technical note technical note

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Satellite Data Link Validation Test Plan

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16. Abstract

This document describes the validation process of a satellite data link which will be conducted by the Federal Aviation Administration (FAA) Technical Center. Aircraft equipped with satellite communication avionics will relay progress reports through a satellite to a ground earth station (GES). These will be compared directly to voice reports made using high-frequency (HF) radio. The results of the comparisons between the different links will be used to determine the suitability of satellite communication as a replacement for HF for oceanic air traffic control.

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EXECUTIVE SUMMARY

This plan describes the validation process of a satellite data link for use in air traffic control (ATC). Aircraft equipped with satellite communication avionics will relay position reports through a satellite to a ground earth station (GES). From the GES, messages will be passed, using the Aeronautical Radio, Inc. (ARINC) Data Network Service (ADNS), to the Federal Aviation Administration (FAA) Technical Center. They will be recorded by a commercially available computer. These messages are position reports which will be compared to reports using high frequency (HF) radio communication which contain similar information. These reports will be compared to measure the relative performance of the two communication links. The results of the comparisons between the different links will be used to determine the suitability of satellite communication as a replacement for HF for oceanic ATC.

INTRODUCTION

OBJECTIVE.

The objective of this test is to determine the suitability of satellite data link for use in oceanic air traffic control (ATC). This will be done by comparing the performance of existing high frequency (HF) voice communications links against the satellite data link, by post-flight comparison of HF and satellite progress reports. The results of the comparisons between the different links will be used to determine the suitability of satellite communication as a replacement for HF for oceanic ATC.

OVERVIEW.

PRESENT OPERATIONAL ENVIRONMENT. Presently, in the oceanic airspace pilots relay progress reports, at fixed points, to air traffic controllers via HF voice communication links. The current procedure for relaying messages in the Pacific is as follows: the pilot reads position information from the Inertial Navigation System (INS) at a specified reporting point and transmits it by voice over HF radio. An operator at the Aeronautical Radio, Inc. (ARINC) facility listens to the message and transcribes it exactly as he hears it. The transcribed report is then transmitted over the data network to the ATC center at Oakland or Anchorage. In Oakland, the progress reports are processed by the Oceanic Display and Planning System (ODAPS), which maintains flight plans, prints flight strips, and provides a situation display for the controller.

The environment in which position reports are transmitted is conducive to human error. Errors may be made when the pilot reads the information to the ARINC operator, and when the operator hears and types the message. Other problems include frequency congestion, garbled messages, delays, the expense of operators and equipment, and the lack of automation due to the use of manual methods.

AUTOMATIC DEPENDENT SURVEILLANCE (ADS). Due to the inadequacy of the voice communications link, the ADS concept was originated to eliminate existing problems and enhance the present ATC system. The most significant improvement of oceanic ATC is the use of satellite as a data link that provides accurate, fast, and reliable ATC information.

ADS is a system that uses a data link for relaying automatic, timely, and accurate position reports to ATC facilities. The information is generated by the aircraft's on-board avionics and sent over a data link. It is then displayed to an air traffic controller for use in planning and separating aircraft.

The FAA is in the process of implementing ADS. This will permit changes in procedures which will result in operational benefits to airlines and the FAA. It is anticipated that ADS will eliminate the need for HF progress reports.

PACIFIC ENGINEERING TRIALS. The FAA is currently operating an ADS Pacific Engineering Trials (PET) program designed to evaluate technical and operational aspects of ADS. As part of PET, an airline-operated aircraft equipped with satellite communication (SATCOM) avionics will send automatic position reports over satellite as well as voice reports over HF at each reporting point. HF reports will be sent to the Oakland Air Route Traffic Control Center (ARTCC) as usual. A copy of the HF reports and the satellite reports will be sent to the FAA Technical Center for comparison. In addition, a conversion will be made by ARINC which will create an ODAPS format message from the satellite position report. Both centers will use an Apollo computer for the purpose of data collection. There will be no changes in procedures during the test.

The PET is an international effort in which commercial aircraft with ADS capability will transmit ADS messages during regularly scheduled flights. The United States has cooperative agreements with Japan, Australia, Canada, and others to jointly participate in data collection and evaluation during the trials. The evaluation of the satellite link as a potential replacement for the HF progress reports will be performed with equipment used in the PET.

Depending upon the equipment installed, the ADS report rate may be changed in the aircraft either manually by pilot input or automatically in response to an uplink command. ARINC will provide multiple addressing capability so that identical messages can be routed to ODAPS, the Apollo workstation in Oakland, FAA Technical Center, and MITRE. During the tests, a two-way data link between pilots and controllers will be tested, automatic position reports will be sent over satellite, data will be displayed graphically to ATC, and data will be collected at the FAA Technical Center for analysis. Air traffic controllers will not use ADS information for oceanic control, only for evaluation purposes.

The flights are scheduled for the first quarter of this fiscal year. Successful results may permit procedures to be modified to allow replacement of the HF reports with the satellite report. The satellite reports are expected to be more reliable, quicker, and to reduce human error.

EQUIPMENT

The equipment required for this test includes on board HF communication equipment, SATCOM avionics, communication links (HF voice link, satellite data link, ground communications network), and an Apollo workstation with a color display. A description of each major component is provided below.

As the test proceeds, new equipment will become available for the Ground Earth Station (GES) and the aircraft. The FAA will decide if this new equipment will require additional certification. If so, this test plan will be expanded to include tests of the new equipment.

AVIONICS.

The communications avionics consist of an Aircraft Communications Addressing and Reporting System Management Unit (ACARS MU) with a control display unit (CDU), a satellite data unit (SDU), a radio frequency unit (RFU), a high power amplifier (HPA), and a low gain antenna (LGA).

The CDU enables the pilot to create downlink messages and view uplink messages through the ACARS system. ACARS provides the crew interface to a VHF data link. It allows limited control of the data link and has the capability to send and receive messages. ACARS units have been modified in order to communicate through the satellite network by providing an interface to the SDU.

The satellite avionics consist of the SDU, RFU, HPA, and LGA. The SDU converts messages from ACARS format to a format suitable for transmission over the satellite link and controls the SATCOM avionics. Signals are presented to the RFU for frequency conversion, amplified in the HPA, then transmitted through the LGA.

Some airlines will require additional equipment in order to participate in this project. Many of these aircraft have an Aircraft Condition Monitoring System (ACMS), which will be used to interface to various aircraft sensors and can perform some limited message creation functions. The ACMS interfaces with the ACARS MU to transmit and receive messages.

COMMUNICATION LINKS.

There are three communications links involved in the HF/SATCOM validation process, as shown in figure 1. The first is the HF voice link. Pilots currently relay all messages from the aircraft via this link. The messages are transcribed by an HF radio operator and transferred as data to the end user (e.g., controller or airline).

The second link is the satellite data link. International Maritime Satellite Organization (INMARSAT) satellites provide coverage of the Pacific Ocean operating through the GES at Santa Paula, California. The GES provides the connection and interface between the RF satellite link and the terrestrial network. Initially, the GES will have the capability to handle 15 aircraft. Communication Satellite Corporation (COMSAT) provides the satellite receiving station services. The satellite system design conforms to international standards.

The third link is the terrestrial data network. During this test, the existing ARINC Data Network Service (ADNS) will be used to send messages from the GES and the HF operations center. Airlines participating in the PET subscribe to this network. ARINC records the messages and identifies the link in use. These are processed through their data link processor (DLP) which converts the satellite message to ODAPS format, and transfers it to the end user.

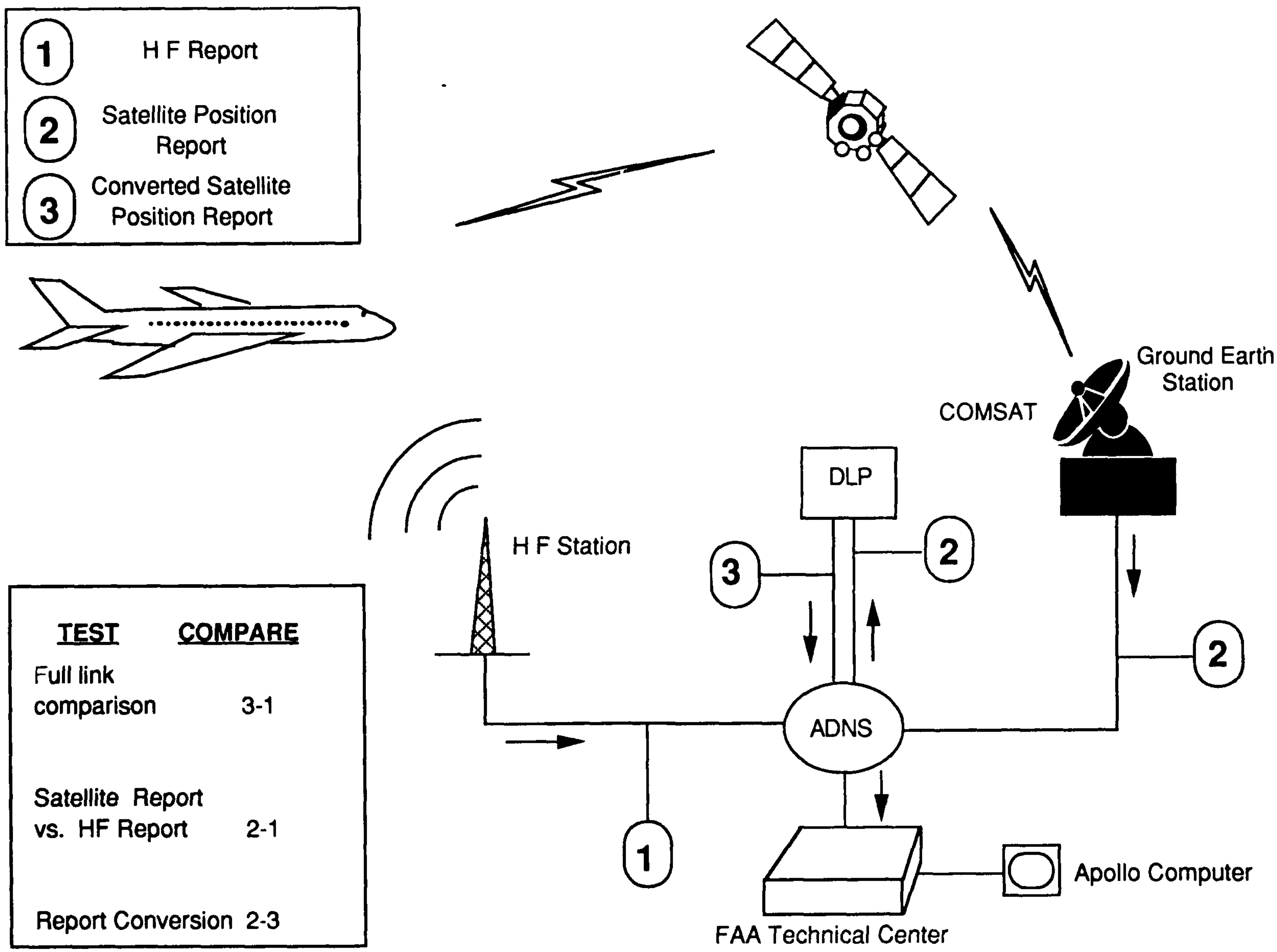


FIGURE 1. TEST CONFIGURATION

DATA COLLECTION SYSTEM.

An Apollo computer workstation will receive, collect, and graphically display the data. It is based on MITRE's ADS situation display software. Flight routes, waypoints, sector and control center boundaries, continental land masses, and aircraft position from HF or ADS reports are displayed on the workstation's 19-inch color monitor. All data will be recorded and analyzed at the FAA Technical Center.

TEST PROCEDURES

During these tests, airline-operated aircraft equipped with SATCOM and ACARS will fly regular routes, making regular reports over satellite and HF. Position reports will be sent over HF to ATC as usual. The FAA Technical Center will receive a duplicate of these position reports from the ADNS. Pilots will create satellite position reports using existing ACARS message types. Note that these are different from the ADS type messages used for the PET.

Initially, pilots will create free text messages manually. At a later date, menu driven display pages will help pilots create messages. Eventually, this process will be fully automated.

These reports will be sent over satellite at each waypoint and transmitted to the FAA Technical Center via the ADNS. ARINC will receive and process these messages through their DLP to convert them to ODAPS format. At the FAA Technical Center, HF and satellite reports will be recorded for post-flight comparison between the different links.

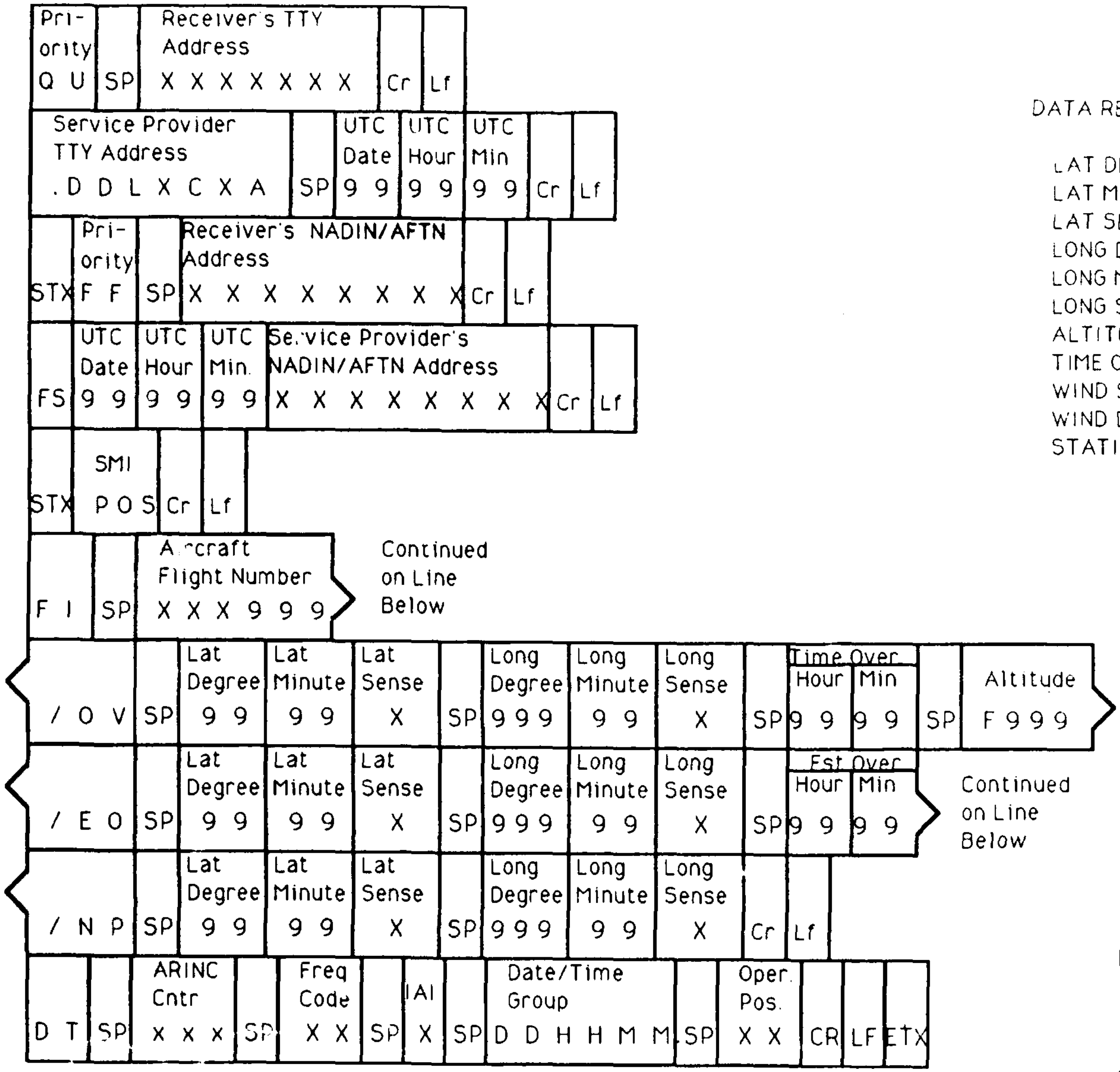
To aid in the comparison, flight strips will be obtained from Oakland Center and used to determine the cleared flight plan and the actual path flown by the aircraft. Pilots will be requested to fill out logs for each flight conducted as part of this test. In addition, transcripts of the communications between controllers and ARINC operators will be provided for use during this test.

DATA ANALYSIS.

The tests involve comparisons between the different message types and will be checked against established formats. Figure 2 shows the format of the HF position report. Figure 3 shows the satellite position report format created by pilots using ACARS.

Figure 4 shows the satellite position report converted to ODAPS format. Specifically, for each set of messages at each reporting point, every field will be compared to the corresponding field of the other messages. The fields should contain the same information. Messages will be matched according to their time of applicability (i.e., when the waypoint was crossed).

If any discrepancy should occur, pilot flight logs, controller flight strips, and ARINC message transcripts will be used to find the source of the error. Three comparisons will be performed as described below.



DATA RESOLUTION

LAT DEGREE	-- 1 Degree
LAT MINUTE	-- 1 Arc Minute
LAT SENSE	-- N or S
LONG DEGREE	-- 1 Degree
LONG MINUTE	-- 1 Arc Minute
LONG SENSE	-- E or W
ALTITUDE	-- Flight Level (X 100 ft.)
TIME OVER	-- GMT
WIND SPEED	-- 1 Knot
WIND DIRECTION (TRUE)	-- Degrees
STATIC AIR TEMPERATURE	-- (Sign) 1/10 Deg. Cent.

NOTES:

POS: Postion Report Without Weather SMI

FI: Flight Identification TEI

OV: Present Position TEI

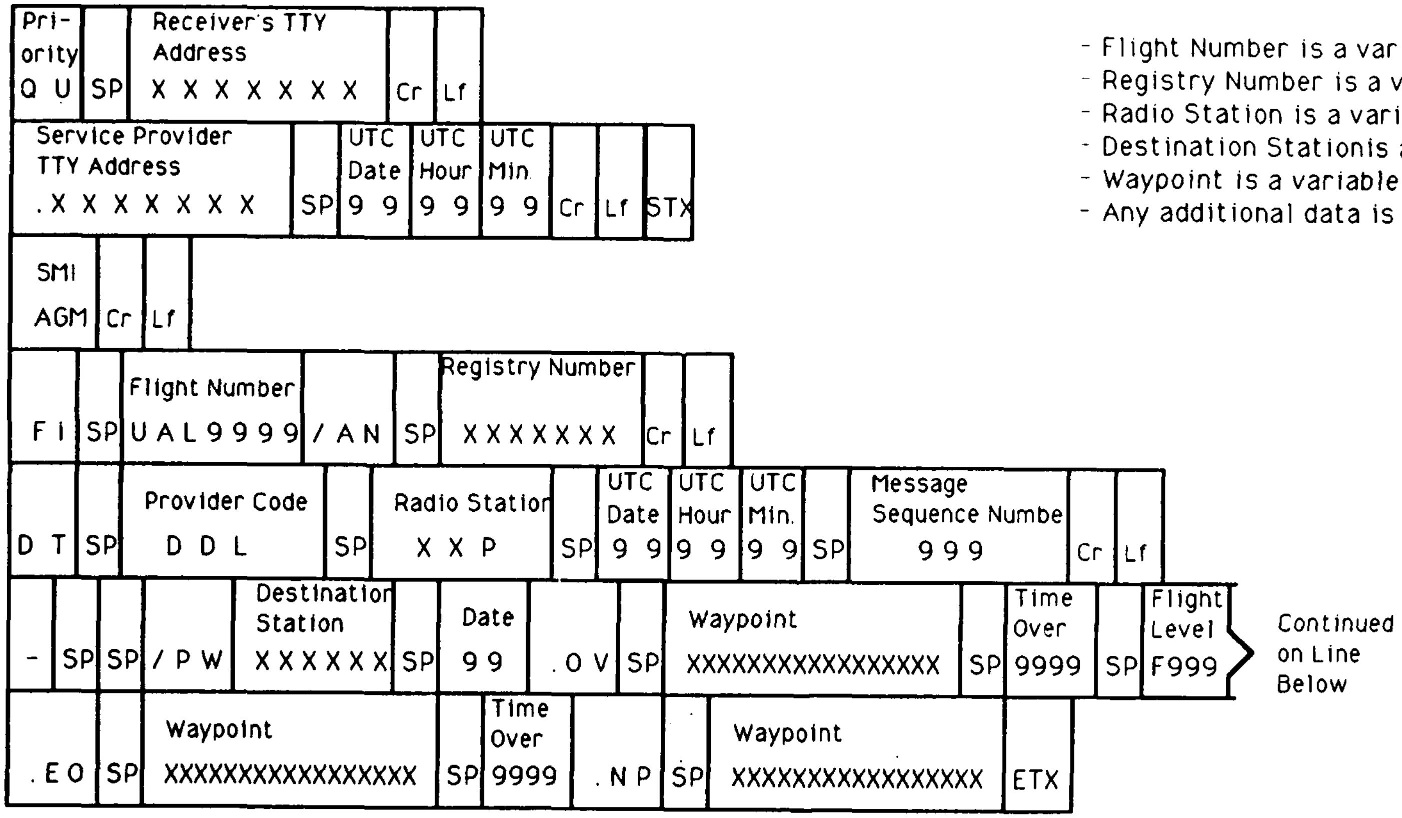
EO: Estimated Time Over TEI

NP: Next Report Point TEI

DT: Communication Service Information TEI

IAI: ARINC Internal Abstracting Indicator

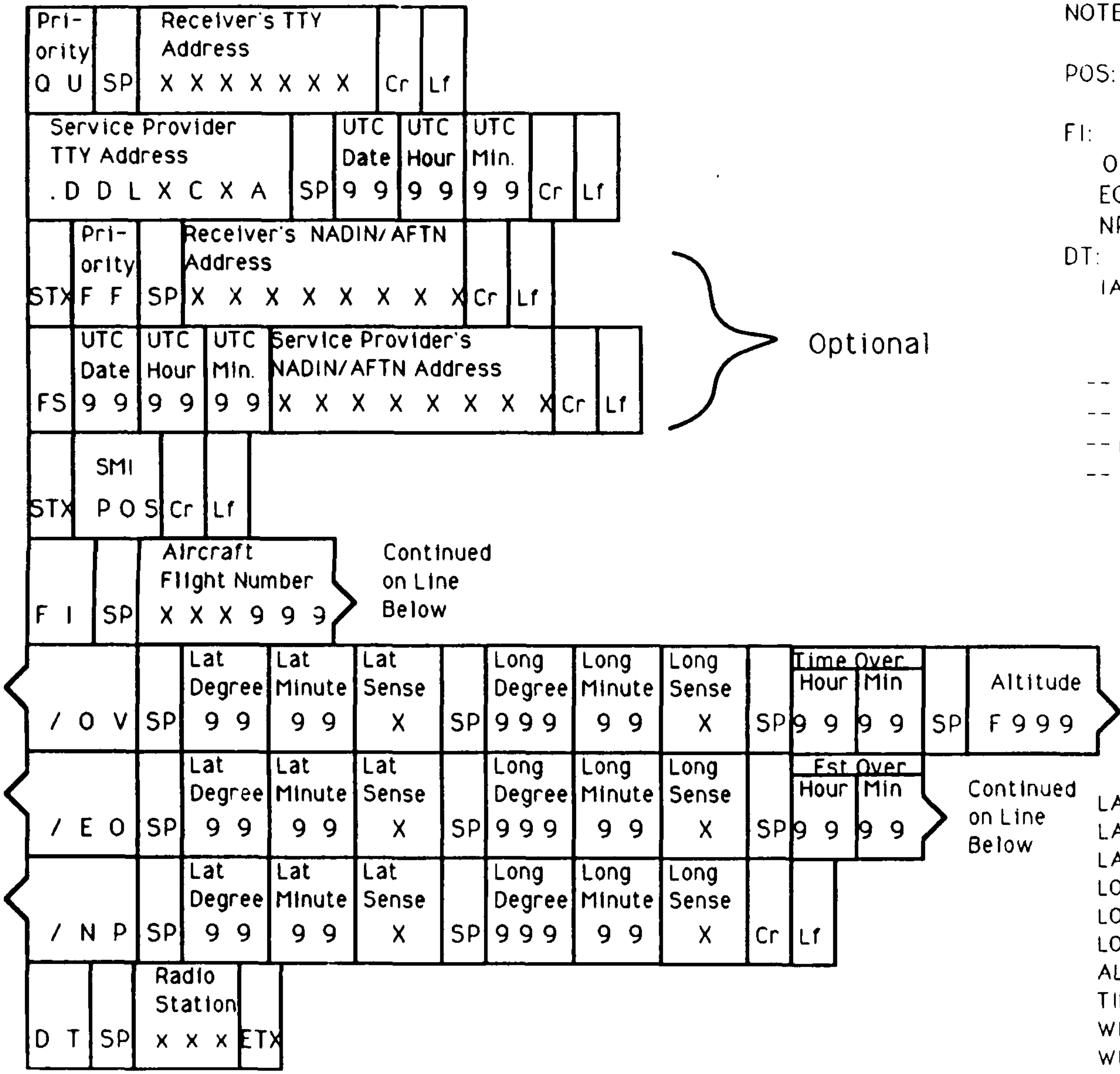
FIGURE 2. HF MANDATORY POSITION REPORT FORMAT



NOTES:

- Flight Number is a variable field (4-7).
- Registry Number is a variable field (4-7).
- Radio Station is a variable field (3-5).
- Destination Stationis a variable field (6-8).
- Waypoint is a variable field up to 17 char.
- Any additional data is included prior to ETX.

FIGURE 3. ACARS SATELLITE POSITION REPORT FORMAT



NOTES:

POS: Postion Report Without Weather SMI

FI: Flight Identification TEI
OV: Present Position TEI
EO: Estimated Time Over TEI
NP: Next Report Point TEI
DT: Communication Service Information TEI
IAI: ARINC Internal Abstracting Indicator

-- Aircraft Flight Number is of variable length.
-- LAT Sense is of variable length.
-- Minutes are an optional field.
-- Waypoints may be received in LAT/LONG terms or as a 5 character name.

DATA RESOLUTION

LAT DEGREE	-- 1 Degree
LAT MINUTE	-- 1 Arc Minute
LAT SENSE	-- N or S
LONG DEGREE	-- 1 Degree
LONG MINUTE	-- 1 Arc Minute
LONG SENSE	-- E or W
ALTITUDE	-- Flight Level (X 100 ft.
TIME OVER	-- GMT
WIND SPEED	-- 1 Knot
WIND DIRECTION (TRUE)	-- Degrees
STATIC AIR TEMPERATURE	-- (Sign) 1/10 Deg Cent

FIGURE 4. CONVERTED SATELLITE POSITION REPORT FORMAT

The first test is to compare the converted satellite data to the HF report. This will provide a simple end-to-end check on performance of both links, and is of primary importance. If discrepancies occur, the source of the problem will be identified by making additional comparisons.

The second test is to compare the satellite position report to the HF report. This will verify that pilot data inputs conform to the pilot voice reports.

The third test is to compare the satellite position report to the ODAPS satellite report. The converted satellite report should have the same information as the original message but in a different format. This will be done to verify that the conversion being done in the DLP is carried out properly.

Typical errors that are expected to occur are missing reports, format errors, missing fields, errors within the field, duplication of messages, message mismatches, and messages that are out of sequence. Each will be identified and tabulated, and presented statistically.

An attempt will be made to determine the time offset between Universal Time Coordinated (used for control) and ADNS (used for time stamp). This offset will be used to determine the delays inherent in each link by comparing the waypoint crossing time to the time the message is entered into the ADNS. An example of a bar plot representing transfer delays on the satellite link is shown in figure 5. A similar plot will be made for the HF link.

Statistical plots will be made for all messages received (HF data, satellite position reports, and converted satellite reports), the errors within the data blocks, the discrepancies between the message comparisons, and time variation. Results of the analysis will be presented on a bar plot. Figure 6 shows an example of total messages received from the three different sources and the results of report comparisons. Monthly cumulative reports will be prepared as the tests progress. Additional analysis will be performed if the need arises.

AREAS OF RESPONSIBILITY

ACD-330 will be responsible for project management, data collection, analysis, data reduction, and publication of a report.

MITRE will supply the software for processing and displaying the ADS reports at the FAA Technical Center and Oakland ARTCC.

United Airlines and Northwest will provide the aircraft.

Collins Air Transport Division will provide the avionics and the ground station interface, as developed under contract to INMARSAT.

INMARSAT will provide satellite services.

COMSAT will provide the satellite receiving station services.

ARINC will provide the data network services.

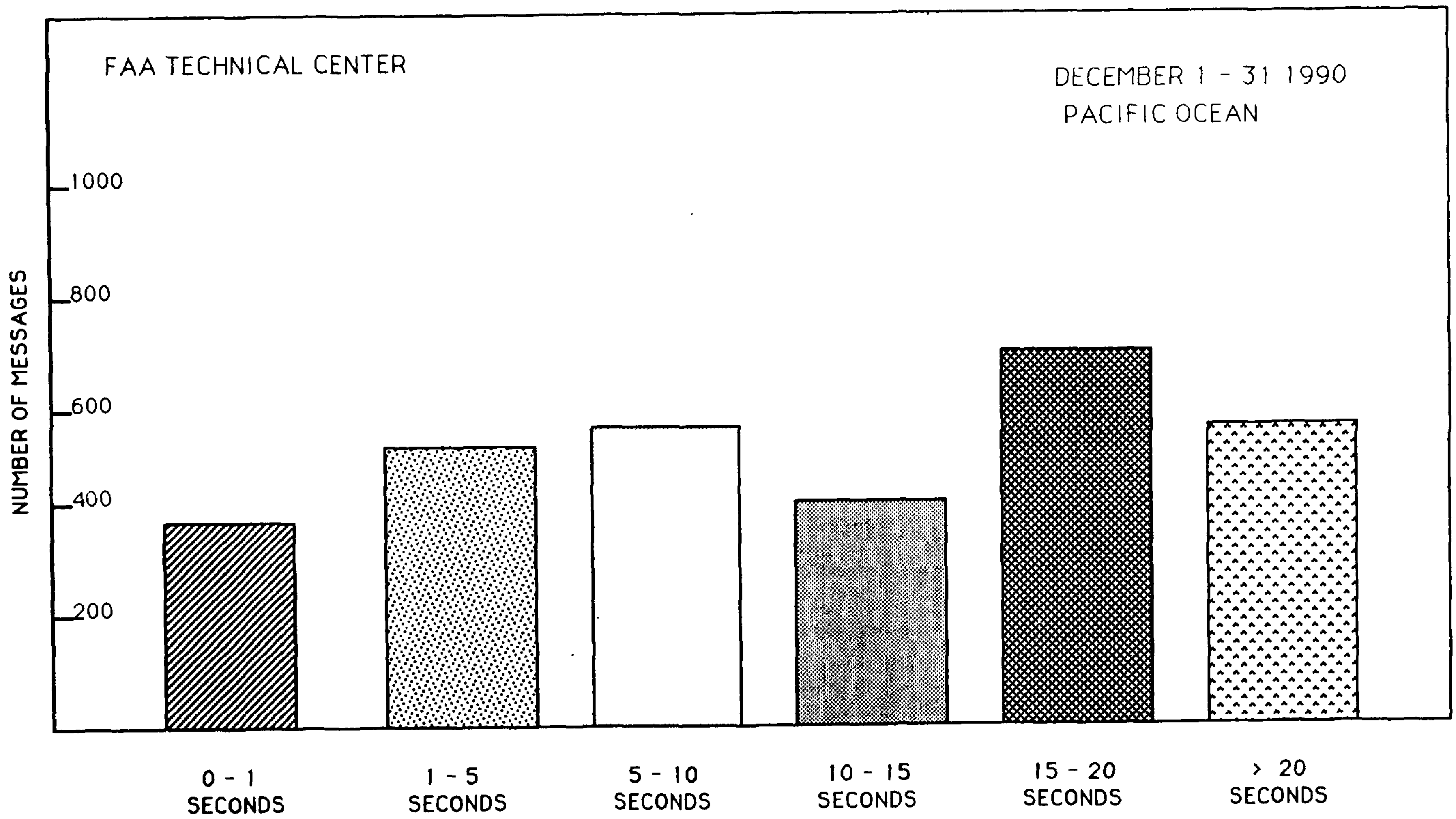


FIGURE 5. END-TO-END MESSAGE TRANSFER DELAY

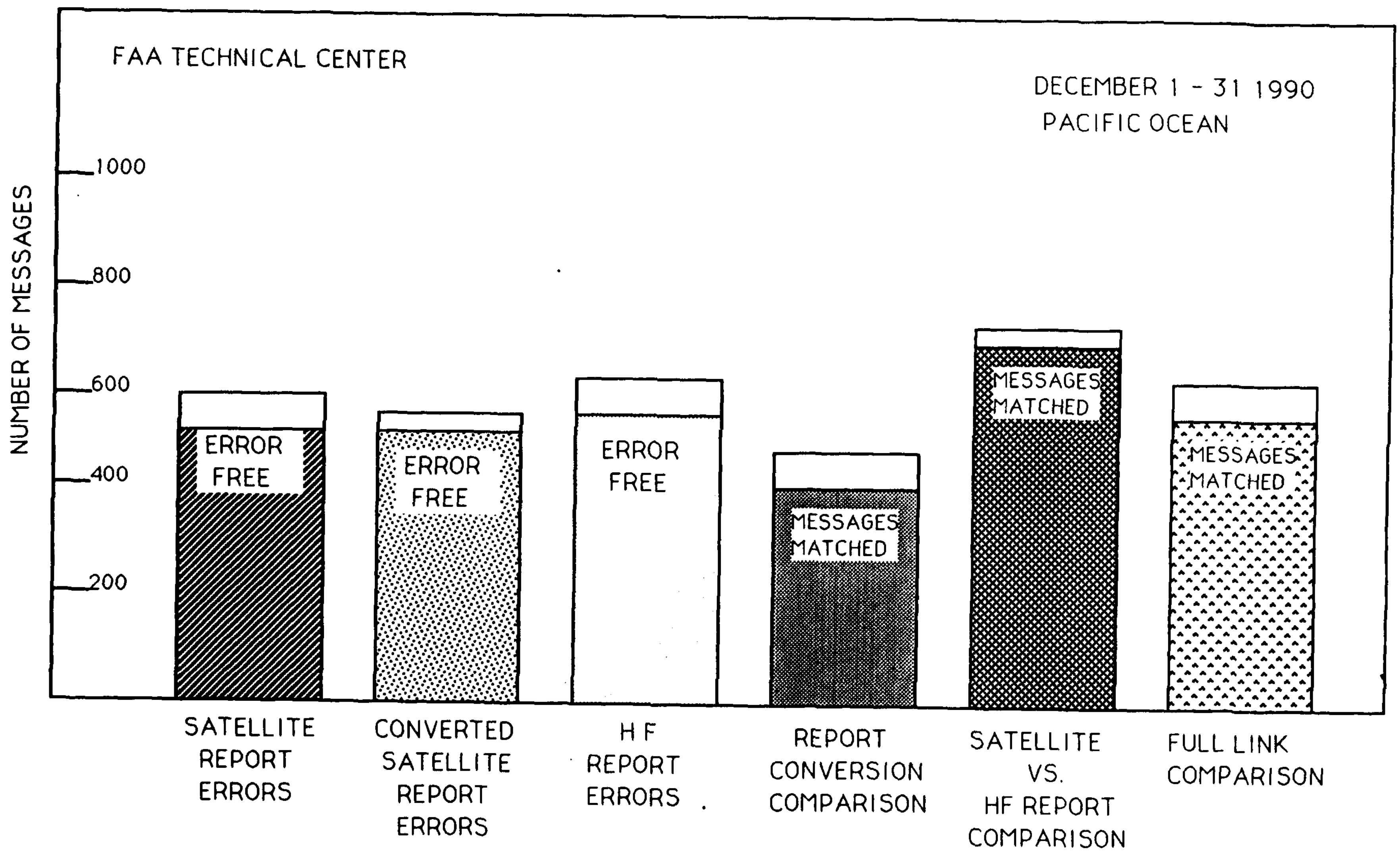


FIGURE 6. DATA LINK VALIDATION REPORT

SCHEDULE

Flight tests began in October 1990. Interim results will be presented in 1991. Also, a final technical report describing the test results based upon the comparison between the voice HF link and the satellite link will be published in October 1991 (see figure 7).

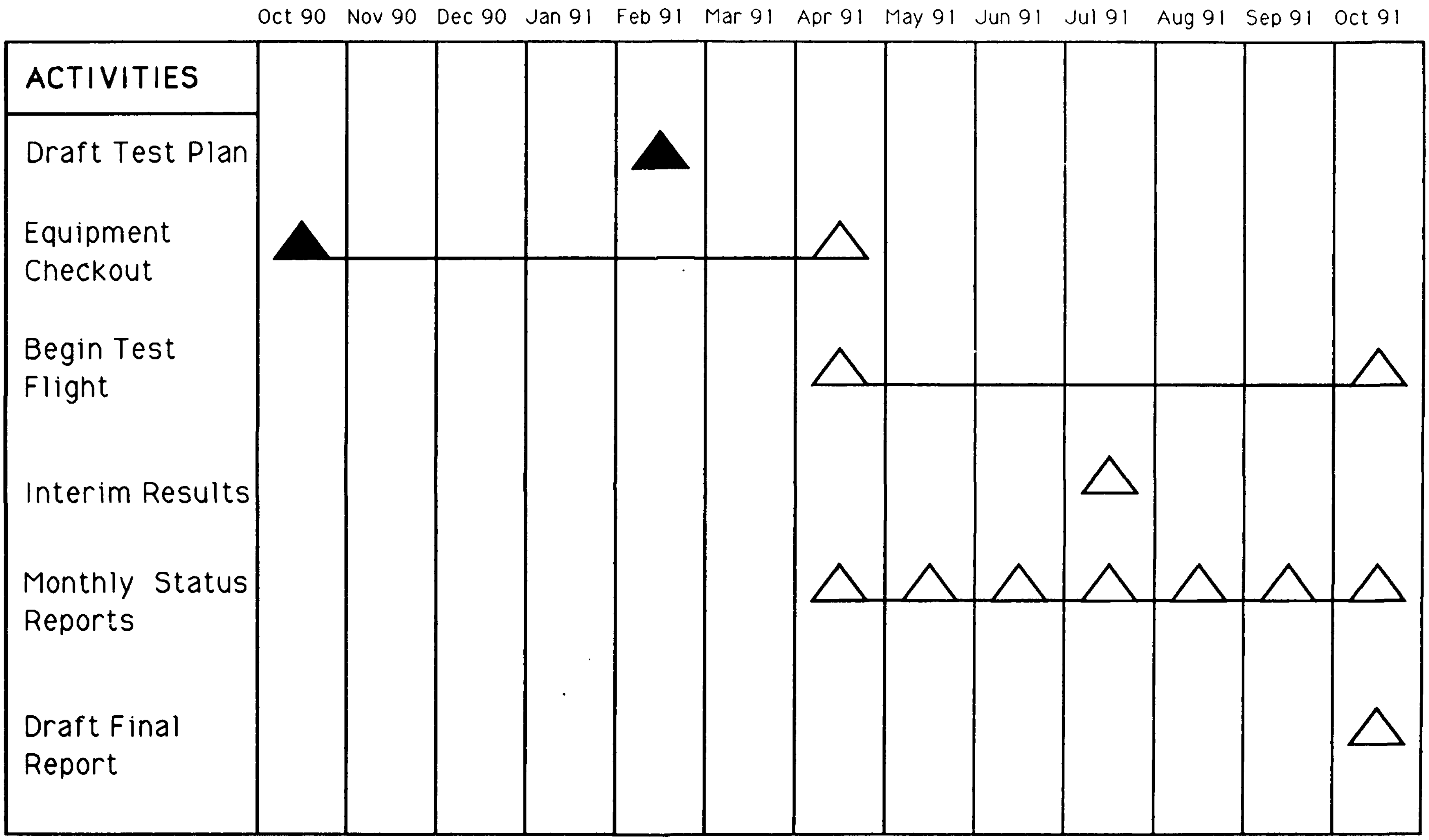


FIGURE 7. SATELLITE DATA LINK VALIDATION SCHEDULE

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