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TEST PLAN FOR EVALUATION OF INITIAL DATA LINK ATC SERVICES FOR ISSS

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1. INTRODUCTION

1.1 Purpose

This document is a test plan for controller evaluation of initial en route Data Link services in the Initial Sector Suite System (ISSS) common console workstation. The intent of the plan is to define test objectives, methodologies, procedures, and schedules in order to provide requirements for planning study logistics, for developing test scenarios, and simulation software/hardware at the Federal Aviation Administration (FAA) Technical Center.

1.2 Background

The design of Data Link air traffic control (ATC) services began in 1988 at the FAA Technical Center with a series of controller-in-the-loop simulation studies aimed at iteratively developing and testing a group of initial services and functions for the currently operational National Airspace System (NAS) en route HOST computer/Plan View Display (PVD) workstation system. Based upon measures of controller workload, performance, and operational suitability, design development studies produced refined PVD displays, command inputs, and communications procedures which were used as the basis for preparing a functional specification for Data Link service implementation in the HOST computer system (Buck et. al., 1991).

The initial services defined within the specification include altitude assignment, transfer of communication, menu text functions, and communication backup. HOST/PVD research conducted subsequent to the publication of the specification also produced a design for receiving downlinked messages from the flight deck of Data Link equipped aircraft, and a capability to receive an initial contact message from Data Link equipped aircraft following the transfer of communication.

As part of the Advanced Automation System (AAS) program, a new controller workstation will be introduced into the en route ATC environment within the next few years. As the AAS evolves, this ISSS common console will eventually replace all HOST/PVD controller interfaces. During the first phase of the transition process, the common console will be supported by the same HOST computer that supports the current PVD workstation and will, as a minimal requirement, provide functional capabilities that are equivalent to the existing system.

This shared functionality and computer support for the common console and PVD are expected to make the design specifications that were developed from PVD research findings directly applicable to the implementation of initial Data Link services in the ISSS common console. However, because the ISSS will introduce new display coding dimensions, non-dedicated display surfaces, keyboard inputs and a new command language syntax, a number of candidate implementation options could be accommodated

under the general specifications. Thus, additional empirical research will be needed to develop an ISSS implementation under these specifications which will optimize controller useability by conforming to general Data Link design principles while being fully integrated with the conventions for user interaction unique to the common console design.

2. TEST OBJECTIVES

As discussed above, research at the FAA Technical Center has yielded several design concepts which may be sufficiently general to guide Data Link implementation on a broad range of potential controller workstations. However, it is imperative that all potential issues and problems that could affect transition of Data Link services from the HOST/PVD system to the ISSS environment be considered during ISSS software development. Because the successful development of a functional user interface will depend upon input from the operational community, air traffic controllers must be used as a major source of information about design requirements.

The overall objective of this study will be to use the validated HOST/PVD Data Link implementation as a comparative baseline for assessing the useability and operational suitability of a candidate implementation in the ISSS common console. Specifically, controllers with prior exposure to the designs of the initial Data Link services and the ISSS common console, as well as simulation experience with both systems, will provide data regarding:

a. Controller workload and operational suitability associated with the user interface and procedural design of a candidate ISSS common console implementation of the initial en route Data Link ATC services.

b. Specific interface design problems detected in the candidate ISSS implementation and recommended solutions.

c. Potential enhancements to Data Link displays and procedures made possible by the increased capability of the ISSS.

d. Additional design issues not tested during HOST/PVD Data Link development, but which may impact ISSS.

Results obtained relative to these objectives will be used to document recommended design specifications for necessary and/or desirable modifications to the candidate designs of Data Link ATC services for the ISSS common console.

An ancillary objective of this study will be to validate the performance fidelity of the newly developed ISSS common console simulation capability at the FAA Technical Center which will be used to support the present research as well as future design development and operational evaluation studies.

3. TEST APPROACH

Unique expertise in the design of en route Data Link ATC services for the HOST/PVD system and in the human-computer interface and operation of the ISSS resides in two separate teams of air traffic controllers appointed by the FAA to represent operational concerns in the development of these new ATC systems. Members of the Sector Suite Requirements Validation Team (SSRVT) have been actively involved in the evolution of the common console hardware and display requirements. Beyond acting as overseers of this effort, SSRVT team members have the highest available level of controller familiarity with the operation of the common consoles.

Members of the Air Traffic Data Link Validation Team (ATDLVT) directly participated in the design of the initial en route Data Link services for the HOST/PVD, and were closely involved with the evaluation exercises conducted in the Data Link test bed. Thus, these controllers are thoroughly versed in the design philosophy underlying Data Link ATC services, as well as the use of the system in the test bed under various air traffic scenarios.

The proposed study will draw upon the expertise from these two teams, as well as the members' shared operational experience in en route ATC by recruiting members from both teams to participate in the evaluation of the candidate ISSS Data Link implementation. In order to maximize the information gained during the study, and to ensure that controller evaluations are based on accurate knowledge of the current HOST/PVD Data Link and ISSS designs, the first phase of this study will be devoted to cross training and familiarizing the ATDLVT and SSRVT participants with the PVD Data Link service designs, the general operation of the ISSS common console, and the ISSS candidate Data Link service designs.

In the second phase of the study, all of the subject controllers will participate in a systematic evaluation of the candidate ISSS service designs. This design review activity will permit the controllers to simultaneously examine descriptions of inputs and displays for each service as implemented in the PVD and in the common console workstations while exercising the services in the ISSS simulation facility.

In the final phase of the study, the controllers will participate in full scale simulation exercises designed to provide them with the experience needed to comparatively assess the overall effectiveness and impact of the ISSS Data Link designs under operational conditions.

4. TEST CONDUCT

4.1 SUBJECTS

The subjects for this study will be eight Full Performance Level (FPL) air traffic control specialists who are currently proficient

in Air Route Traffic Control Center (ARTCC) radar control operations. Four to six of these controllers will be recruited from the ATDLVT, while two to four will be recruited from the SSRVT. In order to optimize the validity of the data to be collected, volunteers with the greatest amount of experience on their respective teams will receive preference in the subject selection process.

4.2 TEST PROCEDURES

4.2.1 Test Facilities and Scenarios

This study will be conducted in two laboratories located at the FAA Technical Center. Training and testing on the HOST/PVD Data Link services will be conducted in the en route portion of the Data Link test bed using pseudo pilots operating the dynamic simulation (DYSIM) function to control aircraft targets and to conduct air-ground voice communications with the subject controllers. Training and testing on the ISSS common console will be conducted using the ISSS prototype facility and associated pseudo pilot capabilities. The HOST/PVD simulation system in the Data Link test bed will provide all current NAS en route functions and displays, and will support all initial Data Link services. The ISSS prototype system will support the primary commands specified in the EN09 specifications document as well as candidate versions of ISSS initial services.

Four sectors of adjacent en route airspace will be simulated on each of the two systems. Scenarios developed for both systems will use the Oakland ARTCC adaptation and identical airspace sectors. As described more fully in later sections of this document, both the ISSS prototype and the HOST/PVD simulation systems will require training scenarios and identical high traffic scenarios with mixed Data Link equipage. In addition, a specialized series of short, scripted 100 percent Data Link equipage scenarios will be required for the ISSS prototype for design review purposes. In all scenarios, total Data Link transaction times will be randomly drawn from a rectangular distribution representing nominal estimated communications system uplink and downlink transmission times plus a pilot response delay. The mean of the distribution will be 18 seconds with a range of 12 to 24 seconds.

Upon arriving at the FAA Technical Center, each of the eight subjects will be randomly assigned to one of the four sectors of airspace in the Oakland ARTCC with two subjects per position. In order to maximize airspace familiarity and focus on Data Link operations, these assignments will be maintained for all training and subsequent testing.

4.2.2 Phase I: System Cross Training

In the first phase of this study, preparations for data collection will begin by providing all subjects with instruction and training on the general operation of the prototype ISSS common console, and

on the HOST/PVD and ISSS implementations of the initial Data Link services. At least one week prior to the study, all subjects will receive a training package containing a reference manual describing all available command inputs for the ISSS prototype as well as detailed descriptions of the Data Link service implementations for both the HOST/PVD and ISSS prototype. The subjects will be asked to study these commands before arriving at the FAA Technical Center.

Formal training will be conducted in three stages as discussed below:

In the first stage, the subjects will be introduced to the Oakland ARTCC airspace and will receive training in the use of the HOST/PVD Data Link services. Training will begin with a 3-hour classroom session during which all HOST/PVD Data Link command inputs, displays and procedures will be explained and illustrated. After any questions are answered, the remainder of the session will be devoted to familiarizing the subjects with the test airspace, applicable ATC procedures, and letters of agreement.

The classroom session will be followed by four hours of hands-on practice in the HOST/PVD Data Link test bed. During this session, the two subjects assigned to each PVD will practice Data Link operation in scenarios which will increase in traffic volume from 50 to 75 percent of airspace capacity after approximately two hours. All aircraft in the scenario will be Data Link equipped in order to maximize training efficiency. The paired subjects will alternate between observing and actively controlling traffic. Because of their prior experience in Data Link research, the ATDLVT subjects will be familiar with the HOST/PVD initial services. However, they will participate in this stage for refresher training, to assist in the instruction of SSRVT subjects, and to become familiar with the Oakland ARTCC airspace.

The second stage of training will introduce the subjects to general operation of the ISSS common console. While SSRVT subjects will have had prior experience in common console operation, they will participate in this exercise for refresher training, to become familiar with the unique characteristics of the ISSS prototype simulation, and to assist in training the ATDLVT subjects.

ISSS training will begin with two hours of classroom instruction intended to supplement and reinforce the reference manual material. Briefings will be used to review all commands and displays implemented on the ISSS prototype. However, the candidate Data Link services will not be introduced. Classroom instruction will be followed by a 4-hour training session in the ISSS simulation facility. Air traffic scenarios with volumes increasing from 50 to 75 percent of airspace capacity and approximately identical to those used in the HOST/PVD training will be presented to permit the subjects to exercise the ISSS functions. During this stage of training, all communications will be conducted using voice radio. Subjects will work in pairs as described in the HOST/PVD training protocol.

This phase of general ISSS training will be followed by an 1-hour session during which subjects will be asked to complete questionnaires and participate in a debriefing designed to provide an assessment of the quality of simulation provided by the ISSS prototype system. While the assessments will be focused primarily on the SSRVT subjects who have had prior experience with actual common console workstations, all subjects will be asked to evaluate the overall fidelity of simulation provided by the system, the operational realism of the system's performance, and the degree to which the prototype emulates the "look and feel" of the actual ISSS common console. In all cases, the controllers will be asked to judge these qualities in relation to simulation requirements for developing and testing Data Link functions rather than against an absolute criterion of perfect ISSS emulation. Debriefing discussions will center on identifying needed improvements to the ISSS prototype simulation system for future Data Link studies.

The final stage of training will provide subjects with instruction on the candidate initial services developed for the ISSS common console. An 1-hour classroom session will be used to brief the subjects on Data Link inputs and displays. This will be followed by four hours of experience in the ISSS prototype facility. The hands-on training will follow the same protocol as that used in the first two training stages and will use identical airspace scenarios. All aircraft will be Data Link equipped.

4.2.3 Design Review

Data collection for this study will begin with a formal review of the candidate ISSS Data Link ATC service designs. The eight subjects will complete the design review while seated in two-controller teams at the prototype common console workstations and controlling aircraft in a series of brief scenarios. Each of these scenarios or frames will be designed to permit the controllers to exercise one of the initial candidate service designs or a group of related design features common to all of the services.

Evaluations will be made by completing sections of a design review questionnaire booklet which are correlated with the individual scenario frames. The subjects will be informed that the object of the simulation activity is to aid them in completing the detailed design review, and that maintaining routine control over the moderate level of air traffic in the scenario frames is secondary to this task. The paired subjects will work together in exercising and examining each service and design feature. However, they will be instructed to answer evaluation questions individually.

The design review scenario software will operate on individual workstations so that the evaluations can be flexibly paced by each pair of controllers. Subjects at a workstation will have the ability to take as much time as required to complete each booklet section and to repeat the associated scenario frame if necessary before moving on to the next section. In cases where a service

would normally require cooperation with an adjacent sector or a simulation pilot (e.g., transfer of communications) the simulation software will be modified for the design review to emulate these inputs. Test facilitators will be available to assist the subjects in exercising the services and to answer any questions regarding inputs or displays.

The design review questionnaire booklet will be similar to that developed for prior Data Link evaluations. Each section will begin with a condensed text description of the service or group of design features as implemented in the ISSS prototype. This description will be organized around functional sub-activities associated with the service and will list detailed inputs and displays. For comparison purposes, the corresponding service description for the HOST/PVD service implementation will appear on facing pages of the review booklet.

Initial questionnaire items in each section will verify the fidelity of the service implementations by requiring the subjects to judge the correspondence between the descriptions and their actual experience with the ISSS prototype. Succeeding items will assess the acceptability of the service implementations observed in the test bed, and solicit recommendations for design modifications.

The following is a tentative set of booklet sections and correlated scenario frames around which the design review exercise will be organized:

- Sector Set Up Commands and Displays
- Data Link Equipage/Eligibility Indicator
- Status List Format and Content and Manipulation
- Data Block Format and Content
- Transfer of Communication
- Forcing/Stealing Data Link Eligibility
- Altitude Request and Initial Contact
- Altitude Assignment
- Menu Text Menu Content and Manipulation
- Interim Altitudes Via Menu Text
- R and Z Menu Text Items
- Communications Back-Up Uplink

Upon completion of the review exercise, all subjects will meet with test personnel for a group debriefing session. This 4-hour session

will be used to perform an item-by-item review of the subjects' responses to the review questionnaire. The emphasis of the debriefing will be (1) to identify and resolve disagreements regarding the fidelity and acceptability of the service designs, and (2) to achieve a consensus regarding recommended changes to the service designs. Designated test personnel will take extensive notes on the issues, resolutions and design modifications discussed during the debriefing. In addition, a complete audio tape record will be maintained for future reference during data analysis.

4.2.4 Full Scale Simulation

The third part of this study will consist of a series of full scale simulation tests in which the subjects will control traffic in the four sectors of Oakland ARTCC airspace. The purpose of these test runs will be to provide the subjects with a realistic simulation experience as a basis for expert evaluation of the workload, operational utility and acceptability of the ISSS Data Link services as implemented for this study.

During these simulation runs, subjects will operate in test scenarios with air traffic at 100 percent of airspace capacity. They will be required to control traffic in the ISSS prototype under voice radio-only and Data Link communication conditions. To provide a comparative baseline, the subjects also will be tested under voice-only and Data Link conditions in the HOST/PVD Data Link test bed. In both Data Link conditions, 80 percent of the aircraft will be equipped for both Data Link and voice radio communication while the remaining 20 percent will be able to communicate only via voice radio.

In order to minimize the effects of airspace learning on controller assessments, two equivalent 60-minute scenarios will be used for these test runs. These scenarios will involve similar traffic patterns and equal numbers of aircraft, but will differ slightly in aircraft sequence and spacing.

The experimental design for the full scale simulation testing is illustrated in table 1. The eight subjects will be divided into two groups containing equal numbers of ATDLVT and SSRVT controllers. Because it is likely that testing time in the HOST/PVD Data Link test bed will be available only in the late afternoon or early evening, the experimental design is configured such that ISSS testing sessions precede HOST/PVD testing sessions on each of the two full scale simulation days. However, as shown in the table, the two groups will alternate between testing in the HOST/PVD Data Link test bed and in the ISSS facility in a manner which counterbalances for order of testing on the two Data Link implementations and minimizes transfers between the two laboratory facilities. The air traffic scenarios will be partially counterbalanced with the independent variables such that both scenarios will be used under Data Link and voice conditions with both system implementations.

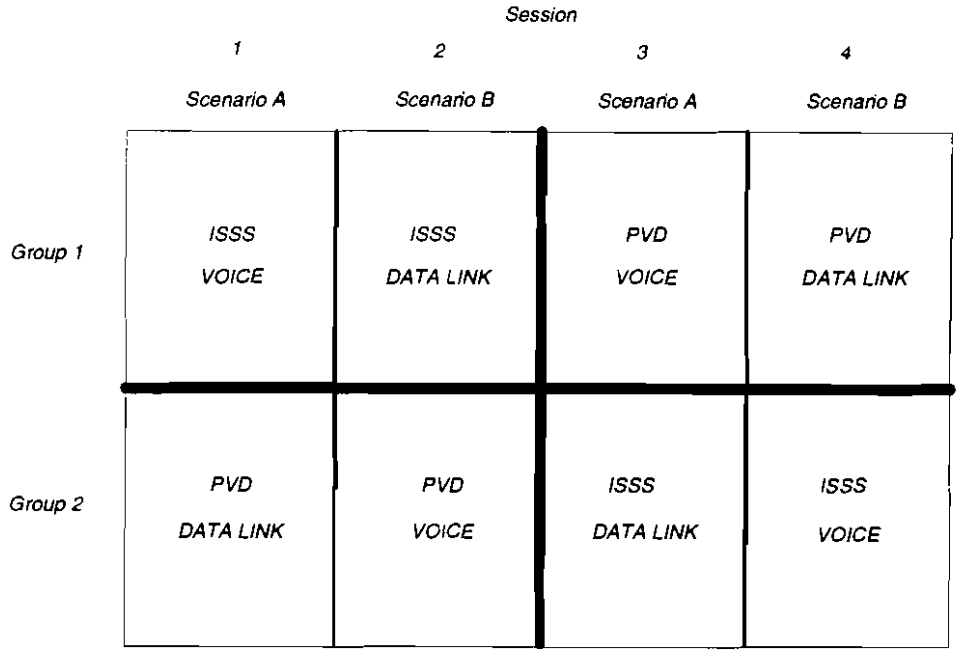


Table 1. Experimental Design for Full Scale Simulation

As an auxiliary control over learning effects in the experimental design, all subjects will participate in warm-up trials in both the ISSS and HOST/PVD test facilities. These warm-up runs will be completed prior to the beginning of testing and will consist of abbreviated versions of the Data Link test scenarios using 100 percent traffic loads and 80 percent Data Link equipage.

During warm-up and test simulation runs in which one of the subject groups is controlling traffic, members of the other group will act as simulation pilots.

Because subjects in this study will have received insufficient training with the airspace to achieve operational proficiency, and the Data Link services under evaluation will be preliminary designs, no attempt will be made to draw conclusions regarding the effects of the ISSS Data Link implementation on ATC system safety, efficiency or capacity, and no measures of these system performance factors will be collected. However, in order to obtain an index of the extent to which Data Link is used by the subjects to substitute for voice communications, data will be collected on radio and Data Link usage during all full scale simulation test sessions. As a minimum, both test laboratories will record the number of voice messages sent

by each controller during each test run, the duration of each voice message, and the number and content of all Data Link messages sent by each controller.

The primary data that will be obtained during full scale simulation testing will be based upon expert judgments provided by the controller subjects. These data will be collected using quantified rating techniques and questionnaires administered after each test session and after all of the test sessions have been completed.

Upon completing each test run, subjects will provide an overall workload rating for the test scenario using the Subjective Workload Assessment Technique (SWAT). They also will be asked to note any factors which contributed to the workload perceived during the run and, on Data Link trials, any operational problems that they experienced which were associated specifically with using the Data Link services.

After finishing all four test runs, Analytical Hierarchy Process (AHP) scales will be completed to obtain comparative workload ratings. These ratings will be used to separate the effects of general differences between the HOST/PVD and ISSS common console systems from those of the two Data Link implementations. In addition to these workload ratings, subjects will be asked to use AHP scales to compare each of the initial services developed for the two workstations on operational suitability and acceptability to controllers.

A final debriefing will follow the full scale simulation testing. This debriefing will revisit the design of the candidate ISSS services, confirm any conclusions from the design review, and solicit from the controllers any additional recommendations regarding changes to the service designs. The subjects also will be asked to express any final comments or concerns regarding the general operational impact of implementing Data Link ATC services in the NAS.

4.2.5 Discussion of Initial Contact Redesign

As an adjunct to the final debriefing, the ATDLVT and SSRVT controllers will participate in a structured discussion focused on impending changes and extensions to the initial Data Link services. These will include a consideration of the effects of altering the initial contact service to become compliant with the Data Link Minimal Operational Performance Standard (MOPS), and requirements for displaying and responding to messages downlinked from aircraft.

The initial contact service which will be tested during the present study requires the pilot to downlink his assigned altitude in conjunction with the Wilco to a transfer of communication message. As Data Link eligibility changes to the receiving controller with the Wilco receipt, this altitude is transferred over ground systems and is automatically checked against the aircraft's flight plan. An error message is displayed in the full data block on the receiving

controller's radar display if the assigned altitude message fails to match the stored flight data.

The recently published Data Link MOPS dictates that, while the aircraft may downlink its assigned altitude with the transfer of communication Wilco, it also is permitted to send the altitude as a separate message directly to the new controller. Thus, the initial contact service will require redesign to accommodate this option.

During the discussion, test controllers will be asked to examine a new design for initial contact in which the transfer of communication Wilco not only changes eligibility, but also causes a "no altitude" (NALT) message to be displayed in the receiving controller's full data block timesharing with the flight plan assigned altitude. Receipt of an assigned altitude either as part of the Wilco message via ground communications or as a separate message from the pilot deletes the NALT display if it matches the stored flight data, or presents an error message if there is a discrepancy. The controller can manually clear the NALT or error display by pressing the Data Link key and designating the aircraft by a slew action or flight plan identification (FLID) input, or by sending any new altitude message to the aircraft.

The primary issue that will be considered during the discussion will be the potential impact of time delays in the modified design. While sending the assigned altitude with the transfer of communication Wilco normally will produce a nearly simultaneous transfer of Data Link eligibility and altitude check, a separate assigned altitude downlink could result in a considerable delay between the receipt of eligibility and the confirmation that the pilot's intended assigned altitude conforms with the flight plan. The length of this delay would depend upon a combination of realized system transmission times, the design of the flight deck Data Link interface, and aircrew procedures.

As part of the discussion, the controllers will be asked to comment on the potential impact of extended delays on their capability to control air traffic, describe specific situations in which such delays may be critical, suggest procedural approaches to dealing with delays, and assist in outlining requirements for a simulation study which could be used to validly determine the maximum tolerable latencies for the initial contact message.

5. SCHEDULE

The following draft schedule for the planned study activities assumes a start date of 7 December 1993.

Monday 6 December

Controller Travel

Tuesday 7 December

0800 - 0900 -- Introductory Briefings (Welcome, Data Link development history, Study objectives, and activity overview)

0900 - 1030 -- Classroom Airspace Instruction

1030 - 1200 -- Classroom HOST/PVD Data Link Instruction

1200 - 1300 -- Lunch

1300 - 1700 -- HOST/PVD Data Link Hands-on Practice

Wednesday 8 December

0800 - 0900 -- Questions and Review HOST/PVD

0900 - 1100 -- Classroom ISSS Prototype Instruction (non-Data Link)

1100 - 1200 -- ISSS Hands-on Practice (non-Data Link)

1200 - 1300 -- Lunch

1300 - 1600 -- ISSS Hands-on Practice (non-Data Link) - Continued

1600 - 1700 -- ISSS Prototype Evaluation

Thursday 9 December

0800 - 0900 -- Questions and Review ISSS

0900 - 1000 -- Classroom ISSS Data Link Instruction

1000 - 1200 -- ISSS Data Link Hands-on Practice

1200 - 1300 -- Lunch

1300 - 1500 -- ISSS Data Link Hands-on Practice - Continued

1600 - 1700 -- Data Link PVD Refresher Instruction and Comparison to ISSS Data Link

Friday 10 December

0800 - 0830 -- Prebriefing on Design Review Process and Materials

0830 - 1200 -- Design Review - ISSS Prototype Lab - Hands-on

1200 - 1300 -- Lunch

1300 - 1700 -- Design Review Debriefing

Monday 13 December

0830 - 1200 -- Prebriefing on Full Scale Simulation
Explanation of Rating Forms
SWAT Sort Procedure

1200 - 1300 -- Lunch

1300 - 1430 -- ISSS Warm-Up

1430 - 1500 -- Relocate to HOST/PVD Lab

1500 - 1630 -- HOST/PVD Warm-Up

Tuesday 14 December

(times as scheduled) -- Group 1 ISSS Test Runs (2) and Post-Run Ratings
-- Group 2 HOST/PVD Test Runs (2) and Post-Run Ratings

Wednesday 15 December

(times as scheduled) -- Group 2 ISSS Test Runs (2) and Post-Run Ratings
-- Group 1 HOST/PVD Test Runs (2) and Post-Run Ratings

-- Groups 1 and 2 Complete Post-test Ratings and Questionnaires

Thursday 16 December

0830 - 1200 -- Final Debriefing

1200 - 1300 -- Lunch

1300 - 1700 -- Initial Contact and Downlink Discussion

Friday 17 December

0900 - 1200 -- Wrap-Up

1200 -- Controllers Depart