MIT AERONAUTICAL SYSTEMS LABORATORY

AN EXPERIMENTAL STUDY OF THE EFFECTS OF AUTOMATION ON PILOT SITUATIONAL AWARENESS IN THE DATALINK ATC ENVIRONMENT

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ABSTRACT

An experiment to study how automation, when used in conjunction with datalink for the delivery of ATC clearance amendments, affects the situational awareness of aircrews was conducted. The study was focused on the relationship of situational awareness to automated Flight Management System (FMS) programming and the readback of ATC clearances. Situational awareness was tested by issuing nominally unacceptable ATC clearances and measuring whether the error was detected by the subject pilots. The experiment also varied the mode of clearance delivery: Verbal, Textual, and Graphical. The error detection performance and pilot preference results indicate that the automated programming of the FMS may be superior to manual programming. It is believed that automated FMS programming may relieve some of the cognitive load, allowing pilots to concentrate on the strategic implications of a clearance amendment. Also, readback appears to have value, but the small sample size precludes a definite conclusion. Furthermore, because textual and graphical modes of delivery offer different but complementary advantages for cognitive processing, a combination of these modes of delivery may be advantageous in a datalink presentation.

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1 INTRODUCTION

The Federal Aviation Administration (FAA) has mandated the use of digital ground-to-air datalink for Air Traffic Control (ATC) services in the mid-1990's timeframe. Possible benefits of datalink include reducing voice congestion and information transfer errors associated with VHF radio communications. In addition, studies have shown that datalink has other potential benefits, such as providing an independent reference of the aircraft clearance [1, 2]. However, there is some concern that datalink, especially when combined with automation, may actually decrease the crew's level of situational awareness [3].

The Aeronautical Systems Laboratory of the Massachusetts Institute of Technology became involved in the investigation of the possible benefits of datalink delivery of ATC clearance amendments in 1989 [4, 5]. In an initial study, datalink combined with automation was found to provide a significant decrease in the time needed by the subject pilots to process ATC clearances. However, one of the side effects of the most automated case was a possible degradation of the subjects' situational awareness as indicated by the ability to detect nominally unacceptable clearances. This thesis document describes the further investigation of the effects of automation on situational awareness when combined with datalink delivery of ATC clearance amendments.

Chapter 2 provides background information about datalink transmission of ATC messages and automation. Chapter 3 explains the factors manipulated and data measured in the experiment. Chapter 4 provides information about the test facilities, procedures, and scenarios. Chapter 5 discusses the performance results of the experiment, while Chapter 6 details the subjective information provided by the subject pilots. Chapter 7 identifies other research issues prompted by pilot comments during the execution of experiment. Chapter 8 summarizes the findings of the experiments and recommends further activities in the datalink transmission of ATC clearances.

2 BACKGROUND

2.1 DATALINK ATC CLEARANCES & SITUATIONAL AWARENESS

Datalink communication of ATC clearances is being developed by the FAA to alleviate voice congestion of VHF communication frequencies, as well as to reduce potential transmission errors in the delivery of clearance amendment information to aircraft. Voice congestion would be reduced through datalink's selective addressing feature, which imparts to a particular aircraft only information which is specifically intended for that aircraft. Additionally, because the datalink system could transmit clearance information in a digital form, potential sources of confusion in ATC-to-aircraft communications, such as transcription errors, could be eliminated.

Past studies have shown that pilots are receptive to the judicious use of datalink for the delivery of ATC messages [1, 2, 4, 5, 6]. Waller and Lohr conducted an simulation study in 1989 using datalink transmission of ATC messages which concluded, "both the pilot and copilot favored ... datalink operations for routine ATC message exchange." In addition, experienced pilots found that the use of datalink decreased workload [2]. Other studies have found that a substantial reduction in operational errors was potentially achievable with datalink [1, 6].

Along with reducing voice traffic and communications errors, another possible benefit of datalink transmission of ATC clearances is that, because digital information is easily stored and recalled, an independent record of aircraft clearance amendments could be implemented in the flight deck. Anecdotes about aircrews occasionally "mishearing" clearance amendment information are not uncommon [7, 10]. A record keeping capability, which datalink avionics could easily provide, would reduce potential safety hazards resulting from erroneous clearance interpretation.

Furthermore, the FAA and the National Aeronautics and Space Administration (NASA) are studying systems which would automatically gate clearance amendment information into the onboard Flight Management System (FMS). Knox and Scanlon conducted a series of flight tests at NASA/Langley Research Center in 1990 designed to validate the concept of automated loading of clearance data into the aircraft FMS. Among the possible benefits cited with automated datalink was that, "the capability of transferring ATC tactical and strategic information into the FMS ... with a single button push, at the pilot's discretion, was a significant work saver." [1]

While all proposed datalink systems would require pilot authorization before an aircraft would automatically execute a new clearance, there is some concern that pilots could become less involved in the clearance amendment processing loop and therefore may not be fully aware of the consequences of new amendments. Figure 2.1 shows the ATC-to-aircraft communications loop, which currently requires all clearance information to be processed by the crew. However, automation of datalink may inadvertently exclude the crew from the loop because they would assume a supervisory rather than participatory role in clearance communication.

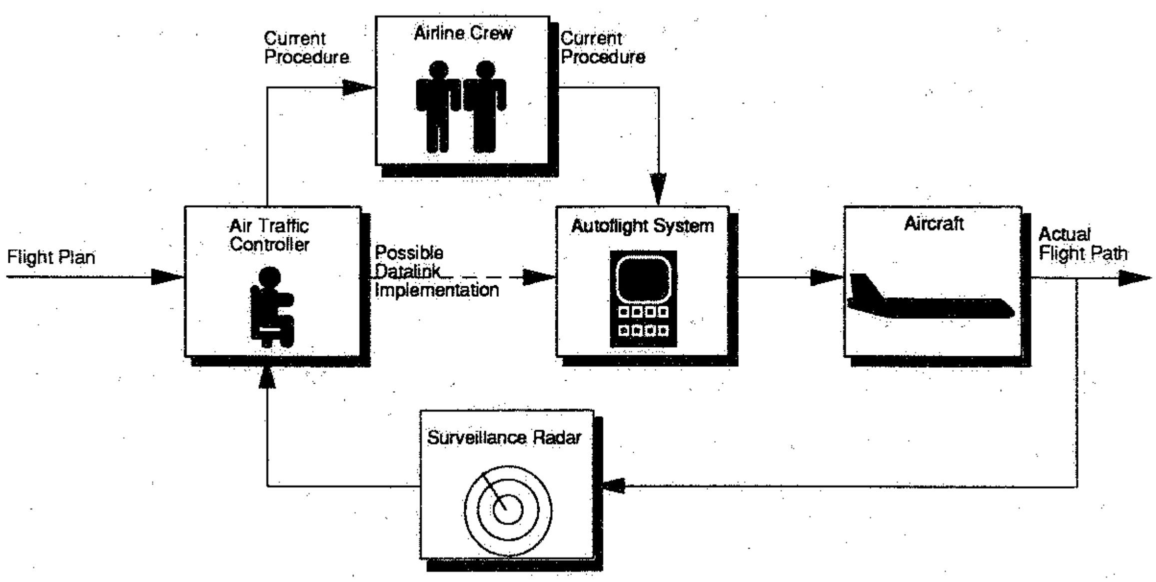

FIGURE 2.1. THE ATC-TO-AIRCRAFT COMMUNICATIONS LOOP

2.2 PRIOR EXPERIMENTS ON DATALINK SITUATIONAL AWARENESS

Prior simulation studies and flight tests have mainly concentrated on differences in pilot response times and message transaction frequency between voice and datalink. Unfortunately, there have been few studies concentrating on crew situational awareness in the datalink environment, and the information on situational awareness in datalink experiments has been largely anecdotal [1, 2, 6].

An experiment which included detection of flawed ATC clearances as a measure of situational awareness was performed by Chandra [4, 5], and was used as a foundation for this study. This experiment, in which six transport pilots participated, focused on the effect of automation on the time required by the subject pilot to process clearance amendments, with workload and situational awareness as secondary measurements. Three levels of automation were used in conjunction with three clearance delivery presentation modes as the independent variables. These were: verbal (voice), textual (alphanumerics), and graphical (pictorial). Each delivery mode had a distinct, fixed procedure associated with it.

A total of 60 erroneous clearances were issued by ATC. The data indicated that, while automation and lack of a readback significantly reduced processing time, these factors may have been detrimental to error detection performance (Figure 2.2). However, the experiment was unable to substantiate any trends between automation, readback, and situational awareness because the number of tests was insufficient for statistical significance. In addition, because the factors of automation level and presentation mode were not independently varied, the results were confounded.

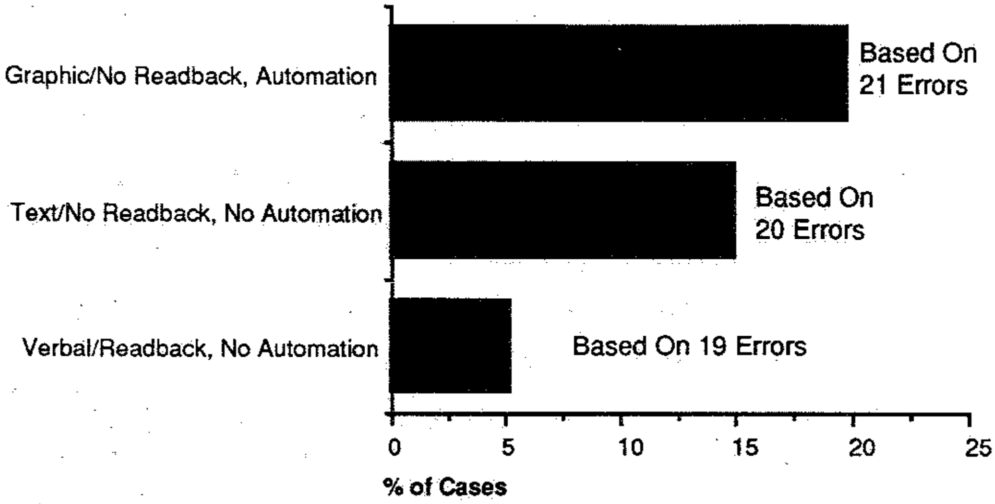

FIGURE 2.2. UNDETECTED CLEARANCE ERRORS – RESULTS FROM A PRIOR SIMULATION STUDY CONDUCTED BY CHANDRA (REFORMATTED FROM [5], WITH PERMISSION OF THE AUTHOR)

3 EXPERIMENTAL METHOD

3.1 OVERVIEW

Because of the possible conflict between automation and situational awareness in the Chandra experiment, a more direct investigation of the effect of automation on the datalink delivery of ATC clearances was undertaken. A simulation study using active airline pilots as subjects was designed. The experiment measured situational awareness as indicated by the ability of the pilot to detect erroneous ATC clearances. The study varied procedural elements, modes of delivery, and type of error.

The general testing protocol was: the subject was presented with nominally unacceptable ATC clearances intermixed with a series of acceptable clearance amendments while in the descent phase of operations. The ability of the pilot to recognize the errors was recorded as the dependent variable[1]. Additionally, subjective ratings and comments by the subjects were collected. The independent variables in the experiment were chosen to modify the number and type of mental review of the clearance. This was accomplished by specifying whether or not the pilot needed to program the clearance into the FMS and whether or not the clearance procedure required a readback to ATC. Furthermore, the mode of clearance delivery to the pilot was varied among verbal, textual, and graphical.

3.2 DEPENDENT MEASURES

The primary measure of situational awareness was the subject's ability to detect the erroneous clearances. The baseline clearance amendment procedure was modeled as three steps: 1) the pilot receives the amendment. 2) The pilot reads the information back to

[1]The testing protocol incorporated the original idea that the pilot's situational awareness was proportional to the number of cognitive reviews of the information that he accomplishes in the course of processing an amendment. Initially, there was an expectation that the number of reviews was more important than type of review. However, in the course of the experiment it became apparent that type of review was more important than the simple number of reviews.

ATC. 3) The pilot programs the FMS. Some errors were detected immediately, others were detected only after some additional review, and the remainder were never detected. Thus, three scoring divisions were used: initially, finally, and never detected. The aggregate percentages of error detection performance in each division were used as the figures-of-merit to describe the overall level of situational awareness.

Each nominally unacceptable clearance amendment, or "error", was scored as an **initial** detection if the subject rejected the clearance before either performing a readback or programming the FMS (i.e. immediately upon the initial review of the information). If the subject initially accepted the clearance, read the clearance back to ATC, and/or accomplished FMS programming, but later rejected the clearance amendment, the error was scored as a **final** detection. Lastly, if the pilot never indicated awareness that the clearance was unacceptable, the error was scored as **never** detected. It should be noted that scenario continuity required the delivery of a new clearance after a predetermined time interval. Thus, the performance may be uniformly biased toward never detected.

In addition to detection performance of the unacceptable clearance amendments, pilots were asked during the experiment to give subjective evaluation scores to the various procedures and presentation modes. Between each scenario, subjects were given the opportunity to rate each combination of delivery mode and procedure in terms of overall effectiveness, time efficiency, and situational awareness. They were also asked to comment about aspects which they desired or disliked about the delivery mode, combination of readback and method of FMS programming, and scenario. The ratings were based on a seven point scale, with a "1" rating signifying an "unsafe" delivery mode and/or procedure. A "4" denoted a rating comparable to current ATC clearance amendment procedures, and a "7" rating meant the pilot thought the mode and procedure were an optimum combination.

At the conclusion of the experiment, subjects were also asked to both rank order and assign a numerical rating to the procedures and delivery modes. The subjects were asked to rate each from 1 (lowest) to 10 (highest) for each. In addition, subjects were asked to make general comments about the simulation and bring up issues which they felt were important to datalink.

3.3 INDEPENDENT VARIABLES

3.3.1 AMENDMENT PROCEDURE

The procedural requirements for readback and automated FMS programming were changed between scenarios to yield differing types and numbers of review. This yielded four procedures with varying levels of review, as summarized in Table 3.1. It should be noted that procedure number 4 is essentially the current procedure used by air crews in normal operations, and procedure 3 (no readback / manual programming) was only tested for the verbal mode because of experimental time constraints.

TABLE 3.1: SUMMARY OF PROCEDURES USED IN THE EXPERIMENT

Name	Readback?	Manual FMS?	Procedure Summary	# of Reviews
Procedure 1	No	No	No Readback / Automated FMS Programming	1
Procedure 2	Yes	No	Readback / Automated FMS Programming	2
Procedure 3	No	Yes	No Readback / Manual FMS Programming	2
Procedure 4 (current procedure)	Yes	Yes	Readback / Manual FMS Programming	3

Manual FMS programming necessitated detailed interaction with the clearance amendment information, as it required the pilot to type all of the specific clearance information elements (such as intersection names or crossing restriction altitudes) into the aircraft FMS via the keyboard. In contrast, readback was a simpler procedural requirement: pilots simply repeated the clearance back to ATC by voice. Thus, manual FMS programming and readback were expected to require different types of mental processing on the part of the subject. In this way, the effect of different kinds of cognitive review were included in the test plan.

3.3.2 MODE OF DELIVERY

The other independent variable was delivery mode, or how the information was displayed to the pilot. The modes evaluated included verbal, textual, and graphical.

The verbal mode was used as a baseline and was identical to the current VHF radio procedure. However, the simulation did not include any message transactions between other aircraft on the frequency and ATC. All controller messages conformed to the current ATC lexicon. An example of a verbal clearance is shown in Figure 3.1.

```
(SPOKEN) "Direct Hartford VOR, direct Boston VOR; after
Boston expect vectors to ILS Runway two-seven; cross
Boston at and maintain seven thousand and two-hundred te
knots"
```

FIGURE 3.1. EXAMPLE OF VERBAL CLEARANCE DELIVERY

Textual clearances were shown on a separate dedicated display. The messages were exact textual transcriptions of the corresponding verbal clearances, with additional text-specific features (these are detailed in Section 4.2). An example of a textual clearance is shown in Figure 3.2.

> direct HARTFORD (HFD), direct BOSTON (BOS); after BOSTON expect vectors to ILS Runway 27; cross BOSTON at and maintain 7000 and 210 knots.

FIGURE 3.2. EXAMPLE OF TEXTUAL CLEARANCE DELIVERY

The graphical mode depicted the assigned routing on the aircraft Electronic Horizontal Situation Indicator (EHSI). In addition, altitude and speed commands were displayed on the altimeter and airspeed indicator, respectively. Since graphical delivery distributed clearance information to several different flight displays, special care was taken to make the amendment appear distinct from the existing symbology. All clearance

amendment information was displayed in an alternating green/orange color at a rate of 1 Hz. (Additional graphical clearance implementation information is discussed in Section 4.2.) An example is shown in Figure 3.3.

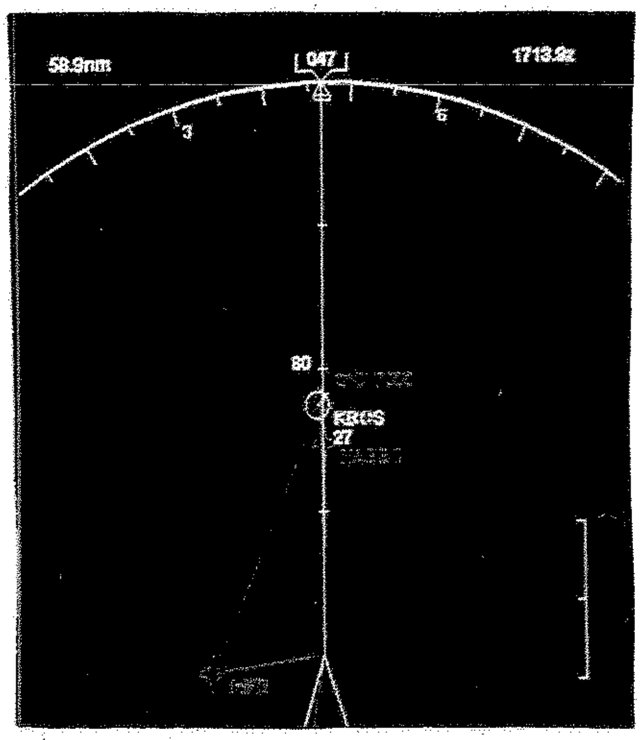

FIGURE 3.3. EXAMPLE OF GRAPHICAL CLEARANCE DELIVERY

3.3.3 TEST MATRIX

The resulting test matrix combined the four different procedures with the three modes of delivery (Table 3.2).

TABLE 3.2: EXPERIMENTAL TEST MATRIX				
	Auto Program / No Readback	Auto Program / Readback	Manual Program / No Readback	Manual Program / Readback (current procedure)
Verbal	●	●	●	●
Textual	●	●		●
Graphical	●	●		●

4 EXPERIMENTAL PROTOCOL

4.1 FACILITIES [8]

The experiment was conducted using the MIT Aeronautical Systems Laboratory (ASL) Advanced Cockpit Simulator (Figure 4.1). The simulator facility was used to provide pilots with an environment consistent with flight operations in modern transport aircraft.

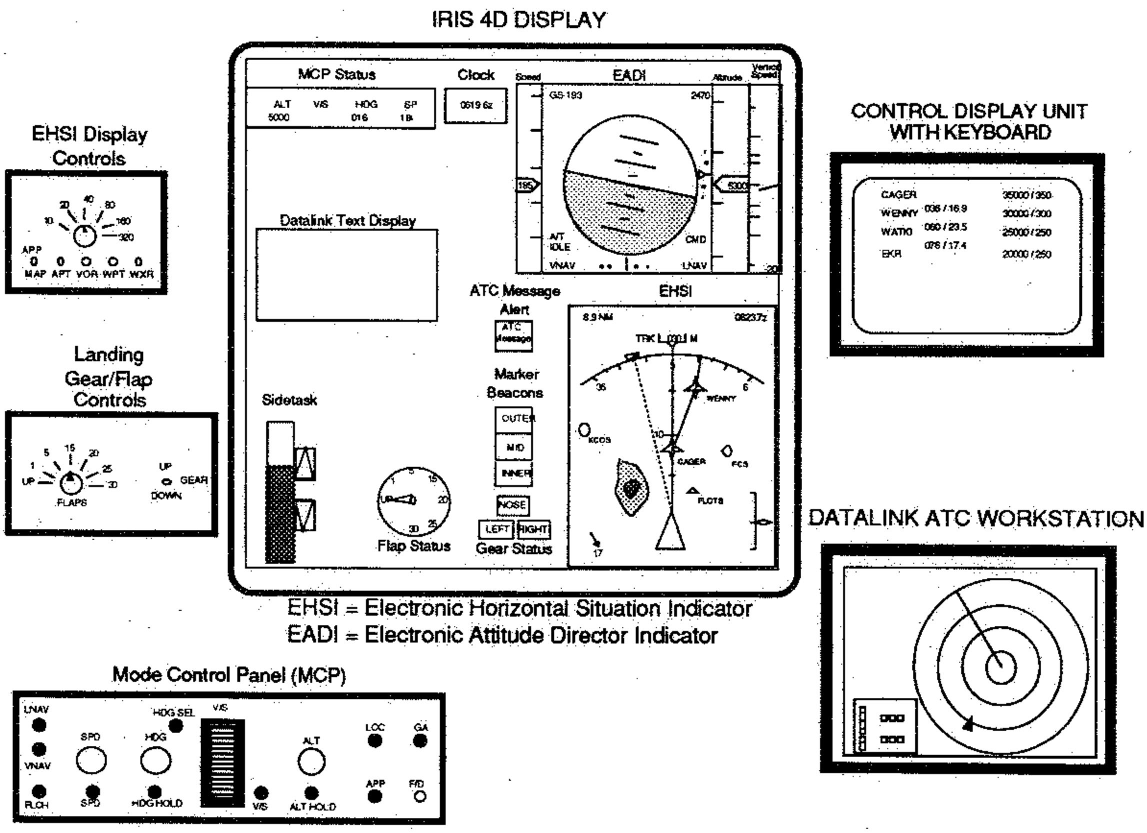

FIGURE 4.1. THE MIT ADVANCED COCKPIT SIMULATOR

The MIT facility is a part-task simulator based on Boeing 757 / 767 and 747-400 flight displays. The facility utilizes three computers and several control panels to emulate the autoflight systems, and was developed over a 3 year period by a number of graduate and undergraduate students.

A Silicon Graphics Personal IRIS 4D/25GT was used to simulate the aircraft dynamics and present the primary flight displays. Airspeed, altitude, and vertical speed were indicated using tape displays similar to those found on the 747-400. An Attitude Director Indicator (ADI) was provided, and was used to display the artificial horizon, ground speed, radio altitude, and Instrument Landing System (ILS) localizer and glideslope deviations.

As shown in Figure 4.1, the Electronic Horizontal Situation Indicator (EHSI) was located below the ADI, as in the 757 or 767. The EHSI displayed the 757 / 767 map mode, including aircraft heading, ground track, programmed route, and weather radar reflectivity (WXR).

The simulator included a Flight Management System which was interfaced through an IBM PC-XT Control Display Unit (CDU). This device replicated the major path management functions available on the Boeing 757 / 767. This included adding, deleting, and modifying waypoints, setting crossing restrictions, and changing destinations and runways. As part of the datalink functionality, automated clearance amendment route loading was provided in the relevant scenarios. This allowed the subject to approve and execute a clearance amendment with two keystrokes. It should be understood that because the keyboard layout on the IBM is different from the layout on actual CDUs, there is probably some bias in the performance results for the manual programming cases.

Additional flight control inputs could be made using an emulation of the Boeing 757 / 767 Mode Control Panel (MCP). Modes were available to the pilot to command airspeed, altitude, heading, and vertical speed. The aircraft autopilot modes could be selected as well, including LNAV (automatic lateral flight path navigation) and VNAV (automatic vertical flight path navigation), altitude capture and hold, vertical speed, heading select and hold, and localizer and glideslope intercept.

An IRIS 2400T was used as a simple datalink Air Traffic Control workstation. Its primary functions were to allow a remote researcher to monitor the flight progress made by the experimental subject, and to transmit datalink messages to the aircraft simulator. A mouse-based graphical user interface provided the ability to select and deselect navigational information, to determine the aircraft location relative to a scenario reference point, and, as illustrated in Figure 4.2, to select and specify content and format of the scripted datalink messages. It should be noted that this display was not intended to reproduce any actual or proposed advanced ATC workstation.

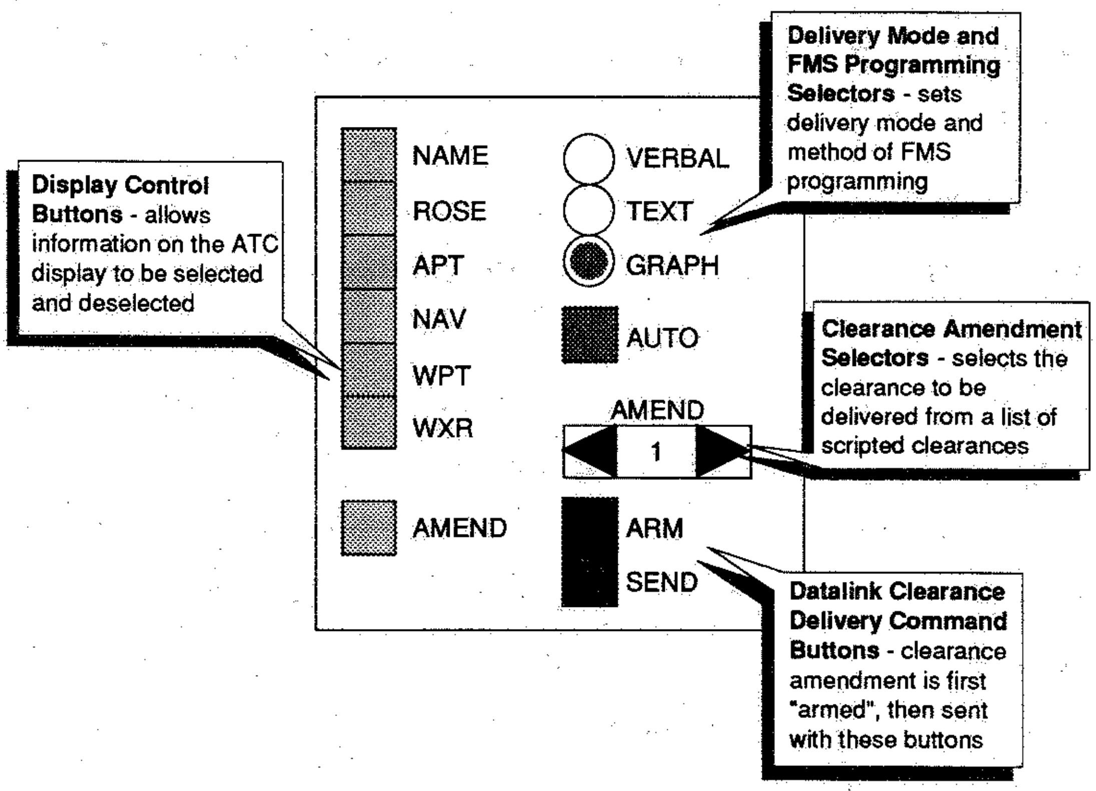

FIGURE 4.2. THE DATALINK ATC WORKSTATION CONTROL PANEL

Global scenario parameters such as mode of delivery and automated FMS programming were generally set by the controller at the beginning of a scenario. During a typical datalink clearance amendment sequence, the controller monitored the subject aircraft until it reached a location predetermined by the scenario script. He then selected the appropriate preformatted scripted clearance using the "amendment selection" buttons. The selected clearance amendment appeared on the map display for verification with the scenario script. The controller then armed the datalink system by activating the "arm" button, and sent the amendment via the "send" button. The controller then monitored the voice channel for a readback (if required by the scenario). If the scripted clearance amendment was designed to be nominally unacceptable, the controller could choose the appropriate ATC correcting action by sending a new clearance, thus repeating the above steps.

4.2 DATALINK CLEARANCE DELIVERY IMPLEMENTATION

Color reproductions of the figures in this section can be found in Appendix E.

4.2.1 TEXTUAL DELIVERY MODE IMPLEMENTATION

The dedicated textual display exhibited the clearance information using a white, 14-point Helvetica Bold typeface on a black background for maximum contrast. The format used in the implementation of textual clearance delivery was a transcription of the current ATC voice lexicon, with some additional enhancements.

All numerical data was written in digital, rather than textual, form (eg. "3500", not "three-thousand, five hundred"). Navigational aids and intersections were emphasized by presentation in capital letters to distinguish them from procedural phraseology. Furthermore, a navigational aid which was part of the clearance routing included its identifier placed in parenthesis after the identifier name. An example of a textual clearance amendment is shown in Figure 4.3.

direct HARTFORD (HFD), direct BOSTON (BOS); after BOSTON expect vectors to ILS Runway 27; cross BOSTON at and maintain 7000 and 210 knots.

FIGURE 4.3. EXAMPLE OF TEXTUAL CLEARANCE DELIVERY

4.2.2 GRAPHICAL DELIVERY MODE IMPLEMENTATION

In the implementation of graphical clearance delivery, special care was taken to display the clearance amendment in a distinct format. All clearance amendment information, for example, was displayed in a green and orange color alternating at a rate of 1 Hz. While routing information of the EHSI in the clearance amendment used existing symbol shapes for waypoints and active route presentation, some information elements present in ATC clearances required the creation of new symbols. Crossing restrictions or runway changes appeared as superscripts to the associated waypoint or airport in the same format as the FMS display (Figure 4.4). Climb and descent commands or airspeed changes were shown on the altitude or airspeed tape displays with arrow symbols and the assigned altitude or airspeed (in the alternating green and orange color). An example of a descent to 14000 feet is shown in Figure 4.5. Heading vectors were given as arrows pointing horizontally in the direction of the turn, with the assigned heading displayed at the tip of the arrow. Simultaneously, a flashing heading "bug" also appeared on the Electronic Horizontal Situation Indicator (EHSI) highlighting the assigned heading (Figure 4.6).

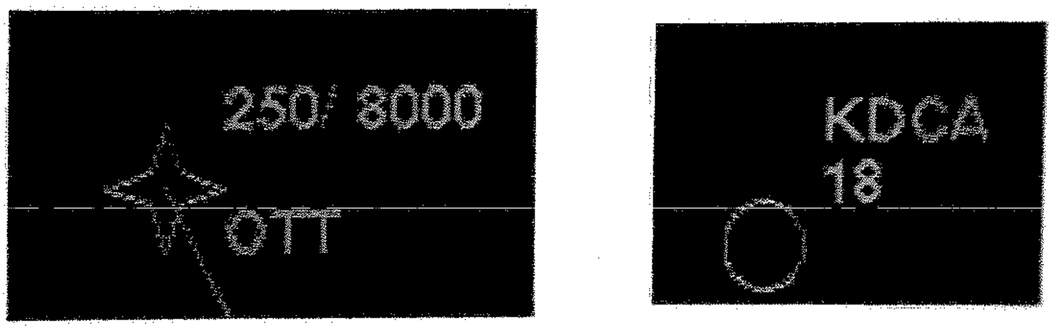

FIGURE 4.4. EXAMPLE OF A GRAPHICAL CROSSING RESTRICTION AND RUNWAY CHANGE

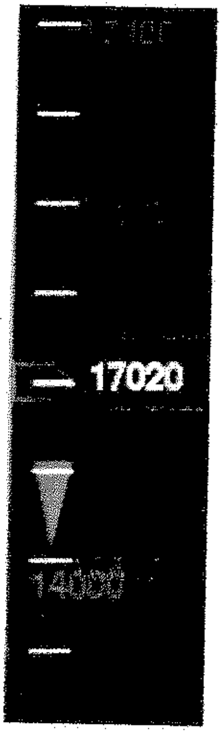

FIGURE 4.5. EXAMPLE OF A GRAPHICAL DESCENT TO 14000 FEET

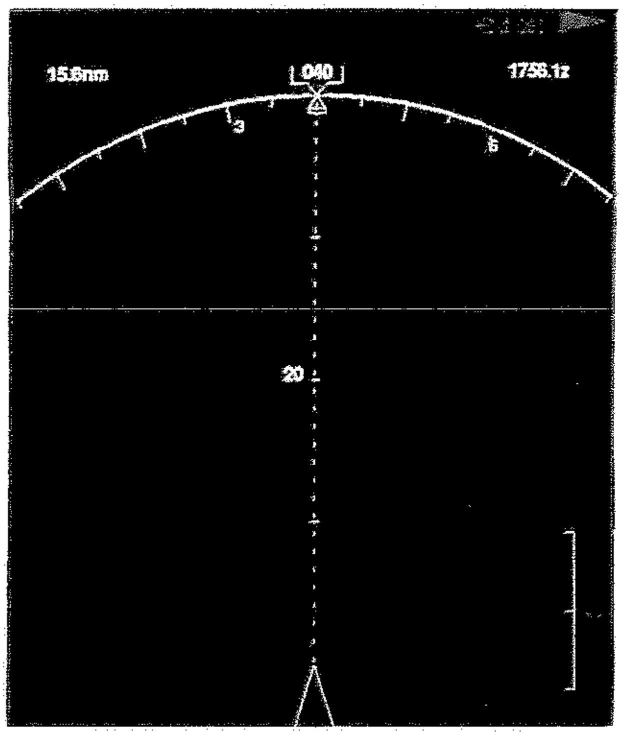

FIGURE 4.6. EXAMPLE OF A GRAPHICAL HEADING VECTOR

4.2.3 DISPLAY BEHAVIOR DURING A CLEARANCE AMENDMENT

In a typical clearance amendment sequence with graphical or textual delivery, the displays behaved in the following manner. When the clearance amendment was initially transmitted to the aircraft, a annunciation light turned on in the alternating green/orange color with the simultaneous playback of a digitized voice alert ("A-T-C Message"). On the simulator displays, the clearance amendment appeared with the appropriate text or symbology. The subject then read the clearance back to ATC if the procedure required a readback, and then pressed an "accept" or "reject" key to let ATC know his intentions. If the reject key was pressed, the clearance amendment annunciation light was extinguished and the displays were cleared of all clearance amendment information. However, if the subject accepted the amendment, the clearance text or symbology would remain lit until he specifically turned it off with a press of the "reset amendment" key. A second press of this key allowed the subject to recall the most recent clearance amendment as a record of the aircraft's present clearance.

4.3 Experimental Procedure

The experiment was a "within subject" design. Each subject flew the 10 scenarios required to fill the entire test matrix to control for differences between subjects. To ensure uniform notification, each amendment was annunciated using aural and visual alerts regardless of delivery mode or procedure. Each experimental run began during descent, approximately 120 nautical miles from the destination airport (thus requiring approximately twenty minutes to complete). The subject was provided with the appropriate charts and approach plates for the scenario destination. After each scenario, subjects were asked for comments on the preceding scenario. Prior to the following run, the subject was briefed on the next scenario (eg. destination, runway, ATIS (Automated Terminal Information Service)) and on the procedure which was to be used for the particular experimental run. A placard summarizing the procedure was put next to the simulator displays for reference. During the experiment, one researcher acted as the Pilot-Not-Flying (PNF), and another researcher acted as a controller at the datalink ATC control station.

4.4 Scenarios

The scenarios involved flights within the Northeast Corridor of the United States (i.e. the airspace between Washington DC, New York City, and Boston), with heavy traffic and weather in the entire region. Each scenario included a total of five clearance amendments, of which two were nominally unacceptable (i.e. an "error"). One error in each experimental run involved a clearance into weather, while the other was related to routing. During unacceptable routing clearances, pilots were given one of the following types of errors: 1) clearance to an incorrect initial fix to an approach for landing, 2) clearance to an incorrect destination, or 3) an illogical routing which headed the aircraft in a direction opposite to the intended flight path.

Twelve simulator scenarios were developed, including four scenarios with each type of routing error. In this way, the order of scenario presentation between subjects could be altered to control for learning effects. Care was taken in the design so that scenarios with the same type of routing error had equivalent difficulty while simultaneously ensuring that it maintained fidelity with the current ATC environment. Scenarios which included incorrect approach fix errors were classified as Type A scenarios. Type B scenarios contained an illogical routing error. Incorrect destination errors defined Type C scenarios, and all twelve scenarios are summarized in Table 4.1.

TABLE 4.1: SCENARIO SUMMARY

Type	Routing Error Type	Destination	Code (Appendix A&C)
A	Incorrect Approach Fix	Boston / Logan Int'l	Boston A (a.bos)
A	Incorrect Approach Fix	Baltimore-Washington Int'l	BWI A (a.bwi)
A	Incorrect Approach Fix	New York / LaGuardia	LaGuardia A (a.lga)
A	Incorrect Approach Fix	New York / Kennedy Int'l	Kennedy A (a.jfk)
B	Illogical Routing	Boston / Logan Int'l	Boston B (b.bos)
B	Illogical Routing	Washington National	National B (b.dca)
B	Illogical Routing	Newark Int'l	Newark B (b.ewr)
B	Illogical Routing	Philadelphia Int'l	Philadelphia B (b.phl)
C	Destination Error	Hartford / Bradley Int'l	Bradley C (c.bdl)
C	Destination Error	Washington National	National C (c.dca)
C	Destination Error	New York / LaGuardia	LaGuardia C (c.lga)
C	Destination Error	Philadelphia Int'l	Philadelphia C (c.phl)

4.4.1 WEATHER ERRORS

In weather errors, pilots were routed into regions of precipitation, indicated as "yellow" or "red" reflectivity levels on the EHSI weather radar display. Flight crews normally attempt to avoid high reflectivity areas because of turbulence, rain, lightning, and icing. In the example scenario shown in Figure 4.7, an aircraft was initially proceeding, "`direct Providence VOR, direct Boston VOR, expect vectors for ILS runway 4R`" at Boston / Logan International Airport. ATC rerouted the aircraft: "`direct DRUNK intersection, direct TONNI intersection, expect vectors to ILS Runway 27`". This clearance would normally be considered unacceptable because the amendment routes the aircraft through a line of thunderstorms.

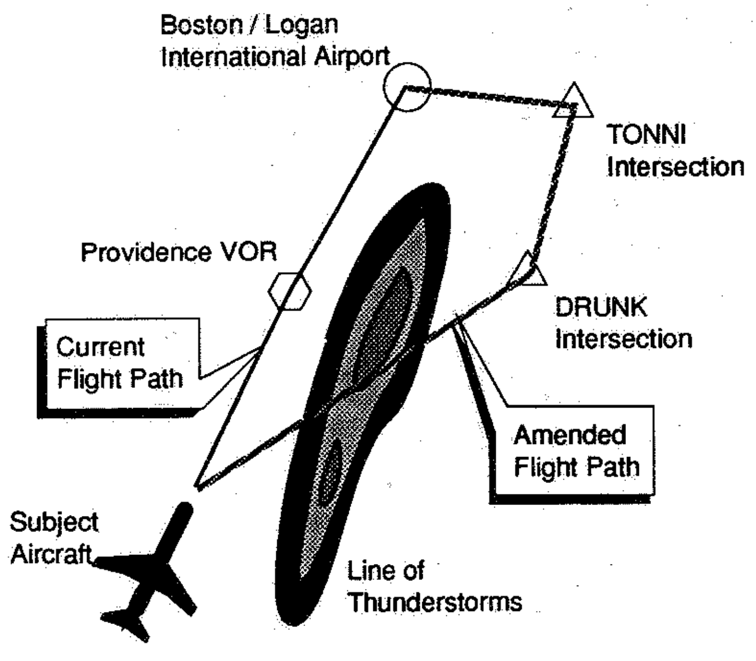

FIGURE 4.7. EXAMPLE CLEARANCE ROUTING INTO WEATHER
NOT TO SCALE

4.4.2 INCORRECT APPROACH FIX ERRORS

Inappropriate approach fix errors were characterized by the aircraft being cleared to an initial approach fix for one approach while simultaneously being cleared by ATC for a different approach. Thus, a discontinuity was created in the flight path between the last waypoint and the specified approach path. For example, in Figure 4.8, an aircraft was proceeding: "`direct RUETT intersection, expect vectors for the ILS Runway 33L approach`" at Baltimore-Washington International Airport. ATC then cleared the aircraft: "`direct BALTO intersection, ... cleared for the ILS Runway 33 Left approach`". Since BALTO intersection is on the approach for runway 28 (and not runway 33L, where the corresponding fix is RUETT), a discontinuity in the path is created, and therefore the clearance is unacceptable.

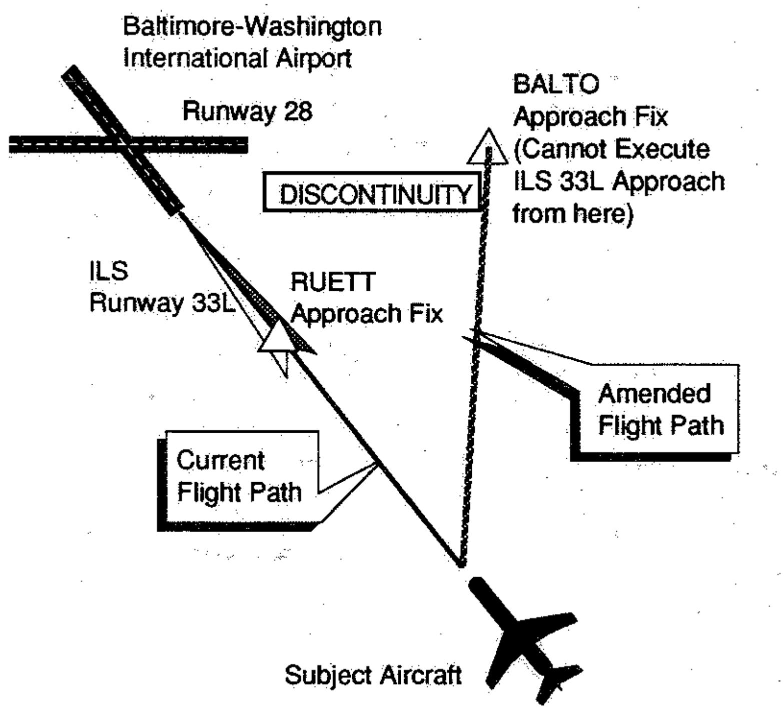

FIGURE 4.8. EXAMPLE INCORRECT APPROACH FIX ERROR
NOT TO SCALE

4.4.3 INCORRECT DESTINATION ERRORS

Erroneous clearances to an incorrect destination were always given as an "expect vectors" clearance to a runway number which did not exist at the intended destination, but which did exist at a nearby airport. For example in Figure 4.9, a pilot was enroute to Washington National Airport via: "`direct Lancaster VOR, expect vectors for River Visual Runway 18 approach`". The flight was then instructed (erroneously) to proceed to Harrisburg, Pennsylvania by the following clearance: "`direct LANCASTER VOR, direct BAARN intersection; after BAARN expect vectors to ILS runway 13`". Since Washington National has no runway 13, there is an unambiguous error in the clearance.

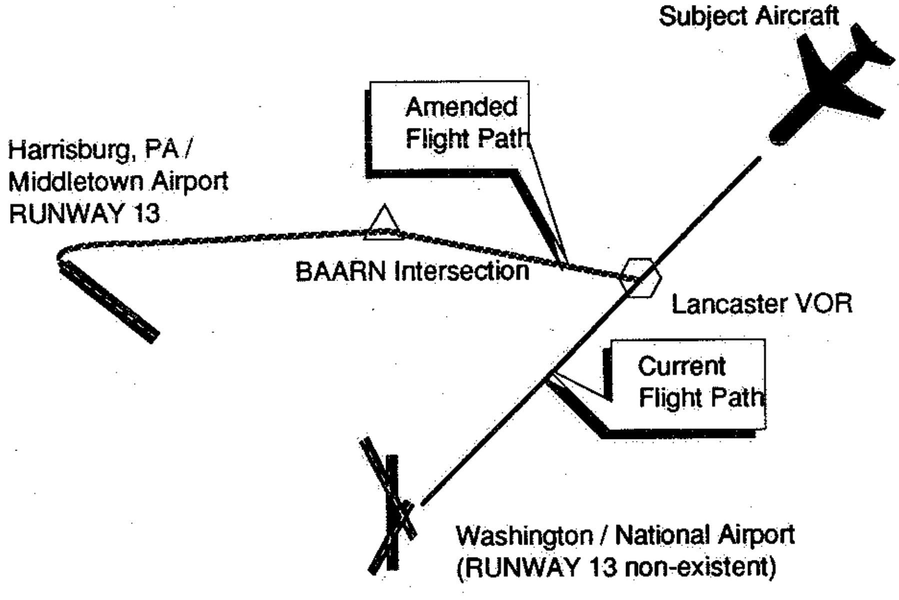

FIGURE 4.9. EXAMPLE INCORRECT DESTINATION ERROR
NOT TO SCALE

4.4.4 ILLOGICAL ROUTING ERRORS

Illogical routings were characterized by the aircraft being cleared to a point inconsistent with the direction to the airport and the current route of flight. For example, in Figure 4.10, a subject was enroute to Boston via: "`direct Putnam VOR, direct Boston VOR`". ATC then instructed him to proceed "`direct Hartford VOR, direct Boston VOR; after Boston expect vectors to ILS runway 27...`" when aircraft was approaching the Putnam VOR. In the course of the experiment, it became clear that this kind of routing error is ambiguous. Whereas the other types of errors were clearly erroneous, pilots are often given apparently illogical vectors for sequencing and spacing in busy terminal areas. One pilot even stated that, when flying into the New York Terminal Control Area, aircrews "expect anything" because of the complexity of the airspace. Because of this ambiguity, the data for the illogical routing errors was not included in the routing error analysis.

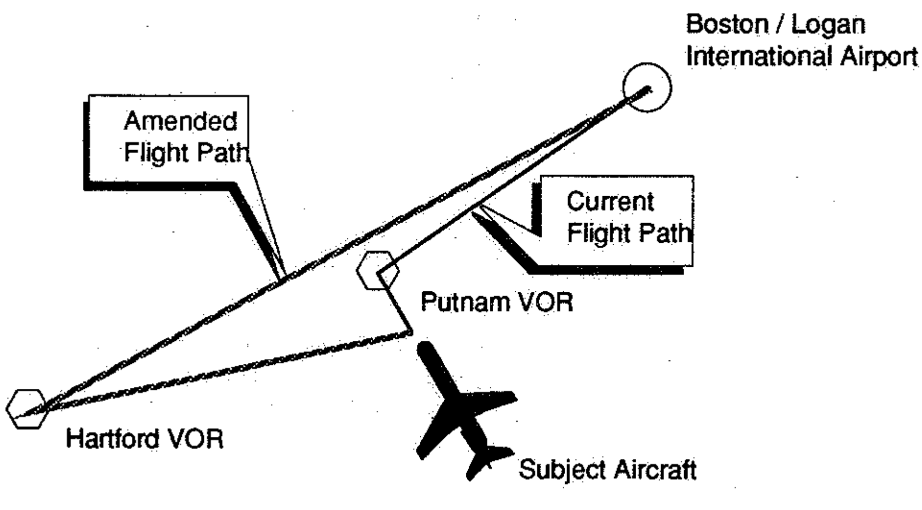

FIGURE 4.10. EXAMPLE ILLOGICAL ROUTING ERROR
NOT TO SCALE

4.4.5 EXAMPLE SCENARIO

An example of an actual scenario including an incorrect approach fix (LaGuardia A) is illustrated in this section. Other scenarios are documented in Appendix A.

Figure 4.11 shows the subject's aircraft was initially located over the Albany VOR at 18000 feet altitude, with a clearance to the New York / LaGuardia Airport via airway V157 – `Albany VOR to Kingston VOR to VALRE intersection to HAARP intersection to LaGuardia`. For the first amendment (which was acceptable), at the GROUP intersection, the subject was cleared "`direct Kingston VOR, direct LaGuardia VOR; after LaGuardia expect vectors for ILS Runway 22`". This clearance was acceptable; however, if the subject rejected it, he was allowed to fly on the previous clearance via V157 as it made no difference in the scenario.

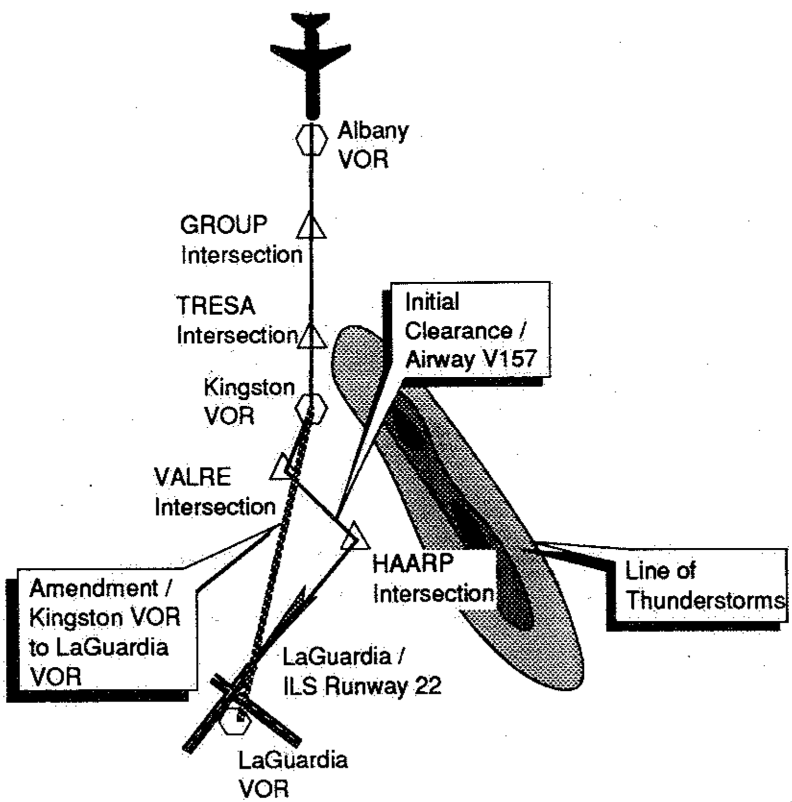

FIGURE 4.11. EXAMPLE SCENARIO – INITIAL CLEARANCE & FIRST CLEARANCE AMENDMENT
NOT TO SCALE

The second clearance amendment, a clearance into weather, was given when the aircraft was 15 miles north of TRESA intersection (Figure 4.12). The amendment was given because of a change in the active runway, and the subject was notified by a change in the ATIS broadcast.

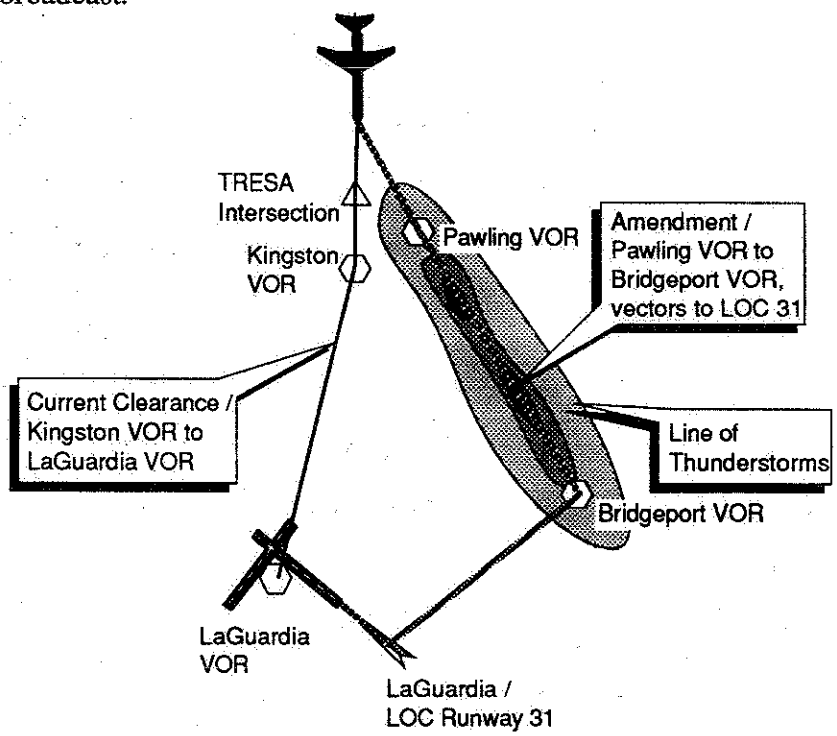

FIGURE 4.12. EXAMPLE SCENARIO – WEATHER ERROR
NOT TO SCALE

Here, the subject was cleared "`direct Pawling VOR, direct Bridgeport VOR, expect vectors for Localizer Runway 31.`" This routed his aircraft directly into a line of thunderstorms stretching over much of the assigned path, and thus was unacceptable. If the subject accepted the clearance, he was allowed to penetrate the thunderstorm cell, and then at Pawling VOR, was given an acceptable third clearance amendment which routed him (as shown in Figure 4.13) via "`direct Carmel VOR, direct Deer Park VOR; after Deer Park expect vectors to Localizer Runway 31; cross Deer Park at and maintain 5000 [foot altitude]; reduce speed`

`250 knots`". If the subject rejected the clearance, he was given essentially the same routing as above as his third amendment.

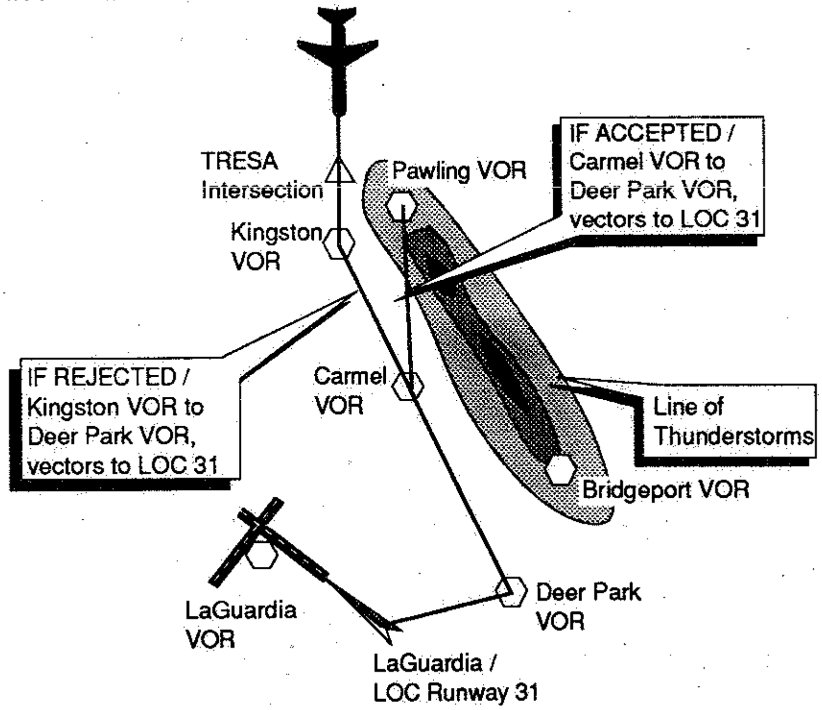

FIGURE 4.13. EXAMPLE SCENARIO – WEATHER ERROR RESOLUTION
NOT TO SCALE

The fourth clearance amendment, which contained an error, occurred when the aircraft ten miles north of the Deer Park VOR. The subject was cleared "`direct DIALS intersection; descend and maintain 2500 [foot altitude] until established on the localizer for Localizer Runway 31; cleared for the Localizer Runway 31 approach`" (Figure 4.14).

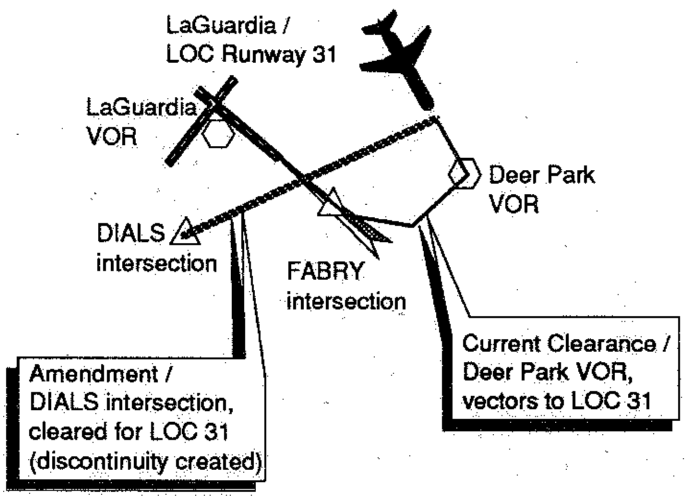

FIGURE 4.14. SCENARIO EXAMPLE – INCORRECT APPROACH FIX ERROR
NOT TO SCALE

The DIALS intersection was the initial approach fix for the Expressway Visual Approach to Runway 31 and was located to the southwest of the airport, well away from the extended centerline and Localizer approach for runway 31. Regardless of his reaction to the clearance, as shown in Figure 4.15, he was eventually rerouted via a fifth clearance amendment "`direct FABRY intersection ... cleared for the Localizer Runway 31 Approach,`" with an acceptable localizer intercept angle. The scenario terminated at the FABRY intersection.

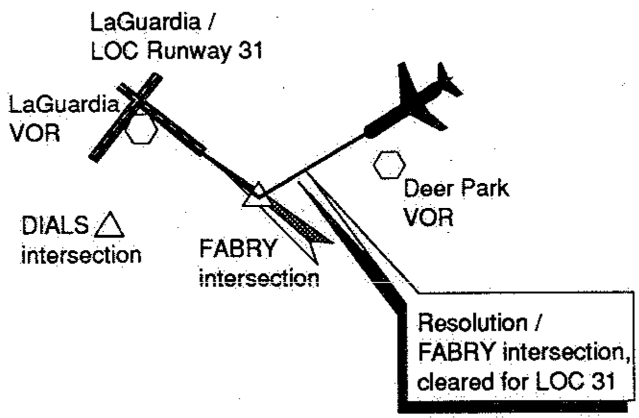

FIGURE 4.15. SCENARIO EXAMPLE – INCORRECT APPROACH FIX ERROR RESOLUTION
NOT TO SCALE

4.5 Data Collection and Scoring

The data was recorded on video tape, software files, and observations sheets. Each scenario run was recorded by an 8mm video camera, focused on the simulator displays which also recorded ATC and intracockpit voice communications. In addition, the MIT Advanced Cockpit Simulator stored flight data and FMS information in a software archive for later analysis. Finally, observation sheets taken during each run by the PNF noted the outcome of each error, along with pilot comments and subjective ratings. Appendix B contains a sample observation sheet.

The observation sheets were the primary data source for the analysis, while the video and software archives were used as secondary sources for ambiguous observations. Observation sheets detailed each nominally unacceptable clearance error and the error detection performance of the pilot as initially, finally, or never detected.

4.6 Ordering of Scenario Within and Between Subjects

Because the test matrix was not rectangular, a Latin square-like arrangement altering procedure, mode of delivery, and scenario type could not be designed. As a practical matter, all runs which used the same mode of delivery were run contiguously in a block.

For example, all verbal runs were accomplished, then all textual runs, and finally all graphical runs. To control for anticipatory effects, procedure and scenario were varied independently of each other so that sequential runs used different types of scenario. Finally, between subjects, the order in which the delivery mode blocks, scenarios, and procedures appeared was varied. Therefore, with the rotation scheme optimized for nine subjects, each element of the test matrix theoretically received three runs in each type of scenario, for a total of nine runs. Note that this yields 180 possible incorrect errors across all combinations of delivery modes and procedures (i.e. ten matrix elements, each with nine subject runs, with two unacceptable clearances per run).

In the course of running the experiment, however, simulator anomalies, subject deviations from the required procedure, and scheduling difficulties led to a total of 163 errors recorded. Of these, 83 were clearances into weather, and 80 were routing clearances. However, since the 28 illogical routing errors were ambiguous, the routing errors were analyzed on the basis of the remaining 52 clearances. Appendix C contains detailed information concerning delivery mode, procedure, and scenario rotation, as well as describing the data losses described above.

4.7 SUBJECT INFORMATION

Nine male volunteer subjects, who were B-757/767 qualified air transport line pilots, participated in the study from August to October, 1992. All were from the same airline, with an average of 2583 hours in "glass cockpit" aircraft. The Assistant Chief Pilot of the airline's local domicile and the Air Line Pilots Association were contacted for assistance in recruiting subjects. Participants were based in the Boston area, where they were contacted by phone, and were reimbursed for their travel to MIT. Information on their experience level is summarized in Table 4.2.

TABLE 4.2: SUBJECT EXPERIENCE SUMMARY

Average Age	48 Years
Average Total Flight Time	13338 Hours
Average "Glass Cockpit" Flight Time	2583 Hours
Flight Qualification	5 Captains / 4 First Officers

5 EXPERIMENTAL RESULTS

In order to evaluate the effect of delivery mode and procedure on situational awareness, it was first necessary to establish the overall ability of the subjects to detect the errors scripted into the scenarios. The difference in detection performance between weather and routing errors are presented in the first section. On the basis of these results, weather errors and routing errors were analyzed separately for delivery mode and procedure performance.

To reiterate, initial detection means that the pilot rejected the amendment before readback, FMS programming, or accepting the clearance. If the pilot rejected the clearance after accomplishing any of these, the error was scored as a final detection. Finally, if the pilot was never aware that the clearance was nominally unacceptable, then the error was scored as never detected. Performance was evaluated statistically using a Non-Parametric Pairing Test, with 95% significance in the difference in performance used as the minimum level of statistical significance (see Appendix D for details of this method).

5.1 WEATHER & ROUTING ERRORS

When examining pilot performance by type of error as shown in Figure 5.1, it was clear that weather errors were much more likely to be detected than routing errors. In the 83 clearances issued into weather, 96% were detected at some point during the amendment procedure. Comparatively, only 55% of routing errors were detected by the subject pilots. In addition, most weather errors were detected initially (i.e. immediately upon receipt of the clearance amendment) when compared with routing errors. Both of these findings are statistically significant at the 99% level.

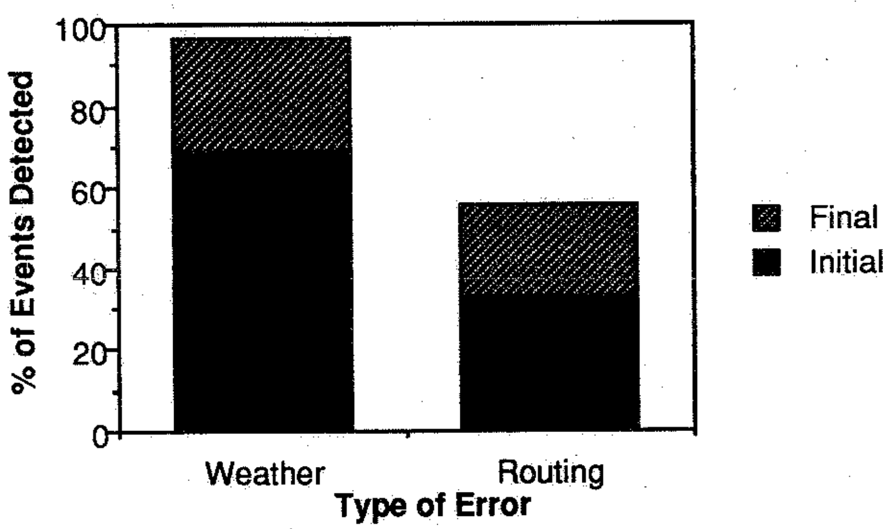

FIGURE 5.1. DETECTION OF WEATHER VS. ROUTING ERRORS

Based on the observations of the PNF, the subjects were aggressive in taking responsibility for weather separation. It may be that the simultaneous presentation of the weather radar reflectivity and navigation information on the EHSI enhanced the pilot's ability to maintain weather separation, as the pilot could visually monitor whether the amended clearance he had just processed would route the aircraft through weather.

Conversely, routing errors appear to have been more difficult to detect. This is possibly due to the fact that ATC often operates with routing or traffic constraints which are not apparent to individual aircrews. Furthermore, while thunderstorms are always a negative intrusion in an assigned clearance due to the possible degradation of safety, amended routings are a normal part of flight operations, and thus appear to be implicitly more subtle than weather errors. Because of the difference in detection performance, routing errors and weather errors were considered separately in the following analysis.

5.2 EFFECT OF DELIVERY MODE

5.2.1 DELIVERY MODE PERFORMANCE FOR ALL ERRORS

In Figure 5.2, the error detection performance for all the errors is analyzed by delivery mode: there appears to be a trend favoring graphical over the textual and verbal mode. Pilots were able to detect 91% of all unacceptable clearances in the graphical mode. This is compares with only 78% for textual and 76% for verbal delivery (however, statistical significance of this effect cannot be shown because of the relatively small number of errors given). A statistically significant finding, in contrast, was that the vast majority of errors in the graphical mode were detected on initial reception of the clearance amendment as compared with sometime later during the procedure.

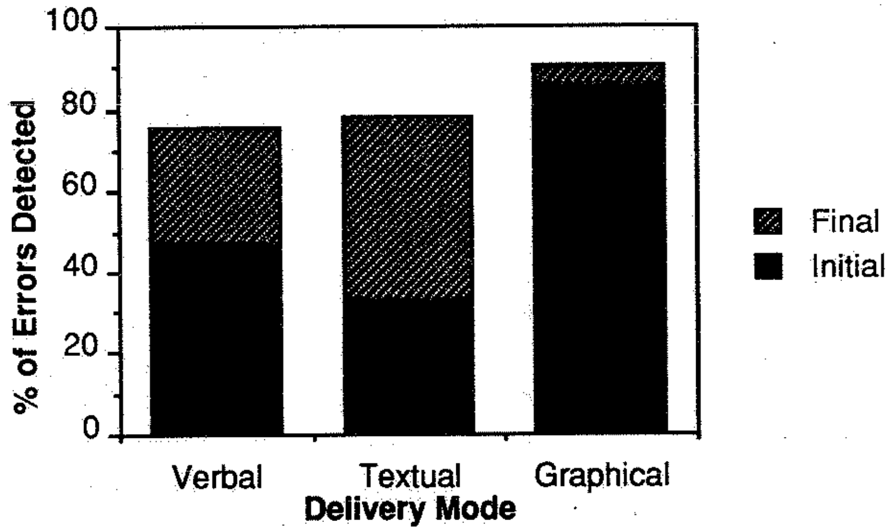

FIGURE 5.2. DETECTION OF ALL ERRORS BY DELIVERY MODE

5.2.2 Delivery Mode Performance For Weather Errors

Strikingly, the subjects were able to detect 100% of the erroneous weather clearances *immediately* upon reception of the amendment with the graphical mode of delivery (Figure 5.3). This compared to 52% and 56% for the textual and verbal modes of delivery, respectively. This performance advantage of the graphical mode was confirmed by statistical analysis. In other words, pilots were immediately able to detect clearances into weather only in about half the situations when using the non-graphical delivery modes. In the graphical mode, because the aircraft's amended route was shown directly on the combination EHSI/weather radar display, it is possible that the subjects were able to immediately recognize conflicts between amended routings and thunderstorm cells. (It should be reiterated that almost all weather errors were detected at some point during the amendment process regardless of delivery mode, with a total of only 3 missed detections out of 83 errors.)

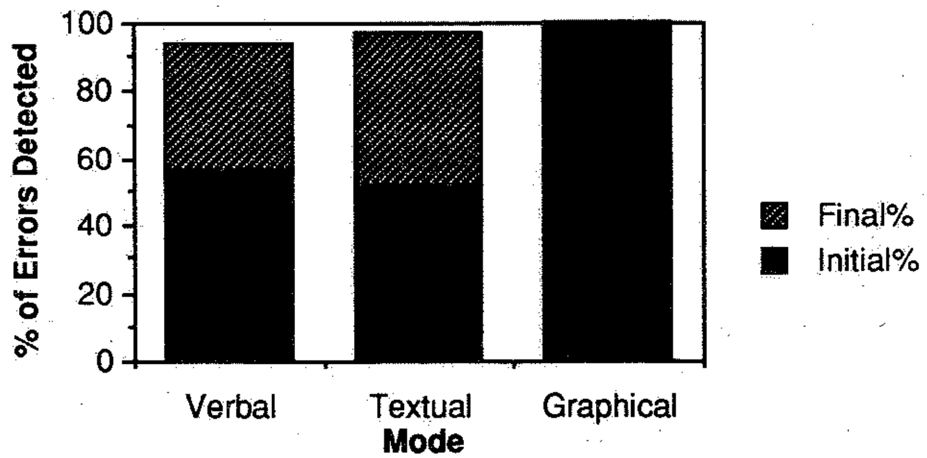

FIGURE 5.3. DETECTION OF WEATHER ERRORS BY DELIVERY MODE

5.2.3 DELIVERY MODE PERFORMANCE FOR ROUTING ERRORS

The graphical mode of delivery also appeared to have a slight advantage in the detection of unacceptable routing clearances as shown in Figure 5.4 (this result is significant when the graphical mode is compared with the verbal mode, but is not significant when graphical mode is compared with the textual mode because not enough data were collected). However, as in other cases, the graphical mode excelled in detections during the initial review of the information by the pilot; this result is statistically significant. A possible reason for this is that, because graphical clearances are displayed on the EHSI, they can be directly compared with the current routing.

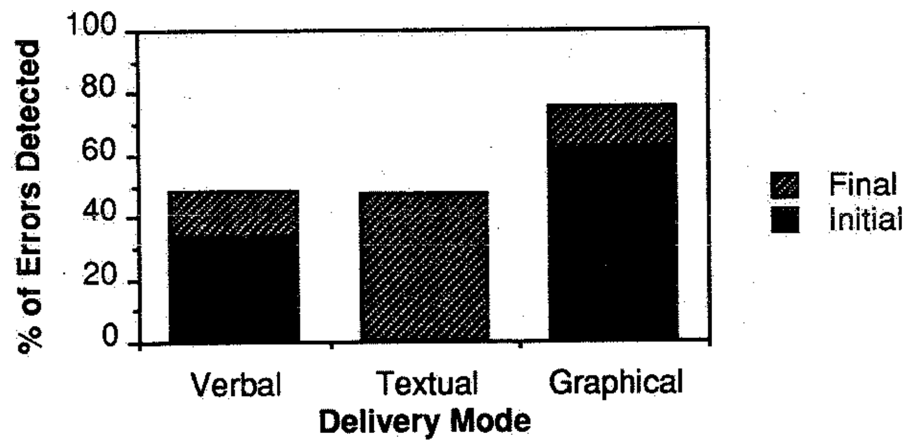

FIGURE 5.4. DETECTION OF ROUTING ERRORS BY DELIVERY MODE

5.2.4 DELIVERY MODE SUMMARY

In summary, the graphical mode appears to outperform both the verbal and textual modes of delivery in two areas. First, subjects appeared to detect a greater percentage of erroneous routing clearances with the graphical mode. Second, there is a strong indication that graphical presentation is useful in helping pilots detect errors more quickly than either of the other two modes. While the quickness in evaluating clearances with the graphical mode is not sufficient by itself to recommend graphical delivery, there may be some subjective benefit to the pilot if graphical delivery aids the timeliness of decision making. Thus, there appears to be a general basis for recommending graphical delivery of clearance amendments.

5.3 EFFECT OF PROCEDURE

Because of the construction of the test matrix, manual FMS programming without readback (procedure 3) cannot be statistically compared with the other procedures. It is included in the performance graphs for qualitative comparison only.

5.3.1 PROCEDURE PERFORMANCE FOR WEATHER ERRORS

Vectors into weather did not yield any statistically significant differences between the procedures because of the high detection rate (near 100%) for all procedures (Figure 5.5). Furthermore, initial detection of weather events also does not appear to change with procedure.

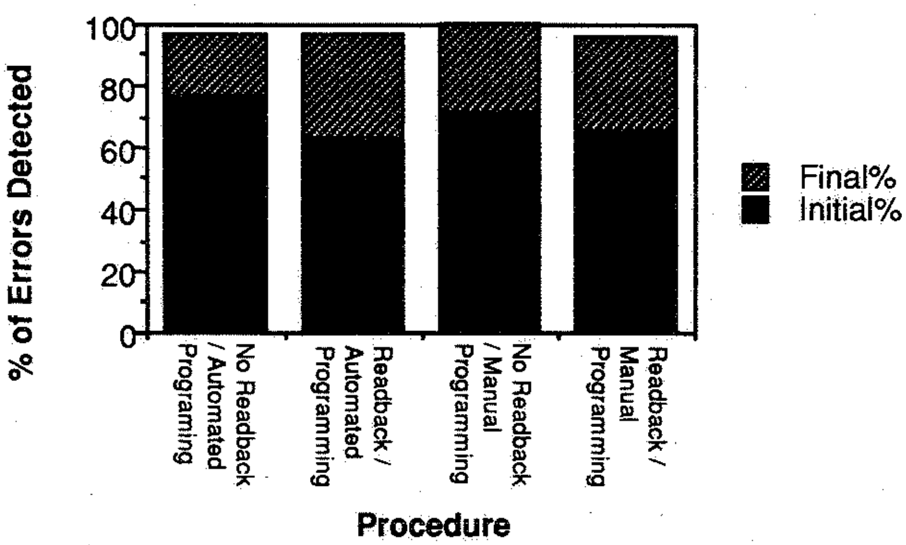

FIGURE 5.5. DETECTION OF WEATHER ERRORS BY PROCEDURE

5.3.2 PROCEDURE PERFORMANCE FOR ROUTING ERRORS

For the routing errors, it appears that the procedures with automated programming may have yielded better detection performance than those with manual programming (Figure 5.6). When the individual procedures are combined, automated FMS programming yielded an aggregate detection percentage of 64%, while the procedures with manual programming combined for only 42%. In contrast, the effect of readback was inconsistent, with readback appearing to help in the automated FMS programming cases and hinder when the FMS was manually programmed. (Insufficient data was collected to confirm these trends statistically).

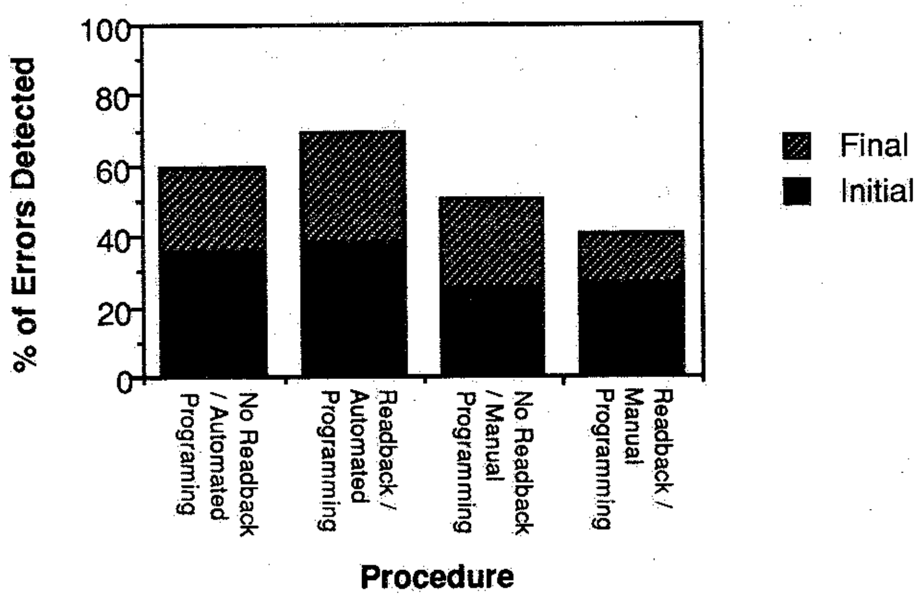

FIGURE 5.6. DETECTION OF ROUTING ERRORS BY PROCEDURE

5.3.3 PROCEDURE SUMMARY

Despite seeming to have a more involved level of review, manual programming appears to be a less desirable for situational awareness. A possible reason for this is that the type of cognitive processing required to program the FMS appeared to reduce the pilot's overall ability to evaluate on a strategic level. In support of this, it was clear from the PNF observations that the clearance amendments processed with manual programming required much more time to execute compared to those with automated programming. This indicates that automated FMS programming may be desirable in that it possibly allows pilots to spend more of their cognitive time and resources at the strategic level thereby potentially increasing situational awareness. However, as stated previously, there may be a bias against manual FMS programming detection performance because the simulator CDU differs from the unit used in actual flight operations.

While the data indicate no overall trend in the value of readback, it appears that the combination of readback with automated programming may be beneficial to situational awareness. Unfortunately, there was not enough data to confirm this trend. A possible explanation for this effect may be that readback inspires additional scrutiny of the clearance amendment which might not occur with automated FMS programming alone. Further study regarding this possible effect is warranted.

6 SUBJECTIVE RESULTS

It should be noted that because only nine subjects participated in this experiment, caution should be exercised in the interpretation of the results in this section due to the small sample size.

6.1 SUBJECTIVE RATINGS OF INDIVIDUAL FORMAT/PROCEDURE COMBINATIONS

Subjective ratings were taken after each experimental run for each format/procedure combination. The subjects were asked for evaluations of overall effectiveness, situational awareness, and time efficiency of the combination of display mode and procedure just flown.

6.1.1 RATINGS FOR OVERALL EFFECTIVENESS

The subjective ratings for overall effectiveness ratings are presented in Figure 6.1. There was an apparent subjective preference for datalink. With only one exception, all procedures with textual and graphical delivery were rated higher than verbal modes, and every procedure which required automated FMS programming rated higher than the current ATC procedure (i.e. verbal with readback and manual FMS programming). The most highly rated procedure was textual presentation with automated programming and readback, with graphical delivery with automated programming and no readback close behind. This implied that, on average, pilots desired readback *with* textual delivery, but that graphical was preferred *without* readback. (Note that this does not contradict the performance data. In the graphical mode of delivery with automated FMS programming, error detection performance was similar with or without readback.)

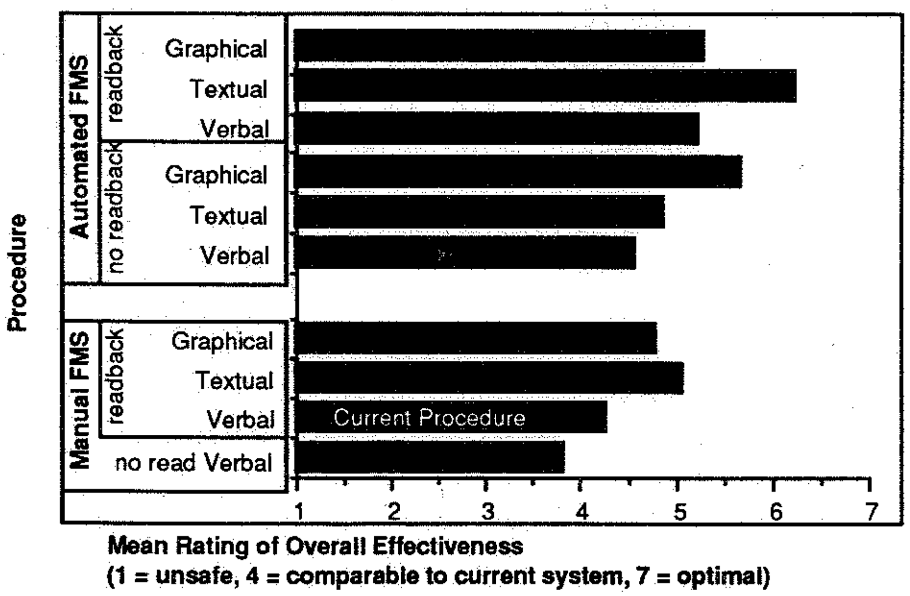

FIGURE 6.1. SUBJECTIVE RATINGS OF OVERALL EFFECTIVENESS OF DELIVERY MODE/PROCEDURE COMBINATIONS

6.1.2 Ratings For Situational Awareness

Similarly, datalink did not imply any perceived loss in the situational awareness ratings, either with automation or with delivery mode (Figure 6.2). With only one exception, the graphical and textual modes of delivery outrated the verbal mode within the same procedure. Also, the subjects indicated that the net effect of automated FMS programming would be beneficial to situational awareness when compared to the current procedure. Some subjects commented that they would be able to devote more time to evaluating the content of new clearances with automated programming, rather than accomplishing data entry tasks on the FMS, thereby increasing their perceived situational awareness. Readback, to a lesser extent, was also seen as an enhancement to situational awareness. The subjects on average rated procedures with readback higher than those without readback within the same method of FMS programming. (An exception to this occurs with automated FMS programming and graphical delivery. A possible reason for this is discussed in Section 7.4.)

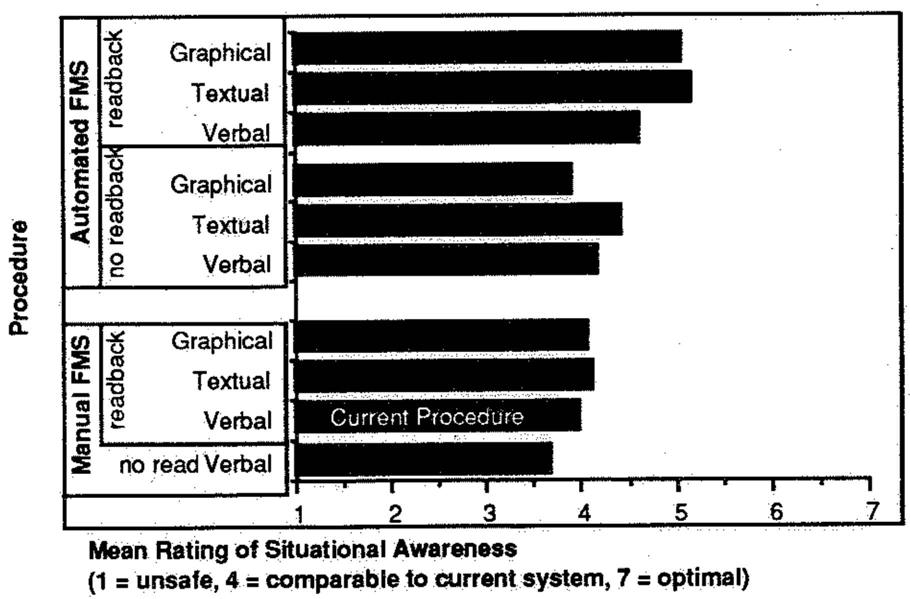

FIGURE 6.2. SUBJECTIVE RATINGS OF SITUATIONAL AWARENESS OF DELIVERY MODE/PROCEDURE COMBINATIONS

It should also be noted that procedures, regardless of mode of delivery, were generally rated similarly for situational awareness by subjects. That is, all cases with automated FMS programming and readback were rated higher than those with other procedures, while manual FMS programming with no readback rated lowest.

6.1.3 Ratings for Time Efficiency

In terms of time efficiency all of the procedures with automated FMS programming outrated those with manual programming (Figure 6.3). However, there seems to be no strong correlation between time efficiency and the requirement for readback. Additionally, textual presentation on average was perceived as an expeditious mode of delivery. Some subjects indicated that this was due to the compact nature of the textual display. Graphical delivery, as some subjects commented, required them to search different displays to find all of the clearance information. Note that this is a result of the particular implementation of the graphical mode used in this experiment, and may or may not apply to other implementations. Other subjects also stated that verbal delivery was more time consuming, as the clearance needed to be written down on paper.

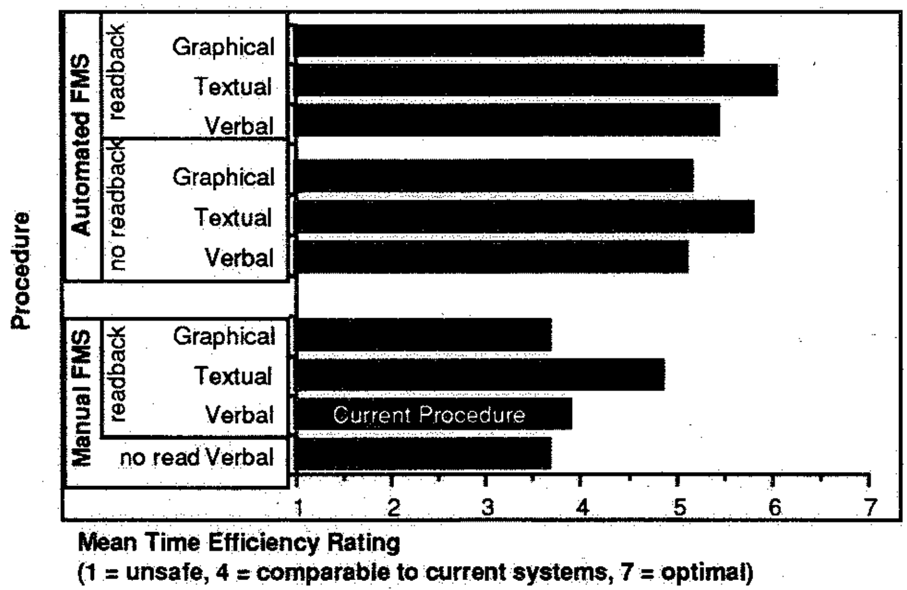

FIGURE 6.3. SUBJECTIVE RATINGS OF TIME EFFICIENCY OF DELIVERY MODE/PROCEDURE COMBINATIONS

6.1.4 Summary of Subjective Individual Format/Procedure Combination Ratings

In summary, the subjective ratings indicated that pilots appeared to prefer automated programming in terms of time efficiency, situational awareness, and overall effectiveness. Pilots also liked the textual and graphical presentations of clearance amendments, particularly in overall effectiveness. Automated programming was not felt to degrade situational awareness, and in fact was perceived as an enhancement, while the perceived benefit of readbacks depended on the delivery mode and method of FMS programming. Finally, the currently used procedure of manual FMS programming with readback rated nearly last in all three categories.

6.2 POST EXPERIMENT SUMMARY RATINGS

After experiencing the entire test matrix, subjects were asked to summarize their opinions of the delivery modes and procedures during an exit interview. They were asked both to rank (i.e. order from most desirable to least desirable) and to rate (i.e. assign a numeric value from 1 (lowest) to 10 (highest)) each delivery mode and procedure.

6.2.1 DELIVERY MODE RANKINGS & RATINGS

In terms of the delivery modes, pilots were evenly split between textual and graphical modes overall in terms of ranking, with each receiving 4 top rankings. However, graphical received a slightly higher numerical rating, thus implying that graphical may possibly have additional benefits over textual delivery. (Figure 6.4). For instance, subjects made the comment that graphical was preferable for quickness in evaluation of the clearance, but they also stated that details such as crossing restrictions or runway changes were often difficult to discern. Conversely, textual mode was praised for being compact and accurate, but was criticized for having few decision-making advantages over voice.

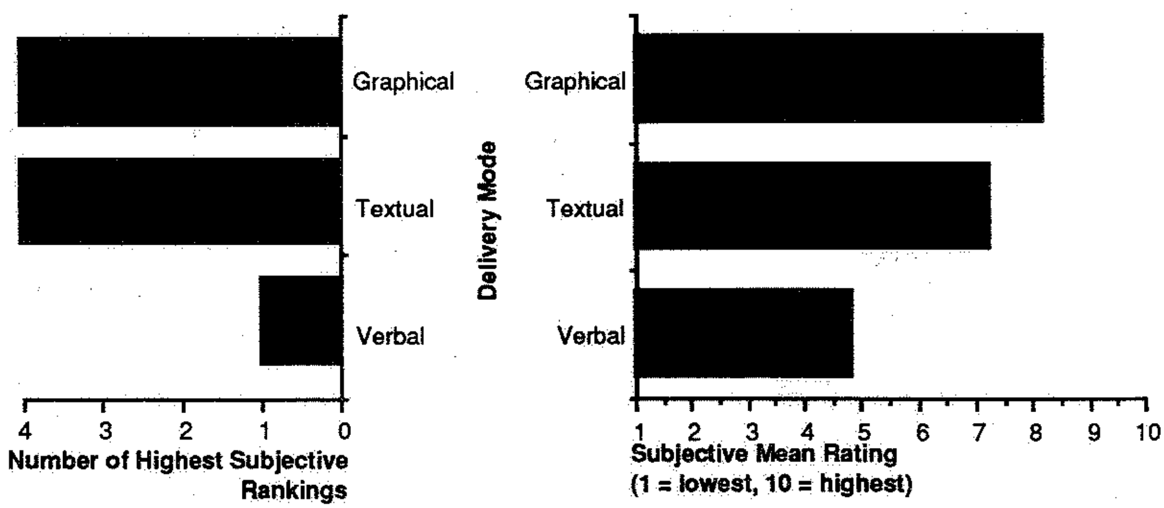

FIGURE 6.4. EXIT INTERVIEW RANKINGS & RATINGS OF DELIVERY MODES

6.2.2 Procedure Rankings & Ratings

When asked to rate procedures, pilots chose the procedures with automated programming highest overall (Figure 6.5). Pilots commented that automated programming allowed for more "heads up" time, or time to concentrate strategic aspects of the clearance. Conversely, there was not a definite preference for readback. The procedure which was ranked and rated highest by most subjects was automated programming without readback. However, the standard deviation of 2.85 for this procedure was the highest among all procedures, indicating a wide range of opinion on its overall value. Readback with automated programming, in contrast, was consistently rated high by the pilots (with the lowest standard deviation of 0.845).

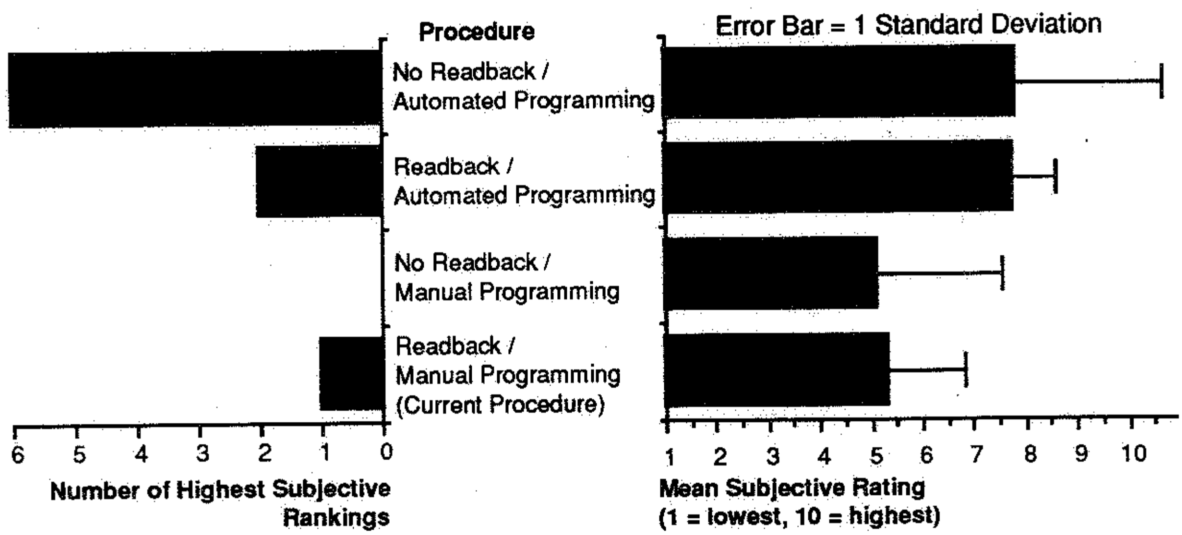

FIGURE 6.5. EXIT INTERVIEW RANKINGS & RATINGS OF PROCEDURES

6.2.3 Summary of Post Experiment Rankings & Ratings

In summary, graphical and textual delivery were given similar subjective scores, with each perceived as having different advantages and disadvantages. Graphical delivery was praised for its decision-making advantage, while textual delivery's benefit was its compact format. Automated programming was almost unanimously endorsed by the subjects. A definite conclusion about readback was not indicated, but there may be benefits for its retention in clearance amendment procedures with automated FMS programming.

7 ADDITIONAL DISCUSSION

In addition to the performance data and subjective ratings, subjects were encouraged to comment about issues which they felt were important about datalink. This section discusses some of the points to be addressed in the implementation of datalink delivery of ATC clearances as originated by the subjects.

7.1 COMBINED TEXTUAL AND GRAPHICAL PRESENTATION

As stated above, subjects were divided about the perceived advantages between the graphical and textual modes of delivery. In particular, subjects often gave contradictory comments about the graphical mode of delivery. Some subjects stated that with the graphical mode, it was sometimes difficult to understand the clearance fully because the information was associated with many different symbols and displays in the cockpit. Text (as some subjects stated) instead placed all of the clearance information in a single location on the dedicated datalink textual display. Nevertheless, most did like the graphical mode because they were able to see on the EHSI where they were cleared to immediately upon receiving the clearance.

Because of this, eight of the nine subject pilots supported the concept of delivering the information using both textual and graphical simultaneously, thus combining the advantages of both modes. In fact, several subjects independently suggested this during the experiment. One subject stated, "text with graphical ... gives redundancy like a readback". In fact, in the absence of getting both text and graphical simultaneously, another pilot did not want to switch from using the voice frequency at all.

7.2 VALUE OF READBACK

The net effect of readback as part of the clearance amendment procedure is not clear. While all subjects felt that verbal delivery necessitated a readback as an error checking procedure, they were unable to provide an consensus on its value in the textual and graphical modes of delivery. However, there appeared to be some value in combining automated FMS programming with readback.

In terms of error detection performance, readback appeared to be beneficial when combined with automated programming, but insufficient data was accumulated to substantiate this trend statistically. The subjective situational awareness scores indicated that automated programming with readback rated higher than any other procedure, regardless of delivery mode. Finally, in the exit interview, automated programming with readback was ranked first or second by every subject and furthermore was given a consistently high subjective score.

Taken together, there appears to be an indication for the use of readback coupled with automated programming in any future procedure for clearance amendments using ATC datalink. Note that it would not necessarily be required to readback the clearance to ATC; it could be maintained as an intracockpit crew procedure.

7.3 TEXTUAL DISPLAY IMPLEMENTATION ISSUES

While the textual display used in the experiment was generally thought to be adequate, pilots did have some comments about its implementation, particularly if the datalink system is retrofitted to existing non-EFIS aircraft. In particular, some subjects were concerned about the readability and placement of the textual screen. Other subjects mentioned that textual displays (and graphical displays, to some extent) may be susceptible to turbulence (i.e. the vibration in turbulence would make the displays unreadable). In general, usage of the visual modes of delivery elicited comments about the potential problem of too much "heads down" time, or time spent looking at instruments in the cockpit rather than visually scanning the airspace surrounding the aircraft. Other comments indicated that, as pilots get older, hyperopia (farsightedness) may become a problem, and that reading small text in the near visual field may become difficult.

Finally, the format used for the textual display in this experiment was based on a simple transcription of the current ATC lexicon. However, more optimal formats may exist which should be investigated. One subject suggested doing away with the standard phraseology, and instead display the textual routing information in a format similar to that of existing FMS displays.

7.4 GRAPHICAL DISPLAY IMPLEMENTATION ISSUES

As demonstrated by the relatively low situational awareness rating of graphical mode and automated FMS programming without readback, implementation issues need to be addressed concerning graphical display of clearance amendment information. In particular, care should be taken to insure that details of the clearance amendment are difficult to overlook. These include: method of annunciation, symbology, color, distribution of information on the flight deck, and the presentation of detailed and/or complex information. In particular, it should be noted that certain complex ATC procedures were not included in this experiment: for example, speed adjustments which would take place upon reaching an assigned altitude rather than a particular location.

In addition, the implementation used in this simulation study distributed information to different graphical displays to provide a more natural context. Advantages and disadvantages to distributing the information to different flight displays may exist. For instance, while it may aid cognitive processing to locate an altitude assignment on the altitude tape display, it may hinder interpretation of the clearance because this information is not grouped with the remain clearance data. Conversely, grouping all the clearance information on one display may be confusing. Further investigation of the effects of this distribution, as well as the optimal method of partitioning data, should be undertaken.

However, because particular care was taken to avoid the presentation of any textual information with the graphical amendment (thus preventing a confounding variable), designers of graphical clearance amendment displays may have more flexibility available to them. Finally, care should be taken to ensure that the implementation of graphical clearance amendment delivery does not contribute to "cluttered" navigational displays.

8 CONCLUSIONS AND RECOMMENDATIONS:

While recommendations can be made on the basis of these results, it should be reiterated that because of the small sample size, the statistically significant results are limited. Also, because the subject pool consisted of volunteers, the sample population may be biased towards favoring new technology when compared with the mean pilot population.

GRAPHICAL MODE YIELDED BEST ERROR DETECTION PERFORMANCE

The graphical mode yielded the best performance in detecting nominally unacceptable clearances. In addition to the best overall performance, it also had the advantage that the vast majority of errors were detected rapidly upon initial review of the clearance. In addition, graphical was outstanding in the detection of vectors into weather, with 100% of all errors detected immediately upon receiving the information. This may illustrate the possible benefit of having a display which is common to both clearance amendments and potential sources of hazard or conflict. However, there was some indication from pilot comments that a purely graphical mode of delivery required additional study to ensure a beneficial implementation.

COMBINED TEXTUAL & GRAPHICAL PRESENTATION DESIRED

The primary advantage of graphical delivery was in the rapid evaluation of clearances. However, because graphical implementation required that information was distributed to many different displays within the cockpit, this made certain details in the clearance amendment difficult to read. Textual delivery has the advantage of having all the information in one place in a concise format. Nevertheless, textual delivery seems to have few decision-aiding advantages over the current verbal delivery. It seems likely that a simultaneous presentation in both text and graphics will combine the advantages of the individual modes, and eight of nine subject pilots desired this. This is also consistent with the current dual representation of information in existing FMS/EFIS Systems. Further investigation into this possible "mixed" delivery mode is warranted.

AUTOMATED PROGRAMMING YIELDED BETTER ERROR DETECTION PERFORMANCE

Pilots appeared to be able to detect more unacceptable amendments with the use of automated FMS programming compared to manual programming. Additionally, the majority of pilots desired automated programming with datalink. It is also clear from subject comments that manual programming does not appear to help pilots understand the overall implications of accepting a particular clearance amendment. In contrast, automated programming appears to allow the pilot to concentrate on evaluating the clearance on the strategic level. It is recommended that automated FMS programming technology be considered for use with datalink delivery of ATC clearances.

READBACK WITH AUTOMATED PROGRAMMING MAY BE BENEFICIAL

The effect of readback on detection performance appeared to be dependent upon the method of FMS programming. Although there is no statistical significance to the error detection performance, readback combined with automated programming appeared to yield somewhat better performance. Additionally, pilots on average rated the procedures with readback and automated FMS programming higher than any other procedure in terms of subjective situational awareness. Taken together, there is an indication that readback may have a benefit when used with automated FMS programming. While it is recommend that readback be retained on this basis, further study on the effectiveness of readback is warranted.

APPENDIX A: SCENARIOS

This appendix contains complete documentation of the scenarios developed for use with this simulation study. These scenarios were designed for the 30 May 1991 edition of the US Government Enroute Low Altitude IFR Charts, specifically Charts L-21, L-23, L-25, and L-27. Table 4.1 describes general information about each scenario.

Scenario Boston A

The aircraft will start at **ALBANY VOR**. *The initial clearance is:* **ALBANY, direct GARDNER VOR, direct REVER intersection.** *ATIS Charlie is active.*

Amendment Series 1: Routing into WX

Reference the ATC station to **GRAVE** *intersection.*

When the aircraft reaches GRAVE, ***do the following:***

> **YOU: "(callsign), clearance amendment"**
> *when the pilot responds ready:*
> **<u>ARM AND SEND AMENDMENT #1</u>**
> **YOU: "(callsign), direct BRADLEY VOR, Victor 4-1-9er BOSOX intersection. After BOSOX, expect vectors to ILS Runway 4 Right."**

IF THE PILOT <u>DOES NOT</u> REJECT THE AMENDMENT:
reference the ATC station to **CHESTER VOR (CTR)**. *When the aircraft reaches* **CHESTER**:
YOU: "(callsign), clearance amendment"
when the pilot responds ready:
<u>ARM AND SEND AMENDMENT #2</u>
YOU: "(callsign), direct FAIDS intersection, direct BOSOX intersection. After BOSOX, expect vectors to ILS Runway 4 Right. Cross BOSOX at and maintain seven thousand feet and 2-1-0 knots."
IF THE PILOT <u>DOES</u> REJECT THE AMENDMENT:
YOU: "(callsign), standby 1"
wait about 10 seconds
<u>ARM AND SEND AMENDMENT #2</u>
YOU: "(callsign), direct FAIDS intersection, direct BOSOX intersection. After BOSOX, expect vectors to ILS Runway 4 Right. Cross BOSOX at and maintain seven thousand feet and 2-1-0 knots."

Amendment Series 2: OK

Reference the ATC station to **FAIDS** *intersection.*

When the aircraft reaches **FAIDS**, ***do the following:***

YOU: "(callsign), clearance amendment"

when the pilot is ready:

<u>ARM AND SEND AMENDMENT #3</u>

YOU: "(callsign), direct MILIS intersection. After MILIS expect vectors for ILS RWY 4 right. Cross MILIS at and maintain 7000 and 2-1-0 knots."

Since this amendment is OK, Don't expect anything to change. If he rejects the amendment, let him continue on his current amendment. Otherwise, stall him until BOSOX and go to the next amendment series.

Amendment Series 3: Bad waypoint

Reference the ATC station to BOSOX *intersection.*

When the aircraft reaches* BOSOX, *do the following:

YOU: "(callsign), clearance amendment, "

when the pilot responds ready:

<u>ARM AND SEND AMENDMENT #4</u>

YOU: "(callsign), direct COHAS intersection. Descend and maintain 3000 until established on the localizer for ILS runway 4 right approach."

<u>AT THIS POINT, VERBALLY CLEAR HIM FOR THE APPROACH</u>

IF THE PILOT <u>DOES NOT</u> REJECT THE AMENDMENT:

reference the ATC station to NABBO. *When the aircraft is about 5 miles from* NABBO:

YOU: "(callsign), clearance amendment"

when the pilot responds ready:

<u>ARM AND SEND AMENDMENT #5</u>

YOU: "(callsign), direct NABBO intersection. Maintain 3000 until established on the localizer for ILS runway 4 right approach."

<u>AT THIS POINT, VERBALLY CLEAR HIM FOR THE APPROACH</u>

IF THE PILOT <u>DOES</u> REJECT THE AMENDMENT:

YOU: "(callsign), standby 1"

wait about 10 seconds

<u>ARM AND SEND AMENDMENT #5</u>

YOU: "(callsign), direct NABBO intersection. Maintain 3000 until established on the localizer for ILS runway 4 right approach."

<u>AT THIS POINT, VERBALLY CLEAR HIM FOR THE APPROACH</u>

This scenario will terminate at **NABBO**.

ATIS-C:
"Boston Logan Airport information Charlie. 2050 Zulu. 5000 Scattered Est Ceiling 10000 broken, visibility 5 haze. Temp: 97 Dewpoint: 96. Wind calm. Altimeter 28.85. Lightning reported W of airport. Approach ILS RWY 4R, ILS/DME 33L. Departing RWY 4L, 9. CONVECTIVE SIGMET NOVEMBER 5 in effect; contact FSS for details. Numerous Cranes and other construction equipment southwest of airportAdvise on initial contact information Charlie"
CONVECTIVE SIGMET NOVEMBER 5
Lines of heavy thunderstorms extending from 10 mi E CON to 30 mi E BDR to 10 mi W ACY to 20 mi E SLT to 10 S of SLK to 10 mi E CON reported moving NE at 25 knots, with tops reaching FL450 or greater. Severe turbulence and hail reported below 10000 feet, with moderate icing above 15000 feet.

Scenario BWI A

The aircraft will start at **HARBO intersection**. *The initial clearance is:* **HARBO, V-268 BALTIMORE VOR.** *ATIS Papa is active.*

Amendment Series 1: Routing into WX

Reference the ATC station to **AVALO** *intersection.*

When the aircraft is 20 NMi from **AVALO,** ***do the following:***

> **YOU: "(callsign), clearance amendment"**
> *when the pilot responds ready:*
> **<u>ARM AND SEND AMENDMENT #1</u>**
> **YOU: "(callsign), direct WATERLOO VOR, Victor 3-0-8 CHOPS intersection. After CHOPS, expect vectors to ILS Runway 3-3 Left."**
> *Note: ATIS Quebec now active*

IF THE PILOT <u>DOES NOT</u> REJECT THE AMENDMENT:
reference the ATC station to **WATERLOO VOR (ATR).** *When the aircraft reaches* **WATERLOO**:
YOU: "(callsign), clearance amendment"
when the pilot responds ready:
<u>ARM AND SEND AMENDMENT #2</u>
YOU: "(callsign), direct BALTIMORE VOR. Expect vectors to ILS Runway 3-3 Left. Descend and maintain eight thousand. Reduce speed 2-5-0 knots."
IF THE PILOT <u>DOES</u> REJECT THE AMENDMENT:
YOU: "(callsign), standby 1"
wait about 10 seconds
<u>ARM AND SEND AMENDMENT #3</u>
YOU: "(callsign), direct SEA ISLE VOR, Victor 4-4 AGARD intersection. After AGARD, expect vectors to ILS Runway 3-3 left. cross AGARD intersection at and maintain one-zero thousand. Reduce speed 2-5-0 knots."

Amendment Series 2: OK

Reference the ATC station to **CANNY** *intersection.*

When the aircraft reaches* CANNY, *do the following:

YOU: "(callsign), clearance amendment"
when the pilot responds ready:
ARM AND SEND AMENDMENT #4
YOU: "(callsign), direct PALEO intersection. after PALEO expect vectors to ILS RWY 33L; cross PALEO at and maintain 8000 and 2-1-0 knots"

This amendment is OK, but if the pilot rejects it, let him maintain current clearance. If he requests something weird, stall him till AGARD and the next amendment series.

Amendment Series 3: Bad waypoint

Reference the ATC station to **AGARD** *intersection.*

When the aircraft reaches* AGARD, *do the following:

YOU: "(callsign), clearance amendment"
when the pilot responds ready:
ARM AND SEND AMENDMENT #5
YOU: "(callsign), direct BALTO intersection. Descend and maintain 3000 until established on the localizer for ILS runway 3-3 left."
AT THIS POINT, VERBALLY CLEAR HIM FOR THE APPROACH

IF THE PILOT DOES NOT REJECT THE AMENDMENT:

reference the ATC station to **SPLAT**. *When the aircraft is about 5 miles from* **SPLAT***:*

YOU: "(callsign), clearance amendment"

when the pilot responds ready:

ARM AND SEND AMENDMENT #6

YOU: "(callsign), direct SPLAT intersection. Maintain 3000 until established on the localizer for ILS runway 3-3 Left."

AT THIS POINT, VERBALLY CLEAR HIM FOR THE APPROACH

IF THE PILOT DOES REJECT THE AMENDMENT:

YOU: "(callsign), standby 1"

wait about 10 seconds

ARM AND SEND AMENDMENT #6

YOU: "(callsign), direct SPLAT intersection. Maintain 3000 until established on the localizer for ILS runway 3-3 Left."

AT THIS POINT, VERBALLY CLEAR HIM FOR THE APPROACH

This scenario will terminate at **SPLAT**.

ATIS-P:
"Baltimore Washington International Airport information Papa. 1650 Zulu. 7000 Scattered Est Ceiling 15000 broken, visibility 10. Lightning reported N of airport. Temp: 90 Dewpoint: 81. Wind 130 at 5. Altimeter 29.17. Visual Approach RWY 15R. Departing RWY 10. Windshear advisories in effect. Bird Activity east of airport. Advise on initial contact information Papa"
ATIS-Q:
"Baltimore Washington International Airport information Quebec. 1723 Zulu. 2000 Scattered, Measured Ceiling 7000 overcast, visibility 3 miles light rain, occassional 1000 overcast, visibility 1/2 in thunderstorms. Temp: 82 Dewpoint: 80. Wind 310 at 20 gusting to 28. Altimeter 28.82. Approach ILS RWY 28 and ILS RWY 33L, Departing RWY 28. Windshear advisories in effect. Advise on initial contact information Quebec"

Scenario Kennedy A

The aircraft will start at **Sandy Point VOR (SEY).** *The initial clearance is:* **SEY, V-268 ERICK intersection, direct JFK VOR.** *ATIS Kilo is active.*

Amendment Series 1: OK

Reference the ATC station to **HAMPTON VOR (HTO)** *intersection.*

When the aircraft is 25 miles from HTO, do the following:

> **YOU: "(callsign), clearance amendment"**
> *when the pilot responds ready:*
> **<u>ARM AND SEND AMENDMENT #1</u>**
> **YOU: "(callsign), direct HAMPTON VOR, direct ERICK INTERSECTION, direct JFK. Expect vectors to ILS Runway 3-1 right."**

This amendment is OK. Allow deviations within reason.

Amendment Series 2: Routing into WX

Reference the ATC station to **ERICK** *intersection.*

When the aircraft reaches ERICK, do the following:

> **YOU: "(callsign), clearance amendment"**
> *when the pilot responds ready:*
> **<u>ARM AND SEND AMENDMENT #2</u>**
> **YOU: "(callsign), direct DEER PARK VOR. After DEER PARK, expect vectors to ILS Runway 3-1 right."**

IF THE PILOT <u>DOES NOT</u> REJECT THE AMENDMENT:

> *Wait about 1 minute:*
> **YOU: "(callsign), sorry to do this to you, but LaGuardia got some of our airspace and we have another clearance amendment for you"**
> *when the pilot responds ready:*
> **<u>ARM AND SEND AMENDMENT #3</u>**
> **YOU: "(callsign), direct SHIPP intersection. After SHIPP expect vectors to ILS Runway 3-1 right. Cross SHIPP at and maintain 5 thousand. Reduce Speed 2-5-0 knots"**

IF THE PILOT __DOES__ REJECT THE AMENDMENT:

YOU: "(callsign), standby 1"

wait about 10 seconds

__ARM AND SEND AMENDMENT #3__

YOU: "(callsign), direct SHIPP intersection. After SHIPP expect vectors to ILS Runway 3-1 right. Cross SHIPP at and maintain 5 thousand. Reduce Speed 2-5-0 knots"

Amendment Series 3: Bad waypoint

Reference the ATC station to SHIPP *intersection.*

When the aircraft is five miles from SHIPP, do the following:

YOU: "(callsign), clearance amendment, "

when the pilot responds ready:

__ARM AND SEND AMENDMENT #4__

YOU: "(callsign), direct NARRO intersection. Descend and maintain 3000 until established on the localizer for ILS runway 3-1 right."

__AT THIS POINT, VERBALLY CLEAR HIM FOR THE APPROACH__

IF THE PILOT __DOES NOT__ REJECT THE AMENDMENT:

reference the ATC station to LORAC. *When the aircraft is about 5 miles from* LORAC:

YOU: "(callsign), clearance amendment"

when the pilot responds ready:

__ARM AND SEND AMENDMENT #5__

YOU: "(callsign), direct LORAC. Maintain 3000 until established on the localizer for the ILS runway 3-1 right approach."

__AT THIS POINT, VERBALLY CLEAR HIM FOR THE APPROACH__

IF THE PILOT __DOES__ REJECT THE AMENDMENT:

YOU: "(callsign), standby 1"

wait about 10 seconds

__ARM AND SEND AMENDMENT #5__

YOU: "(callsign), direct LORAC. Maintain 3000 until established on the localizer for the ILS runway 3-1 right approach."

AT THIS POINT, VERBALLY CLEAR HIM FOR THE APPROACH

This scenario will terminate at LORAC.

ATIS-K:
"John F Kennedy International Airport information Kilo. 1945 Zulu. 5000 Scattered Est Ceiling 2-5000 broken, visibility 15. Temp: 76 Dewpoint: 64 Wind 300@7. Altimeter 29.45. Lightning reported E of airport. Aircraft Landing and departing 31L, 31R. CONVECTIVE SIGMET DELTA THREE in effect; contact New York FSS for details. Advise on initial contact information Kilo"
CONVECTIVE SIGMET DELTA 3
Line of heavy thunderstorms extending from 50 mi N CAR to 30 mi E CON to 10 mi E BDR to 20 mi W BDR to 10 mi W of BML to 50 mi N CAR reported moving SE at 20 knots, with tops reaching FL300. Severe turbulence and hail reported below 10000 feet, with moderate icing above 15000 feet.

Scenario LaGuardia A

The aircraft will start at **ALBANY VOR**. *The initial clearance is:* **ALBANY, V-157 LAGUARDIA VOR.** *ATIS Foxtrot is active.*

Amendment Series 1: OK

Reference the ATC station to **GROUP** *intersection.*

When the aircraft is at* GROUP, *do the following:

> **YOU: "(callsign), clearance amendment, "**
> *when the pilot responds ready:*
> **<u>ARM AND SEND AMENDMENT #1</u>**
> **YOU: "(callsign), direct KINGSTON VOR, direct LAGUARDIA VOR. After LAGUARDIA, expect vectors to ILS Runway 2-2."**

This amendment is OK, and he should accept it. However, if he does not, let him fly the old route. If not, stall him to WIGAN-5 and amendment series 2.

Amendment Series 2: Routing into WX

Reference the ATC station to **TRESA** *intersection.*

When the aircraft is 15 miles from* TRESA, *do the following:

> **YOU: "(callsign), clearance amendment, "**
> *when the pilot responds ready:*
> **<u>ARM AND SEND AMENDMENT #2</u>**
> **YOU: "(callsign), direct PAWLING VOR, direct BRIDGEPORT VOR. After BRIDGEPORT, expect vectors to Localizer Runway 3-1."**

Note: ATIS Golf now active.

IF THE PILOT <u>DOES NOT</u> REJECT THE AMENDMENT:

reference the ATC station to **PAWLING VOR (PWL)**. *When the aircraft reaches* **PAWLING**:

YOU: "(callsign), clearance amendment, "

when the pilot responds ready:

<u>ARM AND SEND AMENDMENT #3</u>

YOU: "(callsign), direct CARMEL VOR, direct DEER PARK VOR. After DEER PARK expect vectors to Localizer Runway 3-1. Cross

DEER PARK at and maintain five thousand. Reduce Speed 2-5-0 knots."

IF THE PILOT DOES REJECT THE AMENDMENT:

YOU: "(callsign), standby 1"

wait about 10 seconds

ARM AND SEND AMENDMENT #4

YOU: "(callsign), direct KINGSTON VOR, direct DEER PARK VOR. After DEER PARK, expect vectors to Localizer Runway 3-1. Cross DEER PARK at and maintain five thousand. Reduce Speed 2-5-0 knots."

Amendment Series 3: Bad waypoint

Reference the ATC station to **DEER PARK (DPK)** *VOR.*

When the aircraft is ten miles from DPK, do the following:

YOU: "(callsign), clearance amendment, "

when the pilot responds ready:

ARM AND SEND AMENDMENT #5

YOU: "(callsign), direct DIALS intersection. Descend and maintain two thousand, five hundred until established on the localizer for Localizer runway 3-1."

AT THIS POINT, VERBALLY CLEAR HIM FOR THE APPROACH

IF THE PILOT DOES NOT REJECT THE AMENDMENT:

reference the ATC station to **FABRY**. *When the aircraft is about 5 miles from* **FABRY**:

YOU: "(callsign), clearance amendment"

when the pilot responds ready:

ARM AND SEND AMENDMENT #6

YOU: "(callsign), direct FABRY. Maintain two thousand, five hundred until established on the localizer for Localizer runway 3-1."

AT THIS POINT, VERBALLY CLEAR HIM FOR THE APPROACH

IF THE PILOT DOES REJECT THE AMENDMENT:

YOU: "(callsign), standby 1"

wait about 10 seconds

ARM AND SEND AMENDMENT #6

YOU: "(callsign), direct FABRY. Maintain two thousand, five hundred until established on the localizer for Localizer runway 3-1."

AT THIS POINT, VERBALLY CLEAR HIM FOR THE APPROACH

This scenario will terminate at FABRY.

ATIS-F:
"LaGuardia Airport information Foxtrot. 2150 Zulu. 10000 Scattered, Est Ceiling 20000 broken, visibility 20. Lightning reported NE of airport. Temp: 75 Dewpoint: 68. Wind 180 at 15. Altimeter 29.14. ILS and visual Rwy 22 approaches in effect. Windshear advisories in effect. Bird Activity south of airport. Advise on initial contact information Foxtrot"
ATIS-G:
"LaGuardia Airport information Golf. 2224 Zulu. 3000 Scattered, Est Ceiling 6000 overcast, visibility 3 miles light rain. Temp: 70 Dewpoint: 68. Wind 300 at 20 gusting to 28. Altimeter 29.02. Arrivals expect Expressway Visual and Localizer Rwy 31. Convective SIGMET Delta in effect for New Jersey and Southeast New York. Contact NewYork FSS for details. Windshear advisories in effect. Bird Activity reported south of airport.

Scenario Boston B

The aircraft will start near **HAMPTON VOR (HTO).** *The initial clearance is:* **HAMPTON, victor-139 PROVIDENCE VOR, direct BOSTON VOR.** *ATIS Juliet is active.*

Amendment Series 1: OK

Reference the ATC station to **HAMPTON** *VOR.*

When the aircraft reaches* HAMPTON, *do the following:

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
ARM AND SEND AMENDMENT #1
YOU: "(callsign), direct BOSTON VOR, expect vectors to ILS Runway 4 right."

This amendment is fine. There should be no reason not to accept it. If he does, roll your eyes and have him maintain present clearance.

Amendment Series 2: Routing into WX

Reference the ATC station to **TRAIT** *intersection.*

When the aircraft reaches* TRAIT, *do the following:

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
ARM AND SEND AMENDMENT #2
YOU: "(callsign), direct DRUNK intersection, direct TONNI intersection. After TONNI, expect vectors to ILS Runway 2-7. Cross TONNI at and maintain 5000 and 2-1-0 knots"
Note: ATIS Kilo now active

IF THE PILOT DOES NOT REJECT THE AMENDMENT:

reference the ATC station to **LAFAY interesection** *When the aircraft reaches* **LAFAY***:*

YOU: "(callsign), clearance amendment, "

when the pilot responds ready:

ARM AND SEND AMENDMENT #3

YOU: "(callsign), direct PROVIDENCE VOR, direct PUTNAM VOR, after PUTNAM, expect vectors to ILS Runway 2-7."

IF THE PILOT <u>DOES</u> REJECT THE AMENDMENT: **YOU: "(callsign), standby 1"** *wait about 10 seconds* **<u>ARM AND SEND AMENDMENT #3</u>** **YOU: "(callsign), direct PROVIDENCE VOR, direct PUTNAM VOR, after PUTNAM, expect vectors to ILS Runway 2-7."**

Amendment Series 3: Illogical routing

Reference the ATC station to **PROVIDENCE** *VOR (PVD).*

When the aircraft reaches* PVD, *do the following:

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
<u>ARM AND SEND AMENDMENT #4</u>
YOU: "(callsign), direct HARTFORD VOR, direct BOSTON VOR. After BOSTON, expect vectors to ILS RWY 2-7. Cross BOSTON at and maintain 7000 and 2-1-0 knots."

IF THE PILOT <u>DOES NOT</u> REJECT THE AMENDMENT: *reference the ATC station to* **FOSTY**. *When the aircraft is at* **FOSTY**: **YOU: "(callsign), clearance amendment"** *when the pilot responds ready:* **<u>ARM AND SEND AMENDMENT #5</u>** **YOU: "(callsign), direct BOSTON VOR. Expect vectors to ILS runway 2-7. Cross BOSTON at and maintain 7000 and 2-1-0 knots."**
IF THE PILOT <u>DOES</u> REJECT THE AMENDMENT: **YOU: "(callsign), standby 1"** *wait about 10 seconds* **<u>ARM AND SEND AMENDMENT #5</u>** **YOU: "(callsign), direct BOSTON VOR. Expect vectors to ILS runway 2-7. Cross BOSTON at and maintain 7000 and 2-1-0 knots."**

This scenario will terminate at BOS.

ATIS-J:
"Logan airport information Juliet. 1947 Zulu. 4000 Scattered, Est Ceiling 10000 Broken, visibility 8 miles. Temp: 88 Dewpoint: 75. Wind calm. Altimeter 29.42. Visual approach RWY 4R, Rwy 33L in effect. Departing RWY 4R, 4L. Windshear advisories in effect. Numerous Cranes and other

construction equipment located southwest quadrant of airport. Advise on initial contact information Juliet"
ATIS-K:
"Logan airport information Kilo. 2014 Zulu. Measured Ceiling 2500 Broken, 6000 Overcast, visibility 3 miles in light rain showers Temp: 77 Dewpoint: 75. Wind 280 at 18 gusting to 25. Altimeter 29.12. ILS DME approach RWY 27 in effect. Windshear advisories in effect. Numerous Cranes and other construction equipment located southwest quadrant of airport. Advise on initial contact information Kilo"

Scenario National B

The aircraft will start near **LAWRENCEVILLE VOR (LVL).** *The initial clearance is:* **LAWRENCEVILLE, victor-157 RICHMOND VOR, V-376 WASHINGTON VOR.** *ATIS X-ray is active.*

Amendment Series 1: OK

Reference the ATC station to **MANGE** *(15 miles after LVL)intersection.*

When the aircraft reaches* MANGE *(LVL+15), do the following:

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
ARM AND SEND AMENDMENT #1
YOU: "(callsign), direct WASHINGTON VOR, expect vectors to MOUNT VERNON VISUAL Runway 3-6."

This amendment is fine. If he rejects it, tell him to maintain current amendment.

Amendment Series 2: Routing into WX

Reference the ATC station to **RICHMOND (RIC)** *VOR.*

When the aircraft reaches* RICHMOND, *do the following:

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
ARM AND SEND AMENDMENT #2
YOU: "(callsign), direct CASANOVA VOR, direct ARMEL VOR. After ARMEL, expect vectors to ROSSLYN Localizer Directional Aid Runway 1-8. Descend and maintain one-four thousand"
Note: ATIS Yankee now active

IF THE PILOT DOES NOT REJECT THE AMENDMENT:

reference the ATC station to **RICHMOND VOR (RIC)***When the aircraft is 30 miles out of* **RICHMOND***:*

YOU: "(callsign), clearance amendment, "

when the pilot responds ready:

ARM AND SEND AMENDMENT #3

YOU: "(callsign), direct COLIN intersection. After COLIN expect vectors to ROSSLYN Localizer Directional Aid runway 1-8. Cross COLIN at and maintain one-one thousand."

IF THE PILOT DOES REJECT THE AMENDMENT:

YOU: "(callsign), standby 1"

wait about 10 seconds

ARM AND SEND AMENDMENT #3

YOU: "(callsign), direct COLIN intersection. After COLIN expect vectors to ROSSLYN Localizer Directional Aid runway 1-8. Cross COLIN at and maintain one-one thousand."

Amendment Series 3: Illogical routing

Reference the ATC station to **TAPPA** *intersection.*

When the aircraft reaches five miles from TAPPA, ***do the following:***

YOU: "(callsign), clearance amendment, "

when the pilot responds ready:

ARM AND SEND AMENDMENT #4

YOU: "(callsign), direct HARCUM VOR, direct NOTTINGHAM VOR. After NOTTINGHAM, expect vectors to ROSSLYN Localizer Directional Aid Runway 1-8. Cross NOTTINGHAM at and maintain 8000 and 2-5-0 knots"

IF THE PILOT DOES NOT REJECT THE AMENDMENT:

reference the ATC station to **COLIN**. *When the aircraft is 5 miles from* **COLIN**:

YOU: "(callsign), clearance amendment"

when the pilot responds ready:

ARM AND SEND AMENDMENT #5

YOU: "(callsign), direct NOTTINGHAM VOR. After NOTTINGHAM expect vectors to ROSSLYN Localizer Directional Aid runway 1-8. Cross NOTTINGHAM at and maintain 8000 and 2-5-0 knots"

IF THE PILOT DOES REJECT THE AMENDMENT:

YOU: "(callsign), turn left heading 040"

wait about 10 seconds

ARM AND SEND AMENDMENT #5

YOU: "(callsign), direct NOTTINGHAM VOR. After NOTTINGHAM expect vectors to ROSSLYN Localizer Directional

Aid runway 1-8. Cross NOTTINGHAM at and maintain 8000 and 2-5-0 knots"

This scenario will terminate at NOTTINGHAM.

ATIS-X:
"Washington National airport information X-ray. 1950 Zulu. 4000 Scattered, Est Ceiling 10000 Broken, visibility 8 miles. Temp: 85 Dewpoint: 76. Wind calm. Altimeter 29.45. Visual approach RWY 36, Rwy 33 in effect. Departing RWY 3. Windshear advisories in effect. Advise on initial contact information X-ray"
ATIS-Y:
"Washington National airport information Yankee. 2017 Zulu. Measured Ceiling 2100 Broken, 5000 Overcast, visibility 2 miles in rain showers. Temp: 77 Dewpoint: 74. Wind 190 at 14 gusting to 21. Altimeter 29.14. ROSSLYN LDA approach RWY 18 in effect. Departing RWY 15. Windshear advisories in effect. Advise on initial contact information Yankee"

Scenario Newark B

The aircraft will start near **WILLIAMSPORT VOR.** *The initial clearance is:* **WILLIAMSPORT, SLATE RUN 6 BWZ arrival.** *ATIS Foxtrot is active.*

Amendment Series 1: Routing into WX

Reference the ATC station to **HAYED** *intersection.*

When the aircraft reaches* HAYED, *do the following:

> **YOU: "(callsign), clearance amendment, "**
> *when the pilot responds ready:*
> **<u>ARM AND SEND AMENDMENT #1</u>**
> **YOU: "(callsign), direct ALLENTOWN VOR, victor 6 SOLBERG VOR, after SOLBERG, expect vectors to ILS runway 4 right."**
> *Note: ATIS Golf now active*

IF THE PILOT <u>DOES NOT</u> REJECT THE AMENDMENT:

reference the ATC station to **WHITT intersection.***When the aircraft is directly south (i.e. BRG-360) of* **WHITT***:*

YOU: "(callsign), clearance amendment, "

when the pilot responds ready:

<u>ARM AND SEND AMENDMENT #2</u>

YOU: "(callsign), direct STILLWATER VOR, direct SPARTA VOR. After SPARTA expect vectors to ILS runway 4 right. Cross SPARTA at and maintain one-one thousand."

IF THE PILOT <u>DOES</u> REJECT THE AMENDMENT:

YOU: "(callsign), standby 1"

wait about 10 seconds

<u>ARM AND SEND AMENDMENT #2</u>

YOU: "(callsign), direct STILLWATER VOR, direct SPARTA VOR. After SPARTA expect vectors to ILS runway 4 right. Cross SPARTA at and maintain one-one thousand."

Amendment Series 2: OK

Reference the ATC station to **STILLWATER VOR (STW).**

When the aircraft is 20 miles from* STILLWATER, *do the following:

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
ARM AND SEND AMENDMENT #3
YOU: "(callsign), direct SPARTA VOR; after SPARTA expect vectors for ILS runway 4 right. Cross SPARTA at and maintain one-one thousand"

This amendment is OK, but let him deviate as necessary.

Amendment Series 2: Illogical routing

Reference the ATC station to SPARTA VOR (SAX).

When the aircraft is 15 miles from **SPARTA,** ***do the following:***

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
ARM AND SEND AMENDMENT #4
YOU: "(callsign), direct HUGUENOT VOR, direct JOELL intersection. After JOELL, expect vectors to ILS Runway 4 right. Cross JOELL at and maintain 7000. Reduce speed 2-5-0 knots"

IF THE PILOT DOES NOT REJECT THE AMENDMENT:

reference the ATC station to SPARTA. *When the aircraft is at* SPARTA*:*

YOU: "(callsign), clearance amendment"

when the pilot responds ready:

ARM AND SEND AMENDMENT #5

YOU: "(callsign), direct JOELL intersection. After JOELL expect vectors to ILS runway 4 right. Cross JOELL at and maintain 7000. Reduce speed 2-5-0 knots."

IF THE PILOT DOES REJECT THE AMENDMENT:

YOU: "(callsign), turn right heading 1-6-0"

wait about 10 seconds

ARM AND SEND AMENDMENT #5

YOU: "(callsign), direct JOELL intersection. After JOELL expect vectors to ILS runway 4 right. Cross JOELL at and maintain 7000. Reduce speed 2-5-0 knots."

This scenario will terminate at JOELL.

ATIS-F:

"Newark airport information Foxtrot. 1752 Zulu. 3500 Scattered, Measured Ceiling 9000 Broken, visibility 6 miles. Temp: 85 Dewpoint: 77. Wind

calm. Altimeter 29.38. Visual approach RWY 22L, RWY 11 in effect. Departing RWY 22R. Windshear advisories in effect. Heavy bird activity all quadrants of airport. Advise on initial contact information Foxtrot"
ATIS-G
"Newark airport information Golf. 1830 Zulu. Measured Ceiling 3000 Broken, 9000 Overcast, visibility 3 miles in rain showers. Temp: 78 Dewpoint: 76. Wind 050 at 16 gusting to 27. Altimeter 29.21. ILS approach RWY 4R in effect. Windshear advisories in effect. Heavy bird activity all quadrants of airport. Advise on initial contact information Golf"

Scenario Philadelphia B

The aircraft will start near **SHERL intersection**. *The initial clearance is:* **SHERL, V-139 BRIGS, Cedar Lake Arrival (VCN).** *ATIS Mike is active.*

Amendment Series 1: Routing into WX

Reference the ATC station to **PLUME** *intersection.*

When the aircraft reaches **PLUME,** ***do the following:***

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
ARM AND SEND AMENDMENT #1
YOU: "(callsign), direct SEA ISLE VOR, direct WOODSTOWN VOR, after WOODSTOWN expect vectors to ILS runway 2-7 right."
Note: ATIS November now active

IF THE PILOT DOES NOT REJECT THE AMENDMENT:

reference the ATC station to **DRIFT intersection.***When the aircraft is at* **DRIFT***:*

YOU: "(callsign), clearance amendment, "

when the pilot responds ready:

ARM AND SEND AMENDMENT #2

YOU: "(callsign), direct DIXIE intersection, direct YARDLEY VOR. After YARDLEY expect vectors to ILS runway 2-7 right. Cross YARDLEY at and maintain one-zero thousand and 2-5-0 knots."

IF THE PILOT DOES REJECT THE AMENDMENT:

YOU: "(callsign), standby 1"

wait about 10 seconds

ARM AND SEND AMENDMENT #2

YOU: "(callsign), direct DIXIE intersection, direct YARDLEY VOR. After YARDLEY expect vectors to ILS runway 2-7 right. Cross YARDLEY at and maintain one-zero thousand and 2-5-0 knots."

Amendment Series 2: OK

Reference the ATC station to **DIXIE** *intersection.*

When the aircraft is 20 miles from **DIXIE,** ***do the following:***

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
<u>ARM AND SEND AMENDMENT #3</u>
YOU: "(callsign), direct YARDLEY VOR, after YARDLEY expect vectors to ILS runway 2-7 right. Cross YARDLEY at and maintain 10000 and 2-5-0 knots."

This amendment is OK. If he rejects it, tell him to maintain current clearance.

Amendment Series 3: Illogical routing

Reference the ATC station to ROBBINSVILLE VOR (RBV).

When the aircraft is at **RBV,** ***do the following:***

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
<u>ARM AND SEND AMENDMENT #4</u>
YOU: "(callsign), direct SOLBERG VOR, direct NORTH PHILADELPHIA VOR. After NORTH PHILADELPHIA, expect vectors to ILS Runway 2-7 right. Cross NORTH PHILADELPHIA at and maintain 4000."

IF THE PILOT <u>DOES NOT</u> REJECT THE AMENDMENT:
reference the ATC station to **YARDLEY**. *When the aircraft is 10 miles from* **YARDLEY**:
YOU: "(callsign), clearance amendment"
when the pilot responds ready:
<u>ARM AND SEND AMENDMENT #5</u>
YOU: "(callsign), direct NORTH PHILADELPHIA VOR. After NORTH PHILADELPHIA expect vectors to ILS runway 2-7 right. Cross NORTH PHILADELPHIA at and maintain 4000."
IF THE PILOT <u>DOES</u> REJECT THE AMENDMENT:
YOU: "(callsign), standby 1"
wait about 10 seconds
<u>ARM AND SEND AMENDMENT #5</u>
YOU: "(callsign), direct NORTH PHILADELPHIA VOR. After NORTH PHILADELPHIA expect vectors to ILS runway 2-7 right. Cross NORTH PHILADELPHIA at and maintain 4000."

This scenario will terminate at NORTH PHILLY (PNE).

ATIS-M:

"Philadelphia International airport information Mike. 2052 Zulu. 4000 Scattered, Measured Ceiling 9500 Broken, visibility 5 miles in haze. Temp: 91 Dewpoint: 80. Wind light and variable. Altimeter 29.58. Visual approach RWY 9R, RWY 9L in effect. Departing RWY 9L. DuPont VORTAC out of service until 0100 Zulu. Advise on initial contact information Mike"
ATIS-N
"Philadelphia International airport information November. 2127 Zulu. Measured Ceiling 3000 Broken, 9500 Overcast, visibility 3 miles in rain showers. Temp: 77 Dewpoint: 76. Wind 270 at 17 gusting to 24. Altimeter 29.31. ILS approach RWY 27R in effect. Departing RWY 27L. Windshear advisories in effect. DuPont VORTAC out of service until 0100 Zulu. Advise on initial contact information November"

Scenario Bradley C

The aircraft will start at **SPARTA VOR (SAX).** *The initial clearance is:* **SAX, V-2-4-9er WEETS INTERSECTION, V-2-0-5 BRADLEY VOR** *ATIS Sierra is active.*

*Amendment Series 1: Wrong destination- **SYRACUSE***

Reference the ATC station to **SHAFF** *intersection.*

When the aircraft reaches* SHAFF, *do the following:

> **YOU: "(callsign), clearance amendment, "**
> *when the pilot responds ready:*
> **<u>ARM AND SEND AMENDMENT #1</u>**
> **YOU: "(callsign), direct WEETS, victor 4-8-3 FAYET intersection, after FAYET expect vectors to ILS runway 2-7"**

IF THE PILOT <u>DOES</u> <u>NOT</u> REJECT THE AMENDMENT:
reference the ATC station to **FLOSI intersection.***When the aircraft is at* **FLOSI**:
YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
<u>ARM AND SEND AMENDMENT #2</u>
YOU: "(callsign), direct KINGSTON VOR, direct JUDDS intersection. After JUDDS expect vectors to ILS runway 6. Cross JUDDS at and maintain seven thousand and 2-5-0 knots."
IF THE PILOT <u>DOES</u> REJECT THE AMENDMENT:
YOU: "(callsign), standby 1"
wait about 10 seconds
<u>ARM AND SEND AMENDMENT #2</u>
YOU: "(callsign), direct KINGSTON VOR, direct JUDDS intersection. After JUDDS expect vectors to ILS runway 6. Cross JUDDS at and maintain seven thousand and 2-5-0 knots."

Amendment Series 2: OK

Reference the ATC station to **KINGSTON VOR (IGN).**

When the aircraft is* 15 miles from KINGSTON, *do the following:

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
<u>**ARM AND SEND AMENDMENT #3**</u>
YOU: "(callsign), direct JUDDS intersection, after JUDDS expect vectors to ILS Runway 6. Cross JUDDS at and maintain 7000 and 2-5-0 knots."

This amendment is OK. If he rejects it, maintain current clearance.

Amendment Series 3: Routing into WX

Reference the ATC station to PAWLING VOR (PWL).

When the aircraft is **DIRECTLY SOUTH OF PWL,** ***do the following:***

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
<u>**ARM AND SEND AMENDMENT #4**</u>
YOU: "(callsign), direct SOARS intersection, after SOARS expect vectors to ILS Runway 6. Cross SOARS at and maintain 7000. Reduce speed 2-5-0 knots."

IF THE PILOT <u>DOES NOT</u> REJECT THE AMENDMENT: *reference the ATC station to* SOARS. *When the aircraft is at* SOARS: <u>**ARM AND SEND AMENDMENT #5**</u> **YOU: "(callsign), turn left heading 0-6-0, descend and maintain 7000."**
IF THE PILOT <u>DOES</u> REJECT THE AMENDMENT: **YOU: "(callsign), standby 1"** *wait about 10 seconds* <u>**ARM AND SEND AMENDMENT #6**</u> **YOU: "(callsign), turn left, heading 0-9-0. Descend and maintain 7000."**

This scenario will terminate about 10 miles from **KBDL.**

ATIS-S:
"Bradley airport information Sierra. 1750 Zulu. Measured Ceiling 2500 Broken, 6000 Overcast, visibility 3 miles in light rain showers. Temp: 77 Dewpoint: 75. Wind 040 at 12 gusting to 18. Altimeter 29.52. ILS approach RWY 6 in effect. Windshear advisories in effect. Advise on initial contact information Sierra"

Scenario National C

The aircraft will start at **ALLENTOWN VOR (ABE).** *The initial clearance is:* **ABE, V-12 LANCASTER VOR, V-499 BALTIMORE VOR** *ATIS Oscar is active.*

Amendment Series 1: OK

Reference the ATC station to **EAST TEXAS** *VOR.*

When the aircraft reaches **EAST TEXAS,** ***do the following:***

> **YOU: "(callsign), clearance amendment, "**
> *when the pilot responds ready:*
> **ARM AND SEND AMENDMENT #1**
> **YOU: "(callsign), direct LANCASTER VOR, direct BALTIMORE VOR, after BALTIMORE expect vectors to RIVER VISUAL runway 1-8."**

This amendment is OK. If it is rejected, have him stay on his current clearance.

Amendment Series 2: Wrong destination- ***HARRISBURG INTL.***

Reference the ATC station to **FLOAT** *intersection.*

When the aircraft reaches **FLOAT,** ***do the following:***

> **YOU: "(callsign), clearance amendment, "**
> *when the pilot responds ready:*
> **ARM AND SEND AMENDMENT #2**
> **YOU: "(callsign), direct LANCASTER VOR, direct BAARN intersection, after BAARN expect vectors to ILS runway 1-3."**

IF THE PILOT DOES NOT REJECT THE AMENDMENT:

> *reference the ATC station to* **LANCASTER VOR.***When the aircraft is about 10 miles from* **LANCASTER***:*
> **YOU: "(callsign), clearance amendment, "**
> *when the pilot responds ready:*
> **ARM AND SEND AMENDMENT #3**
> **YOU: "(callsign), direct LANCASTER VOR, direct BALTIMORE VOR. After BALTIMORE expect vectors to River Visual runway 1-8. Cross BALTIMORE at and maintain 8000 and 2-5-0 knots."**

IF THE PILOT DOES REJECT THE AMENDMENT:

> **YOU: "(callsign), standby 1"**

wait about 10 seconds

ARM AND SEND AMENDMENT #3

YOU: "(callsign), direct LANCASTER VOR, direct BALTIMORE VOR. After BALTIMORE expect vectors to River Visual runway 1-8. Cross BALTIMORE at and maintain 8000 and 2-5-0 knots."

Amendment Series 3: Routing into WX

Reference the ATC station to **TRISH intersection.**

When the aircraft is at WEST of* TRISH, *do the following:

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
ARM AND SEND AMENDMENT #4
YOU: "(callsign), direct DATED intersection, after DATED expect vectors to River Visual Runway 1-8. Descend and maintain 8000. Reduce speed 2-5-0 knots."

IF THE PILOT DOES NOT REJECT THE AMENDMENT:

reference the ATC station to **DATED**. *When the aircraft is 5 miles from* **DATED**:

YOU: "(callsign), clearance amendment"

when the pilot responds ready:

ARM AND SEND AMENDMENT #5

YOU: "(callsign), turn left, head 1-9er-0. Descend and maintain 6000. Reduce 2-1-0 knots."

IF THE PILOT DOES REJECT THE AMENDMENT:

YOU: "(callsign), standby 1"

wait about 10 seconds

ARM AND SEND AMENDMENT #6

YOU: "(callsign), turn left, heading 2-1-0. Descend and maintain 6000. Reduce speed 2-1-0 knots."

This scenario will terminate about 10 miles from DCA.

ATIS-O:
"Washington National airport information Oscar. 2347 Zulu. Measured Ceiling 4000 Broken, 7000 Overcast, visibility 3 miles in light rain showers. Temp: 76 Dewpoint: 76. Wind 1-9-0@8. Altimeter 29.65. River Visual

Appoach to RWY 18 in effect, departing RWY 15. Bird activity reported at all quadrants of the airport. Advise on initial contact information Oscar"

Scenario LaGuardia C

The aircraft will start at **ODESA intersection.** *The initial clearance is:* **ODESA, V-4-4-5 LAGUARDIA VOR.** *ATIS Romeo is active.*

Amendment Series 1: OK

Reference the ATC station to **DUPONT (DQO)** *VOR.*

When the aircraft reaches* DQO, *do the following:

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
ARM AND SEND AMENDMENT #1
YOU: "(callsign), direct NANCI intersection, direct LAGUARDIA VOR, expect vectors to ILS runway 4."

This amenment is OK. If rejected, maintain current clearance.

Amendment Series 2: Wrong destination- ***TETERBORO***

Reference the ATC station to **STEFE** *intersection.*

When the aircraft reaches 8 miles from* STEFE, *do the following:

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
ARM AND SEND AMENDMENT #2
YOU: "(callsign), direct TETERBORO VOR, after TETERBORO expect vectors to ILS runway 6. Descend and maintain one-one thousand."

IF THE PILOT DOES NOT REJECT THE AMENDMENT:

reference the ATC station to **SOMTO intersection.***When the aircraft is about 5 miles from* **SOMTO***:*

YOU: "(callsign), clearance amendment, "

when the pilot responds ready:

ARM AND SEND AMENDMENT #3

YOU: "(callsign), direct ROBBINSVILLE VOR; after ROBBINSVILLE, expect vectors to ILS runway 4. Cross Robbinsville at and maintain one-one thousand."

IF THE PILOT DOES REJECT THE AMENDMENT:

YOU: "(callsign), standby 1"

wait about 10 seconds

ARM AND SEND AMENDMENT #3

YOU: "(callsign), direct ROBBINSVILLE VOR; after ROBBINSVILLE, expect vectors to ILS runway 4. Cross Robbinsville at and maintain one-one thousand."

Amendment Series 3: Rounting into WX

Reference the ATC station to **ROBBINSVILLE VOR (RBV).**

When the aircraft is* 15 miles from RBV, *do the following:

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
ARM AND SEND AMENDMENT #4
YOU: "(callsign), direct COLTS NECK VOR, after COLTS NECK expect vectors to ILS Runway 4. Descend and maintain 9000. Reduce speed 2-5-0 knots."

IF THE PILOT DOES NOT REJECT THE AMENDMENT:

reference the ATC station to COLTS NECK. *When the aircraft is about 5mi from* COLTS NECK*:*

ARM AND SEND AMENDMENT #5

YOU: "(callsign), turn left heading 0-2-0 descend and maintain 7000. Reduce speed 2-1-0 knots."

IF THE PILOT DOES REJECT THE AMENDMENT:

YOU: "(callsign), standby 1"

wait about 10 seconds

ARM AND SEND AMENDMENT #6

YOU: "(callsign), turn left, heading 0-5-0. Descend and maintain 7000. Reduce speed 2-1-0 knots."

This scenario will terminate about 10 miles from KLGA.

ATIS-R:
"New York LaGuardia information Romeo. 0150 Zulu. Measured Ceiling 900 Broken, 7000 Overcast, visibility 1 and 1/2 miles in rain showers. Temp: 68 Dewpoint: 65. Wind 050@5. Altimeter 29.54. ILS RWY 4 approach in effect, departing runway 31. Noise abatement procedures runway 31 in effect after 0200 Z. Advise on initial contact information Romeo"

Scenario Philadelphia C

The aircraft will start at **MARTINSBURG VOR (MRB).** *The initial clearance is:* **MRB, V-1-6-6 DUPONT VOR.** *ATIS Victor is active.*

Amendment Series 1: Wrong destination- ***BRADLEY***

Reference the ATC station to RUANE *intersection.*

When the aircraft reaches **RUANE,** ***do the following:***

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
ARM AND SEND AMENDMENT #1
YOU: "(callsign), direct LANCASTER VOR, victor 3-9er GREKI intersection, after GREKI expect vectors to ILS runway 6. "

IF THE PILOT DOES NOT REJECT THE AMENDMENT:

reference the ATC station to **BINNS intersection.***When the aircraft is about 10 miles from* **BINNS***:*

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
ARM AND SEND AMENDMENT #2
YOU: "(callsign), direct PADRE intersection, direct MODENA VOR; after MODENA, expect vectors to CONVERGING ILS-2 runway 9 right. Cross Modena at and maintain 7000 and 2-1-0 knots."

IF THE PILOT DOES REJECT THE AMENDMENT:

YOU: "(callsign), standby 1"
wait about 10 seconds
ARM AND SEND AMENDMENT #2
YOU: "(callsign), direct PADRE intersection, direct MODENA VOR; after MODENA, expect vectors to CONVERGING ILS-2 runway 9 right. Cross Modena at and maintain 7000 and 2-1-0 knots."

If the pilot requests direct MODENA, say you can expect that in 5 minutes.

Amendment Series 2: OK

Reference the ATC station to **PADRE intersection.**

When the aircraft is at **20 miles from PADRE,** ***do the following:***

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
<u>**ARM AND SEND AMENDMENT #3**</u>
YOU: "(callsign), direct MODENA VOR, after MODENA expect vectors to CONVERGING ILS-2 Runway 9 right. Cross MODENA at and maintain 7000 and 2-1-0 knots."

This amendment is OK. If he rejects it, tell him to fly current clearance.

Amendment Series 3: Rounting into WX

Reference the ATC station to **MODENA (MXE) VOR.**

When the aircraft is at* 15 miles from MODENA, *do the following:

YOU: "(callsign), clearance amendment, "
when the pilot responds ready:
<u>**ARM AND SEND AMENDMENT #4**</u>
YOU: "(callsign), direct DUPONT VOR, after DUPONT expect vectors to CONVERGING ILS-2 Runway 9 right."

IF THE PILOT <u>DOES NOT</u> REJECT THE AMENDMENT: *reference the ATC station to* **DUPONT (DQO).** *When the aircraft is about 5mi from* **DUPONT**:   <u>**ARM AND SEND AMENDMENT #5**</u>   **YOU: "(callsign), turn left heading 0-9er-0 descend and maintain 7000. Reduce speed 2-1-0 knots."**
IF THE PILOT <u>DOES</u> REJECT THE AMENDMENT: **YOU: "(callsign), standby 1"**   *wait about 10 seconds*   <u>**ARM AND SEND AMENDMENT #6**</u>   **YOU: "(callsign), turn left, heading 1-1-0. Descend and maintain 7000. Reduce speed 2-1-0 knots."**

This scenario will terminate near **SAVVY intersection.**

ATIS-V:
"Philadelphia International airport information Victor. 1650 Zulu. Measured Ceiling 3000 Broken, 6000 Overcast, visibility 2 miles in rain showers and fog. Temp: 71 Dewpoint: 71. Wind calm. Altimeter 29.72. Simultaneous ILS approach RWY 9R, 17 in effect, departing RWY 9L. Advise on initial contact information Victor"

APPENDIX B: SAMPLE OBSERVATION SHEET

SUBJECT:______________ RUN#:________________

MODE: Verbal Text Graphical

Readback?: YES (2/3) NO (1/2) FMC: AUTO MANUAL

Amendment series 1: OK 1 2 3 NOT

Amendment series 2: OK 1 2 3 NOT

Amendment series 3: OK 1 2 3 NOT

Questions: Scale of 1 to 7:

efficiency_________ (1: unsafe-too long 4: like current ATC 7: optimum efficiency)

situational awareness_________ (1: unsafe-out of loop 4: like current ATC 7: optimum awareness)

total effectiveness_________ (1: unsafe-info/time 4: like current ATC 7: optimum presentation)

Pros:

Cons:

APPENDIX C: SCENARIO ROTATION INFORMATION

KEY TO SCENARIO ROTATION INFORMATION

1) Run # is the sequence which the runs were accomplished

2) Mode is the delivery mode: V = Verbal, T = Textual, G = Graphical

3) Scenario is the scenario code (see Table 4.1)

4) FMS is the method of FMS programming: auto = automated, man = manual

5) Readback is whether a readback is part of the procedure

6) Procedure # refers to Table 3.1

7) Notes:
   - No WX = weather event was not a valid test
   - No RTE = routing event was not a valid test
   - Neither = neither event in the scenario was a valid test OR run was incomplete

SUBJECT 1

Run #	Mode	Scenario	FMS	Readback	Procedure #	Notes
1	V	b.phl	auto	yes	2	
2	V	a.bos	auto	no	1	
3	V	c.dca	man	yes	4	
4	V	a.bwi	man	no	3	
5	T	b.dca	auto	no	1	
6	T	a.jfk	man	yes	4	
7	T	c.phl	auto	yes	2	
8	G	b.ewr	man	yes	4	
9	G	c.bdl	auto	no	1	
10	G	a.lga	auto	yes	2	

SUBJECT 2

Run #	Mode	Scenario	FMS	Readback	Procedure #	Notes
1	V	b.bos	man	yes	4	
2	V	c.lga	auto	no	1	
3	V	a.bwi	auto	yes	2	
4	V	c.bdl	man	no	3	
5	T	b.ewr	auto	yes	2	
6	T	a.jfk	auto	no	1	
7	T	c.dca	man	yes	4	
8	G	b.phl	auto	no	1	
9	G	a.jfk	man	yes	4	Neither
10	G	c.phl	auto	yes	2	

SUBJECT 3

Run #	Mode	Scenario	FMS	Readback	Procedure #	Notes
1	V	b.dca	auto	no	1	
2	V	a.jfk	man	yes	4	
3	V	c.phl	auto	yes	2	
4	V	b.phl	man	no	3	
5	T	c.dca	man	yes	4	
6	T	a.lga	auto	no	1	
7	T	b.bos	auto	yes	2	
8	G	a.bos	auto	yes	2	
9	G	c.lga	auto	no	1	
10	G	b.ewr	man	yes	4	

SUBJECT 4

Run #	Mode	Scenario	FMS	Readback	Procedure #	Notes
1	T	b.ewr	auto	no	1	
2	T	a.lga	man	yes	4	No RTE
3	T	c.bdl	auto	yes	2	
4	G	b.bos	man	yes	4	
5	G	c.lga	auto	no	1	
6	G	a.bos	auto	yes	2	
7	V	b.dca	auto	yes	2	
8	V	a.bwi	auto	no	1	No WX
9	V	c.phl	man	yes	4	Neither
10	V	a.jfk	man	no	3	Neither

SUBJECT 5

Run #	Mode	Scenario	FMS	Readback	Procedure #	Notes
1	T	b.phl	auto	no	1	
2	T	a.bos	man	yes	4	No RTE
3	T	c.dca	auto	yes	2	
4	G	b.dca	auto	no	1	
5	G	a.bwi	man	yes	4	No RTE
6	G	c.phl	auto	yes	2	
7	V	b.ewr	man	yes	4	
8	V	c.bdl	auto	no	1	
9	V	a.jfk	auto	yes	2	
10	V	c.lga	man	no	3	Neither

SUBJECT 6

Run #	Mode	Scenario	FMS	Readback	Procedure #	Notes
1	T	c.lga	man	yes	4	No WX
2	T	a.bwi	auto	no	1	
3	T	b.bos	auto	yes	2	
4	G	a.jfk	auto	no	1	
5	G	c.bdl	man	yes	4	
6	G	b.ewr	auto	yes	2	
7	V	b.phl	auto	no	1	No RTE
8	V	a.lga	man	yes	4	
9	V	c.dca	auto	yes	2	
10	V	b.dca	man	no	3	

SUBJECT 7

Run #	Mode	Scenario	FMS	Readback	Procedure #	Notes
1	G	b.dca	auto	yes	2	
2	G	c.phl	man	yes	4	
3	G	a.jfk	auto	no	1	
4	V	b.phl	auto	yes	2	
5	V	a.lga	auto	no	1	
6	V	c.dca	man	yes	4	
7	V	a.bos	man	no	3	
8	T	b.bos	auto	yes	2	
9	T	a.bwi	auto	no	1	
10	T	c.lga	man	yes	4	

SUBJECT 8

Run #	Mode	Scenario	FMS	Readback	Procedure #	Notes
1	G	b.ewr	auto	no	1	
2	G	a.lga	man	yes	4	
3	G	c.bdl	auto	yes	2	
4	V	b.bos	man	yes	4	
5	V	c.lga	auto	no	1	
6	V	a.bos	auto	yes	2	
7	V	c.phl	man	no	3	
8	T	b.dca	auto	no	1	
9	T	a.bwi	man	yes	4	
10	T	c.dca	auto	yes	2	No RTE

SUBJECT 9

Run #	Mode	Scenario	FMS	Readback	Procedure #	Notes
1	G	a.bos	auto	no	1	
2	G	c.dca	man	yes	4	
3	G	b.phl	auto	yes	2	
4	V	b.dca	auto	no	1	
5	V	a.bwi	man	yes	4	
6	V	c.phl	auto	yes	2	
7	V	b.ewr	man	no	3	
8	T	c.bdl	auto	no	1	
9	T	a.jfk	auto	yes	2	
10	T	b.bos	man	yes	4	Neither

APPENDIX D: STATISTICAL ANALYSIS

The statistical method used for the performance measurements was a Non-parametric Paired test [9]. This method is appropriate for a "within subjects" experimental design. This appendix will explain the general method and will give a numerical example.

Between treatments of data (i.e. the categories being compared), there were two tests which were performed: 1) the data was either detected or not detected, and 2) the data was either detected initially or not detected initially. (In the numerical example, the treatments are the graphical and verbal mode of delivery, and the test was the initial detection performance for routing events.)

The data was first divided into the appropriate treatments, and the performance for each subject was recorded for the treatments. Care was taken to ensure that the comparisons between treatments was fair: if a particular data point was unusable for one treatment, the corresponding data point for the other treatment was removed from the analysis.

After the scores for each subject were recorded, ties between treatments for individual subjects were discarded, yielding an adjusted number of subjects. The performance of the remaining subjects was compared as to which treatment gave a higher score, and this number was tested against the values in Table D.1. If the number of subjects whose scores for one treatment exceeded the tabulated value, a statistical difference at the corresponding tabulated level was assigned to that test.

TABLE D.1: TEST VALUES FOR THE NON-PARAMETRIC PAIRED TEST [9]		
Adjusted # Of Subjects	# of Subjects Needed to Yield 95% Significance For a Treatment	# of Subjects Needed to Yield 99% Significance For a Treatment
6	5	–
7	6	–
8	7	7
9	7	8

For the numerical example (comparing the initial detection performance for routing events between the graphical and verbal modes), the individual subject scores for each treatment (i.e. graphical and verbal) are shown in Table D.2. Since Subjects 4 and 9 had the same performance for both treatments, their scores are ignored. Of the seven remaining subjects, six garnered a higher score for graphical, rather than verbal, delivery. Since this number (i.e. 6) equals the tabulated value for the remaining subjects, the performance is judged to be significant at the 95% level.

TABLE D.2: DATA FOR NUMERICAL EXAMPLE									
Subject #	1	2	3	4	5	6	7	8	9
Graphical: Initial Detections – Routing	3	1	1	0	1	1	1	2	2
Verbal: Initial Detections – Routing	2	0	0	0	0	0	0	3	2

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