Human Factors Research Plan for Instrument Procedures

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This research will support the development of instrument procedures for performance-based navigation (PBN) operations. These procedures include, but are not limited to, area navigation (RNAV) and required navigation performance (RNP) operations. The research must consider the interactions between flight deck design, implementations, flight operations, local Air Traffic Control (ATC), and Air Navigation Service Providers (ANSP). This research must also address all types of operations: Part 91, (including piston-engine and jet operations), Part 135 (air taxi and charter), and Part 121 (commercial scheduled service). Military and single-pilot operations should also be considered.

An initial plan was developed in FY11 by reviewing past research, Federal Aviation Administration (FAA) planning documents, and other references to PBN operations. This plan is being used to direct research projects and it supports tracking by program managers in the FAA Human Factors Division (ANG-C1). The topics identified in the plan are based on known or anticipated requirements. Funding and project schedule is determined by the program managers and their sponsors within the FAA Offices of Aviation Safety. This plan helps to ensure that the planned research aligns with the Next Generation Air Transportation System (NextGen) implementation goals. This plan is updated annually in June.

The plan describes a variety of human factors research areas and contains some recommendations on how they should be approached. Potential approaches include a combination of human factors analysis, data collection, and coordination among FAA, International Civil Aviation Organization (ICAO), and private sector stakeholders. While many of the research topics are inter-related, an effort has been made to separate the work where possible in order to help structure the different potential research projects.

Sponsors and stakeholders in the FAA Offices of Aviation Safety and elsewhere in the FAA (e.g., Kathy Abbott, AIR-100; Mark Steinbicker, AFS-470; and FAA AeroNav Products, AJV-3), contributed to the development of this plan. Additionally, input was sought from the aviation industry and from other organizations that conduct aviation human factors research. Mark Steinbicker is the sponsor for the bulk of the charting related work. Bruce McGray (AFS-410) is the sponsor for the task on Charting for Low Visibility Operations.

The topics in this plan are listed below in a table of contents. They are divided into three categories (Active, Proposed, and Past) based on whether there are research activities in progress or not. Each topic is then covered in more detail. Summary tables of the active and proposed tasks and their schedules are provided after the topic descriptions. After the summary tables, source documents that refer to the need for this research are listed. Selected references are provided at the end of this plan.[1]

[1] Documents that are broadly relevant to the design, implementation, and operational use of instrument procedures come from a variety of sources, such as working groups and meeting presentations. Related FAA reports and reports by research organizations are publicly accessible, but it can be difficult to determine their relevance to a specific topic. Many other documents are not publicly accessible. The Volpe Center has gathered both public and non-public documents, reviewed them, and posted them on a SharePoint site with password accessibility. An overview of the documents in the database is available on the site. The reference section given at the end of this plan lists only a subset of the reports available on the SharePoint site. A library of public documents will be available at the Volpe Center website.

The first two topics (Research Plan and Document Library; Human Factors Input to Working Groups) cut across technical domains. Topics 3 through 7 all are connected under the general area of "charting." These topics are separated from each other in order to structure this large area. Topics 8 through 11 are relatively independent areas for research; they have different end users and sponsors some of which are still to be determined (TBD).

Active Research Areas

1. Research Plan and Document Library

The product of this effort will be an annually updated plan for use in tracking and managing the research conducted in this area.

Proposed Duration of Effort: FY11 through FY16

> *Background*. This research plan will be updated annually by mid-June in order to incorporate research results from the past year and to add any newly identified research needs. More detail will be provided on projects within the first and second year of the rolling plan.
>
> *Approach*. Work to support future updates to the research plan will continue as needed. A mid-year update will be prepared for the FAA in December. Relevant literature will be gathered and posted publicly when possible.
>
> *Status*. An initial public version of the Volpe Center literature library is available at www.volpe.dot.gov. Each article is summarized briefly. Unpublished documents are available through a password-protected Sharepoint site.

2. Human Factors Input to Working Groups

The product of this effort will be expert human factors input to government and industry groups whose work will affect design, depiction, and use of instrument procedures.

The sponsors for this research are AFS-470 (Mark Steinbicker) and (AIR-100) Kathy Abbott. AJV-3 (Valerie Watson) or others are stakeholders, depending on the specific focus of the working group.

Proposed Duration of Effort: FY11 through FY16

Background. Government and industry groups such as the Aeronautical Charting Forum (ACF), the International Civil Aviation Organization (ICAO), and the Performance Based Operations Aviation Rulemaking Committee (PARC) may have need for human factors expertise during discussions related to chart content and depiction. Issues that may initially be perceived as unrelated to human factors sometimes have unexpected human factors consequences.

Three current discussions of this nature concern (a) phraseology for *climb via* and *descend* via clearances, which is being addressed in a subgroup of the PARC (b) procedure naming conventions, which are being addressed by ICAO and a subgroup of the PARC, and (c) altitude definitions, which are being addressed in an ICAO subgroup. Past discussions have included chart saturation issues and other air traffic control phraseology for RNAV and RNP procedures.

Approach. Ongoing participation in appropriate working groups should be supported on an "as needed" basis by individuals with a background in human factors, PBN operations, and ideally, some technical knowledge of the specific topic as well. Issues that come up may need to be addressed quickly in order to meet the group's schedule. The schedule may allow only time for expert input and/or quick analyses (e.g., of existing operational data). These quick analyses may be helpful if no relevant experimental data are readily available. When the schedule and Research and Development (R&D) budget allow, after a sponsor forwards a related research need to ANG-C1 specific research activities to address the need may be initiated if they are determined to be of sufficient priority in relation to other validated research requirements.

Status. Volpe Center participated in the PARC Action Team meeting on procedure naming in August 2011. Volpe Center also participates in meetings of the ACF and the CNS Taskforce to stay up to date on working group agendas.

3. Chart Usability

The product of this research will be data to support development of guidance and recommendations on chart content, definitions, and depiction of specific chart elements. These materials would be used by FAA AeroNav Products in producing government charts and by industry chart manufacturers and international organizations as well, in order to promote standardization and minimize pilot training needs. These data and findings related to content and depiction of charting information will apply to both paper and electronic charts.

The sponsors for this research are AFS-470 (Mark Steinbicker) and AIR-100 (Kathy Abbott). AeroNav Products (AJV-3, Valerie Watson) is a stakeholder.

Proposed Duration of Effort: FY11 through FY16

Background. There are no FAA regulations regarding the content and design of charts that apply across all chart producers (private and government). However, standards have evolved within and across chart producers. The Interagency Air Cartographic Committee (IACC) specifications are used by the FAA to produce charts. These specifications reflect practices that have worked well for many years. In some cases, court rulings have also affected legal charting requirements.

Chart content is based on multiple uses for the information. For example, charts contain a great deal of information for planning and reference, and some information for use under unusual circumstances (e.g., lost communications). At the same time, charts must be sufficiently uncluttered so as to be usable in real time during a normal flight operation.

Chart content has become so complex these days that pilots are not always clear about the specific meaning or use of certain elements. For example, there are many different types of altitudes and angles shown on charts. Some of the different altitudes that could be or are depicted include: minimum altitude, maximum altitude, recommended altitude, procedure altitude, advisory altitude, operational altitude, and block altitude. Different types of angles used on charts today include: descent angle, descent gradient, VNAV angle, glide slope, glide path, vertical angle, etc. Ideally, the number of similar but distinct elements shown should be prioritized and minimized to limit potential for confusion. There are active discussions about altitude information ongoing within ICAO and the ACF.

With PBN, it is expected that there will be more notes related to functional requirements. However, chart notes can add significant visual clutter and be of relatively low importance in normal operations. Their location is not standardized. As a result, the note might be skipped, or it could impact the readability of nearby information.

RNAV and RNP procedures in particular are increasingly complex and detailed. Chart manufacturers are struggling to depict all of the required information on the limited space available on paper charts. Graphical techniques for handling such large amounts of information (e.g., changing chart scale or adding insets) are not sufficient to ensure usable charts for the most complex procedures. The design solution space is highly restricted and charting manufacturers are seeking guidance on how to address these issues.

Research Topics. Human factors research is needed to address a variety of questions, listed below:

a) Current Charting Issues. Understand and document existing design options and constraints pertaining to paper charting issues in order to develop proposed human factors recommendations.

   Approach. Obtain information from chart manufacturers about their charting challenges and mitigation strategies. Analyze chart parameters that relate to chart complexity. Summarize the chart and procedure development process.

   Status. A draft technical report prepared by the Volpe Center was released for industry review in December 2011. The analysis of chart parameters was expanded and improved in FY12. Revisions to the draft technical report are expected to be completed by September 2012.

Publication.

Butchibabu, A., Midkiff, A., Kendra, A., Hansman, R.J., & Chandra, D.C. (2010). Analysis of safety reports involving area navigation and required navigation performance procedures. *Proceedings of the International Conference on Human-Computer Interaction in Aeronautics (HCI-Aero 2010)*. 3-5 November, Cape Canaveral, FL.

b) Information Use. Information on charts is used differently for different types of flight operations (Part 91, 121, and 135). Who uses what information? For example, what information is typically used and understood by the airline pilot (Part 121) for arrival, departure, and approach charts? What information is typically used and understood by the corporate pilot (jet operating under Part 91)? And, similarly, what does the light general aviation pilot use and understand? Compatibility of charted information with modern flight deck systems must be considered in this assessment.

Approach. Gather baseline data on current use of information from paper charts in modern flight decks by observing corporate and airline operators, taking new flight deck systems into account. Document results of the study.

Status. This work is in being led by Volpe Center researchers, with assistance from the Massachusetts Institute of Technology (MIT). In FY11 and early FY12, the Volpe Center explored different simulator scenarios for exploring chart use. Alternative methodologies will be considered in FY12 into FY13. A research plan is due in March 2013.

c) Separation of Information. What, if any, information on a chart could potentially be moved elsewhere by limiting the purpose of the chart? Consider limiting the purpose in various ways (e.g., by phase of flight, distance and direction from/to runway end).

Approach. Develop realistic modified chart prototypes with separated information. Collect data from airline and corporate pilots on time to retrieve information from the current and modified charts. Document results of the study.

Status. This study was completed by researchers from the Volpe Center and MIT. Modified charts that show fewer paths per page were developed with assistance from Jeppesen and FAA AeroNav Products. Software to run the test was developed and data were gathered. Results show significantly reduced time to retrieve information from the simplified charts. A conference paper and government report are in preparation.

Presentations.
Preliminary results documented in status reports delivered to the FAA program managers in January and March 2012. These results were presented to the Air Transport Association (ATA) Communications, Navigation, and Surveillance (CNS) Taskforce and the Aeronautical Charting Forum in April 2012. The presentation will be posted online.

d) Use of the Profile View. How is the profile view[2] (i.e., a graphical depiction of the allowable altitudes that meet obstacle clearance requirements) used on an approach chart? Is there a need for the profile view on an approach chart, or could it be removed or show significantly less information without negative consequences? Is it useful or feasible to implement a profile view for an obstacle clearance departure?

e) Profile View for Arrival and Departure Charts. Would a profile view be useful for arrival and departure procedures? Is it possible to clearly indicate altitude constraints resulting from airspace design constraints rather than obstacle clearance?

f) Use and Depiction of Altitude Information. How are different altitudes used? How does use of altitudes change based on the specific procedure in use (e.g., arrivals, departures, approaches, obstacle clearance departures, and optimized descents)? What altitudes should be shown when? How can confusion between different altitudes be minimized?

g) Use and Depiction of Vertical Angles. How are vertical angles used? How does use of altitudes change based on the specific procedure in use (e.g., arrivals, departures, approaches, obstacle clearance departures, and optimized descents)? How can confusion between different vertical angle information be minimized?

h) Notes. How can the notes on charts be standardized and their number minimized in order to mitigate their impact on usability of the charts while still providing necessary information appropriately? This issue should be addressed separately for paper and electronic charts, as the best design practices for these two media may differ.

Approach. It may be useful to determine what types of notes are present and to determine whether notes can be prioritized. One way to prioritize notes, for example may be by how commonly they are used. "Boilerplate" (common notes) may be of relatively low importance whereas unusual notes may have higher priority. After determining a way of prioritizing notes, ways of highlighting the higher priority notes should be assessed. For example, within a numbered list of chart notes, could the notes simply be renumbered so that unusual information is listed first? Or would higher priority notes be more noticeable if they were placed in a consistent location, separated from the lower priority notes?

i) Procedure Naming. The current procedure naming convention does not adequately communicate the performance and functional requirements of PBN procedures. An updated convention is being discussed for the United States under the PARC and for international use in the ICAO Instrument Flight Procedures Panel (IFPP). The new convention must address

[2] Although there are electronic displays of vertical profiles in modern flight decks, these should not be confused with the paper chart depiction, as they have very different purposes. Electronic displays of vertical path currently available in modern flight decks show the path that the flight management system is expected to follow. The paper chart profile view shows the range of altitudes that are allowable for an approach. There are always lower bounds on the altitude for terrain clearance, but there may also be mandatory altitudes or maximum altitudes shown on the profile view that are constraints on the path. The maximum altitudes are relatively uncommon and typically arise due to airspace design issues (e.g., crossing arrival and departure paths).

both PBN and hybrid (PGN-conventional) procedures for departures, arrivals, and approaches. It must satisfy needs and constraints of pilots, controllers, chart manufacturers and FMS equipment designers.

Approach. Concepts and proposals for procedure naming conventions may need to be evaluated through human factors studies. One new concept, for example, is the PBN "box" which would provide detailed information about the procedure that cannot be conveyed within the procedure name itself, in a standardized format. The location, content, and format of the box may need further human factors study, especially since the available space on these charts may be extremely limited.

4. Electronic Charts and Other Electronic Flight Deck Displays of Chart and Procedure Data

The product of this effort will be data and recommendations to support development of guidance and recommendations on electronic chart applications as well as information to guide the FAA's evaluation of other flight deck systems that provide chart and procedure data. These recommendations could be used by the FAA to determine evaluation criteria for electronic charts in order to identify operationally unsuitable versions. The recommendations could also be used by industry to develop usable and acceptable electronic charts as well as to improve the display and integration of chart and procedure data on other flight deck systems.

The sponsor for this research is Kathy Abbott (AIR-100). Aircraft Certification (Loran Haworth and Paul Bernado) are interested stakeholders.

Proposed Duration of Effort: FY12 through FY14

Background. Electronic charts are currently in development by industry. These charts are part of a natural evolution away from paper towards dynamic, data-driven charts, which has been in progress for some time. Charts that are data-driven are constructed in real time; their data can be customized by the pilot or through other data on aircraft status. Moving map displays are similar to electronic charts in that they both present navigation information, but moving map displays show only a limited subset of the data required on a full electronic chart. A full electronic chart can *replace* a paper chart. In the future, electronic charts could be integrated into other flight deck systems so that current ownship position may be shown and data that are not relevant to the planned route of flight could be suppressed by the software as appropriate. In addition, more chart and procedure data may be integrated onto other flight deck displays.

Today's electronic charts are typically approved for use by FAA Flight Standards inspectors and/or flight test pilots. FAA Aircraft Certification would only get involved if the software were implemented on installed avionics equipment. Even in this case the electronic chart software human interface may get relatively little notice during the engineering evaluation. Some systems have already been approved for paperless operations.

Guidelines for electronic charts are contained in the Electronic Flight Bag (EFB) Human Factors Considerations Document (2003). Operational issues pertaining to use of static electronic charts (i.e., PDF files) on EFBs have also been documented (2009). Additional guidelines on electronic charts and symbols are contained in an SAE Aerospace Recommended Practice documents (ARP5261 and ARP5289A).

Research Topics. Research on electronic charts should address the following topics:

a) Electronic Chart Usability. Usability of electronic charts will be affected by many different design decisions that are made by chart manufacturer (e.g., how to name and access the charts, how to zoom/pan, how to configure the data, how to change scales, support for user notes). Issues that could be explored include training time and learning curve, comparison with usability of paper charts, potential negative transfer from extensive familiarity with paper charts, and overall task performance.

Approach. This work should begin with an assessment of currently available products to identify what issues require further research. After the issues are identified, they should be prioritized for further evaluation.

Status. Volpe Center will begin work on an assessment of commercially available electronic chart applications in FY12. The goal of the assessment is to understand the current human factors issues in the design of electronic chart software. The work will continue into FY13.

b) Moving-Map Display De-Cluttering. Moving map displays are used for real-time flight path management. There is interest in providing more data on these displays. As a result, there is a need to understand how much information can be displayed without a negative impact of visual display clutter on pilot performance. De-cluttering strategies need to be identified and reviewed.

Approach. Review literature and guidance on de-cluttering moving map displays. Review sample moving map displays to identify different de-cluttering strategies. The analysis should include vertical profile views, lateral moving map views, and airport surface information. The task should be coordinated with a moving-map display manufacturer (Honeywell). Document the findings in a final report.

Status. This effort began in the middle of FY12. Volpe Center is working with MIT to review the literature and guidance on de-cluttering moving map displays. They will also evaluate sample moving-map displays to identify de-cluttering strategies in use.

c) Integration of Chart and Procedure Information on Moving Map Displays. The goal of this effort is to provide information that FAA can use to develop recommended guidance for approval of data-driven charts in a variety of flight deck displays.

Approach. Review applicable industry, FAA, and research literature regarding the integration of procedural chart data with moving map displays. Construct and evaluate data-driven chart prototypes for the flight deck. Use the prototypes to analyze crew procedures related to use of chart and procedural data shown on flight deck displays. Provide recommendations for crew procedures, integration, and configuration of chart data. Conduct a functional decomposition of depicted elements and analysis of display alternatives for their electronic depiction. Define possible failure or degraded modes for data-driven charts and crew procedures and recovery procedures. Collaborate with Wright State University and Volpe Center. Document the findings in a final report.

Status. Honeywell will begin work on these issues in the summer of FY12. The work will continue for 15 months.

d) Transition to Continuous Electronic Charts. There are many different types of paper charts (e.g., high and low altitude instrument-flight-rules charts, visual-flight-rules sectional charts, approach charts, arrival charts, and departure charts) that focus on specific types of operations. Electronic charts can, in theory, transition seamlessly between these different types of charts. However, we do not know what the current uses of different chart types are. For example, do pilots mentally separate chart types, and if so, does that separation cue workflow? Do pilots expect specific types of data based on chart type or phase of flight?

e) Compatibility with Flight Deck Systems. Electronic charts will be integrated into the flight deck system and must be compatible with these systems (e.g., navigation display and control/display unit). Operations under degraded functionality of the electronic chart application may need to be considered. Other considerations include: operational impacts of small screen sizes and potentially suboptimal display locations, crew procedures, minimum dispatch requirements, and reversion modes in case the flight deck display is not functional.

5. Charting for Low Visibility Operations

The product of this research will be data to support development of guidance and recommendations on charts and symbology for operations in low visibility. Both paper and electronic charts must be considered. These products may be used by FAA AeroNav Products and by private chart manufacturers as needed, in order to promote standardization and minimize pilot training needs.

The sponsor for this research is AFS-410 (Bruce McGray and Terry King).

Proposed Duration of Effort: FY11 through FY13

Background. The deployment of Low Visibility Operations (LVO), also known as Surface Movement Guidance and Control Systems (SMGCS) Operations, is accelerating. Charts to support these operations are developed by Jeppesen and Lido on an as-needed basis. The FAA, in coordination with ICAO, is interested in identifying best practices for the design of charts for low visibility operations because there are no current standards for symbology, and inconsistencies have been noted.

Approach: Researchers should identify relevant research. Both paper and electronic media should be considered, as paper charts for surface operations may be supplemented with airport moving map displays that show similar information. This may include gathering and evaluating symbols currently in use. Researchers should work with subject matter experts (e.g., at Jeppesen, Lido, and FAA AeroNav Products) to define the problem space. In particular, researchers and subject matter experts should together determine what form of guidance makes sense and to determine what analyses or data collection are required to support this guidance. These analyses and/or data collection should then be carried out to identify recommendations regarding symbol sets, chart size etc. Researchers should also identify and evaluate operational human factors issues associated with LVO/SMGCS.

Status. FAA ANG-C1 and Volpe are leading an effort in coordination with NASA Langley to conduct related research. These studies will look at electronic displays of surface maps in a simulator study. In addition, Volpe Center will begin to examine symbology issues in FY12. Symbols used by different chart manufacturers have been gathered by the FAA.

Proposed Research Areas

6. Human Factors Considerations for Procedure Designers

The product of this effort would be recommendations for FAA instrument procedures designers on developing procedures that are more straightforward to depict and use by pilots.

This task addresses a variety of end users because there are different groups within the FAA that have responsibility for developing different types of procedures, and they use different criteria and software tools. For example, the criteria for instrument approach procedures come from the Flight Standards office, but arrival and departure procedures are developed by Air Traffic Services.

The proposed sponsors for this research are AFS-470 (Mark Steinbicker) and AIR-100 (Kathy Abbott). AJV-3 (Valerie Watson) is a stakeholder for this research. .

Proposed Duration of Effort: FY13 through FY16

Background. As established in the Chart Usability area above, there is much work to be done to help ensure that charts are usable depictions of procedures. However, one of the reasons that charts for PBN operations become difficult to use is because the underlying procedure itself is complex. Therefore another way to potentially reduce chart complexity is by addressing procedure complexity in the first place. Sometimes procedure complexity is necessary in order to obtain desired efficiencies, but it may be possible to design a usable procedure that is both efficient and easy to depict.

Guidelines based on human factors considerations should be provided to procedure designers. Specific issues are captured below, but have not yet been organized into research topics. Some of the topics are related to chart clutter, others are related to development of new types of procedures, and others are related to procedure complexity.

- What is the boundary between an arrival procedure (STAR) and an approach procedure? When an approach procedure has multiple intermediate segments, could some of these transitions be moved to the arrival procedure, thereby reducing the amount of data that must be shown on the instrument approach chart?

- Is it possible to minimize the number of different route segments? A reduction in tracks and segments will correspondingly reduce the number of waypoints and therefore alleviate chart saturation and reduce the amount of information that the flight crew needs to cross check with flight deck systems.

- Multiple intermediate fixes on a single approach chart present a complex charting problem in many cases. When are these types of procedures acceptable or beneficial?

- What human factors issues may arise if procedures that are currently designated "Authorization Required (AR)" become public?

- How do flight deck systems affect procedure design? What systems are required/optional/desired to fly what procedures?

- Need to understand the components of chart and procedure complexity in order to develop criteria and/or methods for evaluating and designing procedures so that they are not complex.

- Linking RNAV/RNP procedures to conventional procedures and the transition from RNAV/RNP procedure to conventional procedure (smooth and clearly understood).

- Design of procedures for Closely Spaced Parallel Operations (CSPO) based on Satellite Navigation.

- Complexity of missed approach procedure

7. Charting of Dynamic Clearances

The product of this research will be recommendations for the depiction of dynamic clearances for NextGen flight operations. The scope of these guidelines could also include recommendations from an Air Navigation Service Provider (ANSP) perspective, because ANSPs need to be able to communicate with the pilot about the procedure. (See related information in later topic, Air-Ground Human Factors Considerations for RNAV/RNP Operations.) Related research is being performed at Wright State University under the DataComm project, where researchers are prototyping how graphical clearances might be depicted on navigation displays.

The sponsors for this research are AFS-470 (Mark Steinbicker) and AIR-100 (Kathy Abbott).

Proposed Duration of Effort: FY13 through FY15

Background. Today's published charts depict fixed paths that do not change based on dynamic factors such as winds or weather. They provide pilots with basic path compliance information and support situation awareness. In the future, more complex and customized procedures will be developed, as needed based on current conditions. These "dynamic" clearances (e.g., tailored routes with or without Required Times of Arrival and 4-D trajectories, with time as the fourth dimension) will become more common and the distinctions between dynamic and fixed procedures may become blurred.

Research Topics. Research is needed to develop guidance on:

a) Distinction between Dynamic and Fixed Clearances. When should a clearance be depicted as a fixed versus a dynamic clearance? Will the distinction be clear to pilots?

b) Depiction of Dynamic Clearances. How should a dynamic clearance be depicted to the pilot? What information that would normally be shown on a fixed clearance is not necessary for a dynamic clearance? What additional information is needed to support a dynamic clearance? When does consistency between dynamic and fixed clearances need to be maintained? Will dynamic clearances be named, and if so, will there be compatibility between naming conventions for fixed and dynamic clearances? In the long term, would there be any safety benefit for depicting dynamic clearances in three dimensions? What are the benefits and limitations of integrating depictions of special use airspace (SUA) and temporary flight restrictions (TFRs)?

c) Criteria for Operational Suitability. Ensuring obstacle clearance requirements for dynamic clearances will be a key technical challenge. Other criteria for operational suitability of dynamic clearances should be developed.

8. Air-Ground Human Factors Considerations for RNAV/RNP Operations

Proposed product: TBD.

Proposed sponsors: Mark Steinbicker (AFS-470) and Kathy Abbott (AIR-100)

Proposed Duration of Effort: TBD

Background. There are a variety of issues that cut across flight crews and Air Navigation Service Providers (ANSP) related to PBN. For example, phraseology to support PBN operations (e.g., "descend via," "climb via") has been discussed in the PARC Pilot-Controller Procedures Systems Integration (PCPSI) working group. These issues are not covered in the DataComm message set being developed by RTCA. Some topics are proposed below, but these will be further defined and refined in the future.

Research Topics. Research is needed to examine the PBN issues that affect both flight crews and ANSPs. Specifically:

a) Chart Use by Air Traffic Controllers (ATC). Controllers are also users of instrument approach plates and arrival/departures charts. Changes made to these charts to improve their usability for flight crews could impact controller training, workload, and staffing issues.

b) Communications about Operational Capabilities. How is the ability to accept a particular instrument procedure communicated between the controller and crew? The ability to communicate about operational capabilities and requests will be especially important as the system moves toward to goal of "best equipped best served." However, even new proposed ICAO equipage codes may not be sufficient for this communication. If the crew makes a request for a particular procedure, it is not the responsibility of the controller to confirm whether the crew and aircraft are qualified for the procedure.

c) Tradeoffs between Routing Flexibility and Complexity. Some flexibility in routing is desired by the ANSP, in order to maneuver around weather and other traffic, and to optimize traffic flows. More tightly defined RNAV and RNP paths can limit the ANSPs routing flexibility. Flight crews, who may be more dependent on flight deck systems to fly PBN paths, prefer not to have last minute route changes, which can impose a high level of workload, especially when operating below 10,000 ft. These tradeoffs could be considered in procedure design, but they need to take into account the needs of both the ANSP and flight crews.

d) Revised Clearances. Handling PBN clearances pre-flight can be a relatively complex, but manageable task. Handling changes to PBN clearances in flight presents a much higher workload situation to crews. The complexity of clearances will only increase in the future, because clearances will have conditional elements (e.g., they may include time-based or capability-based requirements). The communication, review, and acceptance of these complex revised clearances will be complex for both crews and controllers.

e) ATC Phraseology. It can be difficult to clearly convey the limitations and expectations of a PBN clearance. For example, there must be clear communications about whether the clearance applies to lateral, vertical, or speed constraints, or some of these but not all of these constraints. One current example of a phraseology issue is the *climb via* and *descend via* language. Inconsistencies in interpretation of air traffic clearances could lead to pilot deviations and operational errors. International harmonization efforts must be supported with appropriate research data to ensure that the recommended phraseology produces the desired and expected performance for both flight crews and air traffic controllers.

9. RNAV Airways

Proposed product: TBD.

Proposed sponsor: Mark Steinbicker (AFS-470).

Proposed Duration of Effort: TBD

Background. Q and T routes are airways defined by RNAV waypoints instead of ground-based navigational aids. They are currently used only in the United States and Canada, and may be unfamiliar to pilots who mainly fly in other parts of the world. Q routes are used above FL180 in IFR operations; they are depicted on high altitude en route charts. T routes are for use between 1200 ft and 18000 ft; they are depicted on low altitude en route charts. Q routes can reduce the distance for common flight routes and T routes can provide easier access through Class B airspace.

Research issues for the depiction and operational use of Q routes and T routes need to be identified. For example, international coordination of naming or labeling conventions for RNAV airways on charts may be needed. In addition, charting conventions may need to be developed to clearly distinguish between RNAV routes and conventional navigation routes when they overlap.

10. Design and Evaluation of Flight Crew Procedures for PBN Operations

Proposed product: TBD.

Proposed sponsors: Mark Steinbicker (AFS-470) and AFS-200. Possibly also AFS-800, to be determined.

Proposed Duration of Effort: TBD

Background. General recommendations for training to obtain RNP qualifications and procedures for RNP operations were published for Part 121 operators by Air Line Pilots Association (ALPA) in 2008. As PBN operations are used more widely, there may be a need to update and expand this guidance. For example, pilots may need more specific training on procedures and nuances related to using the Flight Management System for PBN operations to avoid common errors. Procedures for RNAV departures are one example for which additional training has been developed.

Additional research areas to be considered could include:

- RNAV/RNP Training and Procedures for Corporate Operators (Part 91).
- RNAV/RNP Training Needs for Dispatch.

11. Design and Evaluation of Flight Deck Systems to Support PBN Operations

The initial proposed product of this effort could be recommendations for design of flight deck systems to better support PBN operations. A later proposed product of this effort could be recommendations that could be used in the certification and approval of new concepts for flight deck system interfaces.

The proposed sponsors for this research may be in the Flight Standards Aircraft Evaluation Group (for uninstalled displays such as an Electronic Flight Bag) or potentially in Aircraft Certification (for equipment installed in the flight deck).

Proposed sponsor: Kathy Abbott (AIR-100).

Proposed Duration of Effort: FY12 through FY14

Background. There is a significant amount of human factors guidance that is referenced when installed systems are certified by the FAA (e.g., Advisory Circular (AC) 25.11). These systems are evaluated based upon whether they meet the needs of their intended function. Uninstalled displays (e.g., Class 1 and 2 EFBs, and Personal Electronic Devices, or PEDs) are not required to conform to guidance such as that in AC 25.11, but it is considered good practice to do so. New elements of the human interface that are not addressed in existing guidance are addressed through issues papers.

Many flight deck systems in use today were designed several years ago and only incremental improvements have been made to the human interfaces of these installed systems. These systems may need to be upgraded significantly to better support PBN operations. For example, decision support systems may be developed to help the pilot evaluate the consequences of revised PBN clearances. Changes to these systems may result both in an updated evaluation by the FAA and potentially updates to crew training on these systems. Ideally, the upgrades will help to reduce error potential in the future.

Research Topics. Research is needed to examine the functional tasks that pilots do to support PBN operations. For example:

a) Design of Flight Deck Systems for PBN. How do pilots use flight deck systems to enter, review, and execute PBN procedures in modern flight deck systems today? FMS database limitations and chart/database compatibility must be considered. Cross-cockpit allocation of instrument procedure information should also be considered because providing all procedure information on the moving map or vertical profile display will become increasingly difficult due to clutter.

   Approach. One approach to this research would be to select a few FMS systems to survey from a human factors perspective, then select a few representative tasks and record how each task is handled in the different FMS interfaces. Explore the usability issues from a PBN task-oriented perspective.

b) Evaluation of Flight Deck Systems for PBN. What new flight deck systems and interface concepts are being developed by manufacturers? What information would be helpful to the FAA in evaluating and approving these systems? Some areas of interest may be “shared displays” (where a single physical display screen can toggle between several applications)

and integration of color requirements for uninstalled displays with color requirements for installed displays.

Past Research Areas

12. Navigation Reference System (NRS) Waypoints

This research addressed human factors issues related to the naming and depiction of Navigational Reference System (NRS) waypoints. NRS waypoints are in limited use for flight planning by airlines for Instrument Flight Rules (IFR) high altitude operations. The waypoints are depicted on high altitude en route IFR charts. It is anticipated that the numbers of NRS waypoints will be greatly expanded (from roughly 1600 waypoints to 6600 waypoints) in the future. These waypoints and their naming conventions will have implications for the FMS navigation databases and duplicate waypoint search criteria within the FMS software.

The sponsor for this work was the PBN Policy and Support Group (AJV-14) (Joe McCarthy). No additional research requirements have been identified at this time.

Status.

Two phases of the work were completed in 2011. Reports are available (see below). Human factors considerations in the naming and use of NRS waypoints were explored from both a flight deck and air traffic service provider perspective, although the focus was on the flight deck user. A literature and operational review of the use of the waypoint names in the FMS was also completed. Additional research related to NRS waypoints was performed earlier by MITRE prior to NRS implementation, and was reviewed by NASA Ames researchers at the outset of the recently completed effort.

Products.

NASA, Burian, B.K., Pruchnicki, S., & Christopher, B. (2010). *Human Factors Evaluation of the Implementation of the Navigation Reference System (NRS) Phase 1 Final Report.* View Full Document

NASA, Burian, B.K., Christopher, B., Pruchnicki, S., & Cotton, S. (2011). *Human Factors Evaluation of the Implementation of the Navigation Reference System (NRS) Phase 2 Final Report. (155 pages)* View Full Document

Table 1. Summary of Active Tasks and Schedule

Topic/Sponsor	FY12	FY13	FY14	FY15	FY16
Research Plan and Document Library					
Human Factors Input to Working Groups					
Chart Usability/AIR-100 (Kathy Abbott) and AFS-470 (Mark Steinbicker)					
Electronic Charts and Other Electronic Flight Deck Displays of Chart and Procedure Data/ AIR-100 (Kathy Abbott)					
Charting for Low Visibility Operations/AFS-410 (Bruce McGray and Terry King)					

Table 2. Summary of Proposed Tasks and Schedule

Topic/Sponsor	FY12	FY13	FY14	FY15	FY16
Human Factors Considerations for Procedure Designers/ AIR-100 (Kathy Abbott) and AFS-470 (Mark Steinbicker)					
Charting of Dynamic Clearances/ AIR-100 (Kathy Abbott) and AFS-470 (Mark Steinbicker)					
Air-Ground Human Factors Considerations for RNAV/RNP Operations/AFS-470 (Mark Steinbicker) and AIR-100 (Kathy Abbott)					
RNAV Airways/AFS-470 (Mark Steinbicker)					
Design and Evaluation of Flight Crew Procedures for PBN Operations/AFS-470 (Mark Steinbicker) and AFS-200					
Design and Evaluation of Flight Deck Systems to Support PBN Operations /AIR-100 (Kathy Abbott)					

Need for this Research

There are five key source documents that indicate a need for the research described in this plan. The full titles of these documents are shown below on the left side of Table 2 and an abbreviated title is shown on the right side.

Table 4 shows a mapping of research topics to requirements in the source documents listed above. It has a row for each of the ten separate research topics discussed above. As mentioned earlier, the first two topics (Research Plan and Document Library; Human Factors Input to Working Groups) cut across topics, so they are excluded. The abbreviated titles of the source documents are used in this table.

Relevant operational improvements were identified by searching the FAA's NAS Enterprise Architecture Website, https://nasea.faa.gov/. The NextGen Implementation Plan for 2012 was also reviewed.

Table 3. Source documents.

Full Title	Abbreviated Title
National Air Space (NAS) Enterprise Architecture Segment Implementation Plan (NSIP) Alpha	*NSIP Alpha*
FAA Aviation Safety (AVS) and Flight Standards (AFS) FY12 requirements for the NextGen Technical Community Representative Group (TCRG)	*TCRG Requirements*
AVS Work Plan 2012	*AVS Work Plan*
FAA NextGen Integration and Implementation Office *Response to Recommendations of the RTCA NextGen Mid-Term Implementation Task Force*	*Response to RTCA*
PARC Chart Saturation Working Group Recommendations	*PARC WG*

Table 4. Mapping of research topics to source documents.

Topic	Source Documents and Subsections that Reference this Topic
Chart Usability	*NSIP Alpha* OI 107103 RNAV SIDS, STARS and Approaches OI 108209 Increase Capacity and Efficiency Using Area Navigation (RNAV) and Required Navigation Performance (RNP) *TCRG Requirements* "Identify issues and develop human factors guidelines for the design, depiction, usability, and flyability of instrument procedures and associated charts for inclusion in advisory material and standards for instrument procedures and associated charting. Produce guidance and standards that will reduce susceptibility to errors by appropriately qualified pilots." *AVS Work Plan* "New displays and alerting, as appropriate, need to be developed to improve awareness and retain the ability for the flight crew to manage the operation." *PARC WG* "The group recognized…there was limited research data on how, when, and why pilots use various elements on a chart, particularly when some of those elements are also available on a Navigation Display (Moving Map) or on the Flight Management System (FMS) display. The consensus was that further research was required…"
Electronic Charts	*AVS Work Plan* "New displays and alerting, as appropriate, need to be developed to improve awareness and retain the ability for the flight crew to manage the operation."

Topic	Source Documents and Subsections that Reference this Topic
Charting for Low Visibility Operations	*NSIP Alpha* OI 102401 Current Surface Separation OI 107115 Low Visibility/Ceiling Takeoff Operations OI 107116 Low Visibility/Ceiling Departure Operations OI 107117 Low Visibility/Ceiling Approach Operations OI 107118 Low Visibility/Ceiling Landing Operations OI 107119 Expanded Low-Visibility Operations Using Lower RVR Minima OI 107202 Low Visibility Operations *TCRG Requirements* "Data, analysis, and recommendations to support the development of guidance on…charts and symbology for taxi operations in low visibility…"
Human Factors Considerations for Procedure Designers	*NSIP Alpha* OI 102141 Improved Parallel Runway Operations OI 104122 Integrated Arrival/Departure Airspace Management *TCRG Requirements* "Recommendations related for instrument procedure designers on developing procedures that can be depicted and used effectively to mitigate susceptibility to error." *Response to RTCA* Runway Access TF 5 Recommendation Operational Capability 37a (p. 13) "allow the use of satellite navigation-based procedures as an alternative to ILS during simultaneous and/or dependent parallel approaches at airports that support such procedures" Metroplex TF5 Recommendation Operational Capabilities 4, 21a, and 32b (p. 15) "Integrate procedure design to deconflict airports, implement RNP with radius-to-fix (RF) capability, and expand use of terminal separation rules." …"seeks to deconflict metroplex airports by publishing, enabling and providing training for new airspace and procedures with an emphasis on procedures that use RF turns and RNP values less than 1.0" *PARC WG* "Charting implications should be considered during procedure design"

Topic	Source Documents and Subsections that Reference this Topic
Charting of Dynamic Clearances	*NSIP Alpha* OI 104124 Use Optimized Profile Descent *AVS Work Plan* "New displays and alerting, as appropriate, need to be developed to improve awareness and retain the ability for the flight crew to manage the operation." *Response to RTCA* Cross-cutting TF5 Recommendation Operational Capabilities 7b, 8, and 46 (p. 25) 2016: More complex RNAV clearance, dependent on Data Comm
Air-Ground Human Factors Considerations for RNAV/RNP Operations	*NSIP Alpha* OI 104123 - Time Based Metering Using RNAV and RNP Route Assignments
RNAV Airways	*NSIP Alpha* OI 102108 Oceanic In-Trail Climb and Decent OI 102136 Reduced Oceanic Separation and Enhanced Procedures OI 102137 Automation Support for Separation Management OI 102148 Self-Separation Airspace Operations OI 102149 Delegated Separation-Complex Procedures OI 104123 Time Based Metering Using RNAV and RNP Route Assignments *TCRG Requirements* "Identification of human factors research issues related to RNAV airways, their design, use, depiction and development of a plan for research to identify associated recommendations." *Response to RTCA* Cruise TF5 Recommendation Operational Capability 30 (p. 18) "Replace existing "Jet" and "Victor" airway routes with performance-based routing systems, using RNAV and RNP. It further seeks the publication of low-altitude NRS waypoints with appropriate grid spacing and the creation of performance-based routes that lower Minimum En Route Altitudes to support use by low-altitude piston engine airspace users."
Design and Evaluation of Flight Crew Procedures for PBN Operations	*NSIP Alpha* OI 102118 Delegated Responsibility for In-Trail Separation OI 102136 Reduced Oceanic Separation and Enhanced Procedures OI 102149 Delegated Separation-Complex Procedures OI 104123 Time Based Metering Using RNAV and RNP Route Assignments *AVS Work Plan* "New displays and alerting, as appropriate, need to be developed to improve awareness and retain the ability for the flight crew to manage the operation."

Topic	Source Documents and Subsections that Reference this Topic
Design and Evaluation of Flight Deck Systems to Support PBN Operations	*NSIP Alpha* OI 102118 Delegated Responsibility for In-Trail Separation OI 102136 Reduced Oceanic Separation and Enhanced Procedures OI 102149 Delegated Separation-Complex Procedures Support Activities [142] Flight Deck Human Factors: Automation Roles and Responsibilities/Evaluation and Approval of Automated Systems [264] Flight Deck Human Factors: Automation Roles and Responsibilities/Unintended Use of New Automated Systems *AVS Work Plan* "New displays and alerting, as appropriate, need to be developed to improve awareness and retain the ability for the flight crew to manage the operation."
Navigation Reference System (NRS) Waypoints	*Response to RTCA* Metroplex TF Recommendation Operational Capabilities 32a and 29 (p. 14) "The Task force is further calling for procedures that can connect to high-altitude Q and T routes (where structure is needed), or expand the use of the National Reference System(NRS) to enable greater flexibility of routing in en route airspace (where structure is not needed)."

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