# Human Factors Evaluation of the Implementation of the Navigation Reference System (NRS)

**Phase 2**

## Final Report

**Barbara K. Burian, Ph.D.**
NASA Ames Research Center

**Bonny Christopher, M.A.**
**Shawn Pruchnicki, M.Sc.**
**Samuel Cotton**
San Jose State University at
NASA Ames Research Center

August 29, 2011

**This work was sponsored by FAA AJV-14, Performance Based Navigation Group, and funded through FAA AJP-61, Human Factors Research and Engineering Group**
**Study: 09-AJP61FGI-0101**

## ACKNOWLEDGEMENTS

The authors of this report would like to thank the many people throughout the industry who took time out of their busy schedules to share their experiences and insight, assisted with obtaining information and setting up meetings, and provided feedback and guidance. In particular we would like to thank Kyle McKee, Dan Herschler, Joe McCarthy, Steve Bradford, Lynn Ray, Gisele Mohler, Brian Holguin, Pat Moran, Deborah Hoagland, Stacy Van Pelt, Michael Hannigan, Brian Will, Karl Fennell, Craig Layton, Bill Murphy, Steve Sorkness, Wayne McClaskey, Jeff Burrows, Larry Bicknell, Robert St. George, Lee Brown, John Brooks, Daryl Hilderbrand, Heidi Williams, Jon Herriott, Holly Latta, Jennifer Granada, Audra Ruthruff, Patrick Cravalho, Greg Elwood, Art Gilman, Walt Johnson, Vern Battiste, Shu Cheih Wu, Summer Brandt, Joel Lachter, Arik-Quang Dao, and Rob Koteskey.

**TABLE OF CONTENTS**

**TABLE OF CONTENTS, continued**

**TABLE OF CONTENTS, continued**

## FIGURES

## FIGURES, continued

## TABLES

**Table** **Page**

**TABLES, continued**

| Table | | Page |
|---|---|---|

## EXECUTIVE SUMMARY

The Navigation Reference System (NRS) and NRS waypoints were developed as part of the high altitude airspace redesign efforts to support area navigation and the Next Generation Air Transportation System (NextGen) initiative. NRS waypoints are RNAV waypoints which form a grid and are identified through the intersection of lines of latitude and longitude. Currently totaling around 1,600 waypoints, they are deployed in all 20 ARTCCs throughout the continental United States; current density is one waypoint spaced every 30 minutes of latitude and every $2^{o}$ of longitude. The NRS waypoint names in current use consist of two letters followed by two numbers and a final letter (ex. KD54U). The first letter “K” is the ICAO FIR for the United States. The second letter (“D”) represents the ARTCC airspace in which the waypoint is located. The two numbers (“54”) and the final letter (“U”) denote the lines of latitude and longitude, respectively, whose intersection define the waypoint.

A number of human factors issues with regard to NRS waypoints were identified through an earlier phase of this study. The most significant issues discovered are:

Issues Related to NRS Waypoint Nomenclature:

- Possible increased radio frequency congestion
- Easy to forget or confuse NRS waypoint names
- Easy to transpose characters within NRS waypoint names
- Easy to confuse the letters “O” and “I” with the numbers “0” and “1,” respectively, in NRS waypoint names
- NRS waypoint nomenclature is perceived as complicated and not easily understood
- Lack of awareness of waypoint geographical location
- Possible confusion for international pilots

Issues Related to Charts, Displays, and Databases:

- Difficult to locate specific NRS waypoints on enroute charts
- NRS waypoint grid cannot be shown on cockpit navigation or ATC radar displays
- NRS waypoints cannot be displayed on cockpit navigation displays if the map range selected is greater than 60 nm
- Restricted size of flight management system (FMS) waypoint databases limit the number of waypoints that can be stored and used
- Easy to make a data entry error when typing in NRS waypoint
- ATC unable to determine bearing and distance between target aircraft and NRS waypoints

Other Issues:

- Possible future degradation of GPS satellites will limit aircraft ability to navigate to NRS waypoints
- Poor readability of NRS waypoints on flight releases due to dot matrix printer resolution
- Aircraft equipment suffixes are insufficient for ATC to determine if a particular aircraft is capable of navigating to NRS waypoints

- Limitations in strategic use of NRS waypoint grid west of the Mississippi River due to insufficient density of the grid
- NRS names that include ARTCC identifiers may not make sense if airspace boundaries between ARTCCs are flexible in the future and a waypoint might be located within different ARTCCs' airspace at different times

**Purpose and Scope**

There were two primary tasks undertaken during this second phase of the *Human Factors Evaluation of the Implementation of the Navigation Reference System (NRS) Study*. The first was to generate a wide variety of solutions that might be implemented to address the issues identified through the first phase of this study. This was accomplished, in part, through a meeting of industry experts in a focus group held at the NASA Ames Research Center at Moffett Field, California on May 4-5, 2010.

In the second primary task, we evaluated one of the solutions identified by the focus group through an experimental study. We analyzed the constraints affecting NRS waypoint nomenclature design and then developed and evaluated three alternate nomenclatures through a part-task study that was conducted with 28 professional pilots as participants.

**Results**

The results of the first task, the generation of solutions to the human factors issues of NRS waypoints, are captured in a set of Issues-Solutions Maps (see Appendix 2). The solutions proposed are wide ranging and include such things as changing the nomenclature of NRS waypoints to increase usability and geographic awareness of waypoint location, the adoption of advanced technology and related procedures (e.g., datacomm), and making changes to FMS and DSR databases and programming. Some solutions proposed, such as changing the purpose and coding of aircraft equipage suffixes, would be relatively inexpensive to develop and implement, though significant re-training and new procedures for many in the industry would be required. Other solutions, such as changes to FMS programming which might affect aircraft airworthiness determinations, could be quite expensive or difficult to implement. In the Issues-Solutions Maps, the various pros and cons of each are captured, as well as assumptions that would have to be met in order for the solution proposed to have its desired effect.

We began our second task, the development and evaluation of alternate NRS waypoint nomenclatures, by analyzing the constraints affecting waypoint nomenclature and the ways in which those constraints intersect with the overall goals for NRS waypoint implementation and use. These constraints and objectives guide and limit the nomenclatures for NRS waypoints that can be developed:

- The use of a grid system for the definition of waypoints in sufficient number to support point-to-point area navigation
- Ability to add other waypoints in the future (i.e., expandability)
- Waypoint names are limited to five characters in length
- Nomenclature yields geographic awareness as to waypoint location

- Users can distinguish between NRS and traditionally named waypoints
- Minimize likelihood of character transposition
- Need for a simple system that is logical and easily understood

In keeping with these constraints and goals for NRS waypoints, in addition to those identified by others (Boetig & Timmerman, 2003; Hannigan, 2009), we generated a wide number of alternate approaches to NRS waypoint design. A number of these ideas for alternate nomenclatures were proposed by the subject matter experts in our industry focus group meeting. Through further analysis we continued the down select process until we identified three alternate nomenclatures to evaluate experimentally in comparison with NRS waypoints configured in the current configuration (N1).

The four nomenclatures evaluated were:
N1: US FIR ID – ARTCC ID – two numeral latitude indicator – one letter longitude indicator
N2: State abbreviation – two numeral latitude indicator – one letter longitude indicator
N3: State abbreviation – three numeral waypoint ID number
N4: State abbreviation – two numeral waypoint ID number – ARTCC ID

Twenty-eight professional pilots, half of whom had previous NRS waypoint experience, served as the participants in this study which was conducted in four consecutive sessions. In each session the usability of one of the four nomenclatures was evaluated through the completion of three tasks: 1) finding specified waypoints on high altitude enroute charts, 2) entering a flight plan route which included NRS waypoint fixes into an FMS emulator, and 3) selecting and entering fixes to divert around weather. At the end of the last experimental session participants completed a questionnaire assessing their opinions regarding their experiences using NRS waypoints in the previous three tasks across all of the four nomenclatures.

Through a variety of statistical analyses it was found that waypoints configured in the current nomenclature (N1) were preferred the least, were rated as providing the least amount of geographical awareness, and required significantly more time to locate on high altitude enroute charts.

Alternate NRS waypoint nomenclature N3, was preferred by an overwhelming majority of participants who believed that it was superior to all three of the other waypoint types in terms of ease of use and the provision of geographic awareness of waypoint location.

Three types of FMS data entry errors were evaluated: confusion between "I" and "1" and between "O" and "0", transposition errors, and mistypes. No significant differences were found in the number of data entry errors committed across the different fixes used in the flight plan routes (VORs, airports, traditionally named RNAV waypoints, and NRS waypoints).

Recommendations based on the findings of all the work conducted during this second phase of the *Human Factors Evaluation of the Implementation of the Navigation Reference System (NRS) Study* are provided. These recommendations include, in part, the completion of studies to evaluate the usability and preference of air traffic controller with regard to various alternate NRS waypoint nomenclatures (only pilots participated in the current study), and studies to assess possible human factors issues that might exist if the NRS waypoint grid were to be expanded as planned to 6,600 waypoints (from the current 1,600) and used at all altitudes rather than just in the flight levels.

## 1.0 INTRODUCTION

Over the last sixty years, the FAA has developed the current US ground based navigation infrastructure in segments as airspace needs and technology has evolved. This evolutionary process has inadvertently resulted in a variable density in the geographical distribution of navigational aids throughout the National Airspace System (NAS). Closer examination shows logically that waypoint density increases in metropolitan areas but leaves remote geographical areas throughout the central and western US with sparse and insufficient coverage. Fortunately, modern day operators with area navigation (RNAV) and/or GPS technologies can now navigate directly to any point in space which offers a significant increase in flexibility for navigation decision making (FAA, 2006). In 2005, the Navigation Reference System was developed and implemented to support point-to-point navigation using intersections of lines of latitude and longitude.

The Navigation Reference System (NRS) currently consists of a grid of waypoints spaced at a density of one waypoint every 30 minutes of latitude and every 2° of longitude (see Figure 1). They are operational at FL180 and above and are used only in the 48 contiguous states of the U.S.

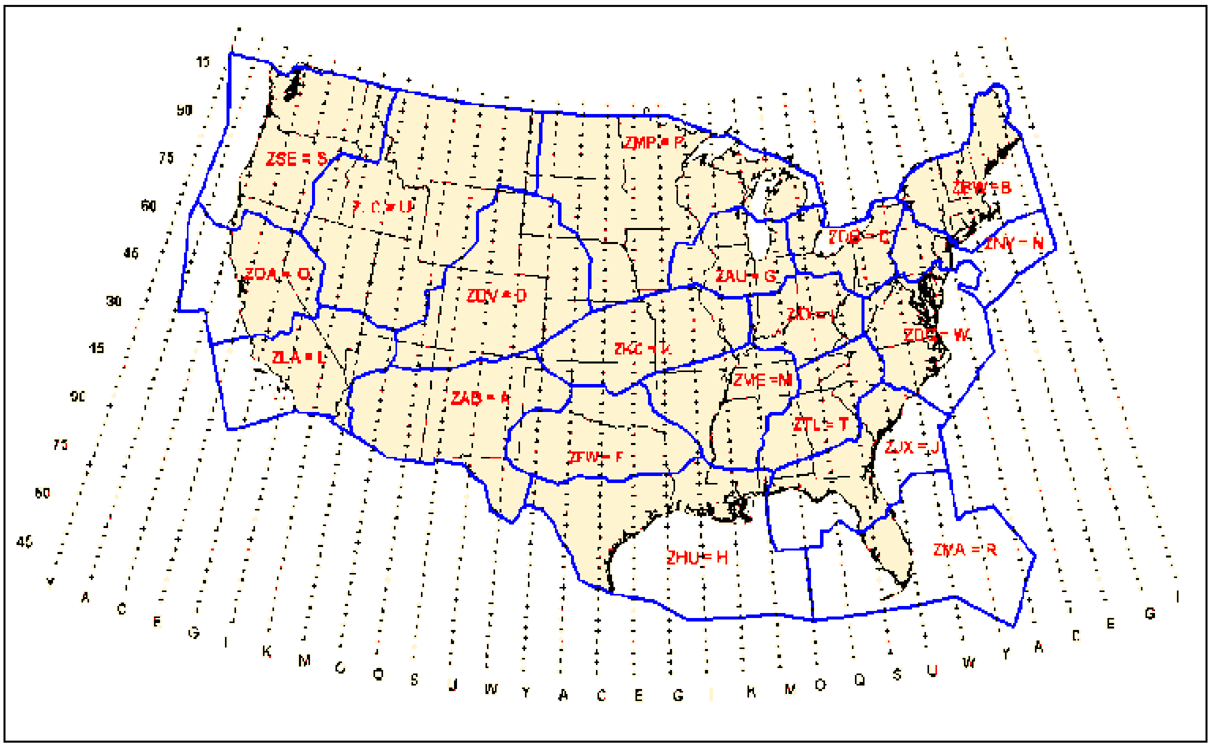



***Figure 1***. Current distribution of 1600 NRS waypoints and US ARTCC regions. (Borowski, Wendling, & Mills, 2004).

In compliance with industry recommended standards put forth in ARINC 424-19 (Aeronautical Radio, 2008) and in International Civil Aeronautical Organization (ICAO) PANS-OPS Vol. II, Chapter 31, paragraph 31.1.2, NRS waypoint names are five characters long. The first character in all NRS waypoints is "K", the U.S. FIR identifier. The second character is a letter indicating the Air Route Traffic Control Center (ARTCC or "Center") airspace in which the waypoint is located. The third and fourth characters are numbers signifying the line of latitude on which the waypoint exists and the final character is a letter identifying the line of longitude on which the waypoint falls (see Figure 2).

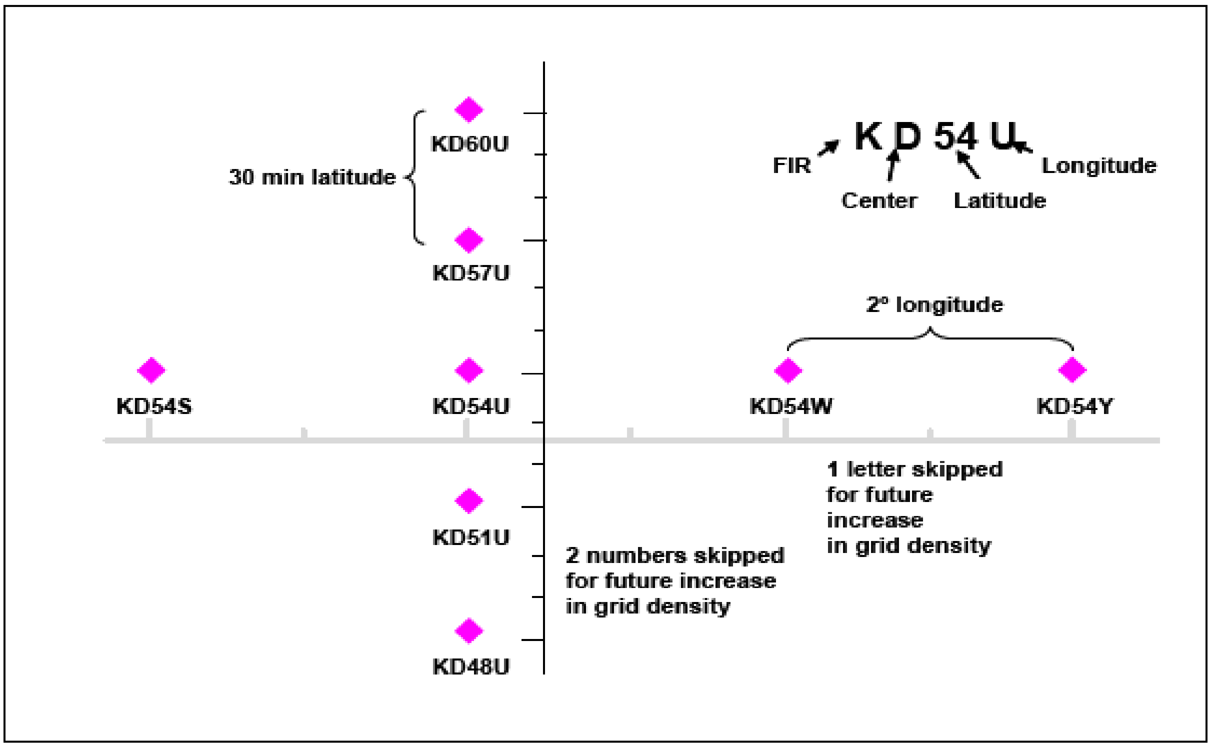



**Figure 2.** NRS waypoint grid structure and nomenclature. (Boetig, et al., 2004).

A number of objectives guided the developers of the current NRS waypoint nomenclature (Boetig & Timmerman, 2003; Hannigan, 2009) and are presented in Table 1 below.

**Table 1**

*Goals for Nomenclature and Waypoint Development and Use*

| |
|---|
| Facilitate user preferred routing that is based on satellite navigation |
| Be consistent with principles that guide names for navigational fixes |
| Satisfy processing requirements for filing at least one fix per ARTCC |
| Minimize impact to airborne equipment |
| Be usable by a majority of current aircraft |
| Incur only minimal changes (i.e., database only) to ground automation |
| Support implementation across the United States |
| Reduce pilot and ATC workload regarding communication and chance for error |
| Tactical aid to resolve traffic conflicts & aid in weather avoidance |
| Be easy to communicate |
| Have a low potential for error |
| Be intuitive as to the general location of the fix (i.e., provide "geographic" awareness) |
| Be easier to use than fixes delineated by full latitude and longitude coordinates |

Boetig & Timmerman, 2003; Hannigan, 2009

Unfortunately, since their deployment in 2005, NRS waypoints have been met with limited industry enthusiasm and usage. Through in-depth reviews of the literature, searches of incident and accident databases, and numerous interviews with developers and users of NRS waypoints conducted through the first phase of this study (see Burian, Pruchnicki, & Christopher, 2010), a number of human factors issues which may contribute to their limited use were identified. These issues are summarized below; readers are encouraged to refer to the *Human Factors Evaluation of the Implementation of the Navigation Reference System (NRS), Phase 1 Final Report* (Burian, et al., 2010) and the Issues-Solutions Maps in Appendix 2 for an in-depth discussion and review of these issues.

<u>Issues Related to NRS Waypoint Nomenclature</u>:

- Possible increased radio frequency congestion
- Easy to forget or confuse NRS waypoint names
- Easy to transpose characters within NRS waypoint names
- Easy to confuse the letters "O" and "I" with the numbers "0" and "1," respectively, in NRS waypoint names
- NRS waypoint nomenclature is perceived as complicated and not easily understood
- Lack of awareness of waypoint geographical location
- Possible confusion for international pilots

<u>Issues Related to Charts, Displays, and Databases</u>:

- Difficult to locate specific NRS waypoints on enroute charts
- NRS waypoint grid cannot be shown on cockpit navigation or ATC radar displays

- NRS waypoints cannot be displayed on cockpit navigation displays if the map range selected is greater than 60 nm
- Restricted size of flight management system (FMS) waypoint databases limit the number of waypoints that can be stored and used
- Easy to make a data entry error when typing in NRS waypoint
- ATC unable to determine bearing and distance between target aircraft and NRS waypoints

Other Issues:

- Possible future degradation of GPS satellites will limit aircraft ability to navigate to NRS waypoints
- Poor readability of NRS waypoints on flight releases due to dot matrix printer resolution
- Aircraft equipment suffixes are insufficient to determine if a particular aircraft is capable of navigating to NRS waypoints
- Limitations in strategic use of NRS waypoint grid west of the Mississippi River due to insufficient density of the grid
- NRS names that include ARTCC identifier may not make sense if airspace boundaries between ARTCCs are flexible in the future and a waypoint might be located within different ARTCCs' airspace at different times

## 2.0 PURPOSE AND SCOPE OF PHASE TWO WORK

There were two overriding goals for the work undertaken during this second phase of the NRS waypoint study. The first was to identify possible solutions or mitigations to the issues discovered through the first phase of this study (Burian, et al., 2010). This was accomplished in part through a meeting of industry experts in a focus group held at the NASA Ames Research Center at Moffett Field, California on May 4-5, 2010 (see section 3.0 below). The second goal was to evaluate one or more of the solutions identified by the focus group through an experimental study. The part-task study that was conducted for this evaluation is described in section 5.0.

On a day-to-day basis, NRS waypoints are used primarily by pilots, air traffic controllers, and flight planners and dispatchers. Thus, all these constituencies were represented in the Industry Focus Group Meeting. However, several other groups were also represented in this meeting including developers of the NRS waypoint grid and NRS waypoint nomenclature, FMS database and human factors experts, and several individuals from the FAA responsible for the development and functioning of area and performance based navigation. This broad representation across the industry ensured the identification of a wide range of possible solutions to the NRS waypoint issues.

The experimental study that was conducted however, was far more narrow in scope as budget and time constraints only allowed for the evaluation of just a few of the solutions identified by the focus group. Because many of the issues discovered during phase one pertained to NRS waypoint nomenclature, the primary focus of the experimental study undertaken here in phase two was to assess alternate NRS waypoint naming structures, or “nomenclatures,” that would ease waypoint location on paper enroute charts, require less working memory to remember, be easy to communicate over the radio, result in fewer errors during FMS data entry, and increase awareness of waypoint geographical location. Due to budgetary and fiscal constraints, only pilots served as the participants in this study. A parallel study involving air traffic controllers and flight planners/dispatchers is still required to validate the findings from this study and ensure that any recommended alternate nomenclature has the greatest utility and fewest human factors limitations for all of the main constituencies in the industry who use NRS waypoints. A third phase of this study is also planned to explore human factors issues with NRS waypoints that might exist if the grid were expanded to 6,600 waypoints and utilized below FL180.

## 3.0 INDUSTRY FOCUS GROUP MEETING

In May of 2010, an industry focus group was convened to discuss the issues that had been discovered during phase one of our research. Those invited were experts from the FAA, NASA, MITRE, pilots, dispatchers, airline management, air traffic controllers, FMS and FMS database experts, aviation human factors researchers and experts, among others, all of whom had experience with or knowledge of NRS waypoints. Additionally, several members of the original NRS design team were in attendance providing in-depth background information for our discussions. The primary objective of this meeting was to provide an open forum where experts in the aviation community could offer their unique perspectives regarding not only the NRS grid and waypoint issues discovered in Phase One, but also offer possible solutions in collaboration with others. By the end of the meeting, an extensive list of mitigations and solutions was developed. This forum proved successful for many reasons, one of which was the rapid collaboration from various segments within the industry. Occasionally, the development of a mitigation, while solving a problem for one group within the industry, was quickly realized to cause additional problems for other groups. By having so many industry representatives available in the same room, solutions offered could be tailored to benefit as much of the industry as possible.

### 3.1 Issues-Solutions Maps

Following the completion of the focus group meeting, we evaluated the various solutions offered, identified the pros and cons of each, eliminated redundancies, condensed and combined where appropriate, added some additional possible solutions that had been overlooked, and re-organized and codified all into a set of tables referred to as Issues-Solutions Maps (see Appendix 2). There are actually three different maps, one focused on issues directly pertaining to NRS Waypoint Nomenclature, a second one centering on issues involving NRS waypoints on paper charts, pilot and ATC displays, and inclusion in FMS and En Route Automation Modernization (ERAM) databases, and a third one addressing other miscellaneous issues.

Each map is comprised of two main sections. The issues section includes four columns of information: 1) Issues, 2) Due To (why the issue exists), 3) Comments (additional explanatory information), and 4) Goals Not Met (goals for NRS waypoint design and usability that guided the developers that have not been met because of the issue. The solutions section also includes four columns of information: 1) Solutions, 2) Pros, 3) Cons, and 4) Assumptions That Must Be Met for the Solution to Work. More than one possible solution is offered for most issues.

Prior to the identification of which development and usability goals were not met as a result of each issue ("Goals Not Met"), we first evaluated the list of goals itself. We discovered that the goals can be roughly separated into three different categories, those pertaining to the design of NRS waypoints and the grid, those involving the implementation of the grid, and the usability of NRS waypoints (see Table 1a). We color coded these three categories of goals in the Issues-Solutions Maps and a scan down the maps easily reveals that the vast majority of the goals which had not been met pertain to the usability of NRS waypoints and the grid (see Appendix 2).

Although they have not been color coded the way they have been in the Issues sections of the Issues-Solutions Maps, some of the goals listed in Table 1a are also not met by some of the of the solutions offered in the maps. This is particularly the case for three implementation goals ("Minimize impact to airborne equipment," "Be usable by a majority of current aircraft," and "Incur only minimal changes (i.e., database only) to ground automation") as several solutions offered involved the use of advanced technologies and changes to pilot and ATC displays.

**Table 1a**

*Goals for Nomenclature and Waypoint Development and Use*

| Goal Type |
|---|
| Design |
| Facilitate user preferred routing that is based on satellite navigation |
| Be consistent with principles that guide names for navigational fixes |
| Satisfy processing requirements for filing at least one fix per ARTCC |
| Implementation |
| Minimize impact to airborne equipment |
| Be usable by a majority of current aircraft |
| Incur only minimal changes (i.e., database only) to ground automation |
| Support implementation across the United States |
| Usability |
| Reduce pilot and ATC workload regarding communication and chance for error |
| Tactical aid to resolve traffic conflicts & aid in weather avoidance |
| Be easy to communicate |
| Have a low potential for error |
| Be intuitive as to the general location of the fix (i.e., provide "geographic" awareness) |
| Be easier to use than fixes delineated by full latitude and longitude coordinates |

Boetig & Timmerman, 2003; Hannigan, 2009

Tables 2, 3, and 4 below summarize the solutions offered across all the issues presented in the three maps. Solutions in colored blocks (e.g. "Transmit NRS waypoints via datacomm") appear in more than one map (table). A review of the summary tables and Table 5, which lists all solutions by the frequency with which they appear in the Issues-Solutions Map, clearly indicates that by far, the most common solution offered for many issues was to come up with an alternate NRS waypoint nomenclature. Before the part-task study that was conducted to evaluate several such alternate nomenclatures can be reviewed (see section 5.0), it is first necessary to thoroughly examine the constraints and options that exist which affect the types of alternate nomenclatures that are permitted and feasible.

Table 2
Issues-Solutions Map Summary: Waypoint Nomenclature Issues

| | Change NRS waypoint Nomenclature | Transmit NRS Waypoints via Datacomm | Develop other technologies to reduce pilot/ATC verbal comms | Use audio recording to playback NRS wpt information | Eliminate NRS wpts and use only conventionally named waypoints | Group characters in wpt names in radio comms (e.g., ten, not one-zero) | Pilots write down ATC clearances | Increase/provide training | Have FMS program prohibit incorrect character entry | Eliminate either O&I or 0 &1 from NRS wpts | Use touch screen or mouse on display to create new wpt | Add large Lat/Long numbers/letters to edge of enroute chart | Create an NRS only enroute chart | Change ARTCC boundaries to regular and uniform shapes | Replace NRS wpt naming system with one consistent with what is used in other countries |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Possible increased frequency congestion | X | X | X | X | X | | | | | | | | | | |
| Easy to forget waypoint name | X | X | | X | X | X | X | | | | | | | | |
| Easy to confuse wpt names | X | X | | | X | | | X | | | | | | | |
| Easy to transpose characters in wpt names | X | X | | | X | X | | | | | | | | | |
| Easy to confuse O & I with 0 and 1 in wpts | X | X | | | | | | X | X | X | | | | | |
| Nomenclature is complicated, not easily understood | X | | | | X | | | X | | | X | | | | |
| Lack of awareness of waypoint geographical location | X | | | | | | | X | | | | X | X | X | |
| Waypoints may confuse international pilots | X | | | | X | | | X | | | | | | | X |

Table 3

Issues-Solutions Map Summary: Charts, Displays, Databases Issues

| | Change NRS waypoint Nomenclature | Transmit NRS Waypoints via Datacomm | Change how NRS wpts are depicted on charts | Review charts, delete information that isn't needed | Eliminate NRS wpts and use only conventionally named waypoints | Create NRS only enroute charts; eliminate all other RNAV wpts | Create NRS only chart as supplement to other charts | Display NRS wpts on NAV & Radar displays | Increase memory for wpts in FMS databases | Include NRS wpts in ERAM databases | Use touch screen or mouse on display - create new wpt | Increase/provide training | Add large Lat/Long numbers/letters to edge of enroute chart | Develop algorithms for construction of wpts by FMS in real time | Use close-based computing for storage of all wpts | Get rid of all named wpts and use only NRS wpts | Allow wpts to be displayed at all map ranges |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Difficult to locate specific wpt on enroute charts | | | X | X | | X | X | | | | | X | X | | | | |
| Most NRS wpts not able to be displayed on cockpit and radar displays | | | | | | | | X | | | | | | | | | |
| Limitation in the number of NRS wpts available for use in FMS | | | | | X | | | | X | X | | | | X | X | X | |
| NRS wpts not displayed on cockpit NAV display if map range >60 nm | | | | | | | | | | | | | | | | | X |
| Easy to make data entry error | X | X | | | | | | | | | X | X | | | | | |
| ATC unable to determine bearing & distance between target & NRS wpts | | | | | X | | | X | | | | | | | | X | |

Table 4
Issues-Solutions Map Summary: Other Issues

| | Change NRS waypoint Nomenclature | Do not allow airspace boundaries between ARTCCs to move/be flexible | Use DME/DME or some other navigation as a backup if GPS is unavailable | Eliminate NRS wpts and use only conventionally named waypoints | Ensure that flight release dot matrix printers always have good ribbons | Use laser printers for printing flight release packages | Transmit flight releases electronically to EFB/FMS using ACARS, datacomm, or memory stick | Increase/provide training | Add equipment suffixes to indicate aircraft capability of using NRS wpts | Change purpose of suffixes to indicate aircraft capabilities instead of equipage on board | Require that all IFR aircraft have the same equipment | Increase density of the NRS wpt grid west of the Mississippi River |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lack of pilot, ATC, and dispatcher knowledge of NRS wpts | | | | X | | | | X | | | | |
| Nomenclature ties NRS wpts to specific ARTCC with possible future flexible boundaries | X | X | | | | | | | | | | |
| GPS may not support nav to NRS wpts in future due to degradation | | | X | | | | | | | | | |
| Possible malfunction of on-board equipment required for nav to NRS wpts | | | X | | | | | | | | | |
| Poor readability of NRS wpts on flight release paperwork | | | | | X | X | X | | | | | |
| ATC errors when marking NRS wpts on paper strips | X | | | | | | | X | | | | |
| ATC difficulty in knowing which aircraft can accept NRS wpts in re-route | | | | | | | | | X | X | X | |
| Limitation in strategic usability of NRS wpts west of Mississippi River | | | | | | | | | | | | X |
| NRS usage east of Mississippi River is very light | | | | | | | | X | | | | |

**Table 5**

*Solutions Ranked by Frequency in Issues-Solutions Maps*

| Solutions | Frequency |
|---|---|
| Change NRS waypoint Nomenclature | 11 |
| Increase/provide training | 10 |
| Eliminate NRS wpts and use only conventionally named waypoints | 9 |
| Transmit NRS Waypoints via Datacomm | 6 |
| Use audio recording to playback NRS wpt information | 2 |
| Group characters in wpt names in radio comms (e.g., ten, not one-zero) | 2 |
| Use touch screen or mouse on display to create new wpt | 2 |
| Add large Lat/Long numbers/letters to edge of enroute chart | 2 |
| Create an NRS only enroute chart | 2 |
| Display NRS wpts on NAV & Radar displays | 2 |
| Get rid of all named wpts and use only NRS wpts | 2 |
| Use DME/DME or some other navigation as a backup if GPS is unavailable | 2 |
| Pilots write down ATC clearances | 1 |
| Develop other technologies to reduce pilot/ATC verbal comms | 1 |
| Have FMS program prohibit incorrect character entry | 1 |
| Eliminate either “O” & “I” or “0” & “1” from NRS wpts | 1 |
| Change ARTCC boundaries to regular and uniform shapes | 1 |
| Replace NRS wpt naming system with one consistent with what is used in other countries | 1 |
| Change how NRS wpts are depicted on charts | 1 |
| Review charts, delete information that isn’t needed | 1 |
| Create NRS only enroute charts; eliminate all other RNAV wpts | 1 |
| Increase memory for wpts in FMS databases | 1 |
| Include NRS wpts in ERAM databases | 1 |
| Develop algorithms for construction of wpts by FMS in real time | 1 |
| Use close-based computing for storage of all wpts | 1 |
| Allow wpts to be displayed at all map ranges | 1 |
| Do not allow airspace boundaries between ARTCCs to move/be flexible | 1 |
| Ensure that flight release dot matrix printers always have good ribbons | 1 |
| Use laser printers for printing flight release packages | 1 |
| Transmit flight releases electronically to EFB/FMS | 1 |
| Add equipment suffixes to indicate aircraft capability of using NRS wpts | 1 |
| Change purpose of suffixes to indicate aircraft capabilities instead of equipage on board | 1 |
| Require that all IFR aircraft have the same equipment | 1 |
| Increase density of the NRS wpt grid west of the Mississippi River | 1 |

## 4.0 NRS WAYPOINT NOMENCLATURE

Before constraints and options affecting the design of alternate nomenclatures are discussed, some readers may find it helpful to first review the in-depth description of the structure and design of and issues associated with current NRS waypoint nomenclature provided in sections 4.1 and 4.2 below. Those readers who are intimately familiar with this background information and with the issues associated with current NRS waypoint nomenclature described in the NRS waypoint study phase 1 final report (Burian, et al., 2010) may wish to skip to section 4.3.

### 4.1. Current NRS Waypoint Nomenclature Design

As stated earlier, NRS waypoints are five characters long, in keeping with the industry recommended standards in ARINC 424-19 (Aeronautical Radio, 2008) and in International Civil Aeronautical Organization (ICAO) PANS-OPS Vol. II, Chapter 31, paragraph 31.1.2. Limited by the use of only five characters, the original NRS waypoint designers had to be clever to meet the desired NRS waypoint objectives.

During development, it was believed that the NRS grid might be expanded on an oceanic or possibly global scale. As such, the first letter in each waypoint name is always a “K” and signifies that the waypoint is located in the contiguous United States. The second letter signifies in which of the twenty ARTCCs the waypoint is located. For example, in Figure 2 the waypoint KD54U has a “D” as the second character indicating that it is located in the Denver ARTCC airspace.

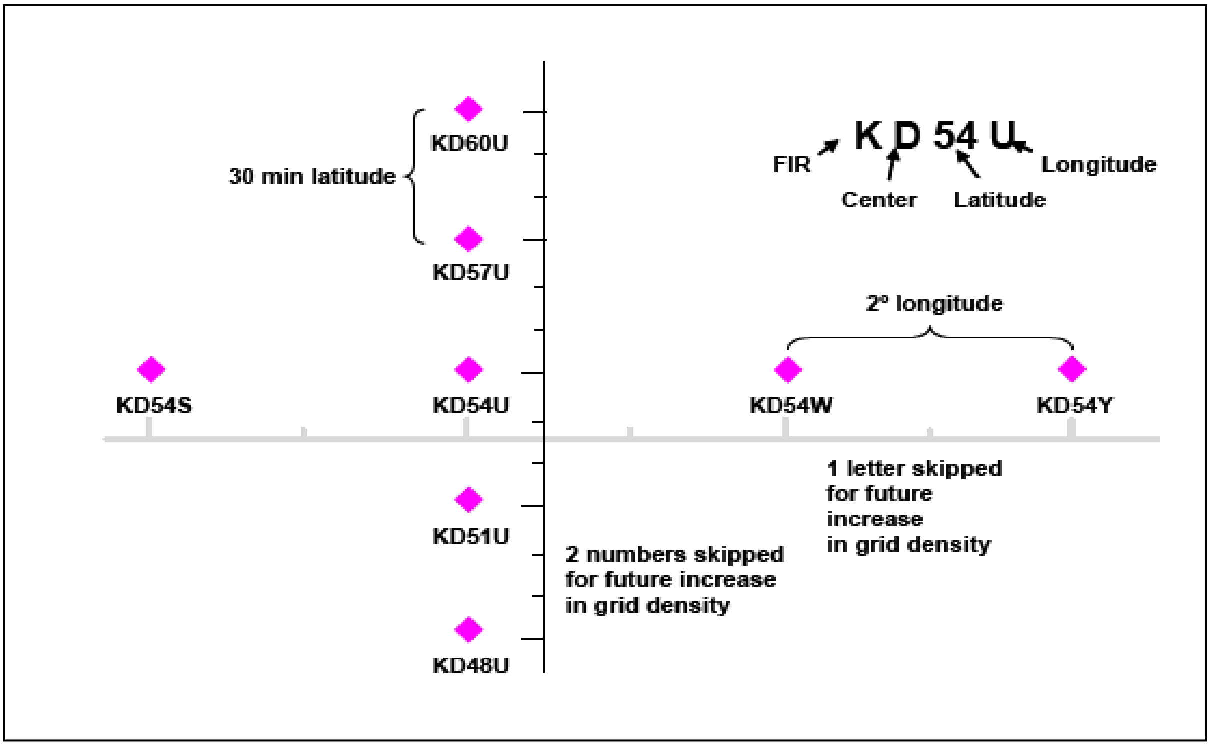



***Figure 2.*** NRS waypoint grid structure and nomenclature. (Boetig, et al., 2004).

The ARTCC airspace boundaries are shown in Figure 1. Following the ARTCC identifier is a two-digit numeric group (characters three and four) representing the latitude of the waypoint (54 in the example, KD54U).

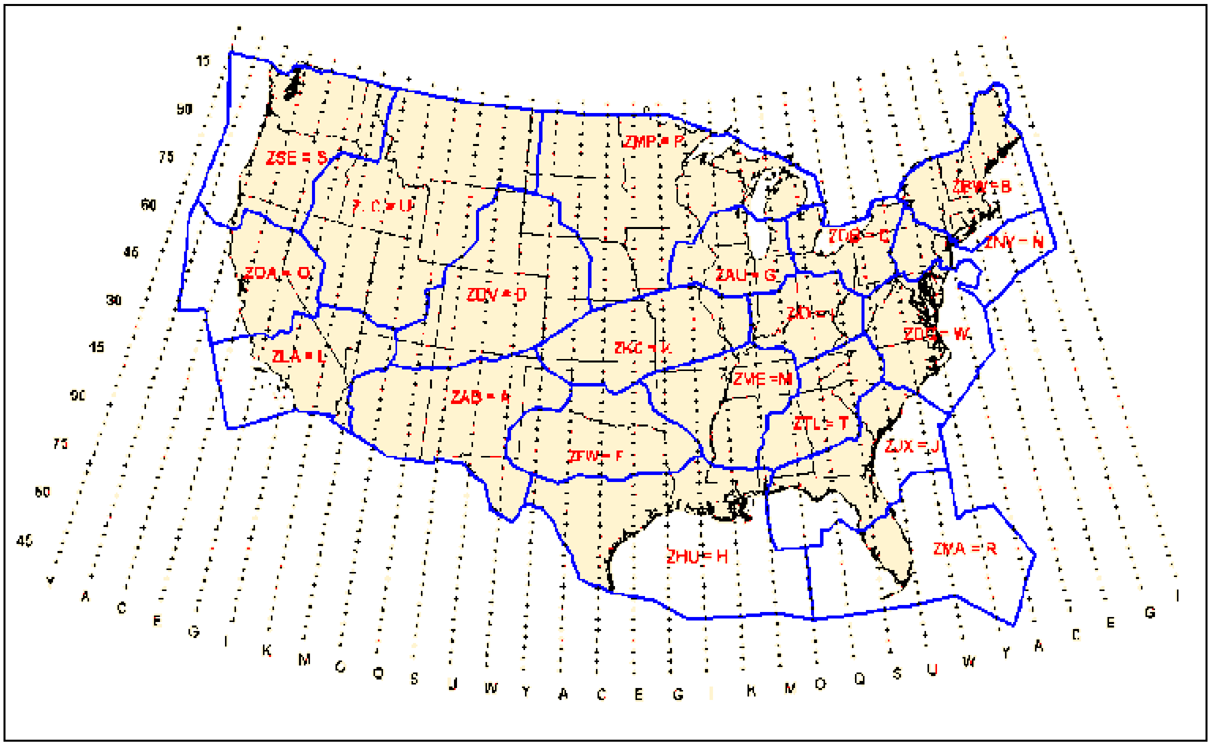



***Figure 1.*** Current distribution of 1600 NRS waypoints and US ARTCC regions. (Borowski, Wendling, & Mills, 2004).

The NRS grid is overlaid on the traditional lines of longitude and latitude although they do not maintain the same numerical labeling system. The numbering of NRS lines of latitude begins at the equator with 00 and ranges from 03 to 90 before repeating. Lines of latitude used for current NRS waypoints correspond with every 10’ of the traditional lines of latitude and repeat every 15 $^{o}$. For example, the number 90 in an NRS waypoint (e.g., KH90G) “could represent 15$^{o}$, 30$^{o}$, 45$^{o}$, 60$^{o}$ or 75$^{o}$” of latitude (Boetig, Domino & Olmos, 2004). To allow for future expansion of the current grid, only every third number is currently used (i.e., 03, 06, 09, 12 and so on). The final letter in an NRS waypoint name signifies the line of longitude on which the waypoint is located. The prime meridian is labeled with the letter A and the letters repeat every 26$^{o}$ of longitude progressing from west to east. The current grid density identifies a waypoint at every 2$^{o}$ longitude, therefore every other letter in the alphabet is also omitted to allow for future expansion of the grid to a waypoint every 1$^{o}$ of longitude if later desired (see Figure 1).

To summarize, the first character in current NRS waypoints identifies a large area in which the waypoint is located (i.e., the contiguous 48 United States). The second character further narrows this area (to the airspace of a single ARTCC). The final three characters define a specific point within that more narrow area.

## 4.2 Current NRS Waypoint Nomenclature Issues

### 4.2.1 FIR Identifier

One common observation was that with no further plans for NRS global or oceanic expansion, the first character in the waypoint name (i.e., "K") is both unnecessary and cumbersome. Additionally, since NRS waypoint names are not pronounceable and each character must be annunciated, many suggested that keeping "K" as the first character adds to potential radio congestion.

### 4.2.2 Working Memory Limitations

When humans are presented with information that will be immediately used, we hold this information in working memory. It is well understood that there are significant limitations to working memory capacity and this capacity can actually decrease during times of stress (Baddeley, 1987). Research has shown that on average, when not under stress, working memory capacity is seven, plus or minus two "items" or "pieces" of data ($7 \pm 2$; i.e., five to nine items; Miller, 1956). An item or "piece" of data might be a single "thing," such as one digit in a person's phone number, or it might actually be several "things" that together carry a single unit of meaning, such as several letters that together make up a person's first name. Some information held in a person's working memory that is full to capacity will drop out to make room for new information that comes in.

Working memory limitations have important significance with regard to the nomenclature of NRS waypoints. A traditional RNAV waypoint name such as "AZELL" is more likely perceived as one item or piece of data to hold in working memory because it spells a single pronounceable word. NRS waypoints, on the other hand, do not "chunk" together to form a single unit of information. The waypoint KD54U is comprised of three to five units of information depending on how the reader interprets and stores the waypoint name in their working memory. For example, if the "K" is not retained (since all NRS waypoints begin with "K") and "54" is retained as "fifty-four" rather than "five – four" then KD54U consists of three units of information: "D" – "Fifty-four" – "U". Therefore, when considering verbal communication and the possible reliance on working memory, one NRS waypoint might come very close to filling one's working memory capacity. Until this information can be written down, entered into a FMS, or typed onto a DSR keyboard, remembering two NRS waypoints in a spoken clearance could easily exceed human memory capacity, presenting serious (and unnecessary) challenges to an already demanding task.

### 4.2.3 Transposition and Data Entry Errors

Because of the current nomenclature structure, many NRS waypoint names appear similar (e.g., KP90G – KP09A) and can lead to confusion and errors when users write them down on paper strips (ATC; Domino, Ball, Helleberg, Mills, & Rowe, 2003) or type them using FMS or DSR keypads (pilots and ATC, respectively; Burian et al., 2010). Additionally, pilots report concern over confusing "O" and "I" with "1" and "0" and with transposing characters and controllers find that shifting back and forth between the letter and numerical sections of their DSR keypad when entering NRS waypoints is cumbersome and contributes to errors (Burian, et al., 2010).

#### 4.2.4 Geographical Awareness and Display Issues

The structure of NRS waypoint nomenclature is intended to provide geographical awareness of waypoint location to users. Despite this original design intent, users frequently report that trying to locate an individual waypoint is difficult and find the nomenclature to be quite confusing, even when they understand the underlying structure (Burian, et al., 2010). This is not a new finding; a July 2004, pre-implementation report issued by MITRE CAASD offered a recommendation that additional studies should be conducted to examine usability issues related to spatial and geographical orientation relative to NRS waypoints (Borowski, et al., 2004).

Pilots and controllers alike state that current display issues only make this task more difficult. Specifically for pilots the most common geographical awareness issues are; 1) the inability to display non-flight plan NRS waypoints on cockpit navigation displays, 2) the inability to show flight plan NRS waypoints on a navigation display if the map range is set beyond 60 nm, 3) lack of awareness of ARTCC identifiers, 4) the characters signifying latitude in NRS waypoints do not match or meaningfully correlate with real latitude numbers, and 5) the character used to signify longitude in NRS waypoints is a letter (rather than a number) and does not meaningfully correlate with real longitude numbers.

Additionally, pilots report that providing the ARTCC region in which the waypoint lies is not particularly helpful since ARTCC areas cover such vast geographical regions. Additionally, although ARTCC boundaries are marked on enroute charts, they are not presented on multifunction display (MFD) navigation screens and flight crews do not typically keep paper charts readily available. It is possible that the lack of pilot familiarity with the location of ARTCC boundaries is aggravated by the fact that commonly used weather reports such as SIGMETS and AIRMETS are given based on relation to ground based navaids.

Like pilots, air traffic controllers report that not being able to depict waypoints on their radar scopes is a significant issue and substantially limits their awareness of NRS waypoint geographic location. Thus, their ability to “visualize” the effect that granting NRS waypoint reroute requests will have on traffic flow, potential conflicts, and airspace limitations is significantly hampered. This is true even for requests to go direct to an NRS waypoint already in an aircraft’s flight plan and is even more problematic for clearance requests to a waypoint outside of the controller’s sector. This impediment to visual-spatial geographic waypoint awareness is the primary reason that the air traffic controllers we’ve interviewed choose not to use NRS waypoints tactically when issuing a diversion (i.e., clear an aircraft to an NRS waypoint that is not already on the aircraft’s flight plan). They report that the time it takes to utilize alternate resources to locate NRS waypoints, such as the URET system or charts depicted above their consoles, can be rather lengthy. Additionally, as also stated by pilots, information from these alternate sources must then be mentally transposed to the radar scope (or navigation display).

#### 4.2.5 Enroute charts

Although pilots and controllers have access to paper high altitude enroute charts, they report that inadequate waypoint depiction on those charts hampers their use. For example, pilots report that utilization of charts for the location of NRS waypoints is low due to conspicuity concerns (font color and clutter) and the inability to overlay this information with real-time navigation information being displayed on the MFD navigation display. The attempted incorporation of navigational information from two distinct sources in a dynamic environment when other navigation solutions exist is extremely cumbersome, fraught with potential for error and hence, unlikely.

### 4.3 NRS Waypoint Nomenclature Constraints and Goals

During the industry focus group meeting and in conversations with other aviation human factors researchers and study participants, there has been no shortage in the number of ideas proposed for alternate NRS waypoint nomenclatures. Indeed, we also initially thought that several acceptable alternatives might be available that minimized or eliminated entirely the drawbacks found with the current nomenclature structure. However, several constraints exist which, when combined with the goals of the navigation reference system itself, significantly limit the number of viable alternate nomenclatures. The constraints and goals which impose the most significant limitations on the development of alternate NRS nomenclatures are reviewed below. The ways in which these constraints affected the development of alternate nomenclatures for evaluation in this study are described in Section 4.4.

#### 4.3.1 The Use of a Grid System for the Definition of Waypoints in Sufficient Number to Support Point-to-Point Area Navigation

A grid system for the identification of NRS waypoints was chosen by developers for ease, to ensure sufficient waypoint coverage, and to simplify the addition of other waypoints in the future as the need for greater density increases (Boetig & Timmerman, 2003). Additionally, a grid system might easily allow some incorporation of location information in a waypoint's name to facilitate user geographic awareness. However, the use of a grid system imposes several expectations and requirements on waypoint nomenclature structure.

First is the requirement that each waypoint have a unique name. This can be extremely challenging as the intersecting vertical and horizontal lines of a grid can produce a large number of waypoints. There is also an expectation that consistent meaning is attached to how the waypoints are defined across the grid. Vertical lines should be all of the same type and located relatively equidistant from each other. Similar expectations exist for horizontal lines. Difficulty ensues with how these vertical and horizontal lines are named since the naming conventions adopted should be both consistent and meaningful. In the current nomenclature system, the naming of vertical and horizontal lines that define the NRS waypoints follows a consistent pattern relative to lines of latitude and longitude (see section 4.1 above) but was found to lack meaning for most of the users. Due to the complexity of the naming system, pilots and air traffic controllers who are less familiar with the nomenclature structure tend to treat the numbers and letters assigned to the lines of latitude and longitude in current NRS waypoints as being largely arbitrary, even though they are not. In and of itself, it is possible to come up with a consistent and meaningful naming system for grid defined waypoints that is more “user friendly” but this task becomes quite difficult when other constraints, particularly the limit of waypoint names to five characters and desire to impart geographic information, are taken into account.

#### 4.3.2 Ability to add other Waypoints in the Future (i.e., Expandability)

It is desirable that whatever waypoint naming system is devised, it allows for the expansion of the grid in the future (i.e., the addition of vertical and horizontal grid lines) if it is anticipated that the current density of waypoints will be insufficient to support NextGen RNAV operations. Current NRS waypoint nomenclature will accommodate just such an expanded grid (see section 4.1 above). Again, the development of a naming system that allows expansion is complicated by the requirement that NRS waypoints be comprised of five, and no more than five, characters.

#### 4.3.3 Waypoint Names are Limited to Five Characters in Length

One of the primary constraints affecting the design of NRS waypoint nomenclature is the five character length limit. This non-negotiable restriction originates from current software design in aircraft FMSs and the agreed upon standards for waypoint naming put forth in ICAO PANS-OPS Vol. II, Chapter 31, paragraph 31.1.2, and supported in ARINC 424-19 (Aeronautical Radio, 2008). It is exceedingly difficult to develop a discrete naming system that is consistent, meaningful to users, expandable, conveys geographic or location information and is also only five characters long.

For example, one of the complaints reported by pilots is that the numbers assigned to the lines of latitude in current NRS waypoints appear arbitrary and have no association with actual latitude numbers. If actual latitude and longitude degrees were used to define waypoints, a minimum of six characters for waypoint names would likely be needed since the lines of longitude and latitude intersecting the contiguous 48 states of the U.S. range from $24^{o}$ to $49^{o}$ and $66^{o}$ to $124^{o}$, respectively, and at least one other number for minutes would be needed for the line of longitude numbers in order to yield a grid with something close to the current waypoint density (e.g., waypoint 403121 = the point at the intersection of $40^{o}$30’N and $121^{o}$W).[1]

#### 4.3.4 Nomenclature Yields Geographic Awareness as to Waypoint Location

There are two main approaches to the naming of waypoints that might provide some level of knowledge about where that waypoint is located. This first is to define an area in which the waypoint is located and then to identify a specific point within that area. The second approach is to just name the waypoints individually without first trying to narrow the geographic region in which the waypoint is located. The current NRS waypoint nomenclature is an example of the first approach: the first character defines a large area (the United States), the second character defines a smaller portion of that area (one ARTCC’s airspace), and the final three characters are used to denote a specific point within those areas. The example of NRS waypoint nomenclature

[1] Such a nomenclature system is unlikely to be particularly usable however because of the ease with which latitude and longitude numbers could be confused and the high likelihood of transposition errors.

defined only by latitude and longitude degrees given in Section 4.3.3 above is an example of the second approach.

Because the number of waypoints needed is large and the geographic area of the contiguous 48 states is great, the first approach to naming waypoints (i.e., breaking this large region into smaller ones before identifying specific waypoints) is likely to be the most feasible and result in waypoints that actually do connote geographic location to users. The current system of using ARTCC identifiers does break down the 48 states into smaller regions, as well as supporting the requirement of filing one fix per ARTCC, but is problematic in that, 1) pilots are not generally familiar with the one letter identifiers for ARTCCs, 2) ARTCC airspace still covers very large geographical regions so doesn't help to narrow down the area in which the waypoint is located to the extent needed, and 3) ARTCC airspace boundaries are quite irregularly shaped making it difficult for them to be used for the location of some waypoints.

To provide the greatest utility and best geographic awareness to users we believe that one or more of the following features of geographic areas that are coded within waypoint names will be needed:

- Areas are relatively small
- Areas are similar sizes and/or shapes
- Areas are consistent and do not change over time
- Area boundaries can be shown on pilot and ATC displays and are conspicuous on paper charts

Furthermore, area delineations that are already in common use and known by users will require less training and working memory demands for determining waypoint location. Even so, it is quite difficult to devise a nomenclature that includes an easily understood coding for geographic location and also meets the other constraints of 5 character names and allowing future expansion of the grid.

### 4.3.5 Users can Distinguish Between NRS and Traditionally Named Waypoints

Within the FAA there exists the desire that users are able to distinguish between NRS waypoints and traditionally named RNAV waypoints (Brian Holguin, personal communication, May 4, 2010). Thus, any sort of coding scheme for an alternate NRS waypoint nomenclature that is comprised of only letters would violate that constraint. One reason for this constraint is that through such an all letter coding scheme, it is possible that the letters assigned to a NRS waypoint would form a "name" that duplicates a traditionally named RNAV waypoint already in existence. Additionally, to the extent that it is desirable to have NRS waypoints easily identifiable as a grid, it makes sense to have a unique nomenclature that sets NRS waypoints apart from traditionally named ones.

### 4.3.6 Minimize Likelihood of Character Transposition

As with the constraint on using all letters for an alternate NRS nomenclature, there is also a constraint on using all numbers. Numbers can be easily transposed by mistake and a group of five numbers that do have not particular meaning for users as a single number set (for example, one's home zip code) tax working memory and are highly vulnerable to being misremembered and mistyped.

### 4.3.7 Need for a Simple System that is Logical and Easily Understood

The final major constraint on the design of alternate nomenclatures is that of usability. A NRS nomenclature coding scheme that is complicated, illogical, confusing, or is difficult to retain in memory will be vulnerable to error and pilots and controllers, in particular, will avoid using those waypoints whenever possible.

The following sections describe the ways in which all of these constraints and objectives came together and affected the development of alternate NRS nomenclatures that were evaluated in this study

## 4.4 Nomenclature Development for Evaluation in the Part-Task Study

Although we contemplated several interesting possibilities, many of the alternate NRS nomenclatures that we considered were discarded because they violated a significant number of constraints and/or did not meet the objectives for NRS waypoints (Boetig & Timmerman, 2003; Hannigan, 2009). As mentioned earlier, we realized early in our research and discussions with subject matter experts (SMEs) that increasing user geographical awareness of waypoint location was particularly important and this goal guided our efforts. Similarly, the five character limit for waypoint names is a hard and fast constraint so all alternatives considered and evaluated met that constraint as well.

### 4.4.1 An Alternative to the Grid Structure

Conversation during the focus group meeting spurred us to consider abandoning the existing longitude and latitude grid structure in favor of a radial system that was centered from either the geographical center of a state or metropolitan areas. This would produce a radial system much like the concept of radials emanating from a VOR and might be spaced every ten degrees (i.e., NRS Waypoint "wheels"). At pre-determined locations along these radii, NRS waypoints could be consistently placed or even strategically allocated as predicated on desired waypoint density and other determining factors. Some of these factors might include concurrently located RNAV waypoints, the presence of special use airspace and desired traffic flow paths. The number of waypoints on each radial could vary from state to state or even radial to radial as suggested by local requirements.

The first two characters of the name could be the abbreviation of the state in which the geographical center resides. Characters 3 and 4 would be the radial in degrees away from the center with the last digit dropped (rounded to the nearest ten). This is similar to the numerical logic used for runway numbering. For example, in South Dakota there could be a "radial" extending away from the center of the state heading directly west. As such, the first four characters of the name would read "SD27" and the fifth character could be reserved for the distance from the center of the radial or state/city in factors of ten with the last zero dropped. For example, a waypoint on the 270 degree radial in South Dakota located 30 miles from the center of the state would read as SD273 (South Dakota, 270 degree radial, located at 30NM). This design possibility provides a more geographically intuitive structure for both pilots and controllers as the existing ground based navigation structure is designed using similar concepts.

Ultimately, a number of problems presented by this alternative led us to abandon it prior to conducting our study. One of the more challenging problems is how to show the distance of the waypoint on the radial with only the remaining single digit. As suggested, the one solution would be to place waypoints every 10 miles on the radial or as needed and drop the last digit in the distance so that a single digit remains. However, utility is reduced as this method would only be functional up to 90 miles from the geographical center and placing waypoints on a radial in distances that are not a factor of 10 is problematic. Devising meaningful codes for multiple center points within a single state could also be problematic and this system also does not allow a way to indicate ARTCC airspace in which waypoints are located. Additional limitations to this approach are that waypoints that might be needed outside of the area covered NRS waypoint "wheels" cannot be defined and some NRS waypoint "wheels" might overlap if established for two or more metropolitan areas that are near each other.

Therefore, in the part-task study we conducted, we decided to use the same lines of latitude and longitude currently in use for defining NRS waypoints and evaluated three different alternative nomenclatures.

### 4.4.2 Alternate Ways of Defining Geographic Regions and Identifying Waypoints

After deciding to retain the current grid structure, we next turned to alternate ways in which the 48 contiguous United States could be broken down into smaller regions. As stated earlier, we believe that first breaking the United States into smaller geographic regions before identifying specific waypoints within those regions will most likely yield waypoints that provide the greatest degree of geographic awareness to users.

There are a variety of issues that must be considered when considering geographical region divisions and they are presented below as numbered questions with comments. Readers can easily see the degree to which the 5-character limit for waypoint name is related to these issues.

1. How many regions are needed?

   The number of regions needed is directly related to the number of waypoints to be located within them and the way in which the individual waypoints are to be identified. Current NRS waypoint nomenclature and most of the alternates we considered required at least three characters for the definition of specific waypoints. Hence, if numbers alone are to be used for the naming of individual waypoints, regions would need to be sized so that there are no more than 999 waypoints within them. The size of regions then, has a direct relationship upon the number of regions that is needed.

2. Is it necessary to further subdivide geographic regions into sub-regions?

   It is possible that sub-regions might provide enhanced geographic awareness over the use of regions alone. A fewer number of waypoints will exist within sub-regions, as compared to the larger regions, thereby eliminating some of the possible difficulties in defining specific waypoints, such as when a numbering system is used. However, devising actual coding for regions and sub-regions that is meaningful and does not carry a heavy working memory load for users can be difficult.

3. How many characters out of the 5-character waypoint name will be required to indicate geographic region and sub-region (if used)?

   Clearly, the fewer characters required the better as that leaves more characters available for the indication of specific waypoints and the inclusion of other desired information such as ARTCC identifier (if ARTCC identifiers are not used for defining geographic regions or sub-regions). In the different approaches to dividing the country into geographic regions we considered, one or two characters were required for indicating geographic region.

4. Is the USA FIR identifier required for inclusion as part of NRS waypoint nomenclature?

   Since it is highly unlikely that NRS waypoints will be expanded beyond the borders and surrounding waters of the 48 contiguous United States, we believe the FIR identifier is unnecessary and does not add meaningful information to the waypoint name. Therefore, we chose to drop the USA FIR identifier from all alternate nomenclatures considered and evaluated. This freed up a character for other uses within NRS waypoint names.

5. Are ARTCC identifiers required for inclusion as part of NRS waypoint nomenclature?

   During our industry focus group meeting several ATC participants and others from the FAA felt strongly that ARTCC identifiers should remain part of any alternate NRS waypoint nomenclature as it "satisfies processing requirements for filing at least one fix per ARTCC." This requirement exists only when flight plans are filed, however; once an aircraft is enroute, pilots may be granted a request to fly direct to a waypoint that is several ARTCCs away from their current location. Inclusion of ARTCC identifier in NRS waypoint nomenclature does provide some measure of geographic awareness to controllers as they know at least which Center's airspace the aircraft is flying toward. As discussed earlier, ARTCC identifiers generally provide little to no geographic awareness as to NRS waypoint location for most pilots. We considered several nomenclatures which did and did not include ARTCC identifiers although in no case was ARTCC identifier used for the definition of geographic region as it is in current NRS waypoint nomenclature.

Keeping in mind these issues, and the ways in which they are interrelated, we considered several approaches to defining geographic regions and specific waypoints within them and they are discussed below. We did not assess any nomenclatures that included both a region and sub-region because including both used up too many of the 5 characters available.

#### 4.4.2.1 Geographic Regions

**The "Egg Crate" Approach.** During our industry focus group meeting, several participants suggested dividing the continental US into evenly sized cubes, like those in an egg crate. There was some debate as to the number of cubes desired: 6, 9, 12 and 15 were all suggested. Regions could be numbered or given labels signifying the location of the cube, such as NW or PN for the Pacific Northwest cube.

There are of course some significant limitations to this approach that pertain to the issues described above. Boundaries of an "egg crate" are not intuitive and would have to be learned. Coding can help or hinder in this but is not an absolute solution. If the regional cubes are numbered, users would have to learn and remember how many cubes there are and the numbering scheme: does numbering begin in the Northwest, Southwest, Northeast, or Southeast? Do cube numbers proceed across the country from left to right (or right to left) or proceed in columns going up and down?

Two letter identifiers, such as NW or PN, may or may not place less demand upon working memory than numbering cubes since the coding of some regional cubes, and the actual location of that cube, also may not be intuitively obvious. For example, NW is commonly understood as Northwest, would the NW cube include waypoints in Idaho? Montana? Additionally, if smaller sized regions are likely to provide better geographical awareness, then many cubes might be needed creating quite a challenge in developing meaningful, easily located, and unique codes for the cubes without using most of the 5 nomenclature characters available (e.g., MCP for Middle Central Plains).

**The Geographical Feature Approach.** Another approach to defining geographic regions that we considered only momentarily was the use of permanent geographic features of the landscape for dividing the country into regions. Very quickly we determined that using the Mississippi River, Rocky or Appalachian Mountain ranges and similar landscape features was completely impractical and unworkable. There are not enough major features that can be used for defining regions and many would not provide a clear boundary line, such as a mountain range comprised of multiple parallel ridgelines.

**The State Postal Code Approach.** A third approach which was initially suggested by individuals we interviewed during Phase 1 of the NRS waypoint study was the idea of using state boundaries and two letter state postal codes in the waypoint nomenclature. An advantage of this approach is that most individuals are familiar with these codes although sometimes they are confused with each other (e.g., AK and AR; ID and IA, and so on). Additionally, most aviation professionals have a fairly good knowledge of where various states are located although we have discovered that this is not so for everyone and may be a particular difficulty for international pilots flying in the United States. Because there were more advantages and fewer limitations for this approach as compared to the others, all three of the alternate NRS nomenclatures evaluated in the part-task study utilized state postal codes to support geographic awareness of waypoint location (see sections 4.4.4.1 through 4.4.4.4 below).

#### 4.4.2.2. Specific Waypoints

There are two major approaches to the identification of specific waypoints after approach to geographic region has been considered. One is to come up with a numbering or coding scheme that cuts across all geographic regions and boundaries (i.e., an "across regions" approach). The current NRS waypoint nomenclature does this. The other major approach is to come up with a numbering or coding scheme within each geographical region (a "within region" approach. In other words, the *structure* of the nomenclatures is the same in each region in terms of what each character stands for, but the actual coding used for identification of waypoints within each region may be different and specific to that region. For example, imagine states are to be used for defining regional boundaries and that the waypoints within those states will be given three digit numbers beginning with 001. A small state like Rhode Island may not even reach 020 before all waypoints have been assigned a number. Texas, however, might have waypoints numbered all the way to 500 because of its size.

**The "Across Regions" Approach.** The current system for coding lines of latitude and longitude, or some variant of it (most likely requiring three characters), could be used. Although most users do not care for the current system, it does support future expansion of the grid and retention of this approach or something like it for identifying specific waypoints would help facilitate training and familiarization with a new nomenclature.

Another approach to an "across regions" approach to a grid design was explored by Boetig and McQueen (2006). Although never implemented, they developed a method for expanding the NRS grid into the North Atlantic to facilitate oceanic route planning with less reliance on traditional latitude and longitude. The approach they devised could be applied across the continental US rather than over the oceans. One difference between the MITRE design and the current NRS grid system was the use of longitudinal lines at every five degrees instead the current two degrees. Because of the expansiveness of the oceanic environment, this might be reasonable but the reduced granularity that would result over the continental US could result in an insufficient number of waypoints. They subdivided the oceanic area into smaller regions, and used the second character in the name to specify the smaller subdivisions, since ARTCC identifiers no longer apply.

**The "Within Region" Approach.** There are several different schemes that could be used for identifying specific waypoints within regions once the approach to defining regions has been determined. For example, in the Pacific Northwest region, A through Z could be assigned to the lines of latitude and 0 through 9 to the lines of longitude. Waypoint PNA02 would be decoded as Pacific Northwest, latitude line A and longitude line 02. Users could fairly easily determine that since this waypoint is the intersection of lines A and 02, the waypoint is located in the upper northwestern corner of the Northwestern region, quite possibly somewhere in the Seattle area. Not all 26 letters of the alphabet or 10 numerals might be needed depending upon the size and shape of the region. Difficulties ensue however when a state is very long or wide and there are not enough letters or numbers available for all the lines of latitude or longitude, especially if some letters and numbers are skipped to allow for expansion of the grid in the future. Furthermore, not all coding is as easily decipherable as the PNA02 example might lead one to believe, particularly depending upon how the regions are defined. For example, without more information about exact grid boundary locations, users might have quite a bit of difficulty guessing where waypoint SEA02 is located other than in the upper left of the southeast region (Tennessee? Georgia? The Carolina's? Maybe even Alabama or Mississippi?).

A variant of this approach might actually provide even better geographic awareness of waypoint location with regions. In this approach A through Z is assigned to lines of latitude as before but the letters "A," "L," and "Z" are always assigned as are the numbers 0, 5 and 9, regardless of the size or shape of the region. "A" could always be used to denote the upper most line of latitude crossing the region, "Z" the lower most line of latitude and "L" the line of latitude that cuts most closely across the middle of the region. Other letters are used as needed for labeling other latitude lines. If a region has many lines of latitude, most or all 26 letters may be used. If a region has very few lines of latitude only a few of the 26 letters of the alphabet may be used. A similar approach would be used with the assignment of numbers for lines of longitude. In this way, waypoint A0 is always in the same place within each region and the waypoint L5 is assigned to the waypoint that is most directly in the middle of the region.

Of course, there are limitations to this approach as well. It may not support expansion of the grid, especially if the geographic regions are large. It is also a bit more complicated to explain than some of the other approaches and users would have to remember where A is located relative to Z (is A at the top or bottom of the region?) and does 0 come at the beginning before 1 or at the end after 9? Some users may count from 1 to 0 rather than from 0 to 9. Additionally, this approach might cause confusion due to numbers and letters switching positions as compared to the current NRS waypoint structure. This switch is required since there will likely be more lines of latitude in any given region as compared to lines of longitude.

As has already been suggested, waypoints within a region could also simply be numbered. For example, waypoint numbering could start with 001 in the most northwestern corner of the region and then moving downward and to the east throughout the region continuing the labeling until finishing in the southeastern corner. As stated earlier, region size would need to be designed so that there are no more than 999 waypoints in any single region since only 3 character digits will most likely be available in each waypoint name, even if ARTCC identification is omitted. However, we should be mindful that possible future expansion of the grid should be considered and if implemented, this method may not work unless regions are fairly small and fewer than 240 waypoints currently need an identification number (assuming an expansion to 6,600 waypoints in the future). Another drawback of this approach is the same one that exists with numbering "egg crate" regional cubes–users would have to memorize where in the region the numbering begins and in which direction numbers increase. Additionally, unless each region is exactly the same shape and size, regions could have a different number of waypoints thereby limiting ability to generalize knowledge of waypoint location from one region to the next. For example, waypoint number 025 might be located in the southwestern corner of one region and be located exactly in the middle of a much smaller region.

If the ARTCC single letter identifier is to be retained in the waypoint name but not be part of the coding for regional definition, region size and future grid expansion are affected as only two characters would be left to label the specific waypoint (assuming two characters are needed for defining the region). Thus, regions would have to be kept small enough to keep the total number of waypoints below 100 in order to free-up the fifth digit for the ARTCC identifier , and below 25 allow for the planned expansion of the grid.

### 4.4.3 Candidate Alternate NRS Nomenclatures Considered for Evaluation

We recognize that the further the alternate nomenclatures deviate from current NRS waypoint structure, the greater the chance for potential issues with familiarity, implementation, and training for current NRS waypoint users. Nonetheless, we believe such a deviation may be warranted if the end result is an alternate nomenclature with significant advantages over the current NRS nomenclature and fewer disadvantages.

During the industry focus group meeting, numerous ideas for changes to the nomenclature were generated. After eliminating those that were completely unworkable and carefully considering the nomenclature constraints and approaches to design explored above, we iteratively down-selected to 10 alternate NRS waypoint nomenclature configurations that are congruent with established goals for NRS waypoints and are potentially functional (see Appendix 3).

Despite the wide variation in these configurations, numerous pros and cons were identified and no single naming method was without disadvantages. When debating which of candidate alternate nomenclatures we would include in the part-task study, we selected three that offered many advantages and had fewer disadvantages than some of the others.

Because waypoint names are limited to five characters, the decision to drop the leading "K" opened up a character space which allowed more options to meet the goal of increasing geographical awareness. The only foreseeable problem with eliminating the US FIR identifier is the possible future re-consideration of NRS expansion to oceanic and/or international regions. Based on our discussions with SMEs, we believe this scenario is very unlikely and therefore omitted the US FIR identifier from all alternate nomenclature designs considered. The benefits realized by having this extra character space to use in alternate design options were significant and without which, none of the alternate configurations would have been possible.

There are similarities across the 10 nomenclature configurations developed with regard to how all of the 5 character spaces were utilized. In five of the 10 developed the two-letter US state abbreviations used in postal codes appear as the first and second characters. Although possible to place the state abbreviations in other positions within the waypoint name (i.e. characters 3 & 4 or 4 & 5), we did not because we believed the region should be identified first and then the individual waypoints specified within the region. This approach was followed for all 10 of the candidate nomenclatures developed and the region was most often specified through the use of the first two characters in the waypoint name, but in some cases only the first character (see Table 6). Several different approaches to the identification of specific waypoints within the regions were considered and in some alternate nomenclatures considered, the ARTCC identifier was also used, although more as a benefit for controllers rather than as a character that was intended to provide much geographical awareness to other users.

#### 4.4.4 Nomenclatures Evaluated in the Part-Task Study

Although we would have preferred to evaluate all 10 of the nomenclature configurations developed, only three of the most promising ones could be evaluated against the current NRS waypoint nomenclature without causing our study participants undo fatigue. A variety of significant limitations were encountered when we attempted to develop a complete waypoint grid using some of the approaches for defining regions listed in Table 6 (e.g., candidate II: SW, NW, etc.). Therefore, all of the alternate nomenclatures assessed utilized the same method for region identification (i.e., state abbreviations). The four nomenclatures evaluated in the part-task study are described below.

##### 4.4.4.1 Nomenclature One (N1): Baseline

It is important to compare alternate nomenclature configurations against the NRS nomenclature currently in use, especially if suggestions for replacing the current nomenclature are to be made. Thus, the current NRS nomenclature was included for evaluation in the part-task study and served as the control or baseline condition. This nomenclature is referred to as N1 throughout this report. Current NRS waypoint nomenclature was described in sections 1.0 and 4.1 earlier, and is illustrated in Figure 3.

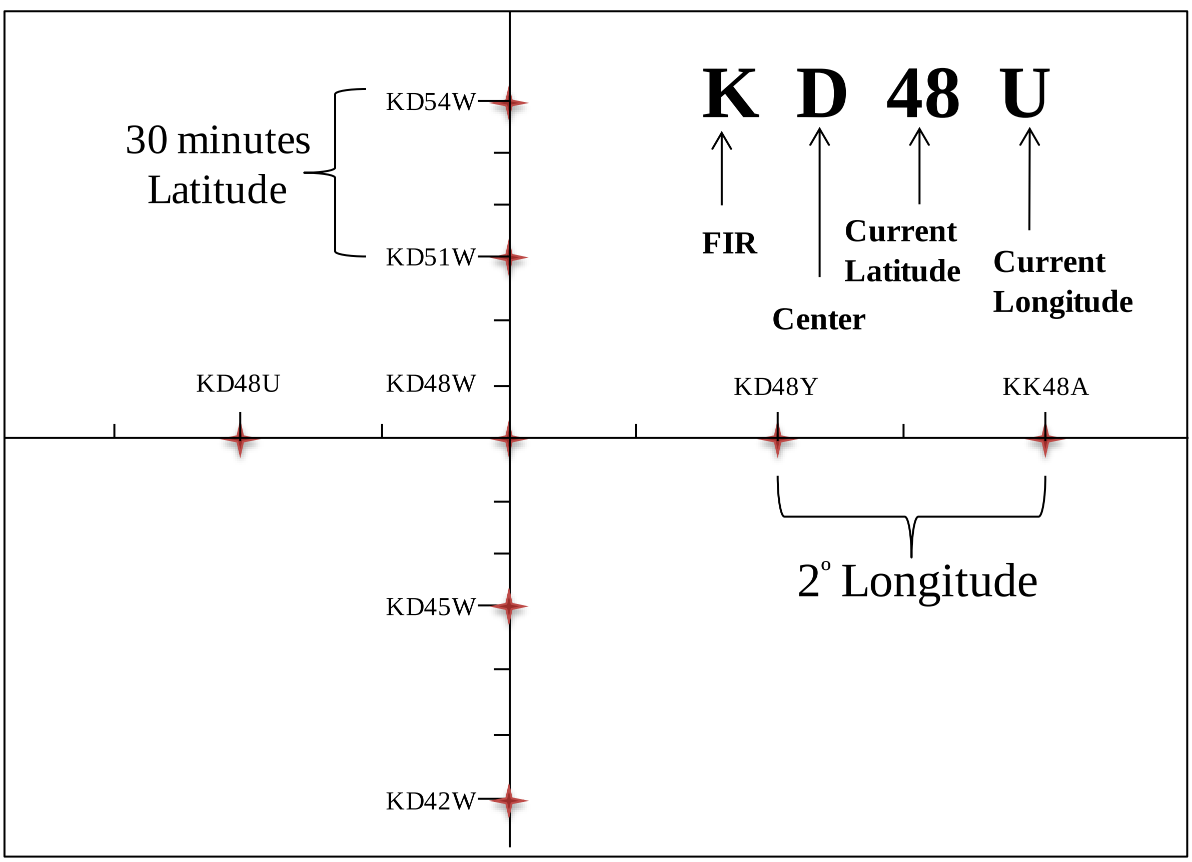



***Figure 3.*** N1: Current NRS grid and nomenclature configuration. (Boetig, et al., 2004).

#### 4.4.4.2 Nomenclature Two (N2)

In an effort to increase geographical awareness with as little deviation as possible from the current NRS nomenclature, the first alternate nomenclature configuration we chose to evaluate dropped the first two characters of the existing nomenclature ("K" and ARTCC identifier) and replaced them with two-letter state abbreviations. For the remaining three characters, the approach used in current NRS waypoints for indicating latitude and longitude is preserved. For example, in Figure 4 waypoint KD48U (using current, N1 nomenclature) becomes CO48U in this (N2) alternate nomenclature (the waypoint is located about 100nm southwest of Denver, Colorado). When seeing this waypoint, the user would immediately know that the waypoint is in the state of Colorado (CO) and on NRS line of latitude "48" and NRS longitude line "U".

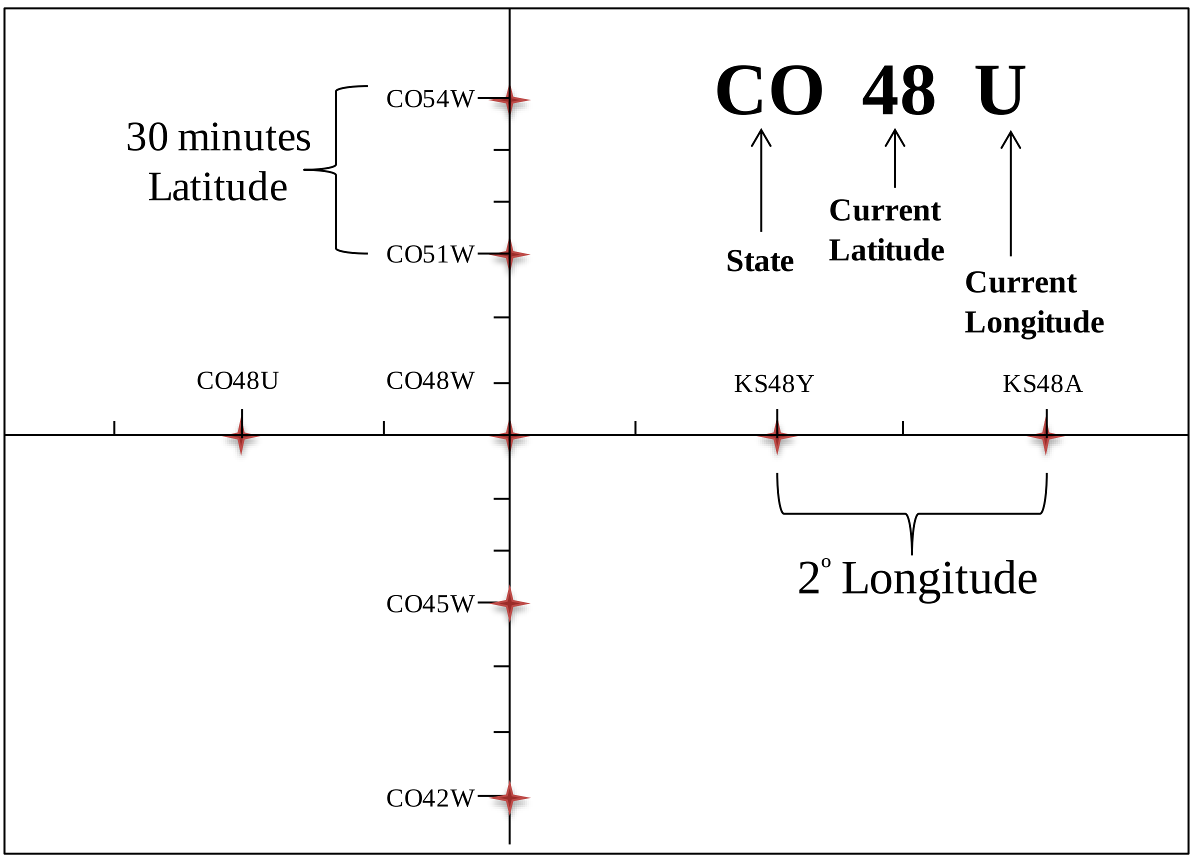



***Figure 4.*** N2: First Alternate NRS grid and nomenclature configuration.

The primary advantage that this method offers is immediate recognition of the general waypoint location as being in the state of Colorado. Previously, upon inspection of the original NRS waypoint (KD48U in this example), the first two characters informed that the waypoint was in the United States and specifically within the Denver ARTCC airspace. This airspace region is about twice the size of the state of Colorado and as such, this new configuration allows the reader to hone in on a smaller and potentially more familiar geographical waypoint location.

As discussed earlier, a waypoint in the current NRS waypoint configuration contains five discrete bits of information and as such, one character can quickly fill up much of the 7 ± 2 bits of information available in working memory (Miller, 1956). By including the state abbreviation in a waypoint name, the total number of data bits will most likely be reduced by one since the CO for Colorado will most likely be encoded as a single bit "Colorado" rather than as two (Charlie-Oscar).

When originally developed, we believed that this nomenclature configuration would offer increased geographical awareness in addition to other benefits. By using the same approach for identifying specific waypoints within a region as is used in the current NRS nomenclature, it is reasonable to assume that less training will be required for current NRS users as compared to a nomenclature that has no similarity to the current configuration. New NRS waypoint users would still need added training on the coding scheme used for lines of latitude and longitude.

Although some users might find the absence of the ARTCC identifier troublesome, controllers can rapidly use the User Request Evaluation Tool (URET) to determine any requested NRS waypoint's location relative to ARTCC airspace as they currently do with requested unfamiliar named RNAV waypoints. As a component of the re-tooling required to implement this N2 alternate nomenclature method, enroute charts will require minimal changes as will currently stored flight plans and playbook routes. Additionally, since so much of the original NRS nomenclature structure is retained, achieving the goal of expanding the NRS is still a realistic goal with this alternate nomenclature configuration.

Despite the benefits of this nomenclature configuration, there are several drawbacks that also require consideration. As mentioned earlier, for not only this design but all of the designs that incorporate state abbreviations, users who are unaware of US state postal code abbreviations or do not know where states are located within the United States will be at a disadvantage. In most cases, we expect this to be mostly a problem for non-US international pilots, but not exclusively.

Additionally, several postal codes are similar, such as ID, IL, IN, IA which may cause confusion for US and non-US pilots alike. In some cases, mistyping one letter may send the user to an entirely different state. Obviously, for this and any case where single digits are misinterpreted, potentially serious navigational errors may result and was voiced by several SMEs. Despite this, it is plausible that this type of error potential is probably similar in frequency as similar error types with the current nomenclature method and may always be a concern with any form of data entry.

For all users, regardless of their familiarity with state abbreviations, finding the exact location on a map or display will require clear depiction of state boundaries on these tools. Although they are already depicted on high altitude charts, NRS expansion below FL180 would require their addition on low altitude charts since state boundaries are not depicted on these charts. Additionally, state boundaries are not depicted on current aircraft MFD displays by most FMS software with which we are familiar. Air traffic controllers can select state boundaries be shown on their displays if that option (state boundaries) is installed in their system software.

#### 4.4.4.3 Nomenclature Three (N3)

The development of alternate nomenclature configuration N3 was spurred by dissatisfaction with the latitude and longitude coding scheme in the current NRS waypoint nomenclature expressed by many of the pilots and air traffic controllers we interviewed. The two digit and single letter codes do not convey geographic awareness information to most users. For example, the location of the "A" lines of longitude in the US is unknown.

As with alternate nomenclature N2, the first two characters of the waypoint name delineate a region of the country and state abbreviations are used. However, instead of adopting the "across regions" approach for the identification of specific waypoints used in nomenclatures N1, and N2, in N3 we decided to assess the functionality of a "within region" waypoint identification approach (see section 4.4.2.2). Thus, in nomenclature N3, coding of individual waypoints is accomplished on a state by state basis. We chose to assess a system whereby waypoints are numbered sequentially from 001 to 999 (depending on the state size). These numbers appear in the last three character spaces after the state abbreviation in the waypoint name. An example of the N3 nomenclature configuration can be seen in Figure 5.

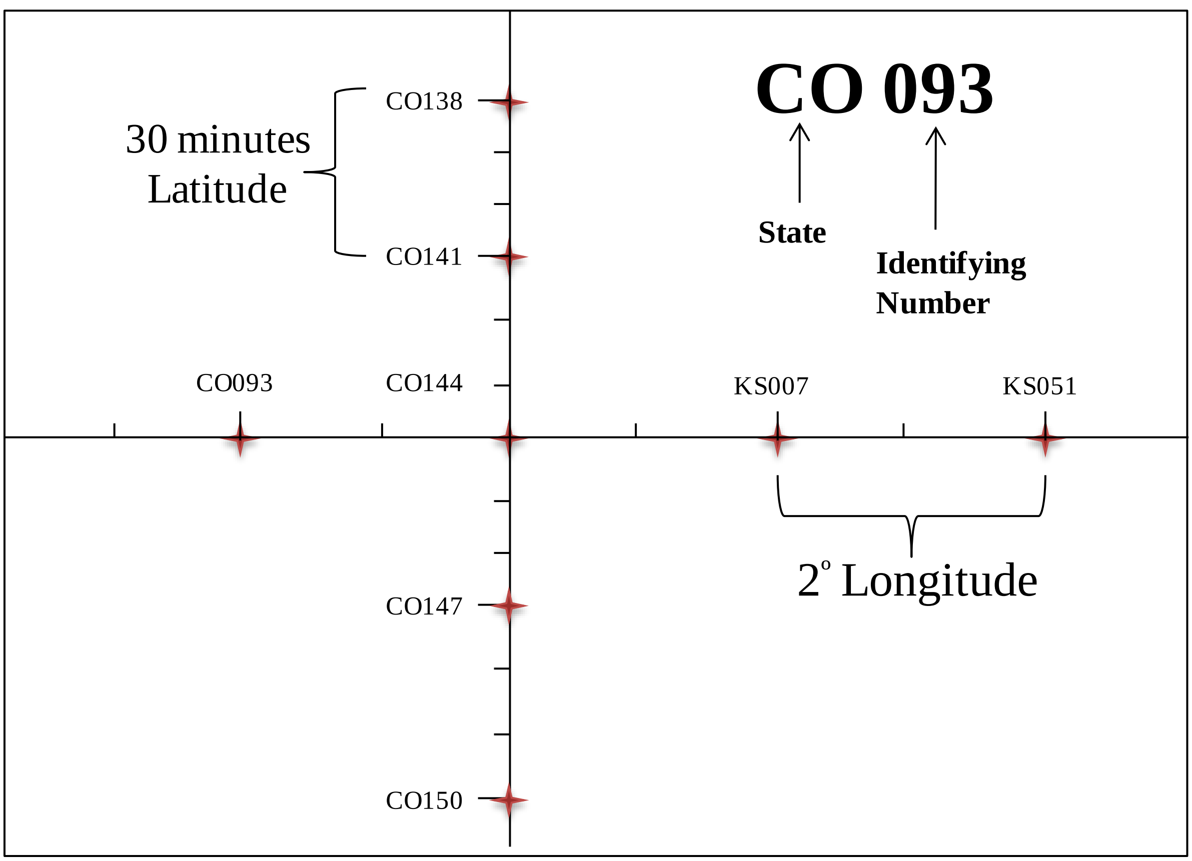



***Figure 5***. N3: Second alternate NRS grid and nomenclature configuration.

One of the challenges we faced when developing this alternate nomenclatures was deciding where to start the numbering of waypoints within the state and in which direction to move when numbering subsequent waypoints: vertically or horizontally. In keeping with how one reads written text in many languages, we chose to start our numbering of waypoints in the upper left (northwest) corner of each state. We debated about the merits of proceeding with waypoint numbering vertically versus horizontally and could identity no advantage of numbering one direction over the other. So we elected to number waypoints vertically, proceeding down in columns along the lines of longitude marking the grid. When the southernmost boundary of a state was reached in one column, numbering was continued by moving to the top of the next column of NRS waypoints in the state. To allow for expansion of the NRS waypoint grid in the future, two numerals were skipped between each numbered waypoint (i.e. 001, 004, 007, etc.). In this way the waypoint in the most northwestern part of a state has a very small number. Although the most southeastern waypoint number would be the highest number for each state, it actually could be a relatively small number in states the size of Rhode Island but a very large number in bigger states such as Texas.

The N3 alternate nomenclature is a significant deviation from the current NRS nomenclature and as such, possible enhanced waypoint geographical awareness does come at a cost. All the benefits and limitations of eliminating the ARTCC identifier and using state abbreviations discussed relative to nomenclature N2, also apply for alternate nomenclature N3.

Furthermore, it is possible that the N3 nomenclature configuration might actually confuse users. For example, unless a user knows approximately how many waypoints are in a state, waypoint numbers beyond 019 or so do not really offer much specificity as to their location. For most states, lower numbers such 001 thru 019 suggest that these waypoints are located somewhere in the western part of the state. More specifically, 001 thru 007 would be found in the northwestern corner since that is where the numbering system begins. However, larger numbers such as 031, 040, or 061 are less helpful as they could be located anywhere in the state depending on its size and shape. For example, California, being very long vertically, has waypoint numbers as large as 058 (CA058) that are still located on the western side of the state, whereas in Tennessee, which is relatively short but quite wide has its waypoint 058 (TN058) in the eastern most portion of the state. This lack of consistency from state-to-state as to where a waypoint with the same number is located decreases the utility of this nomenclature configuration in providing more precise geographic awareness of specific waypoint locations.

#### 4.4.4.4 Nomenclature Four (N4)

Because of the potential importance of ARTCC identifier for some in the industry, we sought to strike a balance between the need for greater waypoint name specificity, easier location within a state, and maintaining the ARTCC identifier. This resulted in the development of nomenclature configuration N4 which like the previous methods discussed, the two letter state abbreviation comprise the first two characters in the waypoint name. Because the ARTCC single letter identifier carries little meaning for most pilots, we chose to place it as the final character in the waypoint name and use the 3$^{rd}$ and 4$^{th}$ character spaces for indicating specific waypoint identification. The only feasible approach we could determine that required only two characters for identifying a specific waypoint was to number them from 01 to 99 (see Figure 6).

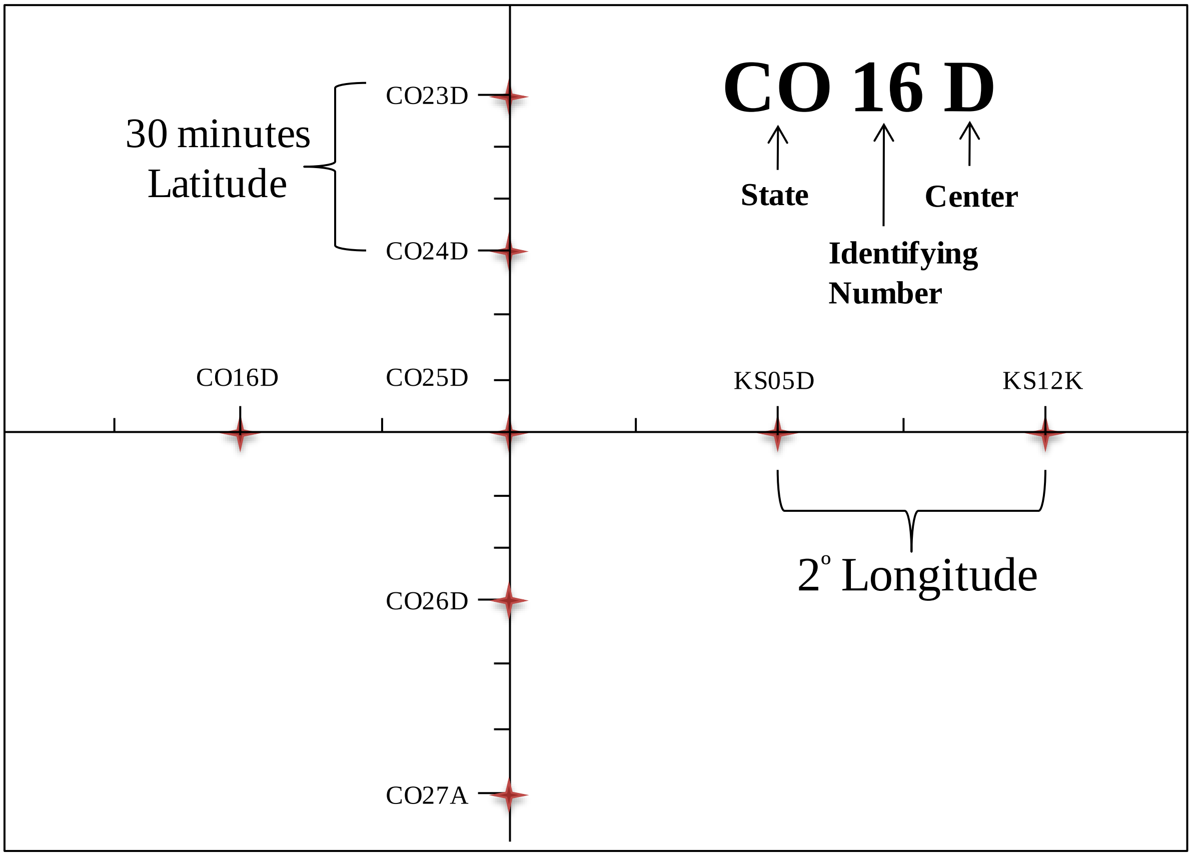



***Figure 6.*** N4: Third alternate NRS grid and nomenclature configuration.

In many states, we found that this range of numbers offered sufficient coverage for the entire state including numbers needing to be skipped for the time being to allow for expansion of the grid in the future. However, the number of waypoints located in larger states, such as California or Texas, exceeded the range of two digit numbers when numbers were skipped to allow for future expansion.

One solution to this problem is to divide large states in half (for example Northern California and Southern California) with each half having its own numbering system as if it were a separate state. However, this approach yields two-letter "state" abbreviations that are not in common use (e.g. ET for East Texas) thereby losing the ability to call upon highly reinforced information from long term memory instead of relying more upon more limited working memory for decoding the "state" name. Additionally, the location of the boundaries between state halves is not intuitive although they could be depicted on charts and displays. Furthermore, some new "state" abbreviations for state halves could be confused with other state abbreviations. For example CN or NC for northern California could be confused with NC for North Carolina.

Thus, we believed that dividing large states in half was not a feasible solution and instead chose to number the waypoints in each state sequentially from 01 to 99, without skipping any numbers to allow for future expansion. This is a significant limitation of alternate nomenclature N4 but was necessary in order to accommodate the current number of waypoints in each state, and also include the ARTCC identifier in the waypoint name.

We chose to use the same numbering pattern as used for alternate nomenclature N3: waypoint 01 was always the most northwestern NRS waypoint in a state and number 02 was the next waypoint below it on the same line of longitude. As before, waypoint numbering continued southward until reaching the bottom of the state and then resumed at the top of the state again on the next line of longitude directly to the east. As with alternate nomenclature N3, users generally will not know, without looking at a chart where in the state the higher numbered N4 waypoints are located.

Another possible limitation of alternate nomenclature N4, as well as for the NRS waypoint nomenclature currently in use (N1), relates to the inclusion of ARTCC identifiers in NRS waypoint names used in the future under NextGen. A potential solution to airspace congestion and flow control issues is to employ ARTCC boundaries that are flexible and can be moved as needed (i.e., dynamic airspace boundaries). When one ARTCC is quite congested the adjacent center may be less busy and the boundary between the two could be adjusted to even out controller workload. Thus, waypoints near ARTCC boundaries might be in two different ARTCC's airspace at different times, depending upon where they boundary has been placed. The inclusion of one ARTCC identifier in the waypoint name might cause confusion when the boundary has been moved and the waypoint is now located in the airspace of the adjacent ARTCC.

## 5.0 NRS WAYPOINT NOMENCLATURE PART-TASK STUDY

### 5.1 Introduction, Purpose, and Scope

The purpose of the part-task study conducted as a part of this second phase of work was to evaluate several alternate NRS waypoint nomenclatures to determine if one or more might have fewer human factors limitations that the current nomenclature, thereby increasing their utility. The development and selection of the alternate nomenclatures chosen for evaluation was guided by the goals and objectives for NRS waypoint design and use (Boetig & Timmerman, 2003), the constraints imposed upon NRS waypoint structure and design, suggestions proffered by the industry focus group in addition to some of our own ideas, and critical evaluation of different approaches to waypoint construction.

Prior to the 2005 deployment of NRS waypoints, a number of studies were conducted by the MITRE CAASD to examine their usability (Boetig, et al., 2004; Borowski, et al., 2004; Domino, et al., 2003; Domino, Boetig, & Olmos, 2004). Since the population participating in our part-task study were pilots, we chose to ask them to perform many of the same types of tasks performed by the pilots who participated in the MITRE CAASD pre-deployment studies: finding waypoints on an enroute chart, entering a flight plan into a FMS, waypoint selection and re-route entry into the FMS when faced with a weather based diversion, and finally completion of a detailed questionnaire soliciting attitudes and opinions with regard to NRS waypoint nomenclature and usability. As stated earlier, completion of other studies involving air traffic controllers is necessary to ensure that alternatives NRS nomenclatures that are of benefit to pilots are of benefit to controllers as well.

### 5.2 Methodology

#### 5.2.1 Participants

Twenty-eight participants were recruited to participate in the NRS waypoint phase 2 study (27 males, 1 female, mean age of 43 years with an age range of 25-64 years). All participants, who fly for part 135 or part 121 operators, were recruited through the San Jose State University testing office at NASA Ames Research Center and were paid approximately $32.00 per hour for their time. Participants spent an average of 3 hours participating in the study. All participants had experience using the Collins 4200 FMS and had piloted an aircraft in the past 90 days. Half the participants had previous experience using NRS waypoints in flight plans and the other half had no previous experience using NRS waypoints. All participants were treated in accordance with American Psychological Association (APA) Ethical Guidelines for Research with Human Subjects (APA, 2002) and were recruited after the approval of the NASA Institutional Research board (see Appendix 4).

#### 5.2.2 Materials

As described in detail in section 5.2.4, participants completed four main tasks in this study: a waypoint finding task on a high altitude enroute chart, flight plan route and weather re-route data entry tasks, and the completion of a final questionnaire. Below are descriptions of the materials developed for the completion of these tasks.

**NRS Waypoint Nomenclature.** As described earlier, the usability of four different NRS nomenclatures were evaluated in this part-task study. The current NRS nomenclature was used as a control or baseline and three alternate nomenclatures were created for the experiment (see section 4.4.4.1 through 4.4.4.4 above for further explanation of the NRS nomenclatures evaluated). The configurations of the four NRS nomenclatures evaluated are summarized in Table 6.

**Table 6**

*NRS Nomenclature Configurations Evaluated in the Part-Task Study*

| Nomenclature Name | Configuration | Example |
|---|---|---|
| N1 (Current) | FIR-Center ID -Latitude-Longitude | KA18U |
| N2 (Alternate) | State Postal Code-Latitude-Longitude | NM18U |
| N3 (Alternate) | State Postal Code-3 Digit Identifying Number | NM121 |
| N4 (Alternate) | State Postal Code-2 Digit Identifying Number-Center ID | NM28A |

**NRS Training Guides.** Training guides were created to aid participants in the understanding of each NRS nomenclature. Each of the guides featured a depiction of the NRS nomenclature and an explanation of what each character in the NRS waypoint name referenced (e.g., postal code, ARTCC identification, etc.). An example of one of the training sheets used can be seen in Appendix 5. Participants had access to the training sheets throughout the experiment.

**High Altitude Charts.** The waypoint finding task was conducted using four High Altitude Enroute Charts featuring each of the different nomenclatures. These charts mimicked one produced by Jeppesen, the High Altitude Enroute Chart (US (HI) 1, Revision March 19, 2010), and was developed using Canvas software (version 11; ACD Systems International). The experimental High Altitude Enroute Charts featured colored text in keeping with that used by Jeppesen, were 16 x 45 inches in size, and laminated. A sample of the high altitude enroute chart used for N2 can be seen in Figure 7. Participants had access to high altitude enroute charts throughout the study, including during the FMS data entry and re-route tasks.

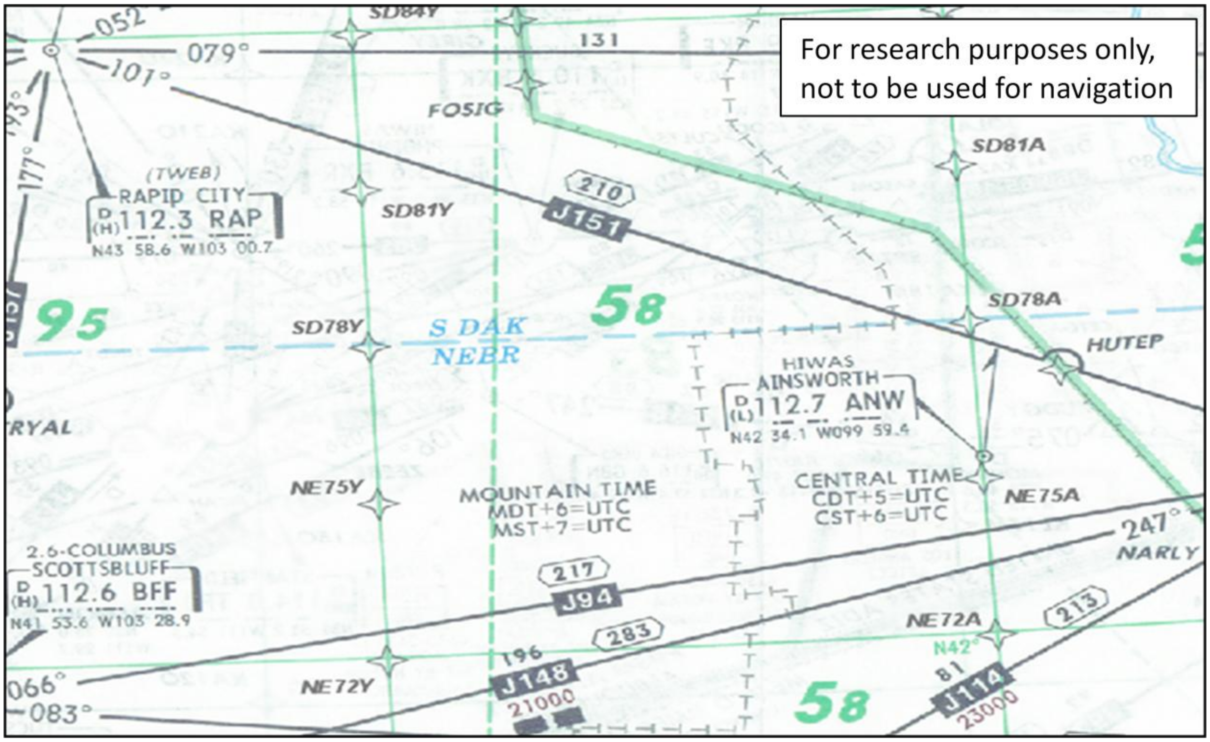



***Figure 7.*** Portion of the high altitude enroute chart used for N2 experimental sessions.

**NRS Waypoint Cards**. For the NRS waypoint location task, participants were given a card on which an individual NRS waypoint was printed and asked to locate the NRS waypoint on the high altitude enroute chart as quickly as possible. NRS waypoints were printed on a 2 x 8.5 inch white card, printed in black in Times New Roman font, size 72. Waypoints used in this task were located in either in low, medium, or high density areas. The classification of low, medium or high density was based on the number of "bits" of information within a 1 inch radius of the NRS waypoint. Examples of "bits" of information are other fixes (RNAV waypoints, VORs and Airports), jet routes, lines delineating ARTCC boundaries, and NOTAM information. Participants were asked to find 24 waypoints total (6 per nomenclature), 8 were located in low density areas (average of 13 "bits" of information), 8 were located in medium density areas (average of 23 "bits" of information), and the remaining 8 were located in high density areas (average 46 "bits" of information). NRS Waypoints used in this task can be seen in Table 7.

**Stopwatch**. A standard stopwatch with a start-stop and clear button was used to time in seconds (with 1/100 of a second precision) how long it took participants to locate the NRS waypoint on the chart during the waypoint finding task.

**Table 7**

*NRS Waypoints used in the Waypoint Location Task*

| Density | N1 (FIR-Ctr-Lat-Long) | N2 (State-Lat-Long) | N3 (State-###) | N4 (State-##-Ctr) |
|---|---|---|---|---|
| Low | KP18A | ND18A | ND078 | ND14P |
| | KP12C | ND12C | ND120 | ND22P |
| | KD78A | SD78A | SD089 | SD17D |
| | KP03C | SD03C | SD110 | SD18P |
| | KU18S | MT18S | MT166 | MT25U |
| | KP15E | MN15E | MN015 | MN03P |
| | KP21G | MN21G | MN073 | MN11P |
| | KP15A | ND158 | ND081 | ND15A |
| Medium | KD81U | WY81U | WY134 | WY20D |
| | KO57I | NV57I | NV055 | NV11O |
| | KU90K | ID90K | ID049 | ID06U |
| | KS03K | ID03K | ID046 | ID05S |
| | KS09K | ID09K | ID040 | ID03S |
| | KU69Q | WY69Q | WY047 | WY08U |
| | KU72I | OR72I | OR167 | OR33U |
| | KP63C | NE63C | NE106 | NE19P |
| High | KK60I | MO60I | MO058 | MO11K |
| | KG69K | IL69K | IL018 | IL03G |
| | KG63K | IL63K | IL024 | IL05G |
| | KK54K | IL54K | IL033 | IL08K |
| | KO63G | NV63G | NV009 | NV03O |
| | KS09E | WA09E | WA044 | WA09S |
| | KO60G | NV60G | NV012 | NV04O |
| | KS15E | WA15E | WA038 | WA07S |

**Flight releases.** Flight releases were created for the flight plan entry task for all twelve routes of flight. Rather than provide the participants with only the route of flight, they were provided a two page flight release package that was modeled after one used by a current US air carrier and contained all flight data parameters for a common turbojet aircraft in service today. Each flight release contained not only the flight plan participants were to enter into the FMS as part of the study, but also, for realism, a navigation log, weight and balance data and weather for their route. Additionally, all airports and fixes used for the routes were located on the experimental high altitude charts provided in the waypoint finding task. None of the NRS waypoints included in the flight releases were also waypoints used in the waypoint finding task so as to prevent a learning effect. The layout of fixes in the routes used for the flight plans can be seen in Table 8.

**Table 8**

*Route Layouts for FMS Data Entry Task*

| Route | Fix 1 | Fix 2 | Fix 3 | Fix 4 | Fix 5 | Fix 6 | Fix 7 | Fix 8 |
|---|---|---|---|---|---|---|---|---|
| 1 | Airport | RNAV | NRS | NRS | RNAV | NRS | VOR | Airport |
| 2 | Airport | NRS | RNAV | RNAV | RNAV | NRS | NRS | Airport |
| 3 | Airport | RNAV | NRS | VOR | NRS | RNAV | NRS | Airport |
| 4 | Airport | VOR | NRS | NRS | RNAV | NRS | RNAV | Airport |
| 5 | Airport | RNAV | NRS | RNAV | NRS | RNAV | NRS | Airport |
| 6 | Airport | NRS | RNAV | NRS | NRS | VOR | RNAV | Airport |
| 7 | Airport | RNAV | NRS | NRS | RNAV | NRS | RNAV | Airport |
| 8 | Airport | VOR | NRS | RNAV | NRS | NRS | RNAV | Airport |
| 9 | Airport | NRS | NRS | NRS | RNAV | VOR | RNAV | Airport |
| 10 | Airport | RNAV | RNAV | NRS | VOR | NRS | NRS | Airport |
| 11 | Airport | RNAV | RNAV | NRS | NRS | VOR | NRS | Airport |
| 12 | Airport | NRS | NRS | NRS | RNAV | VOR | RNAV | Airport |

**FMS Emulator.** An FMS emulator[2] was created to model the Collins 4200 FMS using Java programming language and CANVAS 11 software (version 11; ACD Systems International). This program ran on a laptop PC and was used during the flight plan entry and weather reroute tasks. Unlike a real FMS, only the functions and keys that were required to enter a route and make a modification were available for use on the experimental FMS. Usable functions were, DIR INTC, FPLN, LEGS and EXEC. All letter, number and line selects keys were functional, as well as the PREV PAGE, NEXT PAGE, SP, DEL and CLR keys. Participants interacted with the FMS by using a computer mouse. Figure 8 shows the FMS emulator used in the study with usable keys and functions outlined in red.

[2] Source code for the FMS emulator is available upon request.


***Figure 8***. FMS Emulator used in the Part-Task Study.

**Navigation Display Emulator.** A navigation (Nav) display emulator[3] was created for the weather rerouting task. This Nav display was created using Java programming language and CANVAS 11 software (version 11; ACD Systems International). Unlike an actual Nav display, only certain keys were available for use in our experiment. Usable keys were AIRPORTS, NAVAIDS, WAYPOINTS and AIRWAYS. These keys allowed the participant bring up or hide fixes. The range button was also usable but was set to zoom in and out between 60, 80 and 100 nautical miles. Left, right, up and down arrow keys were not functional.

The Nav display was run on a laptop PC and participants interacted with the program via computer mouse. Figure 9 shows the NAV display used in the study with functional keys outlined in red.

[3] Source code for the navigation display emulator is available upon request.

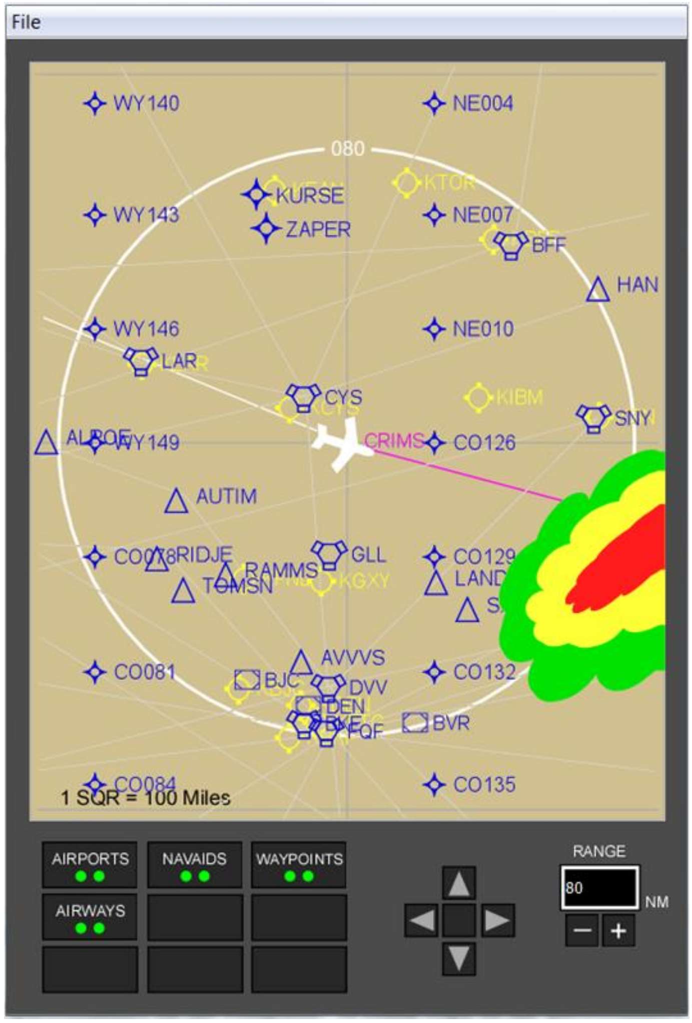



***Figure 9.*** Navigation Display used in the Part-Task Study.

**NRS Evaluation Questionnaire.** After completing all other tasks, each participant was asked to complete an NRS Evaluation Questionnaire on the computer. A blank copy of the questionnaire is located in Appendix 6. The questionnaire with the results for each question inserted is located in Appendix 7.

### 5.2.3 Design

The present study was conducted using a mixed factorial design. The independent variables were nomenclature (with four levels: N1, N2, N3 and N4), density[4] (with three levels: high, medium and low), and fix type (with four levels: VOR, Airport, RNAV waypoints and NRS Waypoint). The dependent variables were: 1) time to locate waypoints on the enroute charts, 2) time to type in flight plan fixes into the FMS, 3) the waypoint(s) chosen during the weather reroute task, 4) errors made during FMS entry of flight plan and reroute fixes. The between variable was experience (with 2 levels; prior NRS waypoint experience and no NRS waypoint

[4] Density was only a variable for the waypoint finding task using the high altitude enroute charts.

experience). In order to negate any possible order or practice effects, nomenclature, density, and routes were randomized throughout the experiment. Participants were randomly assigned to one of four possible groups in which the order of nomenclature presentation had been counterbalanced. Within these counterbalanced nomenclature groups, routes and NRS waypoints were randomized. These groups can be seen in Table 9.

**Table 9**

*Counterbalanced Groups*

| Order of NRS Waypoint Presentation | Participant Group 1 | Participant Group 2 | Participant Group 3 | Participant Group 4 |
|---|---|---|---|---|
| First | N1 | N3 | N2 | N4 |
| Second | N3 | N2 | N4 | N1 |
| Third | N2 | N4 | N1 | N3 |
| Fourth | N4 | N1 | N3 | N2 |

### 5.2.4 Procedure

Prior to starting the experiment all participants were asked to read and sign a consent form and were informed that if they wished to discontinue the study at any time they would be allowed to do so. All participants completed the study tasks in their entirety. Participants were told the experiment was being conducted to research experimental NRS waypoint naming configurations. Each participant was given a brief introduction to the NRS grid as well as training on the use of the FMS and Nav display emulators. Although participants were not blind to the nature of the study, no pilots were told (or reminded) which of the four nomenclatures used the experiment was the current NRS nomenclature until the end of the experiment.

The experiment was divided into four sessions with each session featuring a different NRS nomenclature. Ten minute breaks were provided between the first, second, and third sessions and after the final session was completed participants were instructed to fill out the NRS Evaluation on a computer.

Experimental procedures for each nomenclature session are described below:

1. NRS waypoint finding task (This process was repeated six times per nomenclature as participants were asked to locate six different waypoints).
    a) The experimenter provided high altitude charts developed for the study and nomenclature training sheets to the participant to review and answered any questions about the presented NRS waypoint nomenclature configuration.
    b) The experimenter explained the Waypoint finding task.
    c) The experimenter presented the first NRS waypoint card face down, when the participant flipped the NRS waypoint card over the experimenter began timing using the stopwatch. When the participant circled the waypoint on the chart with an erase

pen the experimenter stopped the timer, recorded the elapsed time and erased the circled waypoint.

2. FMS flight and weather reroute tasks (This process was repeated three times per nomenclature).
   a) The experimenter gave a flight release to the participant and instructed him/her to review the document and, when ready, enter the flight plan into the FMS using the computer mouse.
   b) After the participant executed the flight plan using the FMS emulator, the experimenter brought up the NAV display in which the aircraft was enroute with an area of severe weather depicted 20-70 nm away on their planned trajectory.
   c) The experimenter, playing the part of ATC, read an open-ended clearance asking the pilot to decide upon how to deviate around weather shown on the NAV display (see Figure 9 above; example clearance: "Airline 724, 55 miles ahead there is a stationary area of level 4 and 5 weather 75 miles wide, 15 south of Sidney VOR that crosses your route of flight. Please state your intentions for deviation." The participant then chose a fix to reroute to and asked ATC for clearance. After receiving this clearance the participant updated the flight plan on the FMS.

The experimenter was present throughout the duration of the experimental tasks but left the room while the participant filled out the NRS evaluation questionnaire. The experiment lasted an average of 3 hours.

## 5.3 Results

Prior to the start of data collection, power analyses were conducted and it was determined that data from 28 participants were required to yield sufficient power to ensure confidence in the accuracy of results and the ability to generalize findings from the study sample to the larger population of part 135 and part 121 pilots. Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 18.

### 5.3.1 High Altitude Enroute Chart Waypoint Finding Task

Both errors ($n$ = 2) and outliers ($n$ = 12 out of 672 waypoints) were excluded from the data set prior to analysis. Outliers were those waypoint location times that fell at or beyond three times the standard deviation.

**Nomenclature Type.** In order to make sure that the order in which the four nomenclatures were presented to participants did not affect the amount of time it took participants to locate waypoints on the high altitude enroute charts (for example, due to practice or learning effects), a one way Analysis of Variance (ANOVA) for order of nomenclature presentation was conducted. The result of this ANOVA showed that no effect on time to locate waypoints on the enroute charts was due to the order in which the four nomenclatures were presented $F(3,648) = 1.15$, $p = 0.22$, $\omega = 0.04$.

As a result of removing outliers, a repeated measures ANOVA could not be performed because the assumptions necessary for conducting this test were not met. However 2 one-way ANOVAs and an independent t-test were conducted to test for the effects of nomenclature type, density, and experience on the time it took to locate waypoints. Means and standard deviations of these variables can be seen in Table 10.

**Table 10**

*Descriptive Statistics for the NRS Waypoint Finding Task*

| Variable | *N* | Mean Number of Seconds | SD |
|---|---|---|---|
| Nomenclature* | | | |
| N1 | 161 | 35.66 | 30.36 |
| N2 | 164 | 17.66 | 14.66 |
| N3 | 164 | 14.62 | 15.33 |
| N4 | 163 | 16.81 | 14.78 |
| Density* | | | |
| Low | 218 | 17.04 | 18.49 |
| Medium | 215 | 19.47 | 18.82 |
| High | 219 | 26.83 | 25.4 |
| Experience | | | |
| Non-NRS Experienced | 328 | 20.95 | 22.33 |
| NRS-Experience | 324 | 21.3 | 20.75 |

* $p < 0.01$

The findings of the one-way ANOVA conducted on nomenclature configuration type (N1, N2, N3, and N4)[5] supported our belief that participants would more quickly locate the alternate NRS waypoints (N2, N3, N4) than currently used NRS waypoints (N1); a significant difference in waypoint location time was found among the nomenclatures, $F(3,648) = 38.74$, $p < 0.01$. A series of post hoc planned contrasts revealed that having the state abbreviation as part of the waypoint configuration (N2, N3, or N4) significantly decreased the time to locate an NRS waypoint as compared to the current NRS waypoint configuration (N1), $t(648) = -10.686$, $p < 0.01$, $r = 0.39$.

5

| N1 | N2 | N3 | N4 |
|---|---|---|---|
| FIR-Ctr-Lat-Long | State-Lat-Long | State-### | State-##-Ctr |

A one-way ANOVA on just the three alternate nomenclatures (N2, N3, and N4) revealed no significant differences in waypoint location times occurring among them, $F(2,488) = 1.81$, $p = 0.17$, $\omega = 0.06$. The graphical depiction of these results can be seen in Figure 10.

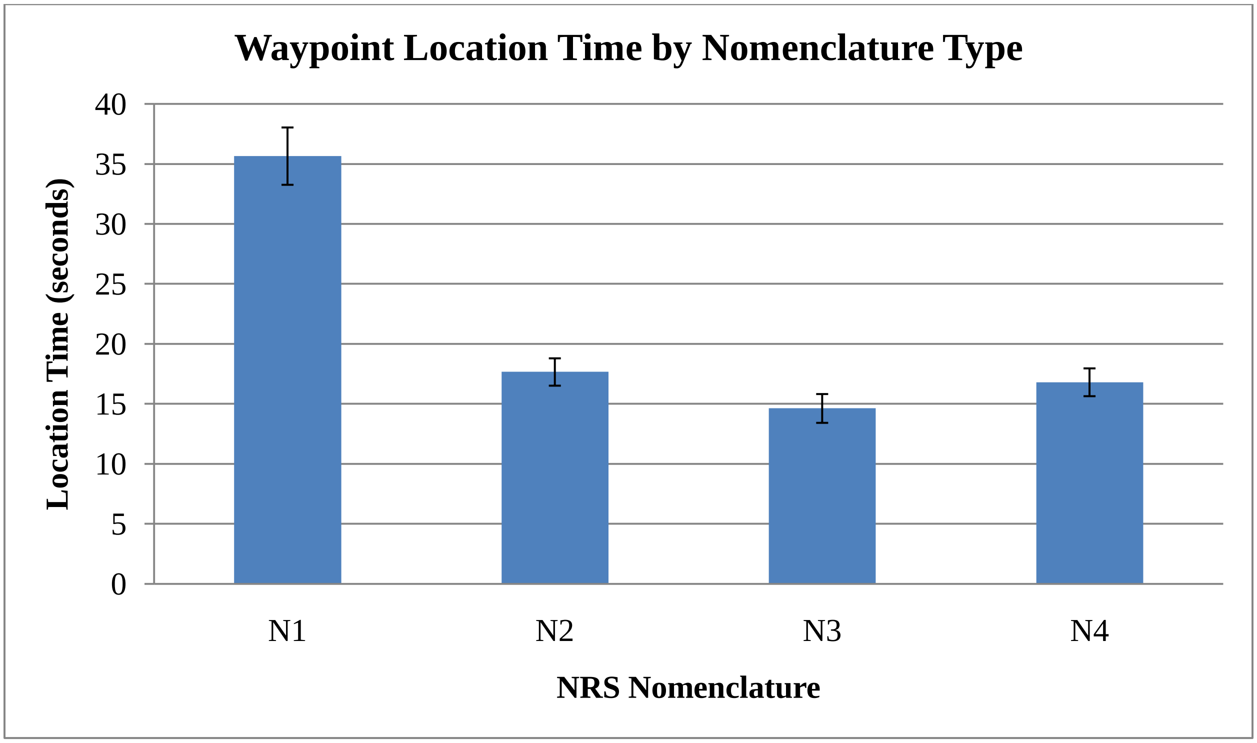



***Figure 10.*** Average amount of time to locate NRS waypoints on an enroute chart.

> ***Summary:*** *Participants took significantly longer to locate NRS waypoints in the current nomenclature configuration (N1) than in any of the three alternate NRS waypoint configurations (N2, N3, and N4) on high altitude enroute charts. Time to locate alternate NRS waypoints did not differ significantly among the three configurations evaluated. These results indicate that the state postal identifier as part of the nomenclature significantly aided in waypoint location as compared to a combination of the U.S. FIR and ARTCC identifiers.*

**Chart Density.** NRS waypoints in the waypoint finding task were located in one of three different densities based on the number of "bits" of information within a 1 inch radius of the NRS waypoint on the enroute chart. Density was controlled to ensure that participants received waypoints that were similarly difficult to find across the four nomenclatures and to determine if participants had more difficulty locating waypoints in more dense areas as compared to those in less dense areas. Through a one-way ANOVA we were able to conclude that time to locate waypoints was significantly affected by density regardless of NRS nomenclature type, $F(2,649) = 12.67$, $p < 0.01$. Post hoc planned contrasts revealed that waypoints located in high density areas took significantly longer for participants to find than those in low density areas, $t(649) = 73.6$, $p < 0.01$, $r = 0.81$, and medium density areas, $t(649) = 3.62$, $p < 0.01$, $r = 0.72$. However, times to locate waypoints in medium and low density areas did not significantly differ, $t(649) = 1.19$, $p = 0.23$, $r = 0.05$. These results are depicted graphically in Figure 11.

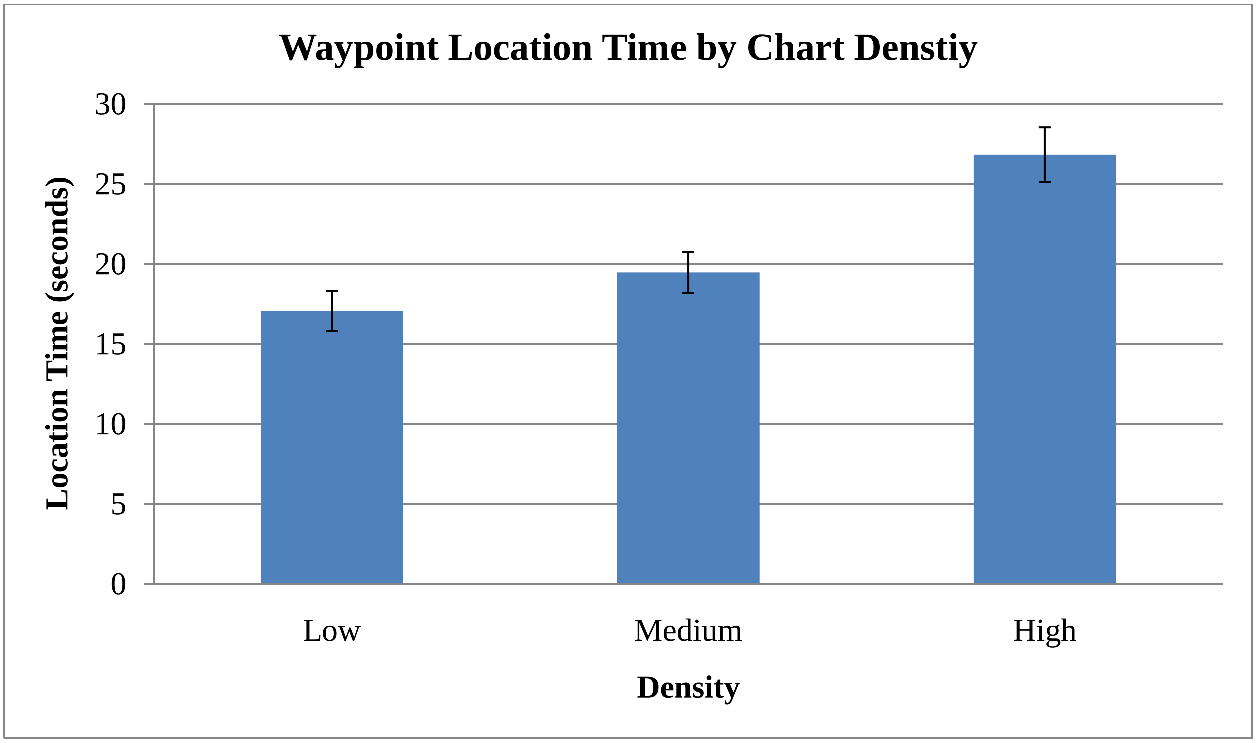



***Figure 11.*** Average amount of time to locate NRS waypoints in low, medium, and high density areas on an enroute chart.

> ***Summary:*** *Participants took significantly longer to locate NRS waypoints located in high density areas than those in either low or medium density areas. Location times did not differ between waypoints located in medium and low density areas.*

**Experience with NRS Waypoints.** In order to assess if previous experience with current NRS waypoints aided in waypoint location time, an independent t-test was conducted. The results of this t-test did not yield significant results, $t(650) = -0.21$, $p = 0.09$, $r = 0.01$, indicating that prior experience with current NRS waypoints did not affect the amount of time it took to locate the NRS waypoints in any of the four configurations evaluated on high altitude enroute charts.

> ***Summary:*** *Previous experience with NRS waypoints did not affect the amount of time it took to locate NRS waypoints in any configuration on high altitude enroute charts. In other words, previous experience with current NRS waypoints did not serve as an advantage, in terms of speed of locating them, over alternately named NRS waypoints.*

**Waypoint Finding Errors.** Unlike errors made during the entry of waypoints into the FMS, discussed in section 5.3.2.2 below, exceptionally few errors ($n = 2$) were made by participants when engaged in the waypoint finding task using high altitude enroute charts. Therefore, no further analyses with regard to these errors were possible.

### 5.3.2 FMS Route Entry and Re-route Tasks

#### 5.3.2.1 Fix Entry Times

The amount of time it took to enter the different types of flight plan fixes in the FMS was recorded in milliseconds by the FMS emulation program. FMS data entry errors ($n$ = 77) and outliers ($n$ = 44 out of 3,163 entries) were excluded from the dataset prior to analysis. Analyses of errors made during data entry were conducted separately and are reported in section 5.3.2.2 below. Average fix entry times for each fix type (VOR, airport, traditionally named RNAV waypoints, and NRS waypoints) for each participant were used in lieu of raw data in order to meet the assumptions required for the performance of a repeated measures ANOVA.[6]

For all tests, previous experience with current NRS waypoints did not influence fix entry time into the FMS nor did it interact with any of the other independent variables.

**All Fix Types.** In order to test the hypothesis that NRS waypoints would take longer to enter into the FMS than VORs, Airports or traditionally named RNAV waypoints, due to differences in fix length and switching between letters and numbers on the keypad for NRS waypoints, a one-way ANOVA for fix type was conducted. Means and standard deviations can be found in Table 11.

**Table 11**

*Descriptive Statistics for Fix Type*

| Variable | *N* | Mean Number of Seconds | SD |
|---|---|---|---|
| Fix Type* | | | |
| VOR (3 characters) | 112 | 2.10 | 0.86 |
| Airport (4 characters) | 112 | 3.28 | 1.06 |
| RNAV (5 characters) | 112 | 4.25 | 1.23 |
| NRS waypoint (5 characters) | 112 | 4.87 | 1.20 |

*$p < 0.01$

Not surprisingly, the results of the ANOVA supported our hypothesis, $F(3,444) = 136.39$, $p < 0.01$, indicating that fix length significantly affected the amount of time it took to enter the fix in the FMS. Post hoc planned contrast analyses revealed that VOR fixes (three characters in

[6] This approach (using average fix entry times rather than raw data) to allow the completion of a repeated measures ANOVA was not possible with the time needed for participants to find waypoints on the high altitude enroute charts discussed earlier because of the small number of waypoints ($n$ = 2) presented to each participant in each of the three chart density conditions. Because a main effect was found for density, it is inappropriate to collapse across all three density conditions to derive an average time needed to locate waypoints.

length) took significantly less time to enter into the FMS than airports (four characters in length), traditionally named RNAV or NRS waypoints (both five characters in length), $t(444) = 16.99$, $p < 0.01$, $r = 0.63$. Similarly, airports were also found to be significantly faster to enter than either traditionally named RNAV or NRS waypoints, $t(444) = 10.11$, $p < 0.01$, $r = 0.43$. Although named RNAV and NRS waypoints are both five characters in length, we anticipated that NRS waypoints would take longer than RNAV fixes to enter into the FMS due to the need to move between letters and numerals on the FMS data entry pad. Post Hoc planned contrast analyses supported this prediction; it took participants significantly longer to type in NRS waypoints (regardless of nomenclature type) than to enter named RNAV waypoints in the FMS, $t(444) = 4.26$, $p < 0.01$, $r = 0.20$. A graphical depiction of these ANOVA results can be seen in Figure 12.

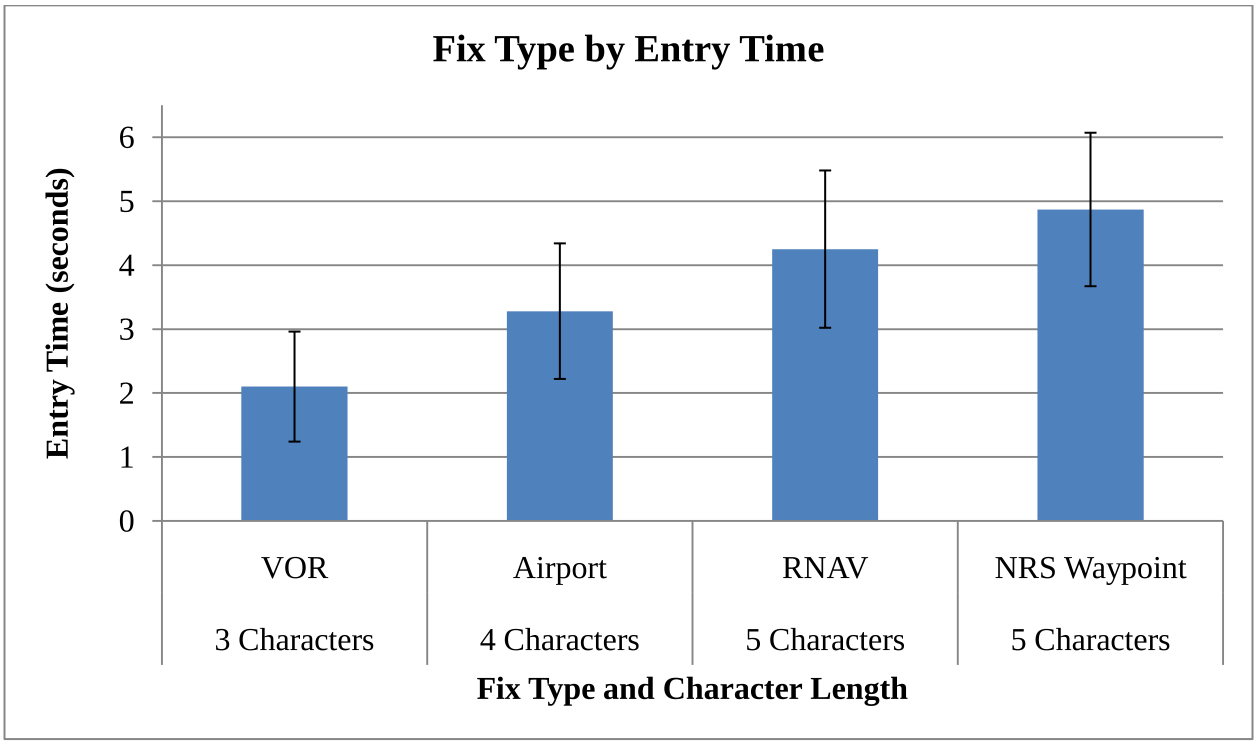



***Figure 12.*** Average data entry time by fix.

***Summary:*** *FMS data entry time was significantly affected by fix length such that the fixes with the fewest number of characters, VOR (3 letters), were entered into the FMS in the least amount of time, followed by airports (4 letters), and then named RNAV and NRS waypoints (5 letters). Entry time was also found to be significantly different for RNAV and NRS waypoints; NRS waypoints of all configuration types took significantly longer to enter into the FMS than traditionally named RNAV waypoints, even though they are the same length.*

**Comparison of RNAV and NRS Waypoints.** In order to evaluate any interactions that might have occurred between NRS waypoint nomenclature type (N1, N2, N3, N4) and fix type (traditional RNAV and NRS waypoints only) a mixed factorial ANOVA was conducted.  In other words, we wanted to determine if the NRS nomenclature configurations had a differing effect on the amount of time needed for entering traditionally named RNAV waypoints.  Means and standard deviations are shown in Table 12.

**Table 12**

*Descriptive Statistics for RNAV and NRS Waypoints by NRS Nomenclature Session*

| Variable | *N* | Mean Number of Seconds | SD |
|---|---|---|---|
| NRS Nomenclature Session and Fix Type | | | |
| N1* | | | |
| RNAV Waypoint | 28 | 4.06 | 1.03 |
| NRS Waypoint | 28 | 5.26 | 1.03 |
| N2** | | | |
| RNAV Waypoint | 28 | 4.42 | 1.42 |
| NRS Waypoint | 28 | 5.24 | 1.44 |
| N3 | | | |
| RNAV Waypoint | 28 | 4.14 | 1.35 |
| NRS Waypoint | 28 | 4.00 | 0.81 |
| N4* | | | |
| RNAV Waypoint | 28 | 4.36 | 1.10 |
| NRS Waypoint | 28 | 4.97 | 1.00 |

* $p < 0.01$

** $p < 0.05$

A significant interaction was found between NRS waypoint nomenclature configuration and fix type, $F(3,78) = 17.35$, $p < 0.01$, indicating that NRS nomenclature configuration influenced the data entry time for both RNAV and NRS waypoints.  To investigate this interaction a series of paired t-tests were conducted for each of the four NRS nomenclature configurations.  The results of these tests revealed that NRS waypoints took longer than RNAV fixes to enter into the FMS when NRS waypoints were presented in the N1 configuration[7], $t(28) = -9.06$, $p < 0.01$, $r = 0.86$, N2 configuration, $t(28) = -3.24$, $p < 0.05$, $r = 0.54$, and N4 configuration, $t(28) = -3.68$, $p < 0.05$, $r = 0.57$.  However, traditional RNAV fixes and NRS waypoints did not significantly differ in entry time when NRS waypoints were presented in the N3 configuration, $t(28) = 0.68$, $p = 0.51$, $r = 0.13$.  The results of these one-way ANOVAs are graphically depicted in Figure 13.

[7]

| N1 | N2 | N3 | N4 |
|---|---|---|---|
| FIR-Ctr-Lat-Long | State-Lat-Long | State-### | State-##-Ctr |

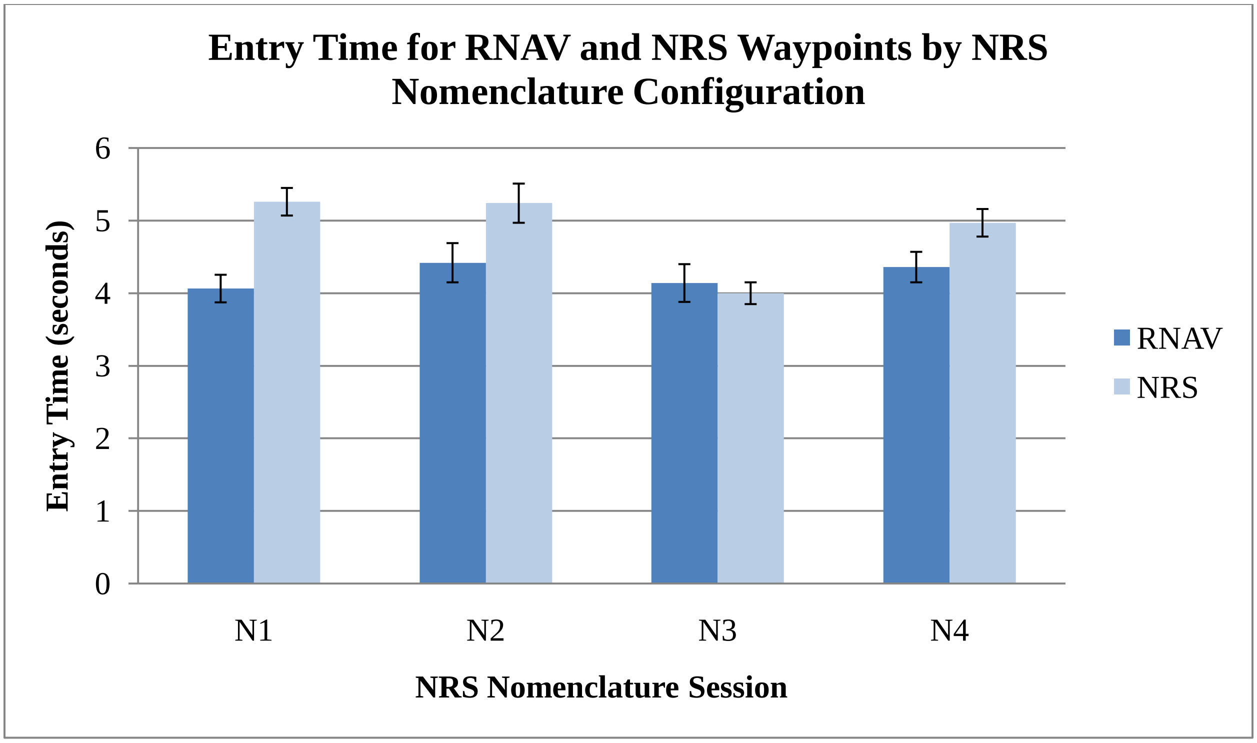



***Figure 13***. Average FMS entry time for RNAV and NRS waypoints by NRS nomenclature session[8].

> ***Summary:*** *Traditionally named RNAV waypoints were entered into the FMS at significantly faster rates than N1, N2, or N4 NRS waypoints. No significant difference in entry time was found between traditional RNAV and N3 NRS waypoints. These results may indicate that some speed is lost when switching back and forth between letters to numbers more than once as is done when entering N1, N2, and N4 NRS waypoint configurations.*

**NRS Waypoints Only.** In order to investigate the influence of nomenclature on NRS waypoint entry time a 4 x 2 between subjects ANOVA was conducted. The independent variables were nomenclature type (N1, N2, N3, and N4) and experience (NRS-experienced and non NRS-experienced). Means and standard deviations for this analysis are presented in Table 13.

---

8

| N1 | N2 | N3 | N4 |
|---|---|---|---|
| FIR-Ctr-Lat-Long | State-Lat-Long | State-### | State-##-Ctr |

**Table 13**

*Descriptive Statistics for NRS Waypoint Entry Time by Nomenclature*[9]

| Variable | *N* | Mean Number of Seconds | SD |
|---|---|---|---|
| Nomenclature | | | |
| N1 | | | |
| Non - NRS Experienced | 14 | 5.22 | 1.16 |
| NRS-Experienced | 14 | 5.30 | 0.92 |
| N2 | | | |
| Non - NRS Experienced | 14 | 5.18 | 1.26 |
| NRS-Experienced | 14 | 5.30 | 1.64 |
| N3 | | | |
| Non - NRS Experienced | 14 | 4.06 | 0.83 |
| NRS-Experienced | 14 | 3.94 | 0.82 |
| N4 | | | |
| Non - NRS Experienced | 14 | 4.85 | 1.05 |
| NRS-Experienced | 14 | 5.01 | 1.24 |

A significant main effect for nomenclature was found, $F(3,104) = 7.94$, $p < 0.01$, indicating that NRS waypoint entry times were influenced by NRS configuration type. Post hoc planned contrasts revealed that data entry time for NRS waypoint configuration N3 was significantly less than configuration N1, $t(108) = -4.31$, $p < 0.01$, $r = 0.38$, N2, $t(108) = -4.24$, $p < 0.01$, $r = 0.38$, or N4, $t(108) = 3.33$, $p < 0.05$, $r = 0.31$. No significant differences in time were found between configuration N1 and N2, $t(108) = -0.70$, $p = 0.94$, $r = 0.07$, N1 and N4, $t(108) = -0.97$, $p = 0.33$, $r = 0.09$, or N2 and N4, $t(108) = -0.90$, $p = 0.37$, $r = 0.09$. The results of these analyses are graphically depicted in Figure 14.

[9]

| N1 | N2 | N3 | N4 |
|---|---|---|---|
| FIR-Ctr-Lat-Long | State-Lat-Long | State-### | State-##-Ctr |

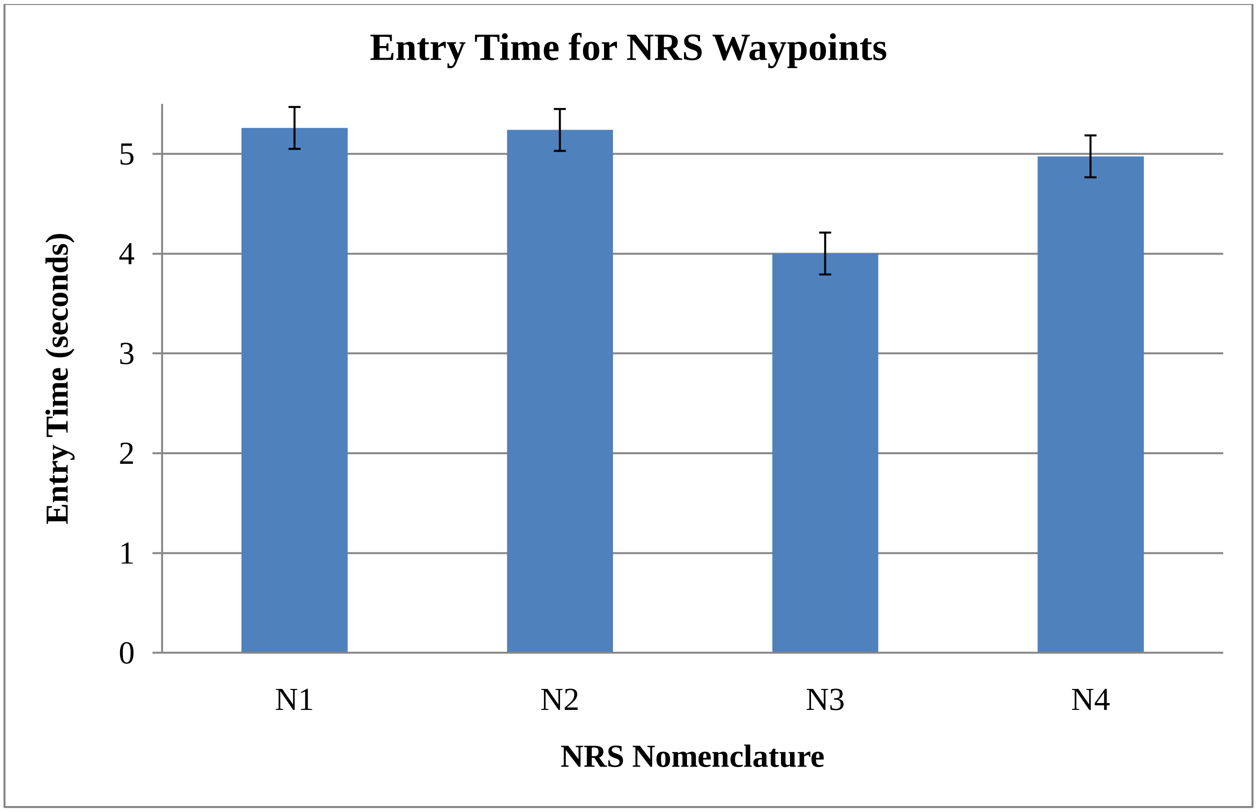



***Figure 14.*** Average data entry time for NRS waypoints.[10]

> ***Summary:*** *FMS entry time for NRS waypoint configuration N3 was found to take significantly less time than current NRS waypoint (N1), and alternate NRS waypoints N2 and N4. There were no significant differences in the amount of time for data entry among N1, N2, and N4 NRS waypoints configurations.*

#### 5.3.2.2 Data Entry Errors

**FMS Entry Error Rate by Type of Fix.** In addition to the time it took to enter fixes in the FMS, the number and types of errors made during data entry were also analyzed. We were particularly interested in determining if errors and error rates were different for the different types of fixes, particularly for the four NRS waypoint nomenclatures being evaluated. The number of errors for each fix and error type can be seen in Table 14.

---

10

| N1 | N2 | N3 | N4 |
|---|---|---|---|
| FIR-Ctr-Lat-Long | State-Lat-Long | State-### | State-##-Ctr |

**Table 14**

*FMS Entry Errors by Fix and Error Type*

| Fix Type | Error Type | | | Total Entries | Percent |
|---|---|---|---|---|---|
| | Transposition | 1/I and 0/O | Mistype | | |
| VOR | 2 | 0 | 3 | 325 | 1.54 |
| Airport | 2 | 0 | 12 | 791 | 1.77 |
| RNAV | 2 | 1 | 16 | 825 | 2.3 |
| NRS Waypoint | 7 | 15 | 12 | 1222 | 2.28 |
| All Fixes | 13 | 16 | 43 | 3163 | 2.28 |

A Pearson's chi-square was conducted to see if fix type influenced the number of data entry errors. No significant association between error rate and fix type was found, $X^2(3) = 3.17$, $p = 0.37$. Participants made three different types of errors during data entry: a) confusion between the letter "I" and number "1" or between the letter "O" and the number "0", b) transposition of characters within the fix name, and 3) mistypes. Transposition errors occurred when participants entered characters within the waypoint name in the wrong order. For example, KD54U was typed as KD45U or KU54D. Mistypes occurred when the participant entered a character into the FMS that was not part of the waypoint name (e.g., KD54U was entered as KD54T). The rate and type of errors for each fix are graphically depicted in Figure 15.

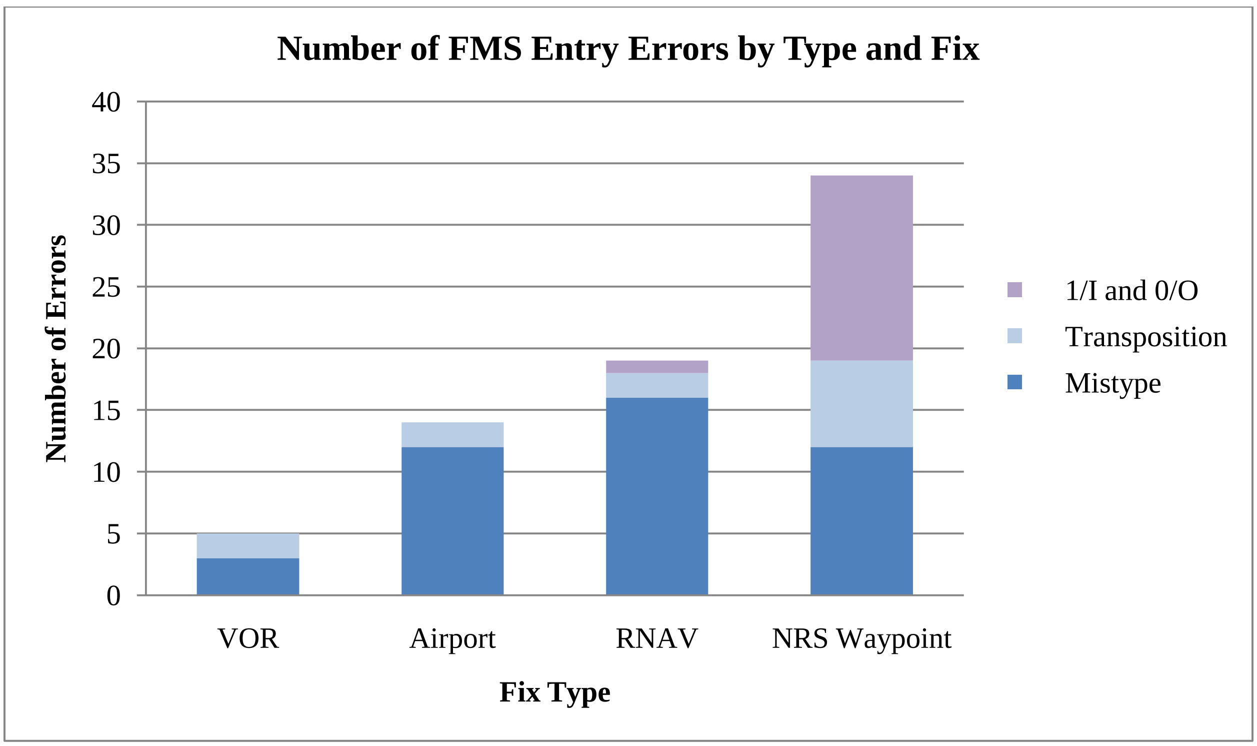



***Figure 15.*** Error Rates for fix and error types.

We were interested in determining if the number of errors committed (I/1 or O/0, transposition, and mistypes) differed significantly across the four different types of fixes. Unfortunately, we could not conduct Pearson's chi-squares analyses to determine this because so few errors of each error type were committed across the four fix types. The investigation of error types across just the four NRS waypoint nomenclature configurations are discussed below.

> ***Summary:*** *Participants made FMS data entry errors at similar rates across each of the four fix types used in the study. As seen in Table 14, error rates ranged from 1.53% for entering VORs to 2.78% for entering NRS waypoints.*

**NRS Waypoint Nomenclatures and Error Type.** A Pearson's chi-square was conducted to assess if error rates were different among the four different NRS waypoint nomenclature configurations. The results revealed no significant difference in the overall error rates across the four nomenclatures evaluated, $X^2(3) = 0.51$, $p = 0.92$. The numbers and types of errors committed for each NRS waypoint configuration can be seen in Table 15 and are graphically depicted in Figure 16.

**Table 15**

*NRS Waypoint Entry Errors by NRS Nomenclature[11] and Error Types*

| Fix Type | Error Type | | | Total Entries | Percent |
|---|---|---|---|---|---|
| | Transposition | 1/I and 0/O | Mistype | | |
| N1 | 2 | 4 | 4 | 310 | 3.23 |
| N2 | 2 | 3 | 3 | 305 | 2.62 |
| N3 | 3 | 2 | 2 | 301 | 2.33 |
| N4 | 0 | 6 | 3 | 306 | 2.94 |
| All Nomenclatures | 7 | 15 | 12 | 1222 | 2.78 |

Again, analyses to conclude if different types of errors were statistically more likely to occur in different NRS waypoint configurations could not be conducted due to the low error rates.

11

| N1 | N2 | N3 | N4 |
|---|---|---|---|
| FIR-Ctr-Lat-Long | State-Lat-Long | State-### | State-##-Ctr |

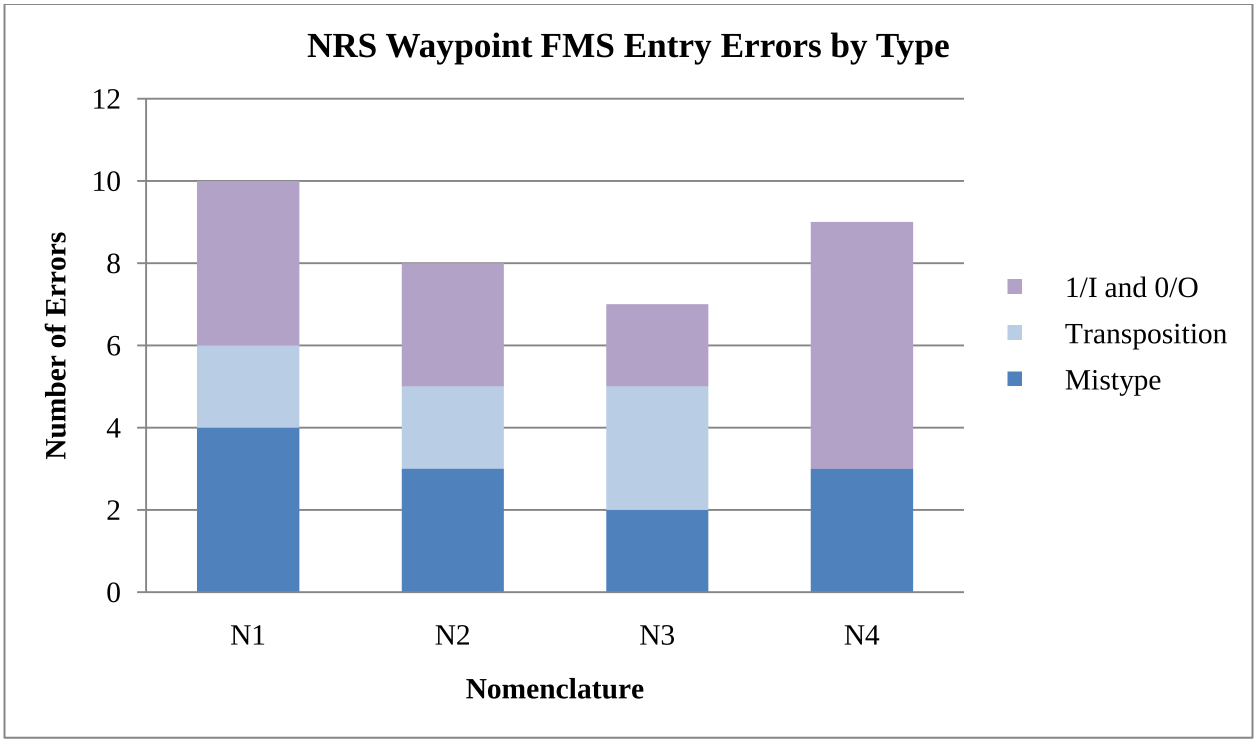



***Figure 16***. Error rates for NRS waypoint[12] data entry.

Even though the number of errors made by participants when typing in the different fix types and different NRS waypoint nomenclatures was not high, the implications of such errors has the potential to be great, especially when not caught. This will be explored in more detail in the Discussion and Implication section later.

> ***Summary:*** *Participants made FMS errors at fairly similar rates among each of the four NRS waypoint configurations used in the study. Error rates for the four nomenclatures ranged from 2.33 % for the N3 nomenclature to 3.23% for the N1 nomenclature.*

#### 5.3.2.3 Weather Re-route Task

Consistent with earlier pre-deployment studies conducted by MITRE (Boetig, et al., 2004; Domino, et al., 2004) we wanted to determine if NRS waypoints would be seen as acceptable re-route alternatives. In other words, would NRS waypoints be used tactically (i.e., for a re-route) in addition to strategically, such as in flight planning. A Pearson's chi-square test was conducted to determine if there was a difference in the type of fix chosen for the weather re-route. It was found that regardless of NRS waypoint nomenclature type, they were chosen significantly more often by participants when requesting a re-route for weather as compared with other types of

---

12

| N1 | N2 | N3 | N4 |
|---|---|---|---|
| FIR-Ctr-Lat-Long | State-Lat-Long | State-### | State-##-Ctr |

fixes such as VORs or traditionally named RNAV waypoints, $X^2$ (2) = 185.62, $p < 0.05$. Although these results show that NRS waypoints were used tactically by our participants, we believe that the high rate of NRS waypoint selection over other types of fixes was probably due to the fact that participants were aware that this was a study of NRS waypoints (i.e., experimental bias). Therefore, further investigation of NRS waypoint use for re-routes was not pursued.

> ***Summary:*** *Participants chose NRS waypoints for deviation around weather significantly more often than VORs, airports, and RNAV waypoints, however this result may have been influenced by the nature of the study.*

### 5.3.3 NRS Waypoint Evaluation Questionnaire

Participant's opinions and thoughts on the four NRS waypoint configurations and overall grid were assessed through the use of a questionnaire. The questionnaire along with results for each question asked can be found in Appendices 5 and 6. Analyses of responses to selected questions from this questionnaire are presented here.

#### 5.3.3.1 Overall Preference and Ease of Use

In order to assess overall preference for the different NRS waypoint nomenclatures, each participant was asked to rank the four nomenclature configurations from "most preferred" to "least preferred." A Friedman's ANOVA revealed that ranks were significantly different among the nomenclature configurations, $X^2(3) = 33.53$, $p < 0.01$. Wilcoxon tests were used to further investigate this finding (statistical results for the Wilcoxon tests are located in Appendix 8). The Wilcoxon analyses revealed that NRS waypoint configuration N3 was ranked first significantly more often than other waypoint configurations and that NRS waypoint configuration N1 (the NRS waypoint nomenclature currently in use) was ranked last significantly more often among the four configurations. A graphical depiction of NRS waypoint configurations by their ranked preferences can be seen in Figure 17.

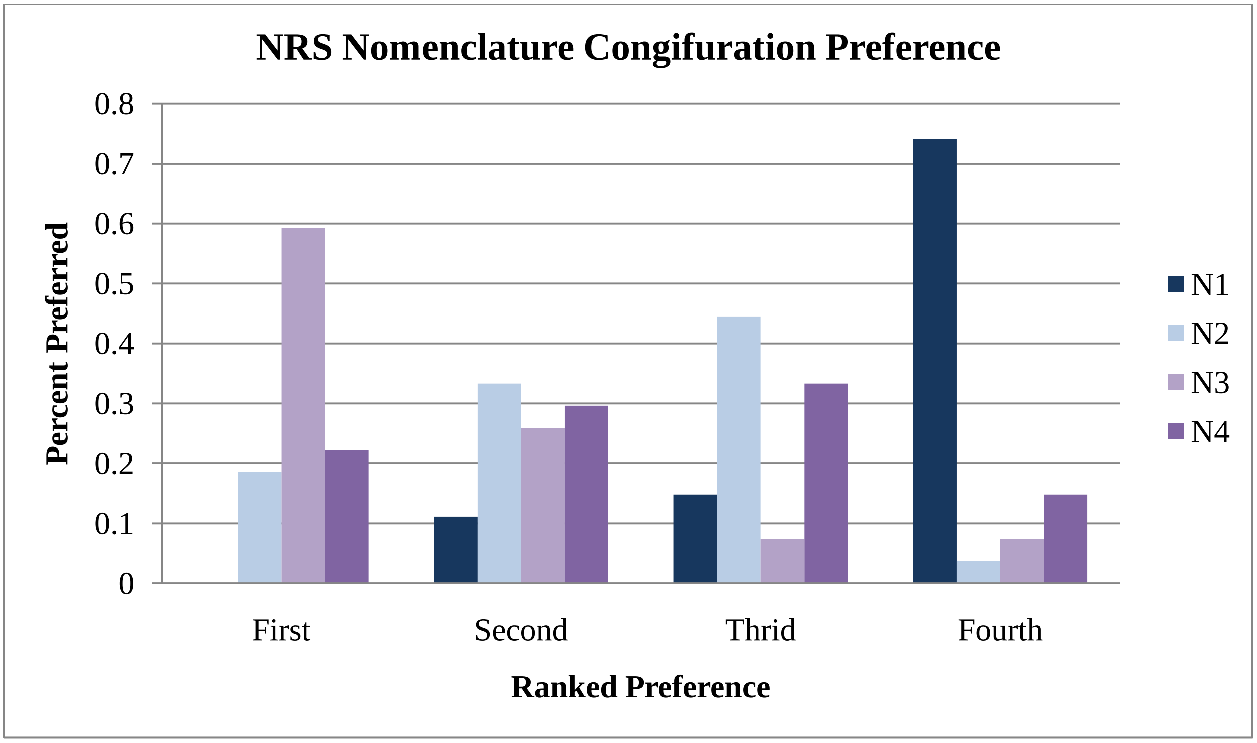



***Figure 17.*** NRS nomenclature configuration[13] preference.

When asked if any NRS waypoint configuration was easy to use, 27 participants responded "Yes" and of those, 17 participants stated configuration N3 was easy followed by N4 (*n* = 8) and N2 (*n* = 3). No participants stated that configuration N1 was easy to use. (Participants were allowed to select more than one nomenclature type as easy to use.)

Not surprisingly, when asked if any NRS waypoint configuration was more difficult to use, 20 out 22 participants who responded "Yes" stated that configuration N1 was difficult. Two participants found configuration N2 difficult to use, one participant found configuration N3 difficult, and two found configuration N4 difficult to use. (Participants were allowed to select more than one nomenclature type as difficult to use.)

> ***Summary:*** *Most Participants preferred to use NRS waypoints in the N3 configuration and least preferred to use NRS waypoints configured as they are today (N1). Likewise, participants generally found N3 waypoints to be easy to use and N1 waypoints to be difficult to use.*

---

13

| N1 | N2 | N3 | N4 |
|---|---|---|---|
| FIR-Ctr-Lat-Long | State-Lat-Long | State-### | State-##-Ctr |

#### 5.3.3.2 Geographical Awareness

Participants were asked the degree to which they agreed or disagreed with the statement "X" nomenclature configuration aided in geographical awareness" using a 5-point Likert scale (geographic awareness is the ability to develop a mental picture of where a waypoint is located within the United States). Pearson's chi-square tests revealed that participants did not find N1 NRS waypoints to aid in geographical awareness, $X^2(4) = 19.91$, $p < 0.01$. However, participants did find all three of the alternate NRS waypoint configurations to aid in geographical awareness, N2, $X^2(4) = 48.92$, $p < 0.01$, N3 $X^2(4) = 33.30$, $p < 0.01$, and N4 $X^2(4) = 18.57$, $p < 0.01$. These results are depicted in Figure 18.

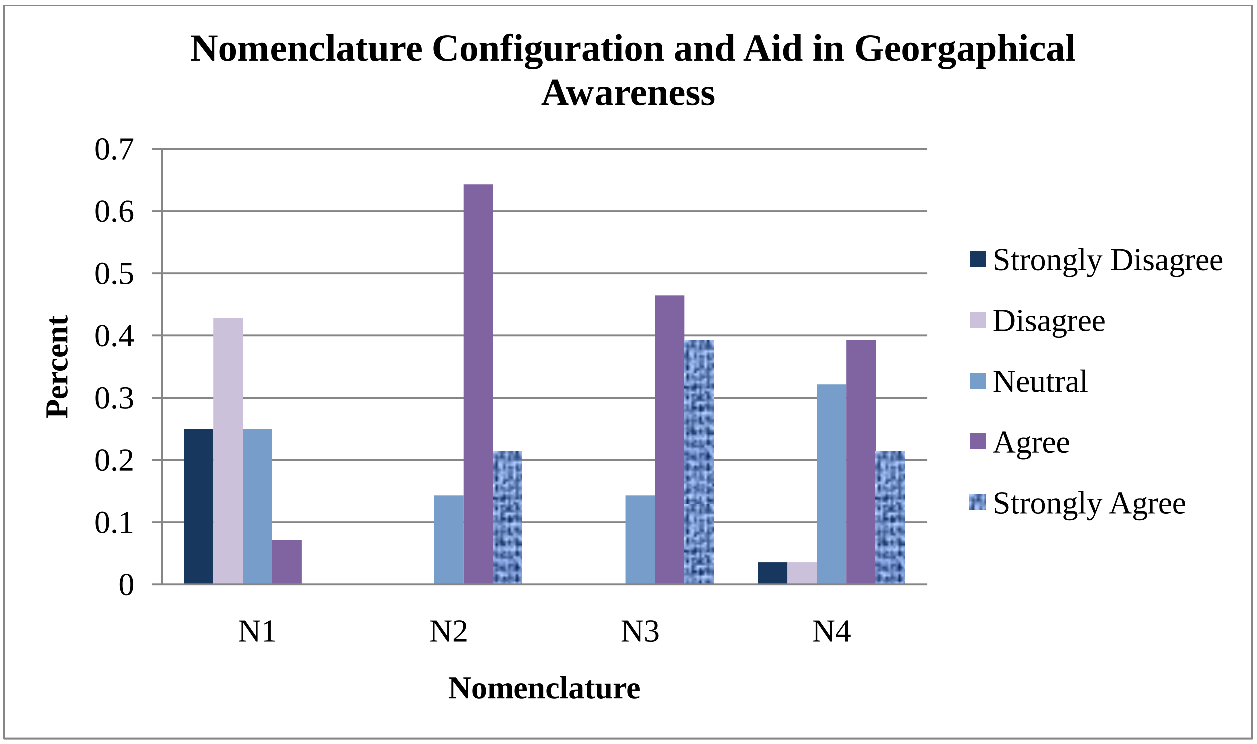



***Figure 18***. NRS nomenclature configuration[14] and aid in geographical awareness. Levels of agreement with the statement "I found "X" nomenclature to aid in geographical awareness".

Participants were also asked to rank the four nomenclatures with regard to the level of geographic awareness provided. The result of a Friedman's ANOVA revealed that participants ranks of the four nomenclature configurations were significantly different, $X^2(3) = 33.22$, $p < 0.01$. Wilcoxon tests revealed that participants ranked current NRS waypoints (configuration N1) as providing significantly less geographical awareness when compared to any of the three

14

| N1 | N2 | N3 | N4 |
|---|---|---|---|
| FIR-Ctr-Lat-Long | State-Lat-Long | State-### | State-##-Ctr |

alternate NRS waypoint nomenclature configurations (N2, N3, and N4). However no differences in level of geographic awareness provided were perceived by participants among the three alternate NRS waypoint nomenclatures. A graphical depiction of NRS waypoint configurations ranked preferences is located in Figure 19 and statistical results for the Wilcoxon tests are located in Appendix 8.

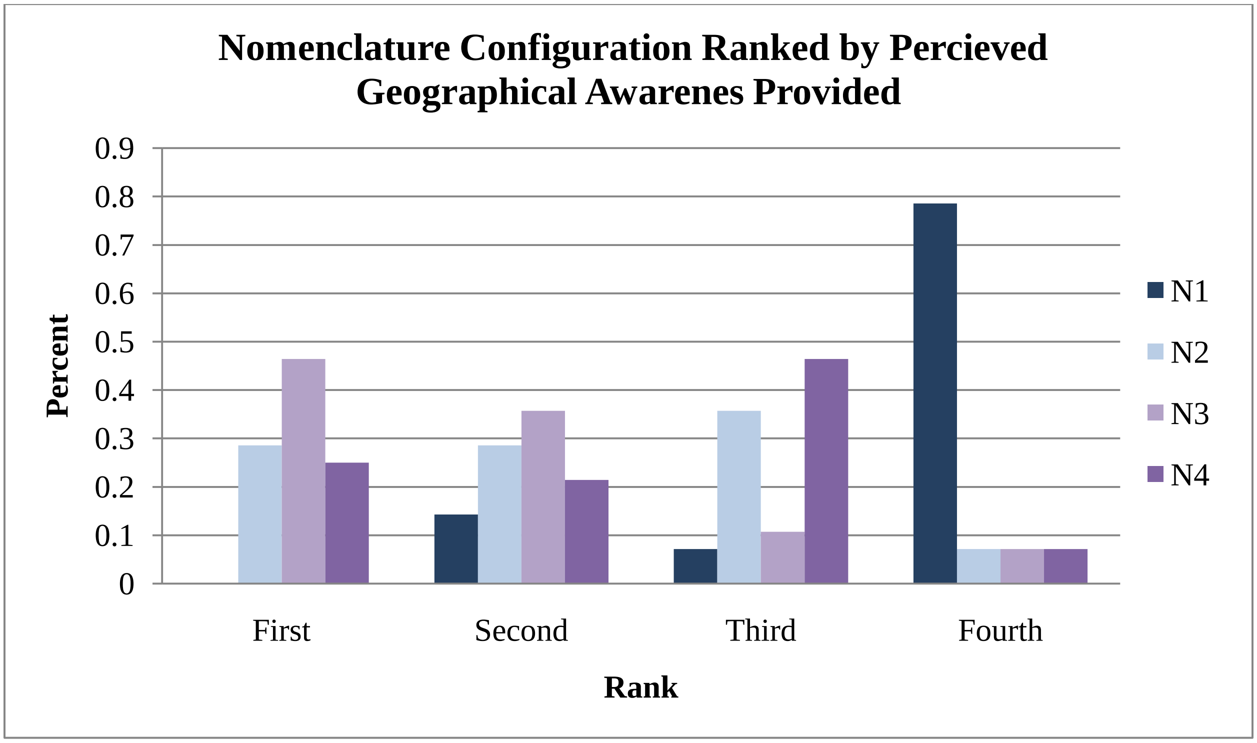



***Figure 19***. Rank of perceived geographical awareness provided across NRS nomenclature configurations[15].

Twenty-five out of 28 participants thought that including state abbreviations in the NRS waypoint nomenclature increased geographical awareness as compared to using the US FIR and ARTCC identifiers. Overall, 26 participants felt that some NRS waypoint configurations were easier to find on a high altitude enroute chart than others. Of these 26 participants, almost half (*n* =12) found N3 NRS waypoints to be the easiest followed by configurations N2 and N4 with 6 participants each. Only two participants found the current NRS waypoints (configuration N1) to be the easiest to locate. Twenty-six participants reported that certain NRS waypoint configurations were more difficult to locate on a high altitude enroute chart as compared to others: N1: 22 participants, N2: 1 participant, N3: 0 participants, and N4: 3 participants.

15

| N1 | N2 | N3 | N4 |
|---|---|---|---|
| FIR-Ctr-Lat-Long | State-Lat-Long | State-### | State-##-Ctr |

***Summary:*** *No significant differences existed among the three alternate nomenclatures with respect to the amount of perceived geographic awareness they provided, however participants rated the current NRS waypoint nomenclature as providing significantly less geographic awareness than the alternate nomenclatures. Overall, NRS waypoint configuration N3 was reported to be the easiest to locate on a high altitude enroute chart and configuration N1 to be the most difficult to locate.*

#### 5.3.3.3 Speaking and Hearing NRS Waypoint Names

NRS waypoints must be spoken over the radio. Although aural comprehensibility of NRS waypoints in different waypoint configurations was not assessed experimentally, participants did state NRS waypoints as a part of the FMS re-route task. Participants were asked to rate their opinions about the ease with which NRS waypoints in different configurations could be communicated over the radio.

Participants were asked their level of agreement or disagreement with the statement "I found "X" nomenclature easy to say phonetically" using a 5-point Likert scale. Pearson's chi-square tests indicated that participants significantly disagreed with the statement regarding NRS waypoint configuration N1, $X^2$ (3) = 8.99, $p < 0.01$. Conversely, participants strongly agreed with the statement when referring to NRS waypoint configuration N3, $X^2$(3) = 47.25, $p < 0.01$. A graphical depiction these findings are located in Figure 20.

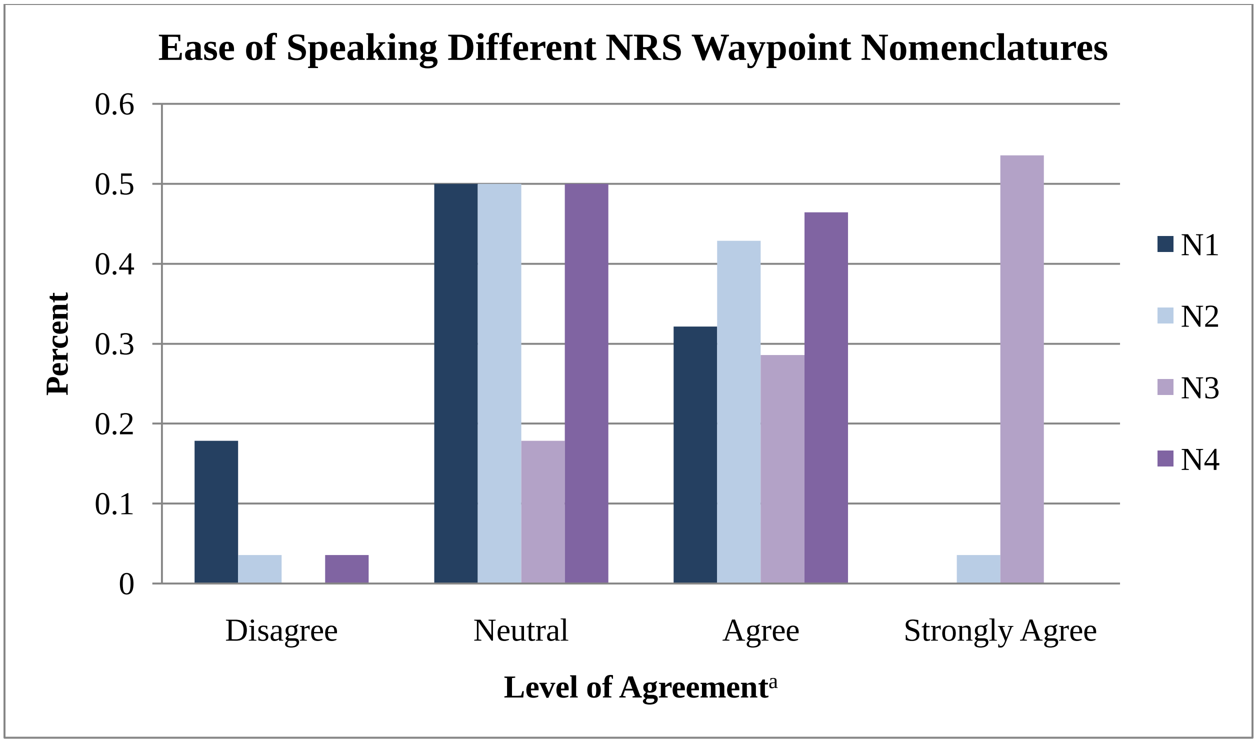



***Figure 20.*** Ease of speaking different NRS waypoint nomenclatures[16]. Levels of agreement with the statement “I found “X” nomenclature to be easy to say phonetically.

[a] No participants selected “Strongly Disagree”

Participants were asked if they found any NRS waypoint nomenclatures to be easy to say or difficult to say. Twenty-two participants stated “Yes” and of those, they found a particular 19 found configuration N3 to be easy, 3 stated that N2 was easy, and 1 stated N4 was easy to say. Of the 11 participants who stated they found any NRS waypoint configurations to be difficult to say, N1, N2, N3, and N4 were found difficult by 8, 4, 2, and 3 participants, respectively. Participants were also asked about how they preferred NRS waypoint to be phonetically spoken in a clearance issued over the radio by ATC. Two waypoints were provided and the list of possible pronunciations and their percentage of preference are shown in Table 16.

16

| N1 | N2 | N3 | N4 |
|---|---|---|---|
| FIR-Ctr-Lat-Long | State-Lat-Long | State-### | State-##-Ctr |

**Table 16**

*Participant preference when hearing Experimental NRS Waypoint Configurations*

| Waypoint | Percent |
|---|---|
| OH127 | |
| Phonetic Combinations | |
| Oscar – Hotel – One – Two – Seven | 39 |
| Oscar – Hotel – One – Twenty-seven | 16 |
| Oscar – Hotel – One hundred twenty-seven | 4 |
| Ohio – One – Two – Seven | 24 |
| Ohio – One – Twenty-seven | 18 |
| Ohio – One hundred twenty-seven | 0 |
| No preference, All are acceptable | 0 |
| | |
| TX15F | |
| Phonetic Combinations | |
| Tango - X-ray - One - Five - Foxtrot | 42 |
| Tango - X-ray - Fifteen - Foxtrot | 9 |
| Texas - X-ray - One - Five - Foxtrot | 36 |
| Texas - X-ray - Fifteen - Foxtrot | 11 |
| No preference, All are acceptable | 2 |

[a] Participants were allowed to select more than one way of hearing the waypoints spoken over the radio.

***Summary:*** *Participants strongly agreed that experimental NRS waypoint configuration N3 was the easiest to say phonetically and agreed that configuration N1 was more difficult to say than the other waypoint configurations. When asked about hearing preferences for alternate NRS waypoints, participants did not have a preference between hearing state names (i.e. "Ohio") and each letter spoken phonetically (i.e., "Oscar-Hotel"). However, participants showed a preference for pronouncing numbers as individual digits rather than groups (i.e., "one-two-seven" vs. "one-twenty seven" and "one hundred twenty-seven).*

#### 5.3.3.4 Working Memory Demands

Participants were also asked if they believed any particular NRS waypoint configuration[17] to be easy to remember. Of the 23 participants who stated they thought certain nomenclature configurations aided in recall, 18 reported configuration N3 was easy to recall; 6 participants believed N4 and 3 participants believed N2 were easy to recall.

> ***Summary:*** *Participants reported that the three alternate NRS waypoint configurations (N2, N3, and N4) were easier to recall than the current NRS waypoint configuration (N1.) Of the three alternate waypoint configurations, the majority of participants believed that configuration N3 was the easiest to recall.*

#### 5.3.3.5 Data Entry Issues

Participants were asked if they found any NRS waypoint configuration easy to enter into the FMS. All of the 23 who responded "Yes," stated that NRS waypoint configuration N3 was easy and 6 of these 23 participants also rated configuration N4 as easy to enter into the FMS. All nine participants who reported that a particular NRS waypoint configuration was difficult to enter chose configuration N1 as difficult; two of these nine participants also rated configurations N2 and N4 as difficult to enter into the FMS.

> ***Summary:*** *The majority of participant's stated NRS waypoint configuration N3 was the easiest to enter into the FMS. Approximately one-third of the participants rated configuration N1 as difficult for FMS data entry.*

#### 5.3.3.6 Summary of "Easy" and "Difficult" Ratings

In several places in the above review of findings from the NRS Waypoint Evaluation Questionnaire, we've reported ratings given by participants in response to questions asking them if something was "easy" or "difficult." For example, participants were asked if the various waypoint nomenclatures were easy or difficult to enter into the FMS, and if so, which ones. Tables 17 and 18 below summarize all of these various "easy" and "difficult" ratings reported above.

---

17

| N1 | N2 | N3 | N4 |
|---|---|---|---|
| FIR-Ctr-Lat-Long | State-Lat-Long | State-### | State-##-Ctr |

**Table 17**

*Summary of "Easier" Ratings*[18]

| Did you find a waypoint to be easier for/provide better___________? If so, which waypoint(s)? | | | | | | |
|---|---|---|---|---|---|---|
| **Item** | **Yes** | **No** | **N1** | **N2** | **N3** | **N4** |
| General Use | 27 97% | 1 3% | 0 0% | 3 11% | 17 61% | 8 29% |
| Geographic awareness | 26 93% | 2 7% | 2 8% | 6 23% | 12 46% | 6 23% |
| Deviate for wx | 11 39% | 17 61% | 0 0% | 3 23% | 7 53% | 3 23% |
| Speaking/ hearing | 22 79% | 6 21% | 0 0% | 3 13% | 19 83% | 1 4% |
| Remember wpt name | 23 82% | 5 18% | 0 0% | 3 11% | 18 67% | 6 22% |
| FMS Data Entry | 23 82% | 5 18% | 0 0% | 1 4% | 23 92% | 6 4% |

**Table 18**

*Summary of "Harder" Ratings*

| Did you find a waypoint to be harder/more difficult for ___________? If so, which waypoint(s)? | | | | | | |
|---|---|---|---|---|---|---|
| **Item** | **Yes** | **No** | **N1** | **N2** | **N3** | **N4** |
| General Use | 22 79% | 6 21% | 20 74% | 2 7% | 1 3% | 2 7% |
| Geographic awareness | 26 93% | 2 7% | 22 88% | 1 4% | 0 0% | 2 8% |
| Speaking/ hearing | 11 39% | 17 61% | 8 47% | 4 24% | 2 13% | 3 18% |
| FMS Data Entry | 9 32% | 19 68% | 10 71% | 2 14% | 0 0% | 2 14% |

18

| N1 | N2 | N3 | N4 |
|---|---|---|---|
| FIR-Ctr-Lat-Long | State-Lat-Long | State-### | State-##-Ctr |

### 5.4 Discussion and Implications of Findings

A part-task study was conducted to evaluate three alternate NRS waypoint nomenclatures, in addition to NRS waypoints configured in the current nomenclature, to assess their usability and the degree to which the nomenclatures provided geographical awareness regarding waypoint location to users. The 28 professional pilots who participated in this study, half of whom had previous experience with current NRS waypoints, completed four tasks: 1) finding specified waypoints on high altitude enroute charts, 2) entering a flight plan route which included NRS waypoint fixes into an FMS emulator, 3) selecting and entering fixes to divert around weather, and 4) completion of a questionnaire assessing opinions with regard to their experiences using NRS waypoints in the previous three tasks.

#### 5.4.1 Ease of Use

The ease with which participants were able to use the NRS waypoints configured in the four different nomenclatures was revealed through the amount of time it took them to:

- find waypoints on the enroute charts
- enter the NRS waypoints into the FMS
- enter NRS waypoints into the FMS relative to time required to enter other fixes, particularly those of the same length (i.e., traditionally named RNAV waypoints).

Additionally, usability was exhibited by the number and kind of errors made while completing these tasks and through participant responses to several different questions on the questionnaire which specifically asked about the ease or difficulty participants had in using NRS waypoints in different nomenclature configurations.

Given the overall level of dissatisfaction that many users expressed with regard to the current NRS waypoint nomenclature during interviews conducted earlier, it was not surprising that in this study, participants' performance in finding current NRS waypoints (N1) on enroute charts was significantly slower than finding waypoints in any of the three alternate configurations. Participants also reported through the questionnaire that of the four configurations evaluated, they preferred N1 the least and found it the most difficult to use, that it was the least easy configuration to say (such as over the radio), and was least easy to remember and enter into the FMS.

These findings were true for both pilots who have and have not had previous experience using current NRS waypoints. The fact that pilots who had previous experience did not perform any better than those without when locating NRS waypoints on the enroute charts appears to indicate that learning is not reinforced through the current NRS waypoint nomenclature. In other words, the structure of the grid, current coding for lines of latitude and longitude, and locations of ARTCC airspace, does not seem to be retained over time or reinforced through use. It is possible, however, that pilots with previous NRS waypoint experience in our sample do not have *a lot* of experience or practice in using NRS waypoint, particularly with regard to locating them on enroute charts; information about actual amount and kind of previous experience was not gathered so we cannot say definitively that current NRS waypoint use has minimal training value, although our findings suggest that this might be the case.

Participants overwhelmingly preferred waypoints in the N3 alternate configuration over all other configurations, found them the easiest to say, easiest to remember and easiest to enter into the FMS. No significant difference was found in their ability to find N3 NRS waypoints on high altitude charts as compared to waypoints in the other two alternate NRS nomenclature configurations (N2, N4), however.

Although participants cared the least for NRS waypoints in the current configuration (N1), it is incorrect to say that their performance using those waypoints on various tasks was always significantly worse than when using NRS waypoints in any of the three alternate configurations. For example, the time required to enter NRS waypoints into the FMS when using the N2 and N4 configurations was not significantly different from when using N1; all three required significantly more time for participants to enter than NRS waypoints in the N3 configuration. Consistent with these results was also the finding that participants took significantly longer to type in NRS waypoints in the N1, N2, and N4 configurations as compared to time required to type in traditionally named RNAV waypoints. Thus, in contrast to Boetig, Domino, & Olmos (2004), we did find significant differences in data entry time for some types of NRS waypoints as compared to traditionally named RNAV waypoints. However, we found no significant difference in the time required to type in alternate N3 and traditionally named RNAV waypoints. A deconstruction of waypoint composition with regard to use of letters and numerals helps to explain all of these findings.

Current NRS waypoints (N1) and the N2 and N4 alternate nomenclature waypoints are all structured as follows: letter, letter, numeral, numeral, letter. Alternate nomenclature N3 waypoints are structured: letter, letter, numeral, numeral, numeral and of course, traditionally named RNAV waypoints are comprised of all letters. Thus, during entry of N1, N2, and N4 waypoints, the participants had to shift between the letters and numerals on the FMS keypad twice: start with letters, shift to numerals, and then shift back to letters. The need to shift between these sets of characters only once, as was the case with N3 waypoints, did not add appreciably to the time required for data entry over never having to shift at all (as with traditional RNAV waypoints). Therefore, if in the future the current NRS nomenclature is replaced with some alternative, we suggest that the structure chosen for this new nomenclature require shifting between sets of characters no more than once.

It is also possible that speed of data entry was influenced by working memory load. As discussed earlier, depending upon how characters within the waypoint are grouped or “chunked,” the current NRS waypoints (N1) are comprised of 3 to 5 chunks of information which must be retained in working memory long enough to be written down or entered into an FMS (3 chunks if the initial “K” is dropped and the two latitude numerals are combined into a single number (e.g., fifty-four); 5 chunks if each character, including the “K,” is processed and remembered as a separate character). Similarly, alternate nomenclatures N2 and N4 are comprised of 3 to 5 chunks of information, whereas alternate nomenclature N3 could be comprised of as few as 2 chunks of information if the two letters for the state abbreviation are processed as a single word (i.e., “Texas” rather than “Tango-X-ray”) and the three numerals that follow are processed as a single, 3-digit number (i.e., “one hundred twenty-seven”).

The findings related to FMS data entry speed, although directly related to ease of use, would be even more important if the requirement to shift multiple times between sets of characters or the working memory load imposed by the nomenclature structure was also related to errors committed during data entry; this was not found to be the case.

Without a doubt, participants made more data entry errors when typing in NRS waypoints (all nomenclatures combined) than when typing in any of the other three types of fixes (VORs, Airports, traditionally named RNAV waypoints). However, readers should remember that far more NRS waypoints were included in the routes to be entered in the FMS than these other types of fixes; we found no significant differences in the *percent* of errors made across the four different kinds of fixes in flight plan routes. Similarly, no significant differences were found among the *percents* of errors committed across the four NRS waypoint nomenclatures evaluated. Therefore, differences in nomenclature structure, the need to shift back and forth among character sets on the FMS key pad, and working memory load imposed by the nomenclatures did not affect the number or type of data entry errors made by participants, at least for the four NRS nomenclatures evaluated in this study.

In terms of the overall number of FMS data entry errors made, the percents were relatively small for each of the four nomenclature types. For example, for the current NRS nomenclature (N1), 10 errors were made out of 310 total entries (3.23%). Although this relatively small percent is reassuring, FMS data entry errors of any type or number at a minimum are annoying when caught and can be catastrophic when not. Various technologies or programming could be developed to catch or prohibit certain types of data entry errors from being committed, such as programming which prohibits entering a numeral in a space where a letter is required and vice versa; this feature disallows substitution errors between “I” and “1” and between “O” and “0.”

The percentage of errors committed during data entry in this study may not be consistent with the percent of FMS data entry errors committed during real line operations. It is possible that the act of using a mouse to click on key pad buttons in this study resulted in fewer or more errors than if participants would have pressed actual buttons on an FMS keypad with their fingers. Participant errors that were obviously related to the use of a mouse were eliminated prior to data analysis but we cannot say certainly that the error rates discovered in this study are generalizable to those that would be found in real life. The fact that one participant clicked on a numeral (0) when entering a named RNAV waypoint (which have no numerals) may, or may not, have been due to using the mouse for data entry. It was not an obvious “mouse” error when it was committed so it was not excluded before data analysis.

All participants had significantly more difficulty finding NRS waypoints when the amount of information on the enroute chart surrounding the NRS waypoint was high. We were unable to analyze if NRS waypoints in different configurations might be easier to locate in these high density areas but we suspect that the difficulty experienced is related to chart clutter rather than nomenclature structure. If this is found to be the case though future studies, solutions other than simply changing the nomenclature of the waypoints will be needed to make them more conspicuous and easier to locate, particularly in chart high density areas.

Although statistically significant differences were found in the performance of some of the tasks, the actual differences in means for some were often fairly small. For example, FMS data entry time for N3 waypoints was statistically significantly less than the time it took to enter N1, N2, or N4 NRS waypoints, however the mean times for data entry were 4.00, 5.26, 5.24, and 4.93 seconds, respectively. Thus, although the differences in data entry times were statistically significant, one must consider if they are "practically" different. In other words, does the difference of one and one-half seconds or less in the time it takes to enter a waypoint have operational significance? In most flight deck situations the answer would be "no." However, when evaluating whether or not a change in NRS waypoint nomenclature might be needed, statistical significance vs. practical significance are not the only aspects to be considered. User perceptions about ease of use and nomenclature preferences greatly influence whether or not NRS waypoints are accepted and used by the operational community must also be part of the deliberation. So too, must be the cost of changing printed enroute charts, FMS and flight planning waypoint databases, and retraining for current NRS waypoint users.

### 5.4.2 Geographic Awareness

As discussed above, participants were significantly slower in finding current NRS waypoints (N1) as compared to any of the three alternate NRS waypoints on enroute charts. This finding indicates that the use of state abbreviations to delineate geographic regions results in greater ease for US pilots when locating NRS waypoints, and hence greater geographical awareness of waypoint location, than does the use of US FIR and ARTCC identifiers. Eighty-eight percent ($n$ = 22) of the 26 participants responding reported that they found current NRS waypoints (N1) difficult to locate on enroute charts, and when asked why, they often stated that they found the use of the FIR identifier to be "worthless," and did not know or could not locate the ARTCC boundaries. As anticipated, the participants who found alternate N4 waypoints difficult to locate ($n$ = 2) stated that they found provision of both state abbreviations and ARTCC identifiers to be redundant. All of these findings taken together indicate that, for US pilots, ARTCC identifiers do not add value over the use of state abbreviations for finding waypoints. Some SMEs we have talked to believe strongly that this is not the case for air traffic controllers and that having the ARTCC identifier as a part of the waypoint nomenclature is of great value, particularly when clearing pilots to an unfamiliar waypoint in a different ARTCC. Other SMEs have disagreed; they believe that because URET can easily be used with unfamiliar NRS waypoints just as it is used for unfamiliar named waypoints, it is not essential that ARTCC identifiers be a part of NRS waypoint nomenclature. These differing opinions will need to be assessed through a future study.

Although almost half of the participants reported that N3 waypoints were easy to find ($n$ = 12), as compared to 6 who found both N2 and N4 alternate waypoints easy to locate, there was no significant different in the amount of time taken by the participants to locate waypoints across the three alternate configurations. All three of the alternate nomenclatures evaluated in this study used the same approach for delineating regions (i.e., state abbreviations) but each used a different approach for the identification of specific waypoints within those regions. Differences in stated preferences aside, none of the three approaches evaluated for the identification of specific waypoints was empirically validated to be superior to any of the others with regard to supporting waypoint location and pilot geographical awareness.

We chose to include the waypoint finding task in this study to learn about how nomenclatures might differ with regard to the degree to which they provide awareness of their location to users. This was the approach adopted by MITRE CAASD to evaluate geographic awareness in the studies they conducted prior to the deployment of NRS waypoints in 2005 (Boetig, et al., 2004; Domino, et al., 2004). When searching for the specified waypoints, participants used the first NRS waypoints they found on the charts to narrow their search for the desired one. Thus, the waypoint finding task in this and the MITRE studies assessed geographic awareness of NRS waypoints *relative to the location of other waypoints found first*. We have come to believe that a more robust assessment of geographic awareness would be to use a blank enroute chart, with only regional boundaries shown, and ask participants to mark where they believe specific waypoints are located; the distance between the marks made and the actual points where the waypoints are located would yield the measure of geographic awareness. This approach is more in keeping with "building a picture in your head about where a waypoint is located" than the waypoint finding task used in this and the MITRE studies which may be more about faster searching than about true geographic awareness of waypoint location.

#### 5.4.2.1 Variation of the N3 Nomenclature

We suggest that a variation of N3 might provide true enhanced geographic awareness as opposed to simply supporting a faster visual search and location of a NRS waypoint relative to other surrounding NRS waypoints. In this N3 variation the first two characters of the waypoint name are still state postal codes but the scheme used to assign the three digit number, which specifies the individual waypoints within the state, is different. Instead of simply numbering the waypoints in order beginning with 001 until the last waypoint in the state is reached, the first of the three numbers (in the "hundreds" space) is associated with current NRS waypoint lines of longitude and the other two numbers (in the "tens" and "ones" space) are associated with the current NRS waypoint lines of latitude (see Figure 21).

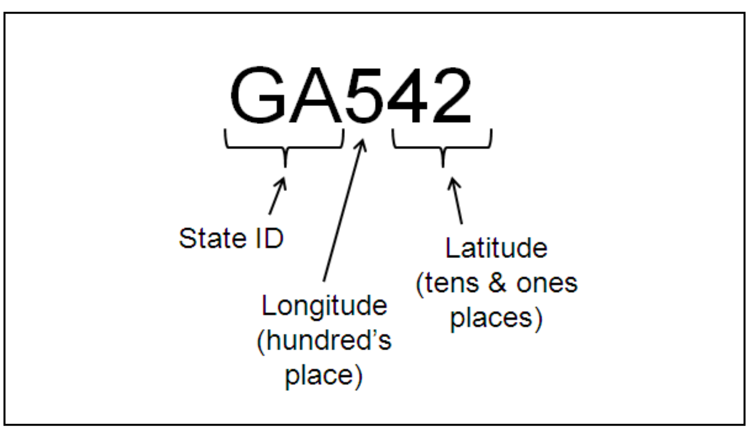



***Figure 21.*** Variation of the N3 nomenclature.

The left most line of longitude in the state is numbered 0 and the right most line of longitude is numbered 9. Additionally, the assignment of numbers to lines of longitude would vary according to the size (width) of the state. Some states that are quite wide (e.g., Texas), might use all or most of the numbers from 0 to 9 to label lines of longitude. Longitude numbers are dropped out proportionally for states that are not as wide so that the left most line of longitude is always 0, the right most line is always 9, and the line that cuts most closely through the middle of the state is always 5. For example, in Figure 22, one can see that the three numbers have been dropped in the labeling of lines of longitude (2, 4, and 7) as only seven current NRS waypoint lines of longitude cut through the state. For Colorado, however (see Figure 23) even fewer current NRS waypoint lines of longitude cut through the state (three) so only 0, 5, and 9 have been used to label waypoints along these three lines.

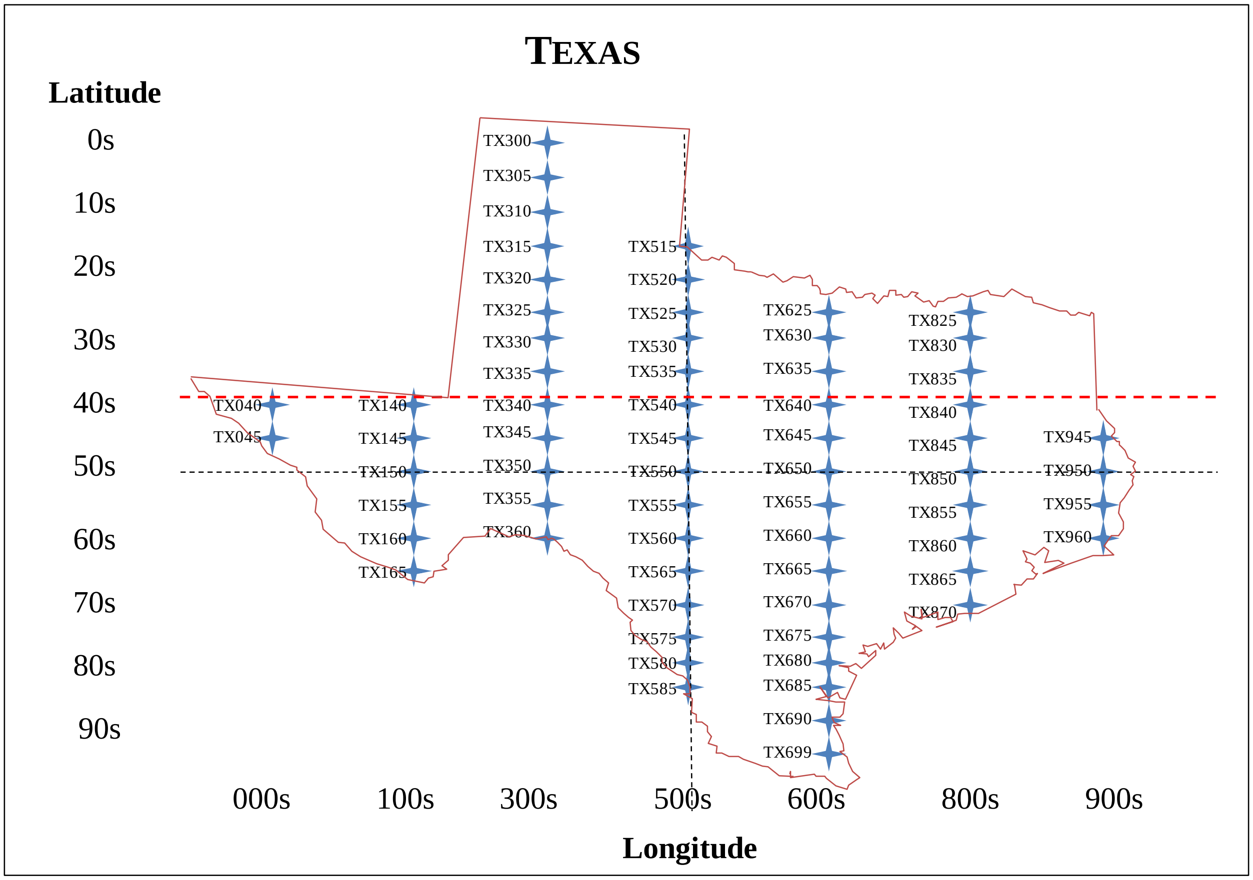



***Figure 22.*** Variation of the N3 nomenclature for NRS waypoints in Texas.

In a similar fashion, the last two digits in the nomenclature are assigned to current NRS waypoint lines of latitude proportionally. The top most waypoint on each line of longitude is given the latitude label of 00 and the bottom most waypoint in the column is given the latitude label of 99 (see Figures 22 and 23). Taken together then, the NRS waypoint numbered 000 is always the one appearing in the upper left hand corner of the state, the one numbered 999 is always in the bottom right hand corner, and the waypoint numbered 550 is always in the middle of the state.

When given an NRS waypoint with 675 as the last three characters, a user would immediately know that the waypoint is just to the right of center and approximately 3/4ths the way down the state.

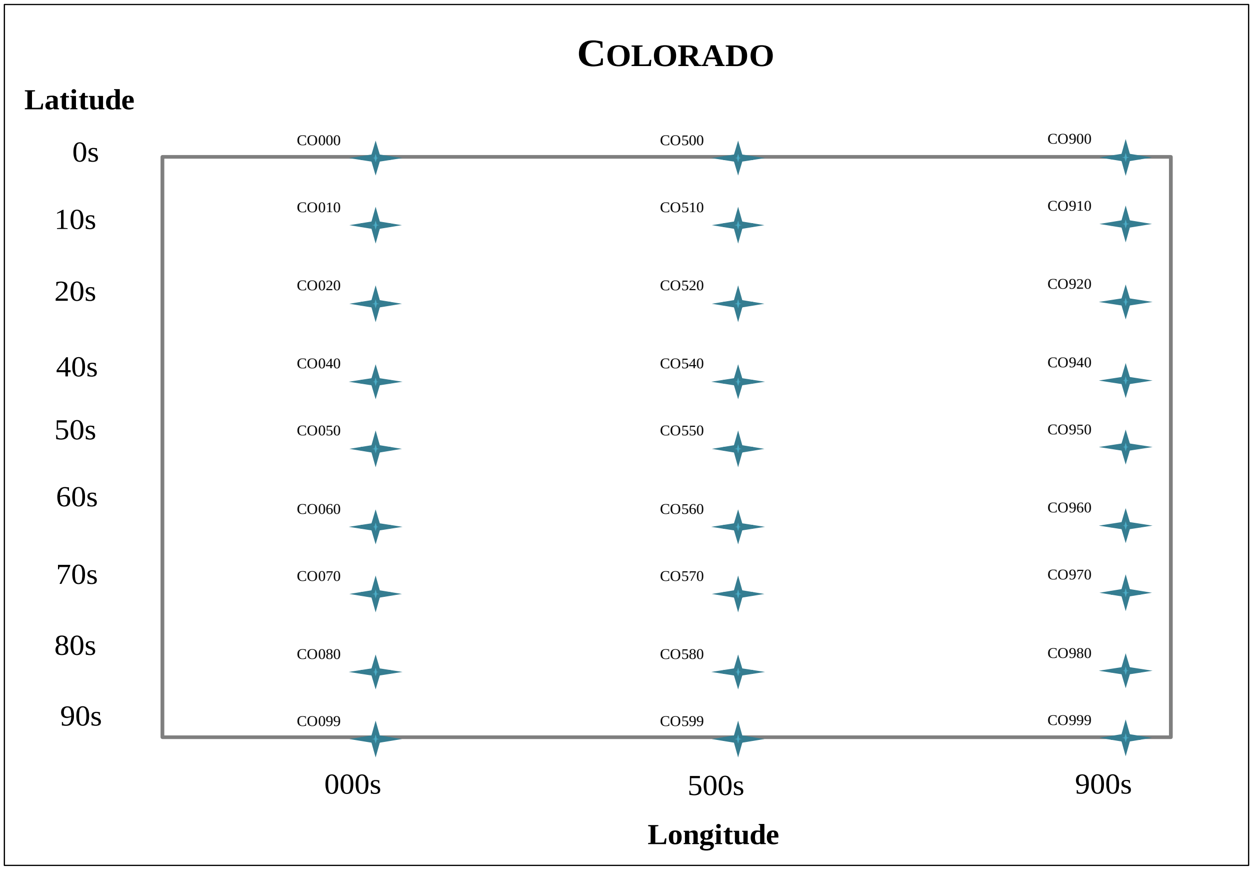



***Figure 23.*** Variation of the N3 nomenclature for NRS waypoints in Colorado

We believe the consistency of this scheme within each state should assist in providing true geographic awareness of NRS waypoint location, i.e., the ability of users to picture in their "minds' eye" the location of the waypoint without reference to displays or charts. This scheme also retains many of the advantages of the original N3 nomenclature evaluated in this study such as the requirement to switch only once between alpha and numeric characters resulting in faster FMS data entry times. It is unknown how this change in numbering will affect the speed with which waypoint finding/search tasks can be accomplished, however. And unfortunately, even this variation on N3 has some limitations. It does not easily support expansion of the grid for some states that are very wide such as Texas and Tennessee.

Additionally, this numbering system may work best for states that are relatively uniform in shape. Note that in Texas, which is quite irregularly shaped (see Figure 22), the top waypoint on the left most line of longitude is numbered 040 rather than 000 because of the state's shape. The two waypoint numbers that currently fall on this line of longitude could be numbered 000 and 099, to be more consistent with the vertical numbering scheme outlined above but this would mean that each line of *latitude* could have numbers that vary widely depending upon the length of each line of longitude cutting through the state. For example, if the NRS waypoints on the same line of latitude falling just beneath the red dashed line in Figure 22 were numbered this way, from left to right they would be labeled something like: TX000, TX100, TX375, TX537, TX625, and TX840. We suspect that a "proportional by each line of longitude within states" numbering scheme such as this would be more confusing for users and yield poorer geographic awareness than having a "proportional by whole state" numbering scheme with users having to make some mental accommodations for states with highly irregular shapes. The functionality of and ease with which this variation of N3 nomenclature can be used would of course need to be assessed in an empirical study.

#### 5.4.3 Study Limitations and Recommended Future Research

As with all research studies, part-task or otherwise, various limitations exist which affect interpretation of findings, analyses that can be performed and/or the degree to which results can be generalized to the real operational environment. In addition to the limitations already mentioned, there is, of course, the fact that we were only able to evaluate a few alternate waypoint nomenclatures. We solicited ideas for alternate nomenclatures from a wide range of subject matter experts and analyzed all options against the constraints imposed on and approaches available for the design of NRS waypoints and completed an iterative, down-select process, resulting in the choice of the three alternate nomenclatures evaluated in this study. All of these alternate nomenclatures used the same approach to regional delineation (i.e., state abbreviations), however. Other studies will be needed to evaluate other nomenclature approaches, if desired.

There were also some functional differences in the ways certain tasks were to be performed in this study as compared to how they are performed in real life. For example, during the weather re-route task, pilots were told that they must pick a fix for their diversion request. In real life, pilots may more often ask to turn a certain number of degrees left or right to divert around weather. Additionally, the map shown on the NAV display was fixed. Although they could change the map range they could not move the map up, down, left or right and this may have influenced the fixes they chose for their diversion. Recall that the vast majority of participants chose NRS waypoints as their diversion fix and we felt this was primarily because they knew they were participating in a NRS waypoint study. To better evaluate the use and usability of NRS waypoints in tactical situations (such as when diverting around weather), they would need to be depicted on NAV displays used in a study that is not obviously focused on NRS waypoints.

As mentioned in the Results section, outlier data, such as FMS entry times that were beyond three standard deviations from the mean, were excluded from the data set prior to conducting analyses. As a result, we ended up with slightly less data than expected from our 28 participants which prohibited us from being able to run some of the analyses planned. So, we were unable to answer some of the questions we had, such as "Do different configurations of NRS waypoint nomenclature affect the ease and speed with which NRS waypoints can be located in high, medium, and low density areas on enroute charts?" In future studies, we can address this issue (the loss of some data because of outliers) by including more participants in the study than the minimum indicated by power analyses. In the current study, we can be very confident that our findings of significant differences truly are significant. For example, the significant finding of a difference in time to locate current NRS waypoints (N1) as compared to any of the three alternate waypoints is a real finding. However, because we excluded outliers and sufficient power was not met for some analyses, we cannot be completely certain that our non-significant findings truly are non-significant. For example, it is possible that there actually was a significant difference in the amount of time it took participants to find waypoints in one of the alternate nomenclature configurations (N2, N3, or N4) but we did not find it because the statistical analysis lacked sufficient power to pick up on the effect.

Due to budget considerations, only pilots were involved as participants in this study. A parallel study conducted with air traffic controllers is necessary to determine if the very positive findings with regard to one of the alternate waypoints (N3) over the other alternates and current NRS waypoints hold true for air traffic controllers as well, or if the inclusion of ARTCC identifier in NRS waypoint nomenclature is important for controller ease of use. Additionally, this was a part-task study meaning that participants were only required to complete discrete tasks with regard to NRS waypoint use. More complete simulation studies involving both pilots and controllers together are required in the future to fully assess NRS waypoint usability, as a function of differences in nomenclature, within the operational environment.

## 6.0 Recommendations

The first overriding goal of the work conducted in this second phase of the *Human Factors Evaluation of the Implementation of the Navigation Reference System (NRS) Study* was to generate a wide variety of solutions that might be implemented to address the issues identified through the first phase of this study (see Burian, et al., 2010).

We began this effort by convening a focus group comprised of subject matter experts representing several different user groups throughout the aviation community. After reviewing the human factors issues of NRS waypoints, the focus group spent two days discussing, debating, and proposing a wide range of possible solutions or ways to mitigate the issues identified. The issues and the solutions proposed, as well as ideas for other solutions that were generated later, have been captured in the Issues-Solutions maps in Appendix 2.

The solutions proposed are wide ranging and are summarized in Tables 2, 3, 4, and 5 located in section 3.1. The solutions range from eliminating NRS waypoints entirely (there are no issues with NRS waypoints if there are no NRS waypoints) to the adoption of advanced technology and related procedures (e.g., datacomm) and making changes to FMS and DSR databases and programming. Some solutions proposed, such as changing the purpose and coding of aircraft equipage suffixes, would be relatively inexpensive to develop and implement, though significant re-training and new procedures for many in the industry would be required. Other solutions, such as changes to FMS programming which might affect aircraft airworthiness determinations, could be quite expensive or difficult to implement. In the Issues-Solutions Maps, the various pros and cons of each solution proposed are captured, as well as assumptions that would have to be met in order for the solutions to have their desired effects.

The solution proffered for the greatest number of issues identified was to develop and implement an alternate nomenclature for NRS waypoints. So, the second overriding goal for the work undertaken in this phase of the study was to generate candidate alternate nomenclatures and to empirically assess a few of the more promising ones in an attempt to find a suitable alternative to the current nomenclature.

Though our work on this effort we gained a keen appreciation for how the goals and constraints for NRS waypoint design and use intersect and greatly restrict the number of viable alternatives that might be generated. Each alternative we considered had limitations but through our part-task study, one of the alternative nomenclatures (N3) stood out from the others in terms of preference and usability compared to the other alternates and the current nomenclature.

Based on our analysis of constraints and approaches to NRS waypoint development and the findings from our part-task study, we make the following recommendations:

- The FAA should sponsor a part-task study involving air traffic controllers that is comprised of parallel tasks to the ones performed by the pilot participants in this study. The purpose of this study would be to assess controller preferences and empirically validate the usability of the three alternate nomenclatures assessed in this study for air traffic controllers. One important question to answer through this study is if ARTCC identifiers appreciably improve controller geographic awareness or are necessary to support controller operational tasks, particularly the handling of re-route requests. Without a definitive and empirically supported answer to this question, we cannot recommend the adoption of the N3 alternate NRS waypoint nomenclature, which is what we would be recommending at this time, if pilots and dispatchers/flight planners were the only users of NRS waypoints.

- In addition to the part-task study for controllers, an analysis should be undertaken to identify the drawbacks that exist, if any, if an alternate nomenclature were adopted relative to the use of NRS waypoints in National Playbooks, wind routes, flight planning software, and FMS and ERAM databases.

- Following the completion of the controller part-task study, we recommend that a simulation study be conducted involving both pilots and air traffic controllers using at least medium fidelity simulation facilities equipped with technology and automation interfaces that replicate those on real operational equipment (e.g., hard buttons for data entry on an FMS instead of a mouse). The primary focus of this study would be to evaluate the tactical usability of NRS waypoints constructed in an alternate nomenclature. Ideally, this nomenclature would be one that was preferred by both pilots and controllers and best supported operations for both groups.

- We suggest that the variation of the N3 nomenclature described above, which we think may provide true enhanced geographic awareness, be included for evaluation in the part-task and simulation studies described above.

- Upon the verification that an alternate NRS waypoint nomenclature has increased acceptance and usability, and provides improved geographic awareness as to waypoint for all user groups, we recommend that the FAA develop a training plan and materials for informing all user groups about NRS waypoints, the grid, and the new nomenclature. This training should provide guidance on how NRS waypoints can be used both strategically and tactically by the different user groups.

- We also recommend that FAA personnel and other members of the aviation industry review the Issues-Solutions map and identify solutions which should be pursued by the industry, not only to address human factors issues associated with NRS waypoints but also broader issues affecting the industry's ability to achieve the goals of NextGen. For example, we believe that the current coding system relative the aircraft equipage suffixes has become quite complicated and will not well support NextGen operations generally, and the use of NRS waypoints specifically (see the Issues-Solutions Maps in Appendix 2). In one of the Issues-Solutions maps, we suggest that the suffix system be changed from one that indicates on-board equipage to one that indicates aircraft capability. The feasibility and usefulness of such a system needs to be considered and then possibly developed and evaluated.

The studies recommended above are in addition to the one already planned for Phase 3 of the *Human Factors Evaluation of the Implementation of the Navigation Reference System (NRS) Study*. In this study, the human factors issues of an expanded NRS waypoint grid (i.e., below FL180, increased density to 6600 waypoint, possible utilization in the terminal operating environment) will be explored.

**REFERENCES**


Aeronautical Radio, Inc. (2008). *ARINC specification 424, navigation system data base standard.* Airlines Electronic Engineering Committee.

American Psychological Association. (2002). Ethical principles of psychologists and code of conduct. *American Psychologist,* 59, 1060-1073.

Baddeley, A. D. (1987). *Working Memory.* Oxford, England: Oxford University Press.

Boetig, R.C., Domino, D.A., & Olmos, B.O. (2004). *Airline pilot usability assessment of the navigation reference system* (MTR 04W0000011). McLean, VA: MITRE CAASD, The MITRE Corporation.

Boetig, R.C., & McQueen, E.A. (2006). *NRS grid considerations over the North Atlantic Ocean.* McLean, VA: MITRE CAASD, The MITRE Corporation.

Boetig, R.C., & Timmerman, J. (2003). *The HAR navigation reference system* (MP 03W0000152). McLean, VA: MITRE CAASD, The MITRE Corporation.

Borowski, M., Wendling, V.S., & Mills, S.H. (2004). *HAR NRS usability study final report* (MP 04W0000163). McLean, VA: MITRE CAASD, The MITRE Corporation.

Burian, B. K., Pruchnicki, S., & Christopher, B., (2010). *Human factors evaluation of the implementation of the navigation reference system (NRS) Phase 1 report.* FAA Office of Human Factors Research and Engineering NextGen Task,09-AJP61FGI-0101.

Canvas (Version 11) [Computer Software]. Victoria, British Columbia.

Domino, D.A., Ball, C.G., Helleberg, J.R., Mills, S.H., & Rowe, D.W. (2003). *Navigation reference system (NRS) naming convention usability study preliminary findings.* McLean, VA: MITRE CAASD, The MITRE Corporation.

Domino, D.A., Boetig, R.C., & Olmos, B.O. (2004). *Corporate pilot usability assessment of the navigation reference system* (MTR 04W0000033). McLean, VA: MITRE CAASD, The MITRE Corporation.

Hannigan, M. (2009a). *Navigational reference system (NRS) and performance based routing (PBR).* Presentation to the CNS Task Force.

International Civil Aviation Organization. (2006). PANS-OPS Vol. II. 5$^{th}$ edition. Montreal, Canada.

Miller, G.A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review,* 63, 81-97.

Statistical Package for the Social Sciences (SPSS). (Version 18). [Computer Software]. New York, NY.

## APPENDIX 1

### Acronyms and Abbreviations

| | |
|---|---|
| **ACARS** | Aircraft Communications Addressing and Reporting System |
| **AIRMETS** | Airmen's Meteorological Information |
| **ANOVA** | Analysis of Variance |
| **ARINC** | Aeronautical Radio Incorporated |
| **ARTCC** | Air Route Traffic Control Centers |
| **ATC** | Air Traffic Control |
| **CAASD** | MITREs Center for Advanced Aviation System Development |
| **DME** | Distance Measuring Equipment |
| **DSR** | Display System Replacement |
| **EFB** | Electronic Flight Bag |
| **ERAM** | En Route Automation Modernization |
| **FAA** | Federal Aviation Administration |
| **FIR** | Flight Information Region |
| **FL** | Flight Level |
| **FMS** | Flight Management System |
| **GAO** | Government Accounting Office |
| **GPS** | Global Positioning System |
| **HAR** | High Altitude Redesign |
| **ICAO** | International Civil Aviation Organization |
| **IFR** | Instrument Flight Rules |
| **MFD** | Multi-functional Display |
| **NACO** | National Aeronautical Charting Office |
| **NAS** | National Airspace System |
| **navaid** | Navigation Aid |
| **NextGen** | Next Generation Air Transportation System |
| **nm** | Nautical Miles |
| **NRS** | Navigation Reference System |
| **PANS-OPS** | Procedures for Air Navigation Services – Aircraft Operations |
| **RNAV** | Area Navigation |
| **SIGMETS** | Significant Meteorological Information |
| **SMEs** | Subject Matter Experts |
| **URET** | User Request Evaluation Tool |
| **VOR** | Very high frequency Omni directional Radio Range |
| **WPT(s)** | Waypoint(s) |

## APPENDIX 2

### Issues-Solutions Maps

Below are three Issues-Solutions Maps for the human factors issues of NRS waypoints identified during the first phase of the NRS waypoint study: a map for NRS waypoint nomenclature issues, a map for chart, displays, and database issues, and a map for other miscellaneous issues. More than one possible solution is offered for most issues listed in the maps.

The three categories of goals for NRS waypoint nomenclature development and use in Table 1a, below, have been color coded. This coding scheme has been used to color nomenclature goals from this table that are not met due to the human factors issues identified in the following maps. The color coding easily shows with just a scan of the maps that most of the goals that have not pertain to the usability of NRS waypoints and the grid.

Although they have not been color coded they way they have been in the issues sections of the Issues-Solutions Maps, some of the goals listed in Table 1a are also not met by some of the of the solutions offered in the maps. This is particularly the case for three implementation goals ("Minimize impact to airborne equipment," "Be usable by a majority of current aircraft," and "Incur only minimal changes (i.e., database only) to ground automation") as several solutions offered involved the use of advanced technologies and changes to pilot and ATC displays.

**Table 1a**

*Goals for Nomenclature and Waypoint Development and Use*

| Goal Type |
|---|
| Design |
| Facilitate user preferred routing that is based on satellite navigation |
| Be consistent with principles that guide names for navigational fixes |
| Satisfy processing requirements for filing at least one fix per ARTCC |
| Implementation |
| Minimize impact to airborne equipment |
| Be usable by a majority of current aircraft |
| Incur only minimal changes (i.e., database only) to ground automation |
| Support implementation across the United States |
| Usability |
| Reduce pilot and ATC workload regarding communication and chance for error |
| Tactical aid to resolve traffic conflicts & aid in weather avoidance |
| Be easy to communicate |
| Have a low potential for error |
| Be intuitive as to the general location of the fix (i.e., provide "geographic" awareness) |
| Be easier to use than fixes delineated by full latitude and longitude coordinates |

Boetig & Timmerman, 2003; Hannigan, 2009

# Issues-Solutions Mapping: Waypoint Nomenclature Issues

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Possible increased frequency congestion | Combination of letters and numbers in NRS waypoint names mean that each character must be pronounced separately | • Not currently much of a problem because NRS wpts not being used tactically<br>• Unfamiliar named wpts must also often be spelled/ pronounced separately | • Reduce pilot and ATC workload<br>• Be easy to communicate | Change NRS waypoint nomenclature | Once a new nomenclature scheme is developed it should be relatively easy to implement | It may be difficult to devise a naming scheme that is completely eliminates the possibility of frequency congestion due to having to pronounce more than one character/word | • New NRS waypoint nomenclature must not include only letters and be pronounceable as a single word<br>• NRS usage increases |
| | | | | Transmit NRS wpts via datacomm and autoload into FMS | • No need to change current NRS nomenclature<br>• Eliminates demand on working memory | • Data entry error may still be committed if initially, a wpt must still be identified by typing it manually<br>• Security of data transmitted wirelessly must be ensured | Aircraft and ATC facilities can and will install necessary datacomm and technologies required for autoloading accepted wpts |
| | | | | Development and implementation of other NextGen Technologies to reduce pilot-controller verbal interaction (e.g., ADS-B) | Offers more airtime for communicating NRS wpts (because of reduction in communications for other things) | Does not address/solve wpt issue directly but instead uses implementation of technologies to create environment where current wpts can be transmitted verbally without causing frequency congestion | All aircraft are suitably equipped with NextGen technologies |
| | | | | Use Audio Recording technology to playback NRS wpt information | • Recording technology exists and is currently available in some types of aircraft (e.g., Cessna Citation Mustang)<br>• Wpt name can be easily played back | • Aircraft and ATC stations must be suitably equipped with recording technology<br>• Can be cumbersome to find recorded information on tape | |

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Possible increased frequency congestion, *continued* | | | | Eliminate NRS wpts and grid and use only conventionally named wpts | More room would exist in FMS database for conventionally named wpts | • Possible lack of wpts in sufficient density to support needed flexibility in routing<br>• Difficulty coming up with enough discrete pronounceable named wpts | • Conventionally named wpts would need to be added in sufficient density to support RNAV operations<br>• Most newly added conventionally named wpts would probably need to be defined through lat/long coordinates rather than through ground based navaids |
| Easy to forget waypoint name | Working memory capacity limitations | This is particularly a problem during tactical use and when something in addition to a NRS waypoint must be remembered | • Reduce pilot and ATC workload<br>• Have a low potential for error | Change NRS waypoint nomenclature | Once a new nomenclature scheme is developed it should be relatively easy to implement | It may be difficult to devise a naming scheme that does not tax working memory limitations in some way or on some occasions (i.e., when given as part of a string of waypoints in a re-route) | |
| | | | | Group characters within wpt names when transmitting them verbally (e.g., then numbers 1-2 are always transmitted as "twelve" not as the individual numbers "one-two" | Chunking of characters reduces the number of units within each wpt name that must be remembered | Chunking characters may contribute to increased frequency congestion in some cases (e.g., "thirty-three" has more syllables than "three-three" | |
| | | | | Transmit NRS wpts via datacomm and autoload into FMS | • No need to change current NRS nomenclature<br>• Eliminates demand on working memory | • Data entry error may still be committed if initially, a wpt must still be identified by typing it manually<br>• Security of data transmitted wirelessly must be ensured | Aircraft and ATC facilities can and will install necessary datacomm and technologies required for autoloading accepted wpts |

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Easy to forget waypoint name, *continued* | | | | Use Audio Recording technology to playback NRS wpt information | • Recording technology exists and is currently available in some types of aircraft (e.g., Cessna Citation Mustang)<br>• Wpt name can be easily played back | • Aircraft and ATC stations must be suitably equipped with recording technology<br>• Can be cumbersome to find recorded information on tape | |
| | | | | Encourage pilots and ATC to write down clearances when given | Wpt name can be easily referenced off notes | • Can be cumbersome<br>• Does not reduce possibility of other errors such as wpt name confusion or transposition of characters | |
| | | | | Eliminate NRS wpts and grid and use only conventionally named wpts | More room would exist in FMS database for conventionally named wpts | • Possible lack of wpts in sufficient density to support needed flexibility in routing<br>• Difficulty coming up with enough discrete pronounceable named wpts | • Conventionally named wpts would need to be added in sufficient density to support RNAV operations<br>• Most newly added conventionally named wpts would probably need to be defined through lat/long coordinates rather than through ground based navaids |
| Easy to confuse different waypoint names | Similarity in waypoint names | K" first character for all waypoints contributes but is not the only similarity feature that can cause confusion | • Reduce pilot and ATC workload<br>• Have a low potential for error | Change NRS waypoint nomenclature | Once a new nomenclature scheme is developed it should be relatively easy to implement | It may be difficult to devise a naming scheme that is completely resistant to confusion | |

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Easy to confuse different waypoint names, *continued* | | | | Increase/provide training | Greater awareness of NRS waypoint grid and nomenclature system | • It is not desirable to rely upon training as a work-around to design problems<br>• Increased training may still not adequately diminish the problem | Appropriate and useful training is developed and airlines and ATC facilities are willing to provide it |
| | | | | Transmit NRS wpts via datacomm and autoload into FMS | • No need to change current NRS nomenclature<br>• Eliminates demand on working memory | • Data entry error may still be committed if initially, a wpt must still be identified by typing it manually<br>• Security of data transmitted wirelessly must be ensured | Aircraft and ATC facilities can and will install necessary datacomm and technologies required for autoloading accepted wpts |
| | | | | Eliminate NRS wpts and grid and use only conventionally named wpts | More room would exist in FMS database for conventionally named wpts | • Possible lack of wpts in sufficient density to support needed flexibility in routing<br>• Difficulty coming up with enough discrete pronounceable named wpts | • Conventionally named wpts would need to be added in sufficient density to support RNAV operations<br>• Most newly added conventionally named wpts would probably need to be defined through lat/long coordinates rather than through ground based navaids |
| Easy to transpose letters/numbers within waypoint names | Human performance/ working memory limitation | | • Reduce Pilot and ATC workload<br>• Have a low potential for error | Change NRS Waypoint nomenclature | Once a new nomenclature scheme is developed it should be relatively easy to implement | It may be difficult to devise a naming scheme that is completely resistant to transposition of characters | |

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Easy to transpose letters/numbers within waypoint names, *continued* | | | | Group characters within wpt names when transmitting them verbally (e.g., then numbers 1-2 are always transmitted as "twelve" not as the individual numbers "one-two" | Chunking of characters reduces likelihood of transposing individual characters | Chunking characters may contribute to increased frequency congestion in some cases (e.g., "thirty-three" has more syllables than "three-three" | |
| | | | | Transmit NRS wpts via datacomm and autoload into FMS | • No need to change current NRS nomenclature<br>• Eliminates demand on working memory | • Data entry error may still be committed if initially, a wpt must still be identified by typing it manually<br>• Security of data transmitted wirelessly must be ensured | Aircraft and ATC facilities can and will install necessary datacomm and technologies required for autoloading accepted wpts |
| | | | | Eliminate NRS wpts and grid and use only conventionally named wpts | More room would exist in FMS database for conventionally named wpts | • Possible lack of wpts in sufficient density to support needed flexibility in routing<br>• Difficulty coming up with enough discrete pronounceable named wpts | • Conventionally named wpts would need to be added in sufficient density to support RNAV operations<br>• Most newly added conventionally named wpts would probably need to be defined through lat/long coordinates rather than through ground based navaids |
| Easy to confuse O & I with 0 and 1 in waypoint names | Human performance limitation | FMS and DSR Programming may not allow entering numerals in a slot for letters and vice versa when entering wpt names | • Reduce Pilot and ATC workload<br>• Have a low potential for error | Have programming prohibit incorrect character entry | No changes needed if required programming is already in place | • Additional programming (FMS, DSR) may be required<br>• Potential for error is not reduced, solution only keeps error from being implemented | |

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Easy to confuse O & I with 0 and 1 in waypoint names, *continued* | | | | Eliminate either O & I or 0 and 1 from possible set of characters that can be included in waypoint nomenclature | Once a new nomenclature scheme is developed it should be relatively easy to implement | It may be difficult to still be able to generate enough unique names for NRS wpts within an ARTCC's airspace (i.e., repetition of wpt names) | |
| | | | | Change NRS waypoint nomenclature | Once a new nomenclature scheme is developed it should be relatively easy to implement | It may be difficult to devise a naming scheme that is completely eliminates the possibility of frequency congestion due to having to pronounce more than one character/word | |
| | | | | Increase/provide training | Greater awareness of NRS waypoint grid and nomenclature system | • It is not desirable to rely upon training as a work-around to design problems<br>• Increased training may still not adequately diminish the problem | Appropriate and useful training is developed and airlines and ATC facilities are willing to provide it |
| | | | | Transmit NRS wpts via datacomm and autoload into FMS | • No need to change current NRS nomenclature<br>• Eliminates demand on working memory | • Data entry error may still be committed if initially, a wpt must still be identified by typing it manually<br>• Security of data transmitted wirelessly must be ensured | Aircraft and ATC facilities can and will install necessary datacomm and technologies required for autoloading accepted wpts |

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Nomenclature is complicated, not easily understood | • Lat and Long coding in NRS nomenclature is not intuitive<br>• Lat and Long identifiers in nomenclature do not correspond in meaningful way with numbers/ letter used for signifying lines of Lat/Long in NRS wpt names<br>• Long coding in nomenclature increases going to the east whereas real Long numbers increase going to the west | • Although both pilots and air traffic controllers understand the coding scheme for Lat and Long they find it difficult to decipher or use the coding to locate waypoints<br>• Coding of two number Lat identifiers/ one letter Long identifiers appears capricious to many users | • Reduce Pilot and ATC Workload<br>• Have low potential for error<br>• Be intuitive as to general location of fix | Change NRS waypoint nomenclature | Once a new nomenclature scheme is developed it should be relatively easy to implement | It may be difficult to devise a naming scheme that meets naming requirements and is intuitive for all users | |
| | | | | Increase/provide training | Greater awareness of NRS waypoint grid and nomenclature system | • It is not desirable to rely upon training as a work-around to design problems<br>• Increased training may still not adequately diminish the problem | Appropriate and useful training is developed and airlines and ATC facilities are willing to provide it |
| | | | | Use touch screen or mouse click on any place on display to create a desired wpt (i.e., eliminate defined grid) | • No need to remember any type of waypoint nomenclature<br>• Allows infinite number of new wpts for use<br>• Faster method for inputting wpt<br>• Potentially eliminates problems with FMS wpt database limitations depending upon design of technology | • Aircraft/ ATC facility must be equipped with appropriate input method for wpt definition<br>• No easy backup method exists for when automation/ technology fails and input/ identification method is unavailable<br>• Some types of FMS programming changes may affect aircraft airworthiness certification | Air carriers and ATC facilities willing and able to upgrade to appropriate input technology |

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Nomenclature is complicated, not easily understood, *continued* | | | | Eliminate NRS wpts and grid and use only conventionally named wpts | More room would exist in FMS database for conventionally named wpts | • Possible lack of wpts in sufficient density to support needed flexibility in routing<br>• Difficulty coming up with enough discrete pronounceable named wpts | • Conventionally named wpts would need to be added in sufficient density to support RNAV operations<br>• Most newly added conventionally named wpts would probably need to be defined through lat/long coordinates rather than through ground based navaids |
| Lack of Awareness of Waypoint Geographical Location | • Pilots lack knowledge of ARTCC single letter identifiers<br>• Pilots lack awareness of ARTCC airspace boundaries<br>• Waypoints are not easily displayed on cockpit and radar displays<br>• Users do not find Lat and Long coding in nomenclature easy to decipher | Although both pilots and air traffic controllers understand the coding scheme for Lat and Long they find it difficult to decipher or use the coding to locate waypoints | • Reduce pilot and ATC workload<br>• Have low potential for error<br>• Be intuitive as to general location of fix | Change NRS waypoint nomenclature | Once a new nomenclature scheme is developed it should be relatively easy to implement | It may be difficult to devise a naming scheme that is consistent with principles that guide naming navigational fixes and also support geographic awareness well | |

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Lack of Awareness of Waypoint Geographical Location, *continued* | | | | Add large latitude and longitude ID numbers/letters to all borders of high altitude enroute charts | Assists with identification of lines of longitude and latitude | • Clutter at the edges of navigation charts<br>• There are only some latitude lines connecting wpts on charts so one might mis-track a lat ID on the chart edge to a wpt in the middle of the chart<br>• Current placement and presentation of long ID on charts is not conspicuous | |
| | | | | Create an NRS only chart | Less clutter | • Not enough information on NRS only chart to be used alone for navigation<br>• NRS only chart will require pilots to look at multiple charts at one time which may cause confusion. | • No other information will be needed on the map<br>• All waypoints on a route are NRS (so you don't have to switch between charts) |
| | | | | Increase/provide training | Greater awareness of NRS waypoint grid and nomenclature system with increased understanding of ARTCC identifiers and airspace boundaries | • It is not desirable to rely upon training as a work-around to design problems<br>• Increased training may still not adequately diminish the problem | Appropriate and useful training is developed and airlines and ATC facilities are willing to provide it |
| | | | | Change ARTCC Airspace Boundaries to regular and uniform shapes | Uniform sizes and shapes of ARTCC airspace may make it easier to identify which airspace one is in | • Requires a major overhaul of airspace and sector boundaries<br>• May not be practical in terms of airspace density and frequency reception | |

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Waypoints may confuse international pilots | Nomenclature scheme unique to USA, contiguous 48 states | | • Reduce pilot and ATC workload<br>• Have low potential for error | Change NRS waypoint nomenclature | Once a new nomenclature scheme is developed it should be relatively easy to implement | A new naming scheme may do little to reduce confusion among international pilots who do not use a similar system in their own countries | |
| | | | | Replace NRS wpt naming system with one consistent with what is used in other countries | Easier for International Pilots to use | • May be more difficult for pilots who do not fly internationally to use<br>• There may be multiple systems used in different countries so difficult to determine which one to adopt in US | |
| | | | | Eliminate NRS wpts and grid and use only conventionally named wpts | More room would exist in FMS database for conventionally named wpts | • Possible lack of wpts in sufficient density to support needed flexibility in routing<br>• Difficulty coming up with enough discrete pronounceable named wpts | • Conventionally named wpts would need to be added in sufficient density to support RNAV operations<br>• Most newly added conventionally named wpts would probably need to be defined through lat/long coordinates rather than through ground based navaids |
| | | | | Increase/provide training for international pilots | Greater awareness of NRS waypoint grid and nomenclature system | • It is not desirable to rely upon training as a work-around to design problems<br>• Increased training may still not adequately diminish the problem | Appropriate and useful training is developed and international airlines are willing to provide it |

## Issues-Solutions Mapping: Charts, Displays, and Databases

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Difficult to locate specific waypoints on enroute charts | • Chart clutter<br>• Type font/ color not visually distinct<br>• Edge markers for Lat lines not used<br>• Nomenclature geographical coding is not intuitive<br>• Pilots do not know ARTCC single letter identifiers<br>• Can be difficult to discern ARTCC airspace boundaries on charts<br>• ARTCC airspace boundaries are irregularly shaped | | Reduce Pilot and ATC workload | Change how NRS waypoints are depicted on charts (bold, coloring, symbol change, size, etc.) | Quicker identification of NRS waypoints | Draws attention away from other information on the map | • Change will depict NRS waypoints so that they are easily seen<br>• All points are depicted equally |
| | | | | Add large latitude and longitude ID numbers/letters to all borders of high altitude enroute charts | Assists with identification of lines of longitude and latitude | • Clutter at the edges of navigation charts<br>• There are only some latitude lines connecting wpts on charts so one might mis-track a lat ID on the chart edge to a wpt in the middle of the chart<br>• Current placement and presentation of long ID on charts is not conspicuous | |
| | | | | Review charts and eliminate information that is not needed | Less clutter | • Difficult to decide/ come to agreement about what stays and what gets deleted from charts<br>• Does not deal directly with issue (difficulty in locating wpt) – merely removes other information so that there is less chart clutter | Some information is not necessary and can be deleted without adverse affects upon navigation |

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Difficult to locate specific waypoints on enroute charts, *continued* | | | | Create an NRS only chart and eliminate all RNAV waypoints (and possibly other features, e.g., NDBs) on enroute charts | Less clutter | Possibly not enough information on NRS only chart to be used alone for navigation | • All waypoints on a route are NRS or other features retained on NRS only chart (e.g., VORs)<br>• NRS wpt grid is of sufficient density to support all navigational needs |
| | | | | Create an NRS only chart for use as a supplement to other existing enroute charts | Less clutter | This will require pilots to look at multiple charts at one time and mentally transpose information from one chart to another. | |
| | | | | Increase/provide training for pilots | Greater awareness of NRS waypoint grid and nomenclature system | Increased training may still not adequately diminish the problem | Appropriate and useful training is developed and air carriers are willing to provide it |
| Most NRS waypoints are not able to be displayed on cockpit and radar displays so it is difficult to use NRS waypoints tactically | NRS waypoints not already part of a flight plan cannot be displayed on cockpit NAV and ATC radar displays | • On radar displays NRS wpts in flight plans are not identified by name but only indicated if the route makes a turns at that wpt<br>• Mixed equipage results in ATC not knowing capabilities of different aircraft | • Reduce pilot and ATC workload<br>• Tactical aid to resolve traffic conflicts & aid in wx avoidance<br>• Be intuitive as to general location of fix<br>• Have low potential for error | Display NRS waypoints on NAV and radar displays | • Easy to see/locate on displays relative to wx and traffic<br>• Reduce mileage for deviations | • Display Clutter<br>• FMS and ERAM databases must be increased to include all waypoints<br>• FMS and ERAM programming must be changed to support wpt display<br>• FMS programming changes affects aircraft airworthiness certification | All aircraft need to be suitably equipped and air carriers are willing to bear the expense of equipage and recertification |

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Limitations in the number of NRS waypoints that are available for use | • Size limitations in aircraft FMS databases<br>• NRS Waypoints not included in ERAM database | • Pilots may be unaware of those NRS waypoints that are not included in the FMS database on a particular aircraft<br>• Mixed equipage (with regard to different sizes/content in FMS wpt databases) results in ATC not knowing capabilities of different aircraft | • Facilitate user preferred routing based on satellite navigation<br>• Reduce pilot and ATC workload | Increase memory available for wpts within FMS databases | Storage will be large enough to hold all NRS wpts | Some types of FMS programming changes may affect aircraft airworthiness certification | All aircraft need to be suitably equipped and air carriers are willing to bear the expense of equipage and recertification |
| | | | | Include wpts within ERAM databases | Wpts will be presented on scopes | Some changes required to ERAM databases | All involved ATC facilities are suitably equipped and are willing and able to bear the expense of the database expansion and upgrade |
| | | | | Develop algorithms for the construction of wpts by FMS in real time | Algorithms will allow for all waypoints to be present without taking up space in the database | Some types of FMS programming changes may affect aircraft airworthiness certification | All aircraft need to be suitably equipped and air carriers are willing to bear the expense of equipage and recertification |
| | | | | Use "cloud-based" computing for storage of all wpts | Cloud-based computing will allow for all waypoints to be stored | • Security will need to be ensured so wpts on cloud are not tampered with<br>• Some types of FMS programming changes may affect aircraft airworthiness certification | All aircraft need to be suitably equipped and air carriers are willing to bear the expense of equipage and recertification |
| | | | | Get rid of all named waypoints and use only NRS wpts | More room would exist in FMS database for NRS wpts | • Pilots/ATC would have to learn new waypoints for familiar routes<br>• New airways, STARS, and SIDS would have to be created<br>• Grid would need to be expanded | NRS waypoint grid would need to be increased in density |

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Limitations in the number of NRS waypoints that are available for use, *continued* | | | | Eliminate NRS wpts and grid and use only conventionally named wpts | More room would exist in FMS database for conventionally named wpts | • Possible lack of wpts in sufficient density to support needed flexibility in routing<br>• Difficulty coming up with enough discrete pronounceable named wpts | • Conventionally named wpts would need to be added in sufficient density to support RNAV operations<br>• Most newly added conventionally named wpts would probably need to be defined through lat/long coordinates rather than through ground based navaids |
| NRS waypoints not displayed on cockpit NAV display if map range is set at > 60 nm | Programming limitation of FMS | Decision made by programmers to reduce clutter | • Reduce pilot and ATC workload<br>• Have low potential for error<br>• Tactical aid to resolve traffic conflicts & aid in wx avoidance | Allow wpts to be displayed at all map ranges | Pilots could use a wider variety of wpts for tactical use for deviating around large wx systems | Increased display clutter | |
| Easy to make data entry error | • Similarity of NRS wpt names<br>• Differences in layout of numerals on commonly used keypads (e.g., DSR vs. computer keypad)<br>• ATC has to shift back and forth between alpha and numeric characters on DSR keyboard | | Have low potential for error | Change NRS Waypoint nomenclature | Once a new nomenclature scheme is developed it should be relatively easy to implement | It may be difficult to devise a naming scheme that is completely resistant to transposition of characters or other data entry errors due to similarity of NRS wpt names | |

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Easy to make data entry error, *continued* | | | | Transmit NRS wpts via datacomm and autoload into FMS | • No need to change current NRS nomenclature<br>• Eliminates demand on working memory | • Data entry error may still be committed if initially, a wpt must still be identified by typing it manually<br>• Security of data transmitted wirelessly must be ensured | Aircraft and ATC facilities can and will install necessary datacomm and technologies required for autoloading accepted wpts |
| | | | | Use touch screen or mouse click on any place on display to create a desired wpt (i.e., eliminate defined grid) | • No need to remember any type of waypoint nomenclature<br>• Allows infinite number of new wpts for use<br>• Faster method for inputting wpt<br>• Potentially eliminates problems with FMS wpt database limitations depending upon design of technology | • Aircraft/ ATC facility must be equipped with appropriate input method for wpt definition<br>• No easy backup method exists for when automation/ technology fails and input/ identification method is unavailable<br>• Some types of FMS programming changes may affect aircraft airworthiness certification | Air carriers and ATC facilities willing and able to upgrade to appropriate input technology |
| | | | | Increase/provide training for pilots and ATC | Greater awareness of NRS waypoint grid and nomenclature system | • It is not desirable to rely upon training as a work-around to design problems<br>• Increased training may still not adequately diminish the problem | Appropriate and useful training is developed and air carriers and ATC facilities are willing to provide it |

| Issues | Due To | Comments | Goals Not Met | Solutions | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| ATC unable to determine bearing and distance between target aircraft and NRS waypoints | NRS waypoints not already part of a flight plan cannot be displayed on ATC radar displays | Must use URET to determine or visualize aircraft position on radar scope | • Reduce pilot and ATC workload<br>• Have low potential for error<br>• Tactical aid to resolve traffic conflicts & aid in wx avoidance | Display NRS waypoints on radar displays | Easy to see/locate on displays relative to wx and traffic | • Display Clutter<br>• ERAM databases must be increased to include all waypoints<br>• ERAM programming must be changed to support wpt display | ATC facilities willing and able to upgrade ERAM databases |
| | | | | Get rid of all named waypoints and use only NRS wpts | More room would exist in FMS database for NRS wpts | • Pilots/ATC would have to learn new waypoints for familiar routes<br>• New airways, STARS, and SIDS would have to be created<br>• Grid would need to be expanded | NRS waypoint grid would need to be increased in density |
| | | | | Eliminate NRS wpts and grid and use only conventionally named wpts | More room would exist in FMS database for conventionally named wpts | • Possible lack of wpts in sufficient density to support needed flexibility in routing<br>• Difficulty coming up with enough discrete pronounceable named wpts | • Conventionally named wpts would need to be added in sufficient density to support RNAV operations<br>• Most newly added conventionally named wpts would probably need to be defined through lat/long coordinates rather than through ground based navaids |

## Issues-Solutions Mapping: Other Issues

| Issues | Due To | Comments | Goal(s) Not Met | Solution | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Lack of pilot, ATC, and dispatcher knowledge with regard to NRS wpt nomenclature and grid | Inadequate training | Lack of education of both strategic and tactical use or NRS wpts | • Reduce pilot and ATC workload<br>• Have low potential for error<br>• Support implementation across the United States | Eliminate NRS wpts and grid and use only conventionally named wpts | More room would exist in FMS database for conventionally named wpts | • Possible lack of wpts in sufficient density to support needed flexibility in routing<br>• Difficulty coming up with enough discrete pronounceable named wpts | • Conventionally named wpts would need to be added in sufficient density to support RNAV operations<br>• Most newly added conventionally named wpts would probably need to be defined through lat/long coordinates rather than through ground based navaids |
| | | | | Increase/provide training for pilots/ ATC/Dispatchers | Greater awareness of NRS waypoint grid and nomenclature system | Increases pilot, ATC, and dispatcher training requirements | Appropriate and useful training is developed and airlines and ATC facilities are willing to provide it |
| NRS Waypoints tied to specific ARTCC airspace does not make sense if airspace boundaries in the future are flexible | Structure of current NRS wpt nomenclature | • A waypoint might end up in two different ARTCCs' airspace at different times<br>• Requirement for including ARTCC identifier in NRS wpt name does not seem relevant when wpt is cited in TRACON or terminal airspace (expand grid below FL180) | • Reduce pilot and ATC workload<br>• Have low potential for error<br>• Be intuitive as to general location of the fix | Change NRS Waypoint nomenclature to eliminate reference to ARTCC airspace | Once a new nomenclature scheme is developed it should be relatively easy to implement | ATC rely on ARTCC identifier being in wpt name to assist with geographic awareness | |
| | | | | Do not allow airspace boundaries between ARTCCs to move/be flexible | Eliminates issue | Does not allow flexibility of ARTCC airspace boundaries that may be needed under NextGen | |

| Issues | Due To | Comments | Goal(s) Not Met | Solution | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| Future possibility that GPS does not support navigation to NRS wpts | Degradation of GPS satellite signals | GAO predicts that estimated probability of maintaining a constellation of least 24 operational satellite falls below 95% during 2010 until 2014 | Facilitate user preferred routing using satellite navigation | Use DME/DME navigation as a backup in case GPS becomes unavailable | Supports navigation to NRS wpts | Possible need for new ground infrastructure to ensure critical DMEs are available and positioned appropriately to support navigation to NRS wpts | Ground infrastructure can be suitably expanded and maintained |
| Inability to accurately and reliably navigate to NRS wpts | Possible malfunction/degradation of on-board equipment (e.g., GPS) | | Facilitate user preferred routing that is based on satellite navigation | Have backup on plane that would allow for other navigation capabilities (e.g., DME/DME) | Safety and reliability of navigational capabilities maintained | Requires multiple technologies on board to achieve the same function | • Air carriers are willing to bear the expense of equipage and recertification<br>• Sensor and warning system is required to inform crew that on-board equipment (e.g., GPS) is degraded or malfunctioning |
| Poor readability of NRS wpts on flight release paperwork | Dot matrix printers used for printing flight releases can make it difficult to distinguish Cs, Gs, Os and Qs from each other | | • Reduce pilot workload<br>• Have low potential for error | Ensure that dot matrix printers always have good ribbons | Improve readability of flight releases | | |
| | | | | Use laser printers for flight release packages and ensure that printers always have enough toner | Improve readability of flight releases | cost | |
| | | | | Transmit flight releases electronically to EFBs or FMS using ACARS, Datacomm, or using a memory stick | Improve readability of flight releases | • Requires availability of necessary technology<br>• Security of flight releases transmitted wirelessly must be ensured | Required technology is available |

| Issues | Due To | Comments | Goal(s) Not Met | Solution | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| ATC errors when marking NRS wpts on paper strips | • Similarity of current NRS wpt names<br>• Structure of current NRS wpt nomenclature<br>• Lack of practice with writing NRS wpt names manually | Paper strips are only used as a back-up system when other automation is not functioning | • Reduce pilot and ATC workload<br>• Have low potential for error | Change NRS wpt nomenclature | Once a new nomenclature scheme is developed it should be relatively easy to implement | It may be difficult to devise a naming scheme that is completely resistant to transposition of characters or other errors when writing on paper strips due to similarity of NRS wpt names | |
| | | | | Increase/provide training for ATC | Greater awareness of NRS waypoint grid and nomenclature system | • It is not desirable to rely upon training as a work-around to design problems<br>• Increased training may still not adequately diminish the problem | Appropriate and useful training is developed and ATC facilities are willing to provide it |
| ATC difficulty in knowing which aircraft can accept NRS wpts in re-route | Equipment suffixes are insufficient to determine if a particular aircraft is capable of navigating to NRS waypoints | Flight plans that include NRS wpts are currently the only indicator to ATC which aircraft can accept/use NRS wpts | Reduce ATC workload | Add equipment suffixes to indicate aircraft capability of using NRS wpts | New suffixes can encompass greater information about airplane equipment | • ATC/Airlines would need to adopt the new equipment suffixes<br>• Running out of suffixes to use and large number that exist already can cause confusion | |
| | | | | Change equipment suffixes to indicate capabilities of aircraft instead of equipage on board | • This could reduce the number of suffixes needed<br>• This may be necessary anyhow for implementing "best equipped/best served" aspect of NextGen | Requires completely new approach to suffixes – new system would need to be devised and all pilots and ATC would need to be educated about it | A meaningful capability suffix system can be devised that meets the needs of ATC in all types of flight regimes with all types of flight operations |

| Issues | Due To | Comments | Goal(s) Not Met | Solution | Pros | Cons | Assumptions for Solution to Work |
|---|---|---|---|---|---|---|---|
| ATC difficulty in knowing which aircraft can accept NRS wpts in re-route, *continued* | | | | Require that all IFR aircraft have same equipment | No need to have equipment suffixes | • Cost<br>• Push-back from industry (including manufacturers) | Air carriers, pilots, flight schools, etc. are willing to bear the expense of equipage and recertification |
| Limitation in strategic usability of NRS grid west of Mississippi River | Density grid in the west is too light to provide the greatest use for flight planning | | • Facilitate user preferred routing that is based on satellite navigation<br>• Tactical aid to resolve traffic conflicts and aid in wx avoidance | Increase grid density west of the Mississippi River | Increased grid density would allow for increased flight planning | Memory in FMS database would have to be increased | |
| NRS usage east of Mississippi river is very light | • High use of preferential routing that does not include NRS wpts<br>• Greater range of other waypoints available in this airspace<br>• Lack of ATC and pilot knowledge of NRS wpts and grid | | Facilitate user preferred routing that is based on satellite navigation | Increase/provide training for pilots/ ATC | Greater awareness of NRS waypoint grid and nomenclature system | Increased training may still not increase usage due to other reasons NRS wpt usage is light east of the Mississippi River | |

# APPENDIX 3

## Candidate Alternate Nomenclatures

| | Character Space | | | | | Example | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | | | |
| I | State Abbreviation | | Current NRS Latitude | | Current NRS Longitude | OH66S | • May provide better geographic awareness for US pilots<br>• State abbreviations are typically widely known so less difficulty decoding the abbreviations<br>• Understanding of a region's boundary possibly an aid in improving geographical awareness<br>• Consistent lat/long. numbering arrangement between states increases predictability and hence awareness<br>• First two characters can be pronounced as a single word instead of two letters thus reducing the number of digits to be recalled (Ohio vs Oscar-Hotel)<br>• Retains current system (Lat. and Long) for identifying waypoint within the state therefore easier transition for current users<br>• System retains expandability<br>• Minimal effort to change all waypoint names on charts, database, pre-planned routes and on-file flight plans<br>• Mix of numbers and letters prevents confusion with current named waypoints or other pronounceable words | • Potential for increased geographical awareness may be lost on international and some US pilots not familiar with state abbreviations.<br>• Confusion may result from states with similar identifiers (ID, IL, IN, IA)<br>• Limits the number of characters available for delineation of lat. and long. to just three characters which could be confused with some airports names as number letter placement is similar [e.g. "02G" (East Liverpool Airport - OH)]<br>• Both Longitude and Latitude numbers are the current NRS configuration and as such do not match with actual latitude and longitude numbers which may lead to confusion<br>• Does not retain ARTCC identifier<br>• Possible frequency congestion during tactical ops as this naming configuration is the same length as the current NRS<br>• Database capacity limitations are still a problem<br>• Latitude and latitude numbers do not match with actual latitude and longitude numbers which may lead to confusion<br>• Still have to memorize an arbitrary number/naming system<br>• |

| | Character Space | | | | | Example | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | | | |
| I cont. | | | | | | | | • Have to type each character individually and alternate between both numbers and letters while entering the data – potential data entry errors i.e. transposition and mistyping<br>• Cost of developing a new system<br>• No reduction in current chart clutter<br>• |
| II | One of nine regional IDs:<br>NW = Northwest<br>CW = Central West<br>SW = Southwest<br>NC = North Central<br>CC = Central Central<br>SC = South Central<br>NE = Northeast<br>CE = Central East<br>SE = Southeast | | Current NRS Latitude | | Current NRS Longitude | SW33I | • May provide better geographic awareness<br>• Most regional IDs are already commonly used (NE, NW, etc.) so less difficulty with training and decoding the abbreviation<br>• Potentially easier for international pilots and those not familiar with state or ARTCC identifiers<br>• Boundaries are more symmetrical as compared to ARTCC boundaries<br>• Understanding of a region's boundary possibly an aid in improving geographical awareness<br>• System retains expandability<br>• Retains current system (Lat. and Long) for identifying waypoint within the state therefore easier transition for current users<br>• Minimal effort to change all waypoint names on charts, database, pre-planned routes and on-file flight plans<br>• Mix of numbers and letters prevents confusion with current named waypoints or other pronounceable words | • Some regional identifiers may be confused with state abbreviations (NC, NE)<br>• Regions are large and provide a limited amount of initial specificity in determining waypoint location<br>• Boundaries between regions are not intuitive – must be learned and shown on charts and displays<br>• Region IDs limit the number of characters available for delineation of lat and long to just three characters<br>• Both Longitude and Latitude numbers are the current NRS configuration and as such do not match with actual latitude and longitude numbers which may lead to confusion<br>• Does not retain ARTCC identifier<br>• Possible frequency congestion during tactical ops as this naming configuration is the same length as the current NRS<br>• Database capacity limitations are still a problem<br>• Latitude and latitude numbers do not match with actual latitude and longitude numbers which may lead to confusion |

| | Character Space | | | | | Example | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | | | |
| II cont. | | | | | | | • Consistent lat/long. numbering arrangement between states increases predictability and hence awareness | • Regions must be crafted so that NRS longitude line does not repeat in region<br>• Still have to memorize an arbitrary number/naming system<br>• Have to type each character individually and alternate between both numbers and letters while entering the data – potential data entry errors i.e. transposition and mistyping<br>• Cost of developing a new system<br>• No reduction in current chart clutter |
| III | State Abbreviation | | Latitude coded within state as single number: 0-9 | Longitude coded within state as double digit number: 00 -99 | | OH756 | • State abbreviations are typically widely known so less difficulty decoding the abbreviations<br>• May provide better geographic awareness for US pilots<br>• Understanding of a region's boundary possibly an aid in improving geographical awareness<br>• First two characters can be pronounced as a single word instead of two letters thus reducing the number of digits to be recalled (Ohio vs Oscar-Hotel)<br>• Possible greater geographical awareness vs current NRS since lines of lat. and long. are simply numbered west to east and north to south and require no special system to learn<br>• Mix of numbers and letters prevents confusion with current named waypoints or other pronounceable words | • Potential for increased geographical awareness may be lost on international and some US pilots not familiar with state abbreviations<br>• Confusion may result from states with similar identifiers (ID, IL, IN, IA)<br>• System is not expandable due to the limiting width and/or height of a few states<br>• Does not retain ARTCC identifier<br>• Some pilots and air traffic controllers are more comfortable with a lat/long type grid system<br>• Possible confusion between digits of lat and long. i.e. which two digits are longitude?<br>• Doesn't give north/south orientation without lat/long indicators<br>• Lack of consistency in lat/long. numbering arrangement between states decreases predictability and hence awareness |

| | Character Space | | | | | Example | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | | | |
| III cont. | | | | | | | • Consistent lat/long. numbering arrangement between states increases predictability and hence awareness | • Latitude and latitude numbers do not match with actual latitude and longitude numbers which may lead to confusion<br>• Significant effort to change all waypoint names on charts, database, pre-planned routes and on-file flight plans<br>• Possible frequency congestion during tactical ops as this naming configuration is the same length as the current NRS<br>• Still have to memorize an arbitrary number/naming system<br>• Have to type each character individually and alternate between both numbers and letters while entering the data – potential data entry errors i.e. transposition and mistyping<br>• Could cause confusion because label for lat. or long. line in one state would not be the same as the continuation of those lines in neighboring states<br>• Cost of developing a new system<br>• Database capacity limitations are still a problem<br>• No reduction in current chart clutter<br>• Hard to figure out where to start the labeling because of irregularly shaped states<br>• |

| | Character Space | | | | | Example | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | | | |
| IV | One of four regional IDs:<br>N= Northeast<br>S = South<br>M = Middle<br>W = West<br><br>OR<br><br>One of the following time zones:<br>A = Atlantic<br>E = Eastern<br>C = Central<br>M = Mountain<br>P = Pacific | Latitude coded as double digit number: 00-99 | | Longitude coded as double digit number: 00 -99 | | N0865 | • May provide better geographic awareness<br>• Understanding of a region's boundary possibly an aid in improving geographical awareness. Increased symmetry of region also helpful<br>• Potentially easier for international pilots and those not familiar with state or ARTCC identifiers<br>• Most regional IDs could be readily learned and are to some degree intuitive so less difficulty with training and decoding the abbreviation<br>• Mix of numbers and letters prevents confusion with current named waypoints or other pronounceable words<br>• System retains expandability | • Regions are so large as to potentially diminish any geographical awareness provided by sector names<br>• Looks very similar in appearance to traditional lat/long numbers<br>• Doesn't give north/south orientation without lat/long indicators<br>• Some pilots and air traffic controllers are more comfortable with a lat/long type grid system<br>• Does not retain ARTCC identifier<br>• Latitude and latitude numbers do not match with actual latitude and longitude numbers which may lead to confusion<br>• Significant effort to change all waypoint names on charts, database, pre-planned routes and on-file flight plans<br>• Possible frequency congestion during tactical ops as this naming configuration is the same length as the current NRS<br>• Database capacity limitations are still a problem<br>• Still have to memorize an arbitrary number/naming system<br>• Have to type each character individually – potential data entry errors i.e. transposition and mistyping<br>• Cost of developing a new system<br>• No reduction in current chart clutter<br>• Lack of consistency in lat/long. numbering arrangement between states decreases predictability and hence awareness |

| | Character Space | | | | | Example | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | | | |
| IV cont. | | | | | | | | • Have to type each character individually and alternate between both numbers and letters while entering the data – potential data entry errors i.e. transposition and mistyping |
| V | One of four regional IDs:<br>N= Northeast<br>S = South<br>M = Middle<br>W = West<br><br>OR<br><br>One of the following time zones:<br>A = Atlantic<br>E = Eastern<br>C = Central<br>M = Mountain<br>P = Pacific | Current NRS Latitude | | Current NRS Longitude | ARTCC ID | N18GS | • May provide better geographic awareness<br>• Understanding of a region's boundary possibly an aid in improving geographical awareness. Increased symmetry of region also helpful<br>• Potentially easier for international pilots and those not familiar with state or ARTCC identifiers<br>• Most regional IDs could be readily learned and are to some degree intuitive so less difficulty with training and decoding the abbreviation<br>• Mix of numbers and letters prevents confusion with current named waypoints or other pronounceable words<br>• System retains expandability<br>• Retains current system (Lat. and Long) for identifying waypoint within the state therefore easier transition for current users<br>• Would assist pilots in making sure at least one waypoint is in each center's airspace<br>• Accommodates ARTCC desire for center identification in waypoint name<br>• Consistent lat/long. numbering arrangement between states increases predictability and hence awareness | • Regions are so large as to potentially diminish any geographical awareness provided by sector names<br>• Doesn't give north/south orientation without lat/long indicators<br>• For the pilot, ARTCC indicator doesn't add to geographical awareness<br>• Both Longitude and Latitude numbers are the current NRS configuration and as such do not match with actual latitude and longitude numbers which may lead to confusion<br>• Significant effort to change all waypoint names on charts, database, pre-planned routes and on-file flight plans<br>• Will not work if/when dynamic airspace boundaries are developed<br>• Possible frequency congestion during tactical ops as this naming configuration is the same length as the current NRS<br>• Database capacity limitations are still a problem<br>• Still have to memorize an arbitrary number/naming system<br>• Have to type each character individually and alternate between both numbers and letters while entering the data – potential data entry errors i.e. transposition and mistyping<br>• |

| | Character Space | | | | | Example | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | | | |
| V cont. | | | | | | | | • Cost of developing a new system<br>• No reduction in current chart clutter |
| VI | One of four regional IDs:<br>N= Northeast<br>S = South<br>M = Middle<br>W = West<br><br>OR<br><br>One of the following time zones:<br>A = Atlantic<br>E = Eastern<br>C = Central<br>M = Mountain<br>P = Pacific | Latitude coded as a single letter: A-Z | Longitude coded as double digit number: 01 -99 | | ARTCC ID | NC05S | • Possible greater geographical awareness vs current NRS since lines of long. are simply numbered west to east and require no special system to learn<br>• Understanding of region's boundary's location possibly improved in additional to being more symmetrical as compared to ARTCC boundaries<br>• Potentially easier for international pilots and those not familiar with state or ARTCC identifiers<br>• Most regional IDs could be readily learned and are to some degree intuitive so less difficulty with training and decoding the abbreviation<br>• Mix of numbers and letters prevents confusion with current named waypoints or other pronounceable words<br>• System retains expandability<br>• Would assist pilots in making sure at least one waypoint is in each center's airspace<br>• Accommodates ARTCC desire for center identification in waypoint name | • Regions are so large as to potentially diminish any geographical awareness provided by sector names<br>• Doesn't give north/south orientation without lat/long indicators<br>• For the pilot, ARTCC indicator doesn't add to geographical awareness<br>• Both Longitude and Latitude numbers are the current NRS configuration and as such do not match with actual latitude and longitude numbers which may lead to confusion<br>• Will not work if/when dynamic airspace boundaries are developed<br>• Significant effort to change all waypoint names on charts, database, pre-planned routes and on-file flight plans<br>• Possible frequency congestion during tactical ops as this naming configuration is the same length as the current NRS<br>• Database capacity limitations are still a problem<br>• Still have to memorize an arbitrary number/naming system<br>• Have to type each character individually and alternate between both numbers and letters while entering the data – potential data entry errors i.e. transposition and mistyping<br>• Cost of developing a new system<br>• No reduction in current chart clutter |

| | Character Space | | | | | Example | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | | | |
| VI cont. | | | | | | | | • Some pilots and air traffic controllers are more comfortable with a lat/long type grid system |
| VII | State Abbreviation | | Two digit waypoint ID number | | ARTCC ID | OH27I | • State abbreviations are typically widely known so less difficulty decoding the abbreviations<br>• May provide better geographic awareness for US pilots<br>• Understanding of a region's boundary possibly an aid in improving geographical awareness<br>• First two characters can be pronounced as a single word instead of two letters thus reducing the number of digits to be recalled (Ohio vs Oscar-Hotel)<br>• Mix of numbers and letters prevents confusion with current named waypoints or other pronounceable words<br>• Would assist pilots in making sure at least one waypoint is in each center's airspace<br>• Accommodates ARTCC desire for center identification in waypoint name | • Potential for increased geographical awareness may be lost on international and some US pilots not familiar with state abbreviations.<br>• Confusion may result from states with similar identifiers (ID, IL, IN, IA)<br>• System is not expandable<br>• Latitude and latitude numbers do not match with actual latitude and longitude numbers which may lead to confusion<br>• Some pilots and air traffic controllers are more comfortable with a lat/long type grid system<br>• Hard to figure out where to start the labeling because of irregularly shaped states<br>• Lack of consistency in lat/long. numbering arrangement between states decreases predictability and hence awareness<br>• Significant effort to change all waypoint names on charts, database, pre-planned routes and on-file flight plans<br>• Some pilots and air traffic controllers are more comfortable with a lat/long type grid system<br>• Doesn't give north/south orientation without lat/long indicators<br>• For the pilot, ARTCC indicator doesn't add to geographical awareness<br>• Will not work if/when dynamic airspace boundaries are developed |

| | Character Space | | | | | Example | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | | | |
| VII cont. | | | | | | | | • Possible frequency congestion during tactical ops as this naming configuration is the same length as the current NRS<br>• Still have to memorize an arbitrary number/naming system<br>• Have to type each character individually and alternate between both numbers and letters while entering the data – potential data entry errors i.e. transposition and mistyping<br>• Cost of developing a new system<br>• No reduction in current chart clutter<br>• Database capacity limitations are still a problem |
| VIII | One of nine regional IDs:<br>NW = Northwest<br>CW = Central West<br>SW = Southwest<br>NC = North Central<br>CC = Central Central<br>SC = South Central<br>NE = Northeast<br>CE = Central East<br>SE = Southeast | | Two digit waypoint ID number | | ARTCC ID | NE27I | • Understanding of region's boundary's location possibly improved in additional to being more symmetrical as compared to ARTCC boundaries<br>• Potentially easier for international pilots and those not familiar with state or ARTCC identifiers<br>• Most regional IDs could be readily learned and are to some degree intuitive so less difficulty with training and decoding the abbreviation<br>• Mix of numbers and letters prevents confusion with current named waypoints or other pronounceable words<br>• Would assist pilots in making sure at least one waypoint is in each center's airspace<br>• Accommodates ARTCC desire for center identification in waypoint name | • Regions are so large as to potentially diminish any geographical awareness provided by sector names<br>• Doesn't give north/south orientation without lat/long indicators<br>• For the pilot, ARTCC indicator doesn't add to geographical awareness<br>• Both Longitude and Latitude numbers are the current NRS configuration and as such do not match with actual latitude and longitude numbers which may lead to confusion<br>• System is probably not expandable depending on the exact size of each region<br>• Some pilots and air traffic controllers are more comfortable with a lat/long type grid system<br>• Lack of consistency in lat/long. numbering arrangement between states decreases predictability and hence awareness |

| | Character Space | | | | | Example | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | | | |
| VIII cont. | | | | | | | | • Will not work if/when dynamic airspace boundaries are developed<br>• Significant effort to change all waypoint names on charts, database, pre-planned routes and on-file flight plans<br>• Possible frequency congestion during tactical ops as this naming configuration is the same length as the current NRS<br>• Database capacity limitations are still a problem<br>• Have to type each character individually and alternate between both numbers and letters while entering the data – potential data entry errors i.e. transposition and mistyping<br>• Cost of developing a new system<br>• No reduction in current chart clutter<br>• Still have to memorize an arbitrary number/naming system<br>• |
| IX | State Abbreviation | | Three digit waypoint ID number | | | TX247 | • State abbreviations are typically widely known so less difficulty decoding the abbreviations<br>• May provide better geographic awareness for US pilots<br>• Understanding of a region's boundary possibly an aid in improving geographical awareness<br>• First two characters can be pronounced as a single word instead of two letters thus reducing the number of digits to be recalled (Ohio vs Oscar-Hotel)<br>• Mix of numbers and letters prevents confusion with current named waypoints or other pronounceable words | • Potential for increased geographical awareness may be lost on international and some US pilots not familiar with state abbreviations.<br>• Confusion may result from states with similar identifiers (ID, IL, IN, IA)<br>• Some pilots and air traffic controllers are more comfortable with a lat/long type grid system<br>• Doesn't give north/south orientation without lat/long indicators<br>• Latitude and latitude numbers do not match with actual latitude and longitude numbers which may lead to confusion |

| | Character Space | | | | | Example | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | | | |
| IX cont. | | | | | | | • Would assist pilots in making sure at least one waypoint is in each center's airspace<br>• System is expandable | • Lack of consistency in lat/long. numbering arrangement between states decreases predictability and hence awareness<br>• Hard to figure out where to start the labeling because of irregularly shaped states<br>• Still have to memorize an arbitrary number/naming system<br>• Have to type each character individually and alternate between both numbers and letters while entering the data – potential data entry errors i.e. transposition and mistyping<br>• Cost of developing a new system<br>• No reduction in current chart clutter<br>• Database capacity limitations are still a problem<br>• Significant effort to change all waypoint names on charts, database, pre-planned routes and on-file flight plans<br>• Possible frequency congestion during tactical ops as this naming configuration is the same length as the current NRS<br>• |
| X | One of nine regional IDs:<br>NW = Northwest<br>CW = Central West<br>SW = Southwest<br>NC = North Central<br>CC = Central Central<br>SC = South Central<br>NE = Northeast<br>CE = Central East<br>SE = Southeast | | Three digit waypoint ID number | | | NW427 | • Understanding of region's boundary's location possibly improved in additional to being more symmetrical as compared to ARTCC boundaries<br>• Potentially easier for international pilots and those not familiar with state or ARTCC identifiers<br>• Most regional IDs could be readily learned and are to some degree intuitive so less difficulty with training and decoding the abbreviation | • Doesn't give north/south orientation without lat/long indicators<br>• Significant effort to change all waypoint names on charts, database, pre-planned routes and on-file flight plans<br>• Some pilots and air traffic controllers are more comfortable with a lat/long type grid system<br>• Hard to figure out where to start the labeling because of irregularly shaped states |

| | Character Space | | | | | Example | Advantages | Disadvantages |
|---|---|---|---|---|---|---|---|---|
| | 1st | 2nd | 3rd | 4th | 5th | | | |
| X cont. | | | | | | | • Mix of numbers and letters prevents confusion with current named waypoints or other pronounceable words<br>• System is expandable | • Lack of consistency in lat/long. numbering arrangement between states decreases predictability and hence awareness<br>• Still have to memorize an arbitrary number/naming system<br>• Have to type each character individually and alternate between both numbers and letters while entering the data – potential data entry errors i.e. transposition and mistyping<br>• Some pilots and air traffic controllers are more comfortable with a lat/long type grid system<br>• Possible frequency congestion during tactical ops as this naming configuration is the same length as the current NRS<br>• Database capacity limitations are still a problem<br>• Have to type each character individually – potential data entry errors i.e. transposition and mistyping<br>• Cost of developing a new system<br>• No reduction in current chart clutter<br>• |

## APPENDIX 4

## NASA Human Subjects Informed Consent

Dear Bonny Christopher:

Protocol **HRII-10-23**, "Navigation Reference System (NRS) Study Phase II--The Effect of NRS Waypoint Nomenclature on Pilot Performance and Usability," has received approval by expedited review from the Chief, OPRP, on July 06, 2010. You are authorized to conduct research studies subject to Ames Procedural Requirements (APR) 7170.1, Human Research Planning and Approval. The approval period is valid from **July 06, 2010** through **July 05, 2011**.

HRII-**10-23** will be presented to the HRIRB for ratification at the next board meeting. You may be contacted for clarification and/or additional information, should any concerns or questions arise.

Please retain a copy of this confirmation message for your files. Submit a renewal request **six weeks** prior to July **05, 2011**, the protocol's expiration date. If you do not renew the protocol, submit the end of study report within **30 days** of the protocol's expiration. Both forms are available on the HRIRB web site, http://hrirb.arc.nasa.gov.

If you have questions, contact me at 650.604.5492 or by e-mail, Ernle.W.Young@nasa.gov. Immediately notify Dr. Ralph Pelligra, Chair, Human Research Institutional Review Board (HRIRB), at 650.604.5163, or by e-mail, Ralph.Pelligra-1@nasa.gov, of any injury to a human participant, whether or not it was considered a risk inherent to the research.

Good luck in your research efforts.

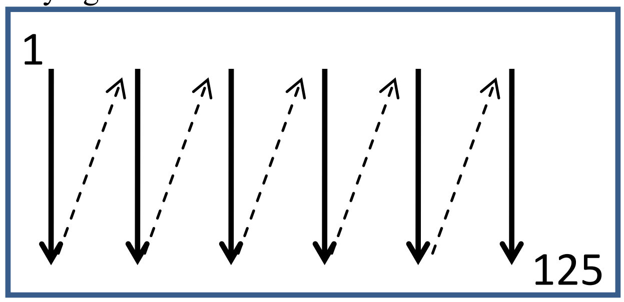
Ernle W.D. Young, Ph.D.
By
Elaine Timm
Recorder, Human Research Institutional Review Board
Assistant to Dr. Ernle Young
Office for the Protection of Research Participants
M/S 243-2, Room 120
voice: 650.604.0119
fax: 650.604.6233
E-mail: Elaine.M.Timm@nasa.gov

**APPENDIX 5**

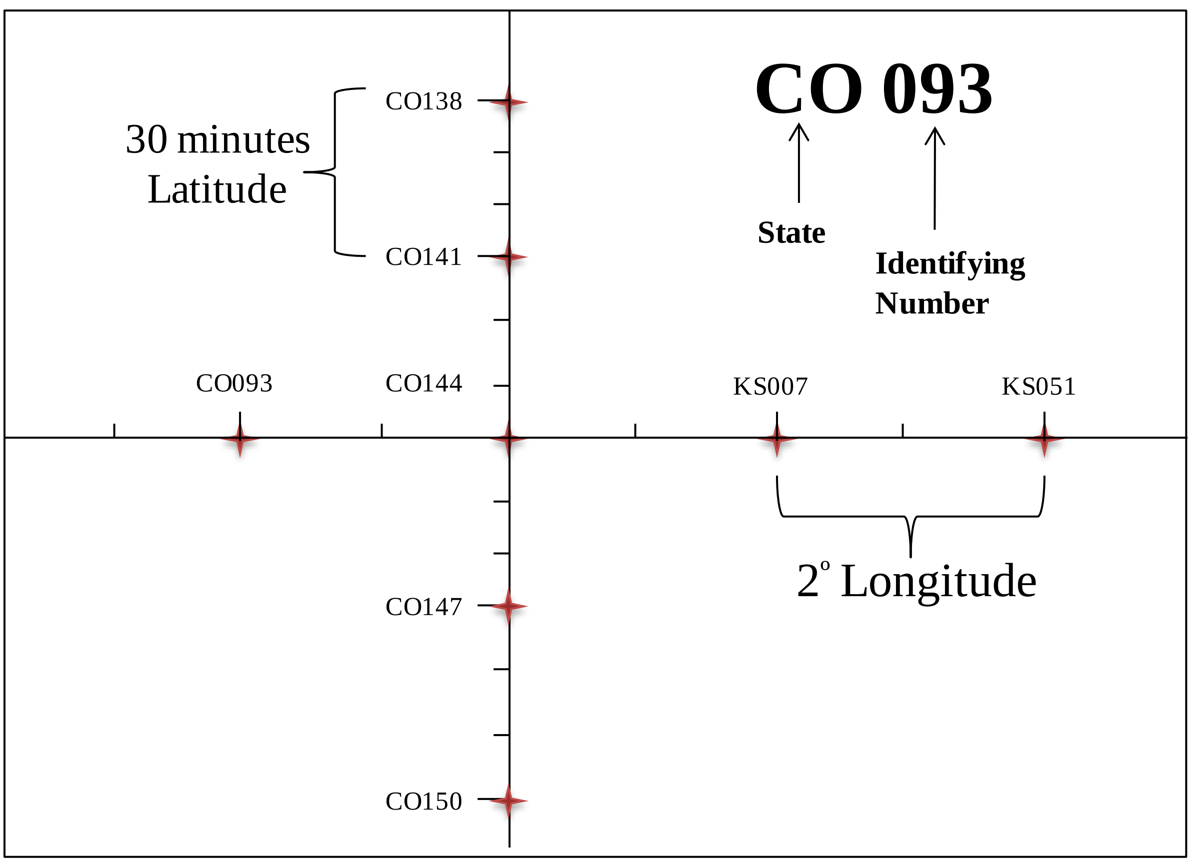
**Nomenclature Training Materials for Study Participants**

**<u>Nomenclature N3 Training Aid</u>**

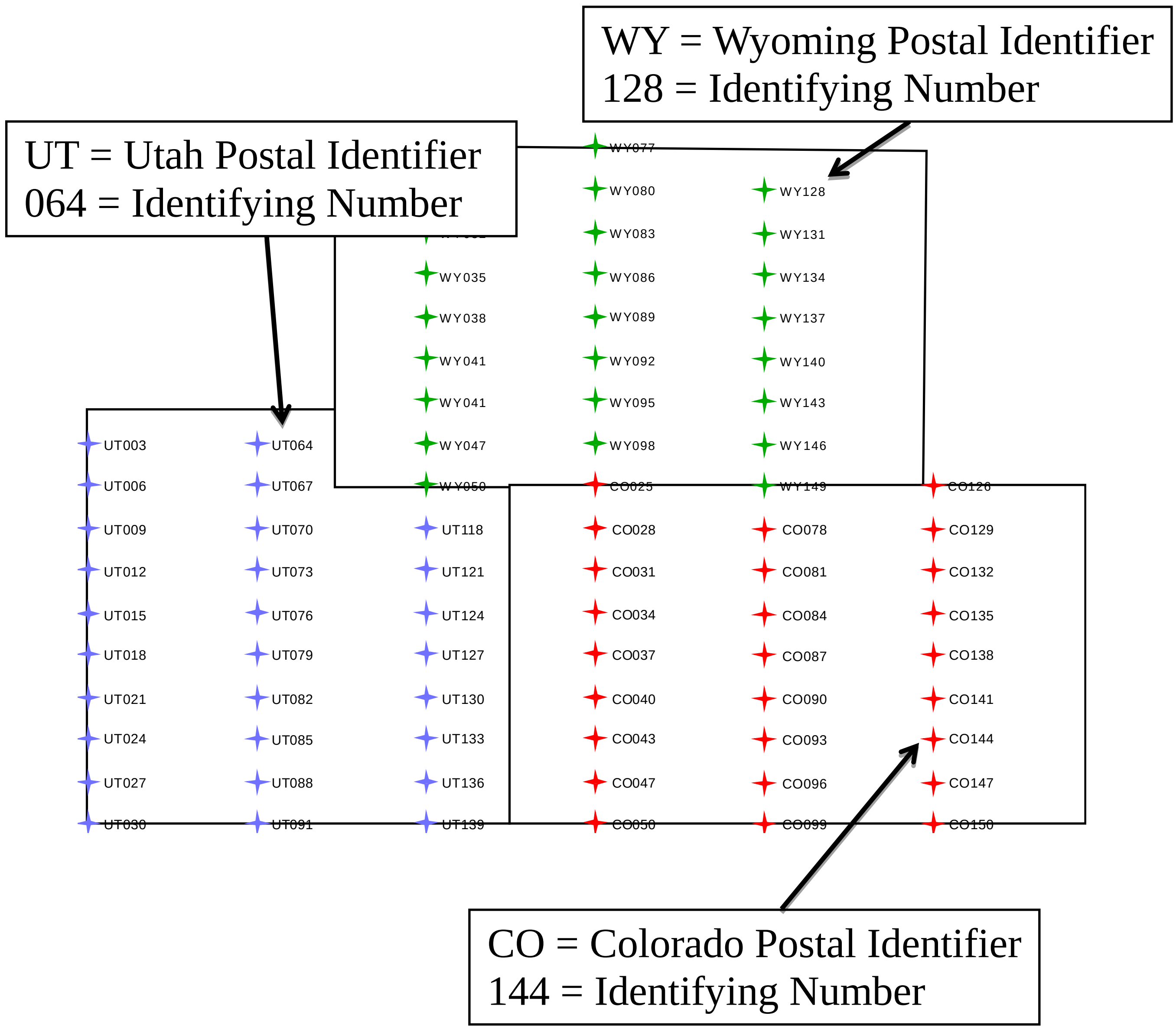
The N3 nomenclature consists of *two letters* followed by *three numbers* (ex. CO144). The first two letters ("CO") are the postal identifier for the state. The following three numbers ("144") is the waypoint identifying number. In this nomenclature each NRS waypoints per state has been given number starting with the number 1 in the northwest corner and continued downward (south) until reaching the bottom of the state. After this, the numbering is continued west to east on the next line of longitude and downward again. This pattern repeats until the southeast corner of the state is reached. When examining the grid, you will notice that *not all states start with 001*, this is to allow for future expansion of the grid.




**<u>N3 NRS Waypoints in Colorado and Kansas</u>**



# Nomenclature N3



## APPENDIX 6

### NRS Waypoint Part-Task Study Questionnaire (Blank)

Overall Preference

1. Please rank your preference for NRS waypoint nomenclature (naming method) with one being the most prefered and four being the least preferred. (For nomencalture review, please refer to images 1-4).

   1.Click here to enter text.
   2.Click here to enter text.
   3. Click here to enter text.
   4.Click here to enter text.

2. In general, did you find any particular waypoint nomenclature to be easier to use? Click here to enter text.

   a. If so, which one was easiest and why? Click here to enter text.

3. In general, did you find any particular waypoint nomenclature to be more difficult to use? Click here to enter text.

   a. If so, which ones were difficult and why? Click here to enter text.

Geographical Awareness

4. In general, did you find waypoint nomenclatures to be (check one) ☐ easier / ☐ harder / ☐ about the same as others, when state abbrevations were part of the nomenclature ( See image 5)?

5. Do you think including the state abbreviation in the waypoint nomenclature provided an (check one) ☐ increased / ☐ decreased / ☐ about the same as other,s in geographical awareness (i.e. ability to develop a mental picture of where a waypoint is located graphically) when compared to waypoint noemclature not including the state abbrievation? (See image 5).

6. For experimental waypoints where the state abbreviations are provided, do you think that numbering the waypoints per state increased geographical awareness? ( See image 6).

   Yes ☐ No ☐

7. Did you find any particular waypoint nomenclature to be easier to find on the map?

   Yes ☐ No ☐

   a. If so which one and why do you think it was easier to locate?

      Click here to enter text.

8. Did you find any particular waypoint nomenclature to be harder to find on the map?

   Yes ☐ No ☐

   a. If so which one and why do you think it was harder to locate?

      Click here to enter text.

Please rate your level of agreement with the following statements (select only one).

9. I found the N1 nomenclature to aid in geographical awareness

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

10. I found the N2 nomenclature to aid in geographical awareness

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

11. I found the N3 nomenclature to aid in geographical awareness

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

12. I found the N4 nomenclature to aid in geographical awareness

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

13. Please rank the waypoint nomenclatures on the level of geograpchal awareness provided with one providing the most geographical awareness and four providing the least.

   1.Click here to enter text.
   2.Click here to enter text.
   3.Click here to enter text.
   4.Click here to enter text.

14. Please rank which of the nomenclature methods that started with the state abbreviation provided more within-state geographical awareness then the others? Rank from greatest(1) to least(3).

   1.Click here to enter text.
   2.Click here to enter text.
   3.Click here to enter text.

15. When you were deviating for weather during the experiment, if you used any NRS wapoints for your new route, did you find any particular NRS waypoint nomenclature easier to use? Why?

   Click here to enter text.

<u>Speaking and Hearing Issues</u>

Please rate your level of agreement with the following statements (select only one).
See images 1-4 for nomenclature refereces.

16. I found the N1 nomenclature to be easy to say phonetically

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

17. I found the N2 nomenclature to be easy to say phonetically

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

18. I found the N3 nomenclature to be easy to say phonetically

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

19. I found the N4 nomenclature to be easy to say phonetically

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
| --- | --- | --- | --- | --- |
| ☐ | ☐ | ☐ | ☐ | ☐ |

20. Did you find any particular waypoint nomenclature to be easiest to say? If so, which one(s) and why?
    Click here to enter text.

21. Did you find any waypoint nomenclatures to be difficult to say? If so, which one(s) and why?
    Click here to enter text.

22. Did you find any particalur waypoint nomenclature to be easier to remember? If so, why do you think that is?
    Click here to enter text.

23. Imagine that you have been issued a clearance by ATC over the radio that includes the NRS waypoint OH127. Check which of the following you would prefer in terms of how ATC would pronounce this waypoint (you may check more than one if you feel more than one is acceptable):

    ☐ Oscar – Hotel – One – Two – Seven
    ☐ Oscar – Hotel – One – Twenty-seven
    ☐ Oscar – Hotel – One hundred twenty-seven
    ☐ Ohio – One – Two – Seven
    ☐ Ohio – One – Twenty-seven
    ☐ Ohio – One hundred twenty-seven
    ☐ No preference, All are acceptable
    ☐ Other (please specify): Click here to enter text.

24. If you checked more than one above, do you have a peference of one way of stating an NRS waypoint over the others you checked?

    Yes ☐ No ☐

    a. If yes, which one? Click here to enter text.

25. Imagine that you have been issued a clearance by ATC over the radio that includes the NRS waypoint TX15F. Check which of the following you would prefer in terms of how ATC would pronounce this waypoint (you may check more than one if you feel more than one is acceptable):

☐ Tango – X-ray – One – Five – Foxtrot

☐ Tango – X-ray – Fifteen – Foxtrot

☐ Texas – One – Five – Foxtrot

☐ Texas – Fifteen – Foxtrot

☐ No preference, All are acceptable

☐ Other (please specify): Click here to enter text.

26. If you checked more than one above, do you have a peference of one way of stating an NRS waypoint over the others you checked?

Yes ☐ No ☐

b. If yes, which one? Click here to enter text.

## Data Entry Issues

Please rate your level of agreement with the following statements (select only one).
See images 1-4 for nomenclature refereces.

27. I found the N1 nomenclature to be easy to enter into the FMS

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

28. I found the N2 nomenclature to be easy to enter into the FMS

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

29. I found the N3 nomenclature to be easy to enter into the FMS

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

30. I found the N4 nomenclature to be easy to enter into the FMS

| Strongly disagree | Disagree | Neutral | Agree | Strongly agree |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | ☐ | ☐ |

31. Did you find any particalur waypoint nomenclature to be easist to enter into the FMS?
    Yes ☐ No ☐
    a. If so, which one(s) and why? Click here to enter text.

32. Did you find any waypoint nomenclatures to be difficult to enter into the FMS?
    Yes ☐ No ☐
    a. If so, which one(s) and why? Click here to enter text.

<u>General Questions</u>

For each statement below, check the response which most closely matches your level of agreement with the statement (select only one response).

| Statement | Strongly Disagree | Disagree | Neither Disagree nor Agree | Agree | Strongly Agree | N/A |
|---|---|---|---|---|---|---|
| 33. When a controller issues a clearance that includes a conventionally named waypoint that I'm not familiar with, I usually ask for the exact spelling before entering the waypoint into the FMS. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 34. The Nav Display used in the study was difficult to use. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 35. To navigate around weather areas, in general I would prefer to fly direct to VORs, and traditionally named waypoints (e.g., CINDI) rather than flying direct to NRS points regardless of naming convention, even if a suitable NRS point is available. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

| Statement | Strongly Disagree | Disagree | Neither Disagree nor Agree | Agree | Strongly Agree | N/A |
|---|---|---|---|---|---|---|
| 36. The sample charts used in this study were easy to use. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 37. I think most pilots will confuse the number zero with the letter "O" or the number one with the letter "I" when entering waypoint data. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 38. The FMS used in this study was easy to use. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 39. The NRS grid system of waypoints will not be very useful to deviate around weather areas. | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

For each statement below, check the response which most closely matches your level of agreement with the statement (select only one response).

| 40. It was easy to modify my flight plan using the following NRS waypoints when route modifcations were necessary. | Strongly Disagree | Disagree | Neither Disagree nor Agree | Agree | Strongly Agree |
|---|---|---|---|---|---|
| N1 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N2 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N3 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N4 | ☐ | ☐ | ☐ | ☐ | ☐ |

*Please continue onto the next page*

| 41. In multi-crew environments, crewmembers should use the same cross check procedures when entering NRS waypoints as for conventionally named waypoints. | Strongly Disagree | Disagree | Neither Disagree nor Agree | Agree | Strongly Agree |
|---|---|---|---|---|---|
| N1 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N2 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N3 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N4 | ☐ | ☐ | ☐ | ☐ | ☐ |

| 42. Even with experience, I believe that NRS waypoints will be/are more difficult to use in voice communication than conventionally named waypoints. | Strongly Disagree | Disagree | Neither Disagree nor Agree | Agree | Strongly Agree |
|---|---|---|---|---|---|
| N1 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N2 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N3 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N4 | ☐ | ☐ | ☐ | ☐ | ☐ |

| 43. In multi-crew environments, using NRS waypoints for normal navigation tasks will require changes to the PF and PNF roles and responsibilities. | Strongly Disagree | Disagree | Neither Disagree nor Agree | Agree | Strongly Agree |
|---|---|---|---|---|---|
| N1 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N2 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N3 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N4 | ☐ | ☐ | ☐ | ☐ | ☐ |

*Please continue onto the next page*

| 44. The NRS waypoint naming convention used in this study makes it more difficult to locate a NRS waypoint on the High Altitude Enroute Chart than it is to locate a conventionally named, five character waypoint. | Strongly Disagree | Disagree | Neither Disagree nor Agree | Agree | Strongly Agree |
|---|---|---|---|---|---|
| N1 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N2 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N3 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N4 | ☐ | ☐ | ☐ | ☐ | ☐ |

| 45. Once I get used to them, I believe that NRS waypoints will be as easy to use in voice communication as conventionally named waypoints. | Strongly Disagree | Disagree | Neither Disagree nor Agree | Agree | Strongly Agree |
|---|---|---|---|---|---|
| N1 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N2 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N3 | ☐ | ☐ | ☐ | ☐ | ☐ |
| N4 | ☐ | ☐ | ☐ | ☐ | ☐ |

46. If you have any other comments to make with regard to NRS waypoints or regarding this study please write them here. Click here to enter text.

## APPENDIX 7

### NRS Waypoint Part-Task Study Questionnaire (With Results)

**Overall Preference**

**1. Please rank your preference for NRS waypoint nomenclature (naming method) with one being the most prefered and four being the least preferred. (For nomencalture review, please refer to images 1-4).**

| | | First | Second | Third | Fourth |
|---|---|---|---|---|---|
| N1 | | 0% | 11% | 15% | 74% |
| | | 0 | 3 | 4 | 20 |
| N2 | | 19% | 33% | 44% | 4% |
| | | 5 | 9 | 12 | 1 |
| N3 | | 60% | 26% | 7% | 7% |
| | | 16 | 7 | 2 | 2 |
| N4 | | 22% | 30% | 33% | 15% |
| | | 6 | 8 | 9 | 4 |

2. **In general, did you find any particular waypoint nomenclature to be easier to use and why?**

| | Yes | No | N1 | N2 | N3 | N4 |
|---|---|---|---|---|---|---|
| Percentage | 97% | 3% | 0% | 11% | 61% | 29% |
| Raw Count | 27 | 1 | 0 | 3 | 17 | 8 |

Participant Responses

| |
|---|
| N2, The state makes it easy to identify and the lat long grid reference makes it easy to find on a chart. |
| N3, Very easy to find waypoints. |
| Of the "new" ones, the "redundant" geographical references in the N4 nomenclature made it easier to find the waypoints |
| N3 and N4, The state in the identifier made the waypoint easier to find and the numerical sequence was more logical. |
| N2, because it gave me information that I found more useful to guide me to the point. |
| N4, was easier due to the State, number, Center |
| N3 is simple due to the fact that has state name, and ID number. |
| N3, we use it now. |
| N3 seemed the most intuitive to me. |
| N3, due to the least amount of info to search for on the map. |
| N3, with image 1, you could quickly identify the State and then move quickly through the coordinates to find the appropriate identifying number |

| |
|---|
| N2, The latitude and longitude actually correspond with the map in a non-arbitrary way. The state code helps to immediately find the general location first. |
| N4 was easiest |
| State and latitude focused the search |
| N3, Simple format, just state and #. The others get complicated. Also like the numbering scheme. |
| N3, was easiest both from both logic and user perspectives. Locate the state, then find the number. FMC keypad entry is also easier because the user can move from letters to numbers then enter without having to move back to the letters pad. |
| state for location and then center for location |
| Easy Grid system, Easy State System with center identifiers. |
| N4, it was very simple and did not have a lot of clutter and numbers to punch in, in high stressed situations, the easier the navigation waypoint is to program in, the less stress the pilot will feel. |
| N3; It was easier to understand and use. |
| Less info to process. Simply state and general area to reference. |
| N3. For US Citizens states are easy and a three digit number is faster for me than using a 2-D grid on aviation maps. Also less likely to confuse numbers and letters. |
| N3 |
| N4 - very logical system, with the center cue aiding in rapid identification when harder to locate waypoint. |
| N3 - Because I am already familiar with where the states are, and I only had to find one 3 digit number which was fairly easy. However, If I were to use this method in another country I would be completely lost as I would have no idea where the states are. Also I believe foreign pilots flying in the U.S. would have a hard time with this nomenclature due to their lack of US geography knowledge. |
| State, # and controlling ARTCC built the most SA in my mind as I searched for the waypoint on the chart and assimilated to a mental image. |

**3. In general, did you find any particular waypoint nomenclature to be more difficult to use and why?**

| | Yes | No | N1 | N2 | N3 | N4 |
|---|---|---|---|---|---|---|
| Percentage | 79% | 21% | 74% | 7% | 3% | 7% |
| Raw Count | 22 | 6 | 20 | 2 | 1 | 2 |

Participant Responses

| |
|---|
| N4. The reference to center doesn't help me find it on a chart but makes it harder to request of report than N3. |
| The order is not as straight forward. Might be better if the numbers corresponded directly with latitude and longitude |
| N1 because I do not think of ARTCC boundaries as easily as I think of state boundaries. |
| N1 is the most difficult due to the amount of info inside the waypoint. |

| |
|---|
| It was the hardest; not knowing where the Control center was took a while to find. |
| N1 relied on knowing where center boundaries were. |
| N1, Having the FIR (K) is a waste of a space to put something more helpful to me (pilots) to use to find the waypoint we're looking for on a map. |
| Once you begin to look in the correct state, the ID number is an arbitrary number that is relative to the other numbers, not relative to an actual location on the map. |
| N1 was difficult to find on a map and seems more prone to error entry. A seems more prone to entry error. It is easier to confuse O and 0. |
| N1. Having to know which center makes it tougher to find. With states, a little easier geographically. |
| N1 was most difficult to use because ARTCC lines do not necessarily follow any apparent logic, the letter for center does not correlate with the name, and the user has to move from letters to numbers back to letters on the FMC keypad prior to entry. |
| State w/ postal code. I didn't know the pattern of the postal codes so had to hunt a bit. |
| One has to determine the extent of the irregularly shaped center boundaries and longitude. |
| N1, Worthless numbering system. |
| N3, I couldn't find the artcc center locations easily, had to look at my tip sheet twice to find out what center I was looking for. |
| N1, It was more difficult to correlate the plotting of the waypoint. |
| Determining center boundaries is a bit more tedious than determining state boundaries and the clutter on chart makes finding lat and long position a bit harder. |
| N1, longitude cycle repetition |
| N1 - Found the leading ICAO identifier K to be extraneous, and numbering system was illogical from a rapid identification standpoint. Lack of state identifier further delayed finding waypoints easily. |
| The most difficult was N1, and N2 was a bit difficult as well. The latitude and longitude coordinates used in both of these was unfamiliar to me and therefore there was a learning curve to get used to it. Once I understood the layout it was easier to find the fixes. N2 was easier than N1 due to the state being included in the name, hence easier to find. N1 was more difficulty because I had to first determine what letter corresponded to what Center and then go from there which added some time in finding the fix. Also the "K" identifier added slightly to the confusion. I had to use a slight amount of brain power to omit it in finding the fix. |
| Since everything is US, the FIR letter was a waste (however, I can see that this might help in EUR.) The lat/long characters took longer to assimilate as I searched the chart. |

## Geographical Awareness

**4. In general, did you find waypoint nomenclatures to be (check one) ☐ easier / ☐ harder / ☐ about the same as others, when state abbrevations were part of the nomenclature ?**

| | Easier | Harder | About the same as others |
|---|---|---|---|
| Percentage | 86% | 4% | 14% |
| Raw Count | 24 | 1 | 4 |

**5. Do you think including the state abbreviation in the waypoint nomenclature provided an (check one) ☐ increased / ☐ decreased / ☐ about the same as other,s in geographical awareness (i.e. ability to develop a mental picture of where a waypoint is located graphically) when compared to waypoint noemclature not including the state abbrievation?**

| | Increased | Decreased | About the same as others |
|---|---|---|---|
| Percentage | 89% | 4% | 7% |
| Raw Count | 25 | 1 | 2 |

**6. For experimental waypoints where the state abbreviations are provided, do you think that numbering the waypoints per state increased geographical awareness?**

| | Yes | No |
|---|---|---|
| Percentage | 75% | 25% |
| Raw Count | 21 | 7 |

**7. Did you find any particular waypoint nomenclature to be easier to find on the map and why?**

| | Yes | No | N1 | N2 | N3 | N4 |
|---|---|---|---|---|---|---|
| Percentage | 93% | 7% | 8% | 23% | 46% | 23% |
| Raw Count | 26 | 2 | 2 | 6 | 12 | 6 |

| Participant Responses |
|---|
| N2 |
| N4, having the center and state was easier to visualize than just the numbering. |
| All were good except 'Image 1' (N1). Some give a good mental picture as to where the waypoint is, others are simply easier to locate on the charts due to their sequencing (N3) |
| N2. Because I generally know where state boundaries are and the latitude in numbers and a long letter where easier to follow. |
| (N4) was easiest due to the state, number, center |
| (N3) Because, it’s all about following the numbers until finding the correct one |
| N3 State then the identifying number. |
| N3, as the numbering was intuitive, and it merely relied on knowledge of states. |
| N3 A. Once the State is found, it's just an issue of finding the number (which are in order) |
| N3 I think listing the State abbreviation and then numerically and "common sense" ordering of the identifying numbers is the best format for quickly finding the waypoints. |

| |
|---|
| N2, same reasons listed above for ease of use. |
| N2 B, it was easier to zoom in on the waypoint using others around it |
| N2. Again using the state and latitude focused the search. |
| N3. With numbering scheme, it's easier than thinking of lat and long grids. |
| N3. See answer to #2 above |
| N3 |
| N4, Easy grid system, Easy state and center location system |
| Had the state abbreviations. |
| N4 |
| N3, It was easier to understand the waypoint plotting. |
| N3, and was quicker to simply find state and the associated number due to the grid system not requiring two entry points (i.e. lat and long) |
| N3 Just a pure number and knowledge of the arrangement is easy to work across and up or down. |
| N3, minimum reference crosscheck |
| N4 - very logical, with state and center cues aiding in rapid identification. |
| N3 - Because I am already familiar with where the states are, and I only had to find one 3 digit number which was fairly easy. However, If I were to use this method in another country I would be completely lost as I would have no idea where the states are. Also I believe foreign pilots flying in the U.S. would have a hard time with this nomenclature due to their lack of US geography knowledge. |
| N1 |

**8. Did you find any particular waypoint nomenclature to be harder to find on the map and why?**

| | Yes | No | N1 | N2 | N3 | N4 |
|---|---|---|---|---|---|---|
| Percentage | 93% | 7% | 85% | 4% | 0% | 8% |
| Raw Count | 26 | 2 | 22 | 1 | 0 | 3 |

<u>Patricipant Answers</u>

| |
|---|
| N1 Finding a center you don't typically fly in is harder than finding states. |
| N1 FIR info was useless in the CONUS and center boundaries are harder to identify |
| N1 not as clean an order as the others. |
| N1 Because I am not as familiar with ARTCC boundaries. |
| (N1) was the hardest to find on the map due to its complexity. |
| (N4) , "center" next to ID number, often located in different places on the map |
| N1 Finding center was the hardest for me, not knowing starting point. |
| N1, as it relied on a knowledge of center boundaries. |
| N1 D. The FIR is worthless, (pilots should know they are flying over the United States), also I do not like to look up points on the map by which Center is controlling that particular airspace. |
| N1 The nomenclature starting with the FIR, then followed by the Center was the most challenging. |
| N4. The redundancy of State and Center only made it more confusing, and there is no easy pattern to find numbers more quickly such as with lat and long coordinates. |

| |
|---|
| N1 Difficult to locate the center without the reference map. |
| N1 is very difficult. Not intuitive grid system to focus the search. |
| N1. Having to know the identifier for the center makes it tougher to locate. |
| N1. |
| N1 |
| N1, worthless numbering system |
| N1 could find the waypoint that incorporated the center designation. |
| N1 |
| N1 |
| N4 is a bit redundant in including both a state and center designation. Must consult two boundaries to find waypoint (state and center) |
| N1 Took a little longer to locate centers than states. |
| N1, skipping letters and resetting again |
| N1 - lack of state identifier, illogical numbering system and leading ICAO identifier all helped make this system more time consuming when needing to find a waypoint. |
| The most difficult was N1, and N2 was a bit difficult as well. The latitude and longitude coordinates used in both of these was unfamiliar to me and therefore there was a learning curve to get used to it. Once I understood the layout it was easier to find the fixes. N2 was easier than N1 due to the state being included in the name, hence easier to find. N1 was more difficulty because I had to first determine what letter corresponded to what Center and then go from there which added some time in finding the fix. Also the "K" identifier added slightly to the confusion. I had to use a slight amount of brain power to omit it in finding the fix |
| N1 |

**Please rate your level of agreement with the following statements (select only one).**
**9. I found the N1 nomenclature to aid in geographical awareness**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Percentage | 25% | 43% | 25% | 7% | 0% |
| Raw Count | 7 | 12 | 7 | 2 | 0 |

**10. I found the N2 nomenclature to aid in geographical awareness**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Percentage | 0% | 0% | 14% | 64% | 21% |
| Raw Score | 0 | 0 | 4 | 18 | 6 |

**11. I found the N3 nomenclature to aid in geographical awareness**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Percentage | 0% | 0% | 14% | 46% | 39% |
| Raw Score | 0 | 0 | 4 | 13 | 11 |

**12. I found the N4 nomenclature to aid in geographical awareness**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Percentage | 4% | 4% | 32% | 39% | 21% |
| Raw Score | 1 | 1 | 9 | 11 | 6 |

**13. Please rank the waypoint nomenclatures on the level of geograpchal awareness provided with one providing the most geographical awareness and four providing the least.**

| | First | Second | Third | Fourth |
|---|---|---|---|---|
| N1 | 0% | 14% | 7% | 79% |
| | 0 | 4 | 2 | 22 |
| N2 | 29% | 29% | 36% | 7% |
| | 8 | 8 | 10 | 2 |
| N3 | 46% | 36% | 11% | 7% |
| | 13 | 10 | 3 | 2 |
| N4 | 25% | 21% | 46% | 7% |
| | 7 | 6 | 13 | 2 |

**14. Please rank which of the nomenclature methods that started with the state abbreviation provided more within-state geographical awareness then the others? Rank from greatest(1) to least(3).**

| | First | Second | Third |
|---|---|---|---|
| N2 | 32% | 43% | 25% |
| | 9 | 12 | 7 |
| N3 | 46% | 25% | 29% |
| | 13 | 7 | 8 |
| N4 | 21% | 32% | 46% |
| | 6 | 9 | 13 |

**15. When you were deviating for weather during the experiment, if you used any NRS wapoints for your new route, did you find any particular NRS waypoint nomenclature easier to use? Why?**

| Participant Responses |
|---|
| Anything is better than N1 |
| No. For that task one is just looking for a geographical point. It didn't really matter what it was called, so the nomenclature method was irrelevant. |
| I did use NRS waypoints along with VOR's and regular waypoints. The naming convention did not really matter because I looked at where I wanted to go and then just picked whatever waypoint was there. Naming really came into play when I was trying to find a waypoint without any idea of where it was. |
| N4 because of the State and identifying number. |
| I was neutral did not make a difference. |
| No. I was merely looking for a waypoint that would avoid the weather with minimal angular deviation. |

| |
|---|
| N3, due to the numbers running in order. It was the easiest to track down what I was looking for. |
| No, not really.  At that point you are looking on the chart for yourself and identifying the waypoints.  The challenge can arise when ATC assigns a waypoint and then attempting to find the new waypoint. |
| N2.  A sense of geographical situational awareness is built into the nomenclature for N2, and it would allow for more intuitive deviation rather than heads-down chart reading. |
| No, I referred to the display to find the most appropriate point to deviate to.  The method of naming a waypoint did not affect my choice.  Most often I will use the display to choose a point to divert to and not refer to a paper map. |
| N3.  Simple numbering scheme made it easy to find desired waypoints.  All the other types required more thinking. |
| N3. Same reason as #2 above |
| Used them more as I got used to finding them and also used more if there were no VORs around. N3 format was the easiest to type and least time consuming to program in.  Helpful during deviations. |
| No, doesn't make a difference. |
| Yes, I was looking for waypoints that would; 1- take me away from the storm, 2- would not deviate me a great distance from my original route. |
| No, they are equally easy to use when looking on the map |
| No, they are all pretty straight forward in identification and location. |
| The ease of inputting text into the FMS is not an issue |
| N3 Slightly easier.  Less chance to mistake an entry due to 2 letters and 3 numbers.  That's easy to remember.  I'm not switching back and forth between keypads. |
| Data entry minimum with N3 |
| Yes - N4. In general, one could surmise where the next waypoint lay, in relation to one's aircraft. This aided in rapidly choosing a prudent and logical deviation. |
| I would say that N2 was the easiest to use because the lat/long type coordinates made more geographical sense, whereas having the fixes numbered gives me no geographical reference without looking at the map and finding the numbers. |
| Not really.  I selected a waypoint based on map display - once I had the 5 characters, I typed it in the FMS.  (If the map display had a larger scale, there may have been some benefit to various nomenclatures due to relative position cues.) |

**<u>Speaking and Hearing Issues</u>**

**Please rate your level of agreement with the following statements (select only one).**

**16. I found the N1 nomenclature to be easy to say phonetically**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Percentage | 0% | 18% | 50% | 32% | 0% |
| Raw Score | 0 | 5 | 14 | 9 | 0 |

**17. I found the N1 nomenclature to be easy to say phonetically**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Percentage | 0% | 4% | 50% | 43% | 4% |
| Raw Score | 0 | 1 | 14 | 12 | 1 |

**18. I found the N1 nomenclature to be easy to say phonetically**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Percentage | 0% | 0% | 18% | 20% | 54% |
| Raw Score | 0 | 0 | 5 | 8 | 15 |

**19. I found the N1 nomenclature to be easy to say phonetically**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Percentage | 0% | 4% | 50% | 46% | 0% |
| Raw Score | 0 | 1 | 14 | 13 | 0 |

**20. Did you find any particular waypoint nomenclature to be easiest to say? If so, which one(s) and why?**

| | Yes | No | N1 | N2 | N3 | N4 |
|---|---|---|---|---|---|---|
| Percentage | 79% | 21% | 0% | 13% | 83% | 4% |
| Raw Count | 22 | 6 | 0 | 3 | 19 | 1 |

<u>Participant Responses</u>

| |
|---|
| N2 and N4 about the same. |
| N3 used to saying numbers |
| N2 - was a little easier but they were all pretty close. I would say the state name, i.e. CO "Colorado", instead of Charlie Oscar. That made the state identified waypoints easier to say then the Image 1 - N1 waypoints. |
| N3 because there is less to say. |
| N3 , has two letters and number: less congestion of characters |
| N3 |
| No |
| N3, due to the fact that you're saying 2 letters and then 3 numbers, instead of letters and numbers then letters again |
| N3 They are all easy enough to say phonetically, however the N3 nomenclature is probably the easiest---- just two letters followed by three numbers. |
| N3. Numbers are simply easier to say than letters. |
| They were all fairly easily spoken |
| N3 because it went from letters to numbers only once |
| N3. Only 2 items, state and #. |
| N3. Letters followed by numbers. |

| |
|---|
| N3, vocalized state and number. |
| N3,  two letters than all numerical |
| Yes, N3 is shorter |
| N3, It was short and simple. Pilots like that! |
| N3, all numbers at the end but not really that big a factor |
| Less letters to say phonetically, therefore takes less time to say |
| N3 All letters followed by all numbers is easiest for me. |
| Minimum read back of letters and numbers, less transposition errors |
| N2 |
| N3 was easiest due to the fact that you only have to say one set of letters followed by one set of numbers.  It's simple to say. |
| N3 - numbers are easier than letters.  (2 letters, 3 numbers) |

**21. Did you find any waypoint nomenclatures to be difficult to say? If so, which one(s) and why?**

| | Yes | No | N1 | N2 | N3 | N4 |
|---|---|---|---|---|---|---|
| Percentage | 39% | 61% | 47% | 24% | 13% | 18% |
| Raw Count | 11 | 17 | 8 | 4 | 2 | 3 |

Participant Responses

| |
|---|
| N1 Letters and numbers without meaning mean you have to say each character separately |
| N1 Image 1 - Alpha was the most difficult because I could not use the state name. |
| N2 and N4 because there's more to say. |
| Shortest |
| N3 A may be slightly more difficult to say and understand |
| The rest are about the same |
| N2, N4, N1.  Only because have to deal with letters after numbers too.  Difficulty with 0 (zero) vs. O.  Have to think about it first.  Possibility for confusion. |
| N1, you have to think of the K, then center identifier, then the numerical lat, followed by the longitude |
| No, all approximately the same |
| Yes, N1, was difficult because it required me to concentrate on looking up the waypoints using the tip sheet, therefore taking my concentration away from flying the aircraft safely, |
| None difficult |
| N4, N1, N2 all require changing from letters to numbers then back again. |
| More crossing of numbers and yields transposition errors on dark, bumpy nights |
| N2 |
| I would say N1 and N2 would be a bit tougher to spit out because it just seems like a lot of digits and the lat/long format is not familiar. |
| N1 - simply because I did not like it :). |

**22. Did you find any particalur waypoint nomenclature to be easier to remember? If so, why do you think that is?**

| | Yes | No | N1 | N2 | N3 | N4 |
|---|---|---|---|---|---|---|
| Percentage | 82% | 18% | 0% | 11% | 67% | 22% |
| Raw Count | 23 | 5 | 0 | 3 | 18 | 6 |

| Participant Responses |
|---|
| N4 was easy in centers I recognized. Then N3 followed by N2 |
| N3; fewer pieces of data |
| N 4 - We have physical locations to use, such at the state and Center region which are in specific areas. |
| The State designated waypoints are easier because I can remember a state name easier than just letters. |
| N3, least amount to remember |
| N3, letters followed by numbers |
| N3, shortest to remember. |
| N3 is probably the easiest to remember because you can group the 3 numbers together. For example: 127, I would remember "one-twenty seven" |
| N3. It involves only two different identifiers; State and ID number. The others have three or four. |
| N2 and N4, It seemed that B & C were slightly easier to remember although all seem relatively easy to remember. An individual combination of letters and numbers may be more or less easier to remember regardless of the nomenclature type. |
| N3 Again, because it went from letters to numbers only once. |
| N3. It is simple with only 2 items. |
| N3. State followed by a three digit number |
| N3, state and number rather than 3 items. |
| N3, Just have to know the state the corresponding number, easy for people who rely on patterns. |
| Yes, N4 and N3 start with the state. |
| N3, numbers and letters separated |
| N3, due to only needing to remember a state and number (CO and 127) vs. (K and D and 48 and U) |
| N3 The least complex. |
| N3 |
| Yes, N4. More logical. |
| N2 was easiest to remember - once I had the state in mind, I only had to remember the lat/long identifier, and this was easier to remember because it had a geographic reference. |
| I would have to say N3 because once you know the state (easy to remember) all you have to remember is one number (the ID #). |

**23. Imagine that you have been issued a clearance by ATC over the radio that includes the NRS waypoint OH127. Check which of the following you would prefer in terms of how ATC would pronounce this waypoint (you may check more than one if you feel more than one is acceptable):**

*Participant preference when hearing Experimental NRS Waypoint Configurations*

| Waypoint | Percent |
|---|---|
| OH127 | |
| Phonetic Combinations | |
| Oscar – Hotel – One – Two – Seven | 39 |
| Oscar – Hotel – One – Twenty-seven | 16 |
| Oscar – Hotel – One hundred twenty-seven | 4 |
| Ohio – One – Two – Seven | 24 |
| Ohio – One – Twenty-seven | 18 |
| Ohio – One hundred twenty-seven | 0 |
| No preference, All are acceptable | 0 |

**24. If you checked more than one above, do you have a peference of one way of stating an NRS waypoint over the others you checked?**

Participant Responses

| |
|---|
| Ohio one twenty seven. More natural to say. |
| Yes. Ohio-One-Two-Seven |
| Prefer Ohio-One-Two-Seven |
| Oscar Hotel One Two Seven |
| Oscar - hotel - one - two - seven |
| Yes. The first is for foreign carriers, the second "Ohio one twenty-seven" is for US carriers. |
| Say the state name |

**25. Imagine that you have been issued a clearance by ATC over the radio that includes the NRS waypoint TX15F. Check which of the following you would prefer in terms of how ATC would pronounce this waypoint (you may check more than one if you feel more than one is acceptable):**

*Participant preference when hearing Experimental NRS Waypoint Configurations*

| Waypoint | Percent |
|---|---|
| TX15F | |
| Phonetic Combinations | |
| Tango - X-ray - One - Five - Foxtrot | 42 |
| Tango - X-ray - Fifteen - Foxtrot | 9 |
| Texas - X-ray - One - Five - Foxtrot | 36 |
| Texas - X-ray - Fifteen - Foxtrot | 11 |
| No preference, All are acceptable | 2 |

**26. If you checked more than one above, do you have a peference of one way of stating an NRS waypoint over the others you checked?**

<u>Participant Responses</u>

| |
|---|
| Yes, Texas-One-Five-Foxtrot |
| Texas-One-Five-Foxtrot |
| Tango-x-ray-one-five-foxtrot |
| State First |
| Same foreign vs. domestic carriers. |
| A letter at the end can be screwed up when tired |

## Data Entry Issues

**Please rate your level of agreement with the following statements (select only one).**

**27. I found the N1 nomenclature to be easy to enter into the FMS**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Percentage | 4% | 14% | 14% | 29% | 0% |
| Raw Score | 1 | 4 | 15 | 8 | 0 |

**28. I found the N2 nomenclature to be easy to enter into the FMS**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Percentage | 4% | 4% | 31% | 29% | 34% |
| Raw Score | 0 | 1 | 9 | 8 | 10 |

**29. I found the N3 nomenclature to be easy to enter into the FMS**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Percentage | 0% | 4% | 39% | 36% | 18% |
| Raw Count | 0 | 1 | 11 | 10 | 5 |

**30. I found the N4 nomenclature to be easy to enter into the FMS**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| Percentage | 21% | 11% | 39% | 29% | 0% |
| Raw Count | 6 | 3 | 11 | 8 | 0 |

**31. Did you find any particalur waypoint nomenclature to be easist to enter into the FMS?**

| | Yes | No | N1 | N2 | N3 | N4 |
|---|---|---|---|---|---|---|
| Percentage | 82% | 18% | 0% | 4% | 92% | 4% |
| Raw Count | 23 | 5 | 0 | 1 | 23 | 6 |

<u>Participant Responses</u>

| |
|---|
| N3 no going "back and forth" between letters and numbers |
| N2, N3, and N4 Those using the State identification. I can remember state names better than just letters. |

| |
|---|
| N3 , less typing takes less time |
| N3 shortest/fastest |
| N3, due, again, to the fact that you're dealing with the letter pad, then the number pad on the FMS, instead of switching back and forth between pads. |
| they are all easy to enter into the FMS |
| N3 You only switch between letters and numbers once. |
| Only had to shift between N3 and numeric keys once. |
| N3. Only have a state and number. |
| N3, noted above #2 |
| N3, less hand switching from letter pad to number pad. |
| N3, keeps you from bouncing back and forth between letters and numbers |
| N3, short and precise |
| N3. You do not have to go back and forth from letters to number pad |
| N3, it is the easiest to remember and enter. |
| N3, as there is no need to go back to the letter pad after entering the state, if one is interested in saving a few seconds in input time. |
| N3 You only changes key pads once. |
| ID and number only |
| N3 - You only have to move your finger one time between the letter pad and the number pad. 2 steps. |
| Easy to remember a state and a number. |

**32. Did you find any waypoint nomenclatures to be difficult to enter into the FMS?**

| | Yes | No | N1 | N2 | N3 | N4 |
|---|---|---|---|---|---|---|
| Percentage | 32% | 68% | 71% | 14% | 0% | 14% |
| Raw Count | 9 | 19 | 9 | 2 | 0 | 2 |

Participant Responses

| |
|---|
| N1 Required more thought |
| N1 was just a little harder because I had to remember fairly arbitrary letters and numbers |
| N1 because you have to glance at the waypoint several times to make sure you enter it correctly into the FMS. |
| N1 The first two letters don't go together as state IDs do, so it seems just a bit more difficult to type than those with State IDs. |
| N1 I recall that D had combined several O's and 0's in the waypoint. Those can become confusing. That can happen with any of the nomenclatures, however. |
| N2, N4, and N1. Have to deal with letters after numbers. Possible confusion of entering an 0 (zero) vs. O. |
| N1, you’re typing all over the pad |
| N1, confusing |
| Not difficult, but I prefer N4 to N3, N2, and N1. |
| letters followed by numbers followed by letter(s) can be transposed |

| |
|---|
| N1 - have to remember 4 distinct references: FIR, Center, Lat & Long. |

**<u>General Questions</u>**

**For each statement below, check the response which most closely matches your level of agreement with the statement (select only one response).**

| Statement | Strongly Disagree | Disagre e | Neither Agree or Disagree | Agree | Strongly Agree |
|---|---|---|---|---|---|
| **33. When a controller issues a clearance that includes a conventionally named waypoint that I'm not familiar with, I usually ask for the exact spelling before entering the waypoint into the FMS.** | 0% | 14% | 0% | 21% | 64% |
| | 0 | 4 | 0 | 6 | 18 |
| **34. To navigate around weather areas, in general I would prefer to fly to direct to VORs, and traditionally named waypoints (e.g., CINDI) rather than flying direct to an NRS point regardless of naming convention, even if a suitable NRS point is available.** | 43% | 29% | 25% | 4% | 0% |
| | 12 | 8 | 7 | 1 | 0 |
| **35. I think most pilots will confuse the number zero with the letter "O" or the number one with the letter "I" when entering waypoint data.** | 4% | 18% | 18% | 32% | 29% |
| | 1 | 5 | 5 | 9 | 8 |
| **36. The NRS grid system of waypoints will not be very useful to deviate around weather areas.** | 36% | 46% | 7% | 7% | 4% |
| | 10 | 13 | 2 | 2 | 1 |

**For each statement below, check the response which most closely matches your level of agreement with the statement (select only one response).**

**40. It was easy to modify my flight plan using the following NRS waypoints when route modifications were necessary**.

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| N1 | 0% | 18% | 29% | 73% | 4% |
| | 0 | 5 | 8 | 12 | 1 |
| N2 | 0% | 4% | 18% | 64% | 14% |
| | 0 | 1 | 5 | 18 | 4 |
| N3 | 0% | 4% | 0% | 68% | 29% |
| | 0 | 1 | 0 | 19 | 8 |
| N4 | 0% | 4% | 11% | 79% | 7% |
| | 0 | 1 | 3 | 22 | 2 |

**41. In multi-cre environments, crewmembers should use the same cross check procedures when entering NRS waypoints as for conventionally named waypoints.**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| N1 | 4% | 0% | 0% | 39% | 57% |
| | 1 | 0 | 0 | 11 | 16 |
| N2 | 4% | 0% | 0% | 43% | 54% |
| | 1 | 0 | 0 | 12 | 15 |
| N3 | 4% | 0% | 0% | 39% | 57% |
| | 1 | 0 | 0 | 11 | 16 |
| N4 | 4% | 0% | 0% | 39% | 57% |
| | 1 | 0 | 0 | 11 | 16 |

**42. Even with experience, I believe that NRS waypoints will be/are more difficult to use in voice communication than convetnionally named waypoints.**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| N1 | 11% | 25% | 32% | 29% | 4% |
| | 3 | 7 | 9 | 8 | 1 |
| N2 | 14% | 29% | 29% | 29% | 0% |
| | 4 | 8 | 8 | 8 | 0 |
| N3 | 21% | 57% | 14% | 18% | 0% |
| | 6 | 13 | 4 | 5 | 0 |
| N4 | 14% | 32% | 25% | 29% | 0% |
| | 4 | 9 | 7 | 8 | 0 |

**43. In multi-crew environments, using NRS waypoints for normal navigation tasks will require changes to the PF and PNF roles and responsibilities.**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| N1 | 43% | 49% | 11% | 0% | 0% |
| | 12 | 13 | 3 | 0 | 0 |
| N2 | 43% | 49% | 11% | 0% | 0% |
| | 12 | 13 | 3 | 0 | 0 |
| N3 | 43% | 49% | 11% | 0% | 0% |
| | 12 | 13 | 3 | 0 | 0 |
| N4 | 43% | 49% | 11% | 0% | 0% |
| | 12 | 13 | 3 | 0 | 0 |

**44. The NRS waypoint naming convention used in this study makes it more difficult to locate a NRS waypoint on the High Altitude Enroute Chart than it is to locat a conventionally named, five character waypoint.**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| N1 | 36% | 32% | 14% | 14% | 1% |
| | 10 | 9 | 4 | 4 | 1 |
| N2 | 39% | 29% | 14% | 7% | 11% |
| | 11 | 8 | 4 | 2 | 3 |
| N3 | 54% | 32% | 11% | 0% | 4% |
| | 15 | 9 | 3 | 0 | 1 |
| N4 | 43% | 36% | 18% | 0% | 4% |
| | 12 | 10 | 5 | 0 | 1 |

**45. Once I get used to them, I believe that NRS waypoints will be as easy to use in voice communicaton as convetionally named waypoints.**

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| N1 | 7% | 10% | 21% | 32% | 29% |
| | 2 | 3 | 6 | 9 | 8 |
| N2 | 0% | 14% | 7% | 50% | 29% |
| | 0 | 4 | 2 | 14 | 8 |
| N3 | 4% | 7% | 7% | 50% | 32% |
| | 1 | 2 | 2 | 14 | 9 |
| N4 | 4% | 4% | 7% | 57% | 29% |
| | 1 | 1 | 2 | 16 | 8 |

**46. If you have any other comments to make with regard to NRS waypoints or regarding this study please write them here.**

| |
|---|
| During this study, I found it easier to work with waypoints named for the states they were located in based on my current familiarity with state boundaries. If I was constantly using waypoints named for the center they were in, I would probably adapt to that as well, and this may be more useful in a world wide application. |
| Having the Center identifier present in the waypoint name is completely useless unless you know the Center region locations better than the US State locations. |
| Waypoints, in general, are difficult to use for navigation around weather. A single thunderstorm as depicted here would be easy to navigate using a waypoint. However, most situations require fluid deviations around multiple cells requiring somewhat frequent heading changes. Seldom, if ever, is an enroute chart used to find a waypoint for use in a deviation. Either the display or a waypoint further along on the flight plan might be used. Additionally, we may ask ATC for a shortcut or a waypoint from our flight plan ahead for a deviation. Navigating thunderstorms while simultaneously looking up waypoints on a map or even on a display would be an unnecessary distraction. As a pilot I would prefer that we be given a heading range to fly and not a specific point in space unless the storm was solitary in nature and a clear deviation would get us around it. |
| Will need to have a state map chart if using the waypoints with the state identifiers. Likewise will need a chart with the center identifiers for the N1 type waypoints. |
| The round of identifying NRS waypoints on the chart took longer than the other rounds; call it a warm up on chart reading maybe. I hope that the N2 nomenclature is not always presented first. If it is, than those particular results might be skewed. |
| NRS waypoints need better color or contrast to find on the chart in congested areas. |
| Very well done! |
| As long as the FMS has a visual depiction of NRS waypoints as it does conventional waypoints, I see no challenge to using this system. If a pilot must consult a chart every time a suitable fix must be found for a deviation, then the time required to do so my negate the advantage in this system. Due to the fixes being displayed on the moving map in this simulation, this was not an issue. Of course, this is also the case with traditional waypoints if they are not shown on the moving map display. |
| Nice Study… thanks for allowing pilot input!! |
| I believe NRS waypoints could make communications much easier between pilots and controllers and provide for much more flexibility in the airspace system. |

## APPENDIX 8

## Results of Wilcoxon Statistical Analyses on Questionnaire Rank Ordered Data

### Rank Order NRS Waypoint Nomenclatures as to Ease of Use

*Results of the Friedman's ANOVA and Wilcoxon Post Hoc Tests*

| Test | Result |
|---|---|
| Friedman's ANOVA* | $X^2$ (3) = 33.53, $p < 0.01$ |
| Wilcoxon Post Hoc | |
| Configuration N1 vs. N2* | $z = -3.94$, $p < 0.01$, $r = -0.37$ |
| Configuration N1 vs. N3* | $z = -4.33$, $p < 0.01$, $r = -0.41$ |
| Configuration N1 vs. N4** | $z = -2.13$, $p < 0.05$, $r = -0.20$ |
| Configuration N2 vs. N3** | $z = -2.41$, $p < 0.05$, $r = -0.23$ |
| Configuration N2 vs. N4 | $z = -0.40$, $p = 0.69$, $r = -0.04$ |
| Configuration N3 vs. N4** | $z = -2.13$, $p < 0.05$, $r = -0.20$ |

* $p < 0.01$

** $p < 0.05$

### Rank Order NRS Waypoint Nomenclatures as to Provision of Geographic Awareness

*Results of the Friedman's ANOVA and Wilcoxon Post Hoc Tests*

| Test | Result |
|---|---|
| Friedman's ANOVA* | $X^2$ (3) = 33.22, $p < 0.01$ |
| Wilcoxon Post Hoc | |
| Configuration N1 vs. N2* | $z = -3.85$, $p < 0.01$, $r = -0.36$ |
| Configuration N1 vs. N3* | $z = -4.13$, $p < 0.01$, $r = -0.39$ |
| Configuration N1 vs. N4* | $z = -3.74$, $p < 0.01$, $r = -0.35$ |
| Configuration N2 vs. N3 | $z = -1.57$, $p = 0.12$, $r = -0.15$ |
| Configuration N2 vs. N4 | $z = -0.55$, $p = 0.58$, $r = -0.05$ |
| Configuration N3 vs. N4 | $z = -1.94$, $p = 0.05$, $r = -0.18$ |

* $p < 0.01$