AR approaches and final controllers issuing clearances, there is clearly the potential for different team combinations to influence into the probability of whether a given aircraft will be cleared on the RNP-AR approach. In addition, individual controllers have different personal tolerances for trying something new:

> *"If you don't do it you will never get comfortable. I just did them. I decided that I was going to do it and get comfortable."* (CPC318)

> *"Change is hard for controllers, it's so hard to see the aircraft get close together when we've always kept them apart. It's about changing the workforce mentality, trusting that the*

equipment will work like it is supposed to, and that the pilots will be the professionals we know them to be, and that they will push the right buttons." (CPC303)

A willingness to learn and develop skills in a new controlling method was also mentioned by controllers at Houston. Controllers take their professional responsibilities extremely seriously and are reluctant to try something that, in their professional judgement, may introduce a level of risk beyond their personal confidence level:

> *"Be patient, watch whether it's going to work - and if it doesn't work, know your outs. If you really have to question whether or not it will work, don't do it. Don't introduce risk to the system."* (CPC315)

> *"It's a matter of seeing the speeds and what is compatible, and what does and doesn't work. You learn a lot when something doesn't work. If we weren't one of the first facilities it would be strange to see only one time that it did not work, especially when they started the curve and screwed it up. The biggest benefit was being able to see the ones that didn't work out and figuring out what sequences didn't work."* (CPC308)

These quotations illustrate the value in sharing experiences of using RNP-AR approaches within EoR operations between facilities, and in ensuring that CPCs are well-prepared for the operational implementation of the EoR concept, and understand how EoR operations may impact on their own professional practices.

3.3. Feedback on human factors implementation guidance materials

This section of the results includes quotations that provide feedback on the human factors implementation guidance materials that were validated at Houston TRACON during the site visit. Questions relating to these materials were posed towards the end of each interview; typically, each interviewee provided comments on only one or two items. This ensured that feedback was obtained on all materials, although typically only from one or two interviewees. Hence, there is a limited quantity of data available, and little convergence in the comments overall.

Encouragingly, much of the feedback on the materials was focused on minor editorial changes, such as changes to formatting or font size. Some feedback also mentioned design principles that had been deployed in developing the materials – such as the use of visuals and graphics and using real-world examples and anecdotes as much as possible. The discussion in this section is therefore not intended as a complete list of comments, but instead aims to provide insights into the range of feedback received from controllers and other personnel at the facility. The quotations selected are those that provide most use in terms of enhancing, deploying, or supplementing the human factors guidance materials, rather than providing details on more superficial or surface elements of the guidance. Suggested changes to the materials have been made where appropriate, and the versions contained within this report reflect this validation feedback.

a. Phase 1 & 2 Human-Centered EoR Implementation Process

These two graphic resources are both hybrid process charts and checklists, detailing some suggested activities that would be undertaken by facility managers and the NATCA facility representative (FACREP) to increase the

likelihood of a successful EoR implementation. The first chart/checklist (Phase 1) describes activities associated with the "plan and design" phases of an EoR implementation project. The second (Phase 2) addresses activities associated with implementing and sustaining the EoR operation, to increase adoption, utilization and benefit realization. These two charts/checklists are intended to be used together as tools for facility leadership – including bargaining unit leadership – to assist in achieving as smooth an implementation as possible. Feedback on the hybrid process charts/checklists included the following:

> *"These are good for facility leadership, but not for controllers." (CPC320)*

This comment was made by a controller and probably reflects that the intended audience for these materials is the facility leadership team.

An additional comment focused on the need to maintain positive comments about the EoR implementation project, referring to the need for leadership to be "change champions":

> *"You have to be positive, especially with NATCA - the more positive and encouraging will do a lot for your own facility implementation. You have to keep to the project timeline… we'd do it to every runway if we could. It has to be sustainable… you start with who you can start with, staffing wise – whatever crew is available. And you will always have people who will love it or hate it."* (CPC303)

A further comment addressed the need – highlighted within the Phase 2 process chart – to monitor the EoR operation once implemented:

> *"If we have an EoR that strays we want to know about it. Although we don't always know about it, but we want to. We don't track internally how many are not successful, even if controllers report it through it ATSAP. We have no real process for full-circle communications of when something failed and why, so that everyone can learn. Nobody wants to deviate a pilot, so instead of going down that road it doesn't get reported. But, having the information would help in the future."* (CPC303)

This is an important element of lesson learning – to find out what hasn't worked, and why, and share those lessons within not just the facility implementing EoR operations, but with other facilities who may be considering introducing this type of operation.

These were the most significant comments on the process charts, suggesting that most of the content material was appropriate and potential useful for the intended audience. The current versions of these process chart/checklists, incorporating appropriate changes following both the validation workshop held in Washington DC and the Houston site visit, are available in Annex A and Annex B. It is anticipated that facilities will use these resources as a starting point; the materials may be edited as desired.

b. ATC Facility Toolkit for EoR Implementation

This implementation guidance resource is a deck of index-sized cards, including one cover card and a range of content cards. The content cards summarize key lessons learned and take-aways from the early adopter research, aiming to provide accessible and actionable hints and tips to support EoR implementation projects.

The cards were validated by showing one or two to each interviewee and asking for feedback; there is limited data on each individual card. However, feedback on the cards overall suggested that the materials contained appropriate content, were appropriate to the intended audience, and would be a useful resource to facilities. Illustrative comments on specific cards included the following comments (the card the quotation refers to is also detailed).

> *"I agree with everything said. The ghost targets look faster - the winds aren't the same because the ghost isn't a real plane. CRDA not accounting for winds would be common sense… but maybe some others don't understand that."* (CPC313 talking about the CRDA Toolkit Card)
>
> *"SPLAT-T is very useful but sometimes you can just eyeball it. There's a feel to eyeballing it, you can sometimes extrapolate the relationships between all the aircraft. Other times it's really complex. Yes, the information is valuable. Maybe put less writing on the reverse side and maybe have more pictures? Maybe use one quote instead of two and make it fun. As to how to use… you could incorporate this into training and have it as a discussion tool. This would be great in training team meetings with the OJTI, the supervisor, the trainee and maybe some and additional OJTIs in the room as well."* (CPC309 talking about the Decision Support Toolkit Card).
>
> *"All of this is beneficial. Most controllers want to know the basics of the techniques of what works and what doesn't. I like to see the different techniques so I can use them to do better when I have the situation."* (CPC316 on Controlling Techniques Toolkit Card)
>
> *"Watching recordings of things that went wrong, displaying the videos and the circumstances of what you need to look for and this is what happened. Videos of the lessons learned are extremely beneficial. If you can get a heads up of what is to come or what to watch for future facilities. Showing the highlight reel is the best. All the information can then be turned into a technique that works for them personally."* (CPC316 on Controlling Techniques Toolkit Card).
>
> *"Don't just show me a simulation, show me someplace real, with real controllers, with real planes and what is happening… then they'll start to come around. I would say repetition is probably the best thing – have them do it over and over and over. That last bullet – this is a BIG DEAL. Bring a pilot in from the main carrier if nothing else, just to observe and take it back and train their side. Don't shortchange the training. Bring in the pilots."* (CPC314 on the Training Index Card)
>
> *"This HOV is kind of like we do with runway 9. I don't necessarily agree that a single dedicated runway is good unless you have an extremely high fleet mix that will be able to do the approach, and then the non-equipped approach can go to other runways. I agree with speed control! You have to be proactive, you can't wait – I agree with this all, as it is. Trust the ghost target! Trust the technology of the arc!"* (CPC318 on the Controlling Techniques Card)
>
> *"Anything outside of just telling someone something is a good idea. They'll read and not know what something means, but if it is short and quick, they will easily digest it and ask a question. You could leave this on the deck or do a team brief. Every third day at the end of the day you do a crew brief, and you could use this. Or in refresher training and safety training, or as a hot topic for an hour. This would be a great way to share information and open the eyes for those that don't use this or aren't as familiar."* (CPC315 on the Fight Deck Considerations Index Card)

"I agree with almost everything on this one. The idea of a runway being used just for EoR is a good idea, but that requires a lot of coordination to the point that it would even be needed at an en route level to get them all lined up." (CPC310 on the Controlling Techniques Index Card)

Taken together, most of the substantive comments relating to content were generated by the cards that might be of most interest to CPCs; this is not surprising given that many interviewees were operational controllers. The feedback generally appears to indicate that the cards are a useful starting point for facilities to begin preparing for an EoR implementation. The material on the cards may have value in preparing briefings and training for operational controllers. It is also evident that printed implementation guidance is unlikely to be sufficient to persuade controllers that RNP-AR approaches can be used effectively within EoR operations. It is known that CPCs relate well to being shown how EoR works "on the glass " – so videos, radar replays and other dynamic resources are likely to be of great value in supporting controllers with using RNAV approaches in EoR operations. This is demonstrated in the following quotation:

"There is not a good video that represents the pilot's perspective, cutting out the "dead" time between actions in sequence. You could have a video that shows a split-screen with the flight deck, and the gauges and what the pilots might see out of the window. Or one with a chart and video. Show what they do when they are told to expect the RNAV to runway 9 approach, show them typing it into the FMS and how long it takes. That would help controllers to understand that side of it. Add transmissions and actions that occurred. Have an overlay of what is on the glass with STARS. If someone was good at this kind of thing, they could simulate this and create the airplane flying in." (MGR306)

The current versions of the ATC Facility Toolkit for EoR Implementation, incorporating appropriate changes following the validation workshop held in Washington DC and the Houston site visit, is available in Annex C. This toolkit is a suite of index cards containing content tailored to specific facility roles; it is anticipated that facilities would use these as a starting point and edit the materials as needed.

c. Air Traffic Controller's EoR Journey Map

This implementation guidance resource is a visual representation of a "journey" explaining some typical controller reactions to EoR operations as RNP-AR procedures were implemented at the "early adopter" sites. The reactions included in the map are essentially as described in the early adopter research, although these have been represented in the context of a change management process and simplified for the purposes of the graphic. This resource was validated with a small number of interviewees during the Houston site visit, and the feedback from one interviewee was very encouraging:

"This is dead-on!" (CPC313)

As well as helping CPCs to recognize some common responses to new procedures, the journey map could also be used by the training department to brief, train and support controllers with the changes associated with EoR implementation.

"In the training department, this would help… this journey map would be very helpful that they could put into a PowerPoint about developing EoR procedures… for messaging the benefits to

you as controllers and users. To put this in front of controllers might be too busy, but it's good information, and the flow works…. It is short, sweet and to the point - What am I doing? How is the effecting my job? Why? That is what they care about. You can preach about "why" … shorter flight times, less emissions… but really controllers want to know 'how does this effect my job' and 'why are you making me do this'? So that is what this journey map is" (MGR304)

While the experience of every air traffic controller will be unique, the journey map illustrates some typical experiences reported by controllers in becoming comfortable and confident in using EoR. The journey map also suggests some facility management actions that would support controllers through the transition, to increase the probability that a greater proportion of CPCs will eventually begin using EoR. There is also a potential use for this resource in communicating to individuals without an operational background about possible controller responses to EoR/RNAV projects. For example, project managers, pilots, airport authorities and others may find the insights on the journey map useful. The current version of the journey map, incorporating appropriate changes following the validation workshop and the Houston site visit, is available in Annex D. Personnel at operational air traffic control facilities are free to edit this journey map as desired for their own use.

4. CONCLUDING REMARKS

The aims of the Houston TRACON site visit were to explore the experience of facility personnel in implementing EoR operations within a duals and triples configuration, to identify lessons learned from a human factors perspective; and to obtain feedback on draft human factors implementation guidance from staff who have experience in implementing EoR operationally within air traffic control. The site visit afforded the research team an opportunity to conduct twenty interviews with facility personnel, including eleven certified professional controllers (CPCs).

Analysis of the interview data using the framework of "success factors" that emerged from the interview data collected at Seattle and Denver showed that this framework has value for considering the drivers of controller adoption and utilization of RNP-AR procedures within EoR operations. The acceptance of certified professional controllers is important, because without controllers consistently assigning and clearing RNP-AR approaches, overall adoption and benefit realization will remain low.

The Houston site visit allowed the research team to gain feedback on the draft human factors implementation guidance that had been developed based on the interviews conducted at the Seattle and the Denver site visits. These materials were updated and revised based on feedback from the Houston site visit, and the current versions are contained in the annexes to this report. The materials included within each annex are not "final" versions; facilities are encouraged to adapt them for use within their own EoR implementation projects.

The implementation guidance materials were developed via an iterative process employing human factors, user-centered design and visual communication methods. A set of "design principles" guided the development of these materials. This approach ensured that air traffic controllers – as "end-users" – were placed at the heart of the EoR change management considerations. The guidance materials are directed at increasing the use of EoR among this specific user-group; different user groups may be best served by different guidance materials. These materials may not transfer readily to other user groups – such as line pilots or procedure designers - without additional development work being undertaken.

The human factors implementation guidance included within this report was developed and validated based on "lessons learned" from three "early adopter" sites within the National Airspace System. These included Seattle (dependent simultaneous approaches), Denver (widely spaced simultaneous approaches) and Houston (duals and triples). Each of these facilities implemented EoR operations based on RNP-AR approaches that consider an aircraft to be established on its approach while downwind of the airport, prior to turning inbound and aligning with the extended runway center line for landing. These materials may not transfer readily to other forms of RNAV approaches, or to other types of simultaneous operations, without additional development work being undertaken.

The human factors implementation guidance materials included within this report were validated via an interview-based protocol. Higher quality data could be obtained by assessing the utility of these materials at a key-site where they could be used "live" within EoR planning and implementation; feedback from future EoR implementation projects would support their continued development.

As more facilities adopt EoR procedures in different configurations, and more experience is gained within the NAS in managing the behavioral and cultural shifts in the way that controllers manage air traffic, it would be

valuable to continue to collate lessons learned and revise and update the guidance provided to facilities. Effective deployment of advanced procedures and technologies requires careful monitoring to ensure that best practices are identified, and operational experiences are shared. This is especially important as the responsibility for new technologies transitions within the FAA, from concept validation, research and development, into deployment, implementation and operational use.

5. REFERENCES

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Human-Centered EoR Implementation Process

Planning a phased and structured project around controller needs is the key to the successful implementation of EoR procedures. This process chart highlights some of the suggested activities to be undertaken by facility leadership and staff during planning and design of the project. It is assumed that the bargaining unit will be involved throughout as a major stakeholder, since collaboration is the foundation of successful EoR implementation.

Phase 1: Plan & Design

Air Traffic Manager

- ☐ Establish EoR team to work on EoR project and include key stakeholders.
- ☐ Coordinate with regional management team.
- ☐ Attend initial EoR team meetings and request regular briefings and progress updates.
- ☐ Network with other facility ATMs and learn from their RNAV/EoR experiences.
- ☐ Balance your facility's commitment to EoR with other projects to avoid overloading key staff.

NATCA Facility Rep

- ☐ Coordinate with NATCA at national level to provide leadership within facility.
- ☐ Provide leadership to EoR team ensuring that CPC concerns are represented.
- ☐ Appoint designees as required to ensure CPC representation in planning, meetings & activities.
- ☐ Ensure CPC views are considered throughout - and especially in training and decision support*.
- ☐ Network to stay up-to-date on RNAV/EoR issues.

Operational Manager

- ☐ Where possible, prioritize resources and staff for EoR activities, including briefings, team meetings, and user trials of decision support tools.
- ☐ Consider the best times to introduce EoR in "baby steps", so that the new techniques are initially used in lower demand and lower traffic situations*.
- ☐ Consider segregating EoR operations to begin with where possible (e.g. having an EoR dedicated runway at certain times)*.

Training Departments

- ☐ Develop visually engaging interactive CPC briefings to provide awareness of EoR, and include radar replays and facility success stories*.
- ☐ Use video clips of CPCs who have done EoR to provide operational controlling hints and tips.
- ☐ Develop EoR training that includes practical simulation scenarios**.
- ☐ Consider conducting joint simulation training with airline partners where geographically feasible.

Front Line Manager

- ☐ Release CPCs for EoR implementation team activities.
- ☐ Set the stage by talking positively about EoR to CPCs on your sector.
- ☐ Report on controller feedback/perceptions to Airspace & Procedures.
- ☐ Be positive and supportive of trials of decision support tools, and trust the EoR implementation team to address any issues.

Airspace & Procedures

- ☐ Lead facility EoR team.
- ☐ Conduct assessments & analyses for EoR project*
- ☐ Develop EoR project work plan and timeline.
- ☐ Keep in regular contact with stakeholders throughout the process.
- ☐ Lead procedure design process in accordance with FAA guidance**.

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What do the symbols mean?

* Indicates that a csupporting resource is available within the HF implementation guidance.
** Indicates that an FAA procedure or process supports this activity.

Human-Centered EoR Implementation Process

Planning a phased and structured project around controller needs is the key to the successful implementation of EoR procedures. This process chart highlights some of the suggested activities to be undertaken by facility leadership and staff to implement and sustain use of EoR procedures. It is assumed that the bargaining unit is involved throughout as a major stakeholder, since collaboration is the foundation of successful EoR implementation.

Phase 2: Implement & Sustain

Air Traffic Manager

- ☐ Show your support for the EoR team by providing encouragement and resources.
- ☐ Manage stakeholder relationships*
- ☐ Limit the number of projects within the facility while EoR project work is underway.
- ☐ Encourage your management team to be positive about EoR and the value it will bring to your operation.

NATCA Facility Rep

- ☐ Coordinate with NATCA at national level to provide facility leadership.
- ☐ Consider how to plan a phased implementation, so that CPCs can adjust progressively to EoR*.
- ☐ Network with other facilities to ensure EoR lessons learned are captured, shared and used.
- ☐ Actively seek feedback on project progress, so that issues can be identified early and mitigated or resolved appropriately.

Operational Manager

- ☐ Continue to prioritize releasing staff for EoR related briefings and training.
- ☐ Work with the training support manager to release OJTIs for sessions to discuss how EoR might impact the way that live training is conducted on the floor in EoR operations.
- ☐ Encourage FLMs to maintain positive reinforcement when CPCs use EoR methods.

Training Departments

- ☐ Deliver training, starting with the most capable and adaptable CPCs of varying experience levels.
- ☐ Design & provide training on a variety of support tools such as tie-points and CRDA (if using)**.
- ☐ Consider differences between the certified CPCs and new hire training needs.
- ☐ Provide guidance to contract instructors on training new staff (including integrating EoR into existing approach course materials).

Front Line Manager

- ☐ Release CPCs for EoR team implementation.
- ☐ Ensure that new trainees are trained by EoR-positive OJTIs.
- ☐ Provide trainees with training hours at times when EoR is most likely to be used by their OJTIs.
- ☐ Monitor EoR use and provide feedback and encourage to CPCs who are trying to introduce this into their controlling "toolkit" and style.

Airspace & Procedures

- ☐ Liaise with QA/QC about proactively monitoring for any changes once EoR operations begin.
- ☐ Obtain regular feedback from airlines, including data on EoR use and any possible concerns regarding pilot/CPC communications.
- ☐ Share feedback and lessons learned with other facilities.
- ☐ Use the HF toolkit cards to support EoR conversations and project activities*.
- ☐ Find ways to share lessons learned with other facilities, so that the NAS can benefit from your experiences.

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What do the symbols mean?

* Indicates that a supporting resource is available within the HF implementation guidance.

** Indicates that an FAA procedure or process supports this activity.

ANNEX C: ATC FACILITY TOOLKIT FOR EOR IMPLEMENTATION

These cards are intended for double-sided printing at an appropriate size. It is envisioned that they would be laminated for use in decks as index cards. These materials could also be printed as posters.

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ATC Facility Toolkit for EoR Implementation

This toolkit summarizes some of the lessons learned from facilities that have implemented EoR within their operation. This toolkit is intended to support air traffic managers, supervisors and specialists in preparing for a successful EoR implementation, with a focus on supporting the people impacted by the change.

Practical

Practical tips to help with managing change.

Shareable

Sharing "tried and tested" solutions between CPCs.

Applicable

Real-world suggestions that work in ATC.

Evidence based

- Backed by research at FAA ATC facilities that have implemented EoR .
- Based on guidance developed with NATCA involvement and review.
- Includes tips and hints from certified professional controllers at facilities.

Benefits

- Provides information to those most impacted by the change.
- Visually appealing way to share experiences and lessons learned.
- Provides ideas to help facilities build their EoR operations over time.

Produced by Evans Incorporated for FAA ANG-C1 Human Factors Division

About this toolkit

This is a toolkit intended to support air traffic facilities in implementing an EoR operation, with a focus on the human elements of the change. Each card provides a brief description of the research or lesson learned from FAA ATC facilities that have previously implemented EoR operations.

This toolkit takes the form of cards containing practical suggestions and ideas. The cards are color coded by intended audience group, so that you can quickly identify key insights relevant to different groups of people within your facility/operation. Most cards will be of some interest to all ATC facility staff, but some suggestions will be most useful for particular professional roles within the facility.

The information contained within these cards is primarily taken from a research report:
Thomas, L.J., Serrato, A. & Kirby, N. (2018) Established on Required Navigation Performance (EoR) (RNP) Concept Validation and Implementation Plans: Human Factors Gap Analysis. Evans Incorporated Report for the Federal Aviation Administration. Contract DTFAWA-15-D-00026.

Intended Audience Groups

Air Traffic Managers & Operational Managers (ATMs/OMs)
These cards provide guidance on management support and resourcing for EoR projects at facilities, including the involvement and management of stakeholders.

NATCA Facility Representative (FACREP)
These cards provide guidance on leadership from the bargaining unit at facilities, to ensure that the CPC perspective is fully considered within an EoR implementation project.

Front Line Managers and Controllers-in Charge as operational supervisors (FLMs/CICs)
These cards provide guidance to those supervising or overseeing certified professional controllers who will be adapting to the use of EoR operations within the facility.

Air Traffic Controllers (CPCs)
These cards provide guidance to controllers who will be seeking to integrate new RNP-AR procedures into their own controlling style, including their preferred controlling methods and techniques.

Airspace and Procedures Managers and Specialists (A&P)
These cards provide guidance to facility personnel who are involved in designing and updating procedures and operational guidance for EoR implementation.

Training Departments (TRNG)
These cards provide guidance to training support managers, contract instructors and on-the-job-training-instructors in developing EoR related skills among operational staff.

Produced by Evans Incorporated for FAA ANG-C1 Human Factors Division

Procedure Design Tips

Guidelines for human-centered procedure design

Procedure design is an important factor in RNP-AR adoption and utilization, since without an acceptable design there would be little advantage in adopting and utilizing these approaches, and benefit realization would be expected to be low.

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Key takeaways

- Engage all stakeholders and interested parties, internal and external to your organization, and formally consider/analyze the different motivations between them.
- Successful design initiatives are likely to be those that include some short-term wins for all operators, including those not yet fully equipped to fly an RNP approach.
- The design must be sufficiently effective to overcome some common controller beliefs, habits and preferences. These might include perceptions such as “you can’t beat a straight-in,” “vectoring is best,” and “I can run finals tighter myself.”
- Try to ensure that your design provides efficiency from the perspective of a controller – reduced track miles, vectoring, transmissions and workload are all appealing outcomes.

Procedure Design Tips

Providing 'something for everyone' is the key to success

Procedure design takes time and is a delicate balancing act between different stakeholder desires and motivations. Try not to view it as 'zero sum' game. Providing a benefit for one stakeholder does not always mean a disadvantage for others.

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What have we learned?

One primary goal of the procedure design process is to generate win-win solutions that provide some benefit to all stakeholders. Even airlines with a relatively small proportion of operations at a given airport can then be motivated to take part in the project.

If the procedure design doesn't incorporate at least some benefit for everyone around the table, then not everyone will have an incentive to participate in the project. Ideally, there would be no losers - everyone will gain as a result, though to varying extents.

Remember that not all stakeholders will be from the aviation industry. National and local organizations might include environmental groups, lobby groups and resident groups. Taking the time to understand their concerns will pay off in the long run.

Phased Implementation

Start with simple steps, and gradually add more complexity

It will take time for both controllers and pilots to adjust to EoR operations. Facility CPCs need to be given the time and opportunity to practice assigning and clearing RNP-AR approaches. Planned steps or phases help to ease the transition.

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Key takeaways

- Develop a structured implementation or change management plan that includes a phased or graduated approach.
- For example, you may decide to start with EoR operations segregated onto a separate runway, to run EoR operations in VFR conditions only, or only at off-peak traffic times.
- Carefully consider the timing of the implementation along with other facility projects. Too much change at one time may reduce the probability of success with an EoR implementation.
- Build in time for CPCs to have opportunities to "play" with RNP-AR approaches within EoR operations, and get comfortable.
- Encourage controllers to try RNP-AR approaches when appropriate and keep motivating them to "try it out".

ATM/OM NATCA A&P TRNG

Phased Implementation

It takes time to become comfortable with a new controlling technique

CPCs are successful experts because they rely on methods that have been shown to work through their own previous experience. It takes time for controllers to trust something new, and to figure out how they can use it successfully.

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What have we learned?

Planning a phased implementation avoids controllers being "thrown in at the deep end", and helps to identify and remedy any issues before EoR operations are used in complex situations.

"We could land EoRs without disturbing the straight ins. That meant that our controllers could run a few and see if they liked it…. controllers could "experiment" a little and see what they thought and whether they worked."

"From a CPC perspective, you need to give them time to "play" with the approaches, check that they are trying them, and make it easy for them to try them out."

ATM/OM NATCA A&P TRNG

Decision Support Tools

Providing a range of tools can help controllers find opportunities to use EoR

Facilities can provide a variety of decision support tools to help controllers find opportunities to assigning and clear aircraft within EoR operations.

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Key takeaways

- Provide controllers with a variety of decision support tools, so that they can try several and decide which would work best for them personally, under which conditions.
- "Old school" air traffic control methods include speed matching, counting miles and eyeballing.
- Additional options include the use of SPLAT-T range rings to show distance, showing tie-points on approach plates at the controller workstation, teaching tie-points in advance on an airspace map, and/or providing dash marks indicating miles along final approach lines on the video map.
- If a facility cannot support the provision of multiple tools, it's advisable to consult with controllers and seek input from across the operation before narrowing down the options.
- Converging Runway Display Aid (CRDA) is an automation based decision support tool that requires an adaptation to STARS. CRDA is included on a separate index card within this toolkit.

NATCA FLM/CICs CPC A&P TRNG

Decision Support Tools

Preferences for different decision support tools vary between controllers

Some controllers are comfortable using "old school" air traffic control methods; others might prefer visual support aids when making speed/time/distance decisions. Providing several options is valuable, so controllers can use whichever they prefer.

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What have we learned?

"We presented three tools to controllers to brainstorm ways to anticipate the position of aircraft: CRDA, dash marks along the finals representing distances, and tie-points on the video maps".

"It might help to teach the tie points, and define to controllers exactly 'this is the point you need to watch'."

"It's not about intuition or gut feeling - you can show them it works in a lab. It's not intuitive, I know that, but you can show them a replay and say 'Bad as that might have looked – IT WORKED!' It's all about knowing the tie points."

"They are counter-intuitive, but there is a tie point with a fix on the downwind and the initial approach fix when they are on a 25-mile final. When they hit that fix, that's when you know you need 3 miles."

NATCA FLM/CICs CPC A&P TRNG

Training Tips

Focus on learning and practice, rather than telling controllers 'what to do'

Effective training combines a balance of 'knowing why' and 'knowing how'. Classroom sessions are mainly useful at an introductory level - professional controllers will need plenty of hands-on opportunities to put theory into practice.

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Key takeaways

- Ensure that controllers are aware of EoR operations before being formally trained, by delivering briefings in advance. This helps to focus the training on practical application and techniques.
- EoR operations may seem counter-intuitive for some controllers, who might report difficulty trusting that it works until they see it for themselves. Use videos and radar replays to help demonstrate the effectiveness of RNP-AR "on the glass".
- Controllers will need the opportunity to experiment with EoR operations under a range of conditions. The best training will include simulation sessions as well as opportunities to use RNP-AR 'live' in low complexity or low traffic situations, or in a segregated operation.
- Consider joint training with pilots, possibly as part of the design process, if feasible. This helps controllers to understand what is happening on the flight deck, and vice versa.

ATM/OM NATCA A&P TRNG

Training Tips

Use training methods that allow controllers to 'experiment' with EoR

To implement EoR successfully within a facility, each controller needs time to work out how best to integrate EoR operations into their own personal 'toolkit'. The training plan should also include training on a range of decision support tools.

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What have we learned?

"We are bit confused because for EoR to be used, the controller must have gone through the class and simulations we built. The whole facility had to do that, but we were never told what to do with subsequent people who arrive here. When we train them, do we incorporate EoR in the regular training? Do they need special classes? We never really got an answer… "

"Simulators would help a lot, and joint training of controllers and flight deck. That would help both parties better understand each other. I don't know what the pilot is doing other than typing in fixes. It would really help to show what this all looks like from the pilot's side."

ATM/OM NATCA A&P TRNG

Controlling Techniques

PBN procedures can shift the emphasis of a controller's role

Use of RNP-AR approaches within EoR operations can shift the nature of a controller's role from providing tactical instructions to pilots, to taking more of a monitoring role in air traffic.

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Key takeaways

- Managing a mixed fleet is often reported by controllers to be the biggest single challenge with EoR operations, since controllers are sequencing RNP equipped aircraft along with unequipped aircraft. Some controllers are more comfortable doing this than others; this is normal and to be expected.
- Pilots appreciate as much advance notice of an RNP-AR assignment as possible. Late changes to the availability of an approach, or to the runway assigned, increase workload on the flight deck during a critical phase of flight.
- Controllers cannot vector an aircraft that they want to leave on the RNP-AR procedure. Controller feedback indicates that dynamic and proactive speed control helps to successfully manage aircraft within EoR operations.
- Controllers should expect to make fewer transmissions to aircraft on RNAV procedures; this is less about providing tactical guidance and instructions, and more about monitoring the approach to ensure the aircraft follows the route.
- Feeder and finals controllers will need to be aware of each other's preferences and work effectively as a team to be able to provide the best service to airlines/aircraft who are eligible for RNP-AR approaches in EoR operations.

NATCA CPC TRNG

Controlling Techniques

Speed control becomes more important with RNAV approaches

Not all controllers are equally comfortable with the less tactical approach to air traffic control that is possible with RNAV procedures. Proactive speed control is reported to be a great help integrating RNP-AR approaches with the rest of a planned sequence.

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What have we learned?

"The blending is the hardest. It doesn't matter how veteran you are the eyeballing is a challenge."

"You have to use speed control – if there's a tail wind on the turn, you have to account for that before passing it, so you give them a little more space. If you're going to be good at this, then you have to use speed control."

"Clear everything early – and then use speed control to make it work. If you clear too close to the initial fix, the flight crew won't have it loaded and they cannot capture the initial fix in time. Clear them early."

"Speed control is all about miles, if you match speed, the one further away will come in later. Trust your flying miles, break the ties."

"You know how it is with a new way of doing anything. 10% will be the champions and the trendsetters, 80% might not be into it to start with, but will give it a try, and 10% will drag their heels. It takes time to change behavior and change culture. It's about habits, and trust, and knowledge."

NATCA CPC TRNG

Converging Runway Display Aid

A STARS tool with a new application in RNAV decision making

The Converging Runway Display Aid (CRDA) is a STARS tool originally developed for converging runways. With the support of OSF engineers, facilities can build a local adaptation of CRDA that can support controller decision making in EoR operations.

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Key takeaways

- All local adaptations of CRDA need to be tailored to the specific application and operation at each facility.
- The adaptation process includes identifying issues and fixing glitches before the software is used on the operations floor. It is advisable to appoint a CRDA team to support the design and test of the adaptation. This team must include operational air traffic controllers from the facility.
- CRDA works by generating a "ghost" target where the aircraft would be if it were on a "straight in" approach. The ghost target is moving at the same speed as the aircraft on the RNP-AR approach, which may be faster than aircraft on the straight-in.
- Controllers report that sequencing with CRDA is significantly easier than sequencing without it, although CRDA does not take into account all relevant factors (such as wind).

NATCA FLM/CICs CPC A&P

Converging Runway Display Aid

CRDA is a sequencing tool - not a sequencing guarantee

An adaptation to Converging Runway Display Aid (CRDA) can help controllers manage a mixed sequence. It provides controllers with a ghost target that moves along the "straight-in" extended runway centerline, and helps controllers assess spacing.

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What have we learned?

"CRDA helps make the assessment more consistent, now I can tell earlier if I can make it work. It's the time window. The feeders use it too. They can see 35 miles out, so it's much more predictable".

"CRDA takes a lot of the work out, you know in advance if they will be a fit, or if they will be a tie."

"The ghost looks faster than it would normally be, and normally an aircraft on straight in would be slower at that point, so you have to get comfortable with this."

"Without CRDA, EoR can be difficult to do, because you have to go 'old school' and count the miles. At that point, it becomes a numbers game. Ultimately, we don't want to guess at separation. CRDA takes the numbers and the guessing away."

NATCA FLM/CICs CPC A&P

Flight Deck Considerations for PBN

Understanding the flight deck perspective helps CPCs provide excellent service.

Flight crews enjoy RNP-AR approaches because they are predictable and stable. If an EoR RNP-AR approach is not likely to be cleared, pilots may prefer it wasn't assigned. Communicate EoR/RNP-AR availability on ATIS to better prepare flight crews.

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Key takeaways

- Assign an RNP-AR approach as early as possible. Late assignments and changes leave pilots with little time to prepare for the approach, and may dramatically increase workload on the flight deck.
- Avoid assigning an aircraft for an RNP-AR approach unless the feeder/final team is almost certain the aircraft can be cleared on that approach. Ideally, late changes should be rare exceptions.
- Be aware that if you need to change the approach/runway, it can take several minutes for a flight crew to re-program the FMS and brief the approach, while also completing other tasks on the flight deck.
- The optimal situation is where the FMS can be programmed early, the pilots have time to brief, and the approach/runway does not change. This creates a predictable and stable approach that delivers the benefits of performance based navigation.
- If the aircraft deviates from the RNP-AR approach procedure, discontinue the approach and vector the aircraft appropriately.

Flight Deck Considerations for PBN

"EoR" is not a concept that many pilots are familiar with. Flight crews may simply regard EoR operations as RNP approaches.

Approach is a critical phase of flight and a time of high workload on the flight deck. Pilots perform an approach briefing every time they fly an instrument approach, so any change to an assigned runway or approach increases their workload.

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What have we learned?

A key challenge for pilots flying RNAV procedures is the time it takes to program route segments into the Flight Management System (FMS). This includes the procedures used for EoR operations (e.g. RNP-AR).

FMS programming challenges can be exacerbated by procedure designs which do not link transitions (called a disconnect, or a "DISCO"). Where this occurs, pilots need to manually link route elements, and this takes time.

RNP-AR approach procedures may appear to be hand-flown on the radar. This may happen when the flight crew are using "Flight Director" or when the flight crew are flying a disconnect between segments (this is truly manual, without guidance).

RNP-AR approaches used within EoR operations should not be flown on a fully manual basis because of the precision required to meet performance tolerances.

Pilots and air traffic controllers use different terms. Pilots may not recognize "EoR", since this term is not used often operationally. CPCs sometimes abbreviate full approach names to the letter label (RNP-ARs may be called Mike, Zulu or Yankee at different airports).

Communication Strategies

Keep all stakeholders informed and regularly updated

The EoR team should provide regular project updates, coordinating with the ATM as needed where external stakeholders are involved. Internal communications should focus on supporting air traffic controllers - the 'end-users' in ATC.

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Key takeaways

- Regular project updates, especially during the procedure design stage, will help to keep everyone engaged and motivated to participate in the project. This is especially important for keeping external stakeholders informed between meetings, because informal 'corridor' conversations are not likely to happen.
- Within the facility, consider preparing some 'key talking points' for leaders to brief supervisors and controllers. These should address the most common questions and concerns and could be supported by answering the most frequently asked questions in an 'FAQ' newsletter or fact sheet.
- Tailor your message to your audience. For example, consider why would controllers want to use RNP-AR? What are the potential benefits? What concerns might controllers have, given the nature of your facility's operation?
- Brief controllers as part of your preparation for designing EoR training. This way, you can design the training to address controller concerns and questions.
- Prioritize the use of face to face briefing methods wherever possible. Use videos, PowerPoint animations, FALCON replays and guest speakers to bring the content to life and allow for interactive discussions and question and answer sessions.
- Use electronic briefings sparingly, since these focus more on information delivery than having a two-way conversation.

Communication Strategies

Tips to engage and inform facility air traffic controllers

Communicating with controllers effectively means demonstrating an understanding of their perspective and concerns, and using a range of methods to share ideas, messages and best practices. Visual and dynamic communication methods often work well with this group of expert professionals.

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What have we learned?

Communicating with controllers about effective EoR implementation is not a one-way street. Effective communication includes opportunities to listen and collect feedback, as well as to ask and answer questions.

Formal communication methods that are effective with controllers tend to include ways of showing what RNP-AR within an EoR operation looks like - including videos and radar replays. Controllers also value knowing how this has worked for controllers at other facilities.

Regularly reach out to NATCA and FLMs to find out what controllers on the floor are thinking - informal communication can provide the project team with valuable information and feedback.

Leadership Support

A powerful driver for introducing change

A successful implementation of EoR requires leadership support. Without facility leaders, NATCA, managers and supervisors providing resources, guidance and encouragement, an operational change cannot be sustained.

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Key takeaways

- The Air Traffic Manager, NATCA FacRep, OMs and FLMs need to talk positively about introducing EoR and be clear on the benefits and value it brings when talking about the change.
- Provide the resources required to support the change. This is more than "time off the floor" - it includes the development of communication and briefing materials, and training resources.
- Establish a team to support the change and empower them to do what is needed to make it happen. This team should include representation from operational air traffic controllers.
- Provide ongoing coaching to encourage controllers to try these approaches - and let them know that they may need to encourage pilots to try them, too! Ongoing reinforcement and encouragement help to sustain use of new procedures.

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Leadership Support

Everyone can be a leader, and everyone can lead by example

Successful implementations have leadership support. Formal leaders can provide access to the resources needed to create change. Informal leaders also have a powerful influence on the successful adoption of a new operational procedure.

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What have we learned?

"It fell apart without support. It was sad because I thought it had potential. There was a lot of visibility at the time. When rolled it out, it was against other critical timelines, so it was damned to begin with because it wasn't timed right."

"On the implementation side, you need a plan. You cannot implement without a plan and just hope that EoR will be 'adopted' by the operation. You have to convince controllers to give it a try."

"The other thing you need to know is that we had to encourage the pilots to use them. We went through that phase, the TMU will tell you all about it – we had to use baby steps."

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Stakeholder Collaboration

Try to maintain regular contact with every party impacted by the EoR implementation

Collaborative working relationships help people to see each other's perspective, increasing the chance that the EoR implementation provides something to meet everyone's needs.

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Key takeaways

Spend some time thinking about who might be impacted by an EoR implementation at your facility. You probably have more stakeholders than you might initially expect. Keeping a list of stakeholders will help you to manage and communicate with key contacts. If EoR implementation at your facility will require procedural design work, you are likely to need to consider a wide range of external stakeholders. This **checklist** may help with identifying interested and impacted individuals/organizations:

- ☐ TRACON air traffic controllers
- ☐ Tower air traffic controllers
- ☐ A&P managers and specialists
- ☐ Training departments
- ☐ OSF engineers and technicians
- ☐ Bargaining unit representatives
- ☐ Pilots
- ☐ Airline officials and managers
- ☐ Airline operations personnel
- ☐ Airport authorities
- ☐ FAA officials
- ☐ Environmental/lobby groups
- ☐ Chart and mapping specialists
- ☐ Local resident/homeowner groups

Stakeholder Collaboration

Collaborative working relationships are fundamental to success

Some facilities will need to design new procedures suitable for use within EoR operations - this provides an opportunity to develop strong working relationships. However, stakeholder engagement and communication is also important where a facility wishes to introduce EoR operations using existing procedures.

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What have we learned?

Collaborative working relationships between stakeholders are vital to ensure a successful EoR implementation. The procedure design process can provide valuable opportunities to develop relationships and understand different perspectives and motivations.

There are often relationships within every facility that can be harnessed to help with EoR efforts. As well as liaison at the management level, remember that CPCs who hold pilots' licenses, or who have contacts within airlines, or who support operator training and outreach activities, may also be able to help.

Regular communication and engagement with ALL stakeholders - even where there are differences of opinion, perspective and/or motivation - will help to ensure a smooth implementation.

Alerts, Alarms & Advisories

The challenge of inappropriate alarms

New procedures and new decision support tools may change the frequency and nature of alerts, alarms or advisories. If inappropriate alerts, alarms or advisories are frequently generated, they can cause controllers to lose confidence in these communications.

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Key takeaways

- Before introducing EoR operations, obtain a baseline measure of the level of current alerts, alarms and advisories.
- Systems to consider include Final Monitor Alert (FMA) and Traffic Alert and Collision Avoidance System (TCAS) Resolution Alerts.
- Analyze how the proposed EoR operation might impact the nature and frequency of alerts, alarms and advisories.
- Once implemented, conduct routine monitoring of alerts, alarms to advisories, to assess whether change has occurred.
- Ensure that you include operational users (controllers and/or pilots) in your analysis. Their insights will be very valuable.

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Alerts, Alarms & Advisories

Inappropriate triggering can be similar to "the boy who cried wolf"

When safety-critical alerts, alarms and advisories are triggered inappropriately, controllers may lose confidence in those communications. Therefore this potential issue needs to be carefully monitored.

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Key takeaways

By the time controllers mention that they don't have confidence in an alert, alarm or advisory, they may already have lost some trust in that communication. Facilities need to be proactive in monitoring the potential impact on alerts, alarms and advisories when EoR operations are planned and introduced. Because these types of communications are safety critical,
it is vital to maintain controller confidence.

"Once controller confidence was broken....
Once it's gone you don't get it back."

ATM/OM **NATCA** **A&P**

ANNEX D: AN AIR TRAFFIC CONTROLLER'S EOR JOURNEY MAP

An Air Traffic Controller's EoR Journey Map

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Air traffic controllers are experts, and have different styles and preferences in how they control traffic. Although there is no one "right" way to help a controller integrate a new method or technique into their professional toolkit, we know that specialists often have similar experiences when learning something new. This journey map, while simplified, represents some typical experiences, and provides suggestions for activities that facilities can use to support certified professional controllers (CPCs) in making the transition towards using more RNAV procedures and/or EoR operations. In reality, not everyone will experience all of these stages, and they may not be experienced in the same order shown here - the journey to adopting EoR is unique to every controller.

Awareness

Controllers who have not been exposed to RNAV technology or approaches may not know much about how they are intended to be used within the NAS.

- *Provide accurate information in briefings about what EoR is, and the benefits it can bring to the NAS.*
- *Try using face-to-face briefings with videos, and provide opportunities to ask and answer questions.*

Skepticism

Controllers use expert judgement to maintain separation, using "tried and trusted" techniques. It's natural for experts to be reluctant to try something new, since they have no experience of whether this works, under what conditions, and what the potential pitfalls might be.

- *EoR is counter-intuitive to some controllers. Share information from CPCs at other facilities who have made EoR work for them.*
- *Play radar replays of EoR operations to help controllers see that this works - and can save them workload and transmissions.*

Reluctance

Some controllers will be reluctant to try something new, while others will be more open to new ideas and methods.

- *You cannot require CPCs to try something - you can only encourage them to try it.*
- *Speak positively about the potential benefits of EoR, and allow CPCs time to talk, watch others, and learn.*
- *Accept that CPCs will use their own judgement on whether or not to try RNP-AR approaches..*
- *Provide "user-tested" decision support tools to assist CPCs in making use of EoR.*

Exposure

Controllers often need to "see it to believe it", and will need opportunities to practice so that they can integrate EoR-related techniques and decision support tools into their own personal controlling style.

- *Where possible, plan to implement EoR in phases so that controllers are exposed on a "little and often" basis.*
- *For example, segregate EoR operations on a different runway, or encourage the use of RNP-AR approaches at low traffic times of the day.*
- *It doesn't matter what "other" CPCs do - each controller will need to figure out their own way of using EoR in the way that works best for them.*
- *Controllers trust their own judgement above the experience of others.*

Experimentation

CPCs don't just need to practice until they get EoR "right". They need experiences with EoR that allow them to work out what to do when things don't go to plan - like when a pilot doesn't follow an approach, or when the wind speed is not as expected. Learning about EoR comes from experimentation.

- *Provide controllers with access to FALCON as a method of re-watching their own RNP-AR approaches within EoR operations.*
- *Understand that CPCs need to be able to use EoR under a variety of conditions to be able to figure out what works for them, as well as when and why.*
- *Allow controllers the time to become familiar and confident with EoR operations.*

Adoption

- *Share airline feedback and success stories about the use of EoR operations with controllers and union representatives.*
- *Encourage controllers to keep using EoR operations as appropriate.*
- *Share lessons learned from your facility with other facilities who are considering EoR.*

Utilization

To realize the full benefits of EoR, a facility will need the majority of controllers to use EoR when it is appropriate to do so. Sharing feedback from airlines will help CPCs to understand the benefits from the airline and pilot perspective.

Maximum Benefit Realization

Revert to usual

When CPCs are unable to find a way to integrate a new technique into their own controlling style, they will usually just stop using it. With EoR, this means that individual adoption rates will be low, impacting overall facility utilization rates.

- *Try to make every controller's experience of learning about EoR a positive one. Then if they choose not to use RNP procedures much, they may at least be positive about the potential of EoR when talking to other controllers.*
- *Remember that successful EoR operations need both assignment and clearance - encourage final and feeder controllers to try this as a team.*