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Aeronautical Mobile Satellite Service (AMSS) Capacity Analysis and Protocol Performance Simulation Plan

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16. Abstract

This plan describes the simulation and analysis which will be performed on the Aernautical Mobile Satellite Service (AMSS) communication system. Two system aspects which are examined in this effort are AMSS capacity and message transit delay. The capacity results are generated by software written as a part of this effort; the message transit delay results are generated by a simulation program called ADSSIM written by Boeing and provided to the Federal Aviation Administration (FAA). The analysis of the results will include a comparison to project system requirements.

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EXECUTIVE SUMMARY

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1. OBJECTIVE.

This test plan describes the analysis and simulation of the Aeronautical Mobile Satellite System (AMSS) to determine the ability of the AMSS subnetwork system and protocol to support projected air traffic control (ATC) applications (i.e., Automatic Dependent Surveillance (ADS) message transmission and voice call setup message transmission). These applications result in system requirements of capacity and message transit delay which will be examined in this analysis/simulation effort.

2. BACKGROUND.

Several papers were presented at the third meeting of the AMSS Panel (AMSSP/3) which contained estimates of Federal Aviation Administration (FAA) requirements for the AMSS subnetwork. Papers were also presented which provided initial estimates of the performance of the AMSS protocol, especially message transit delay under loaded channel conditions. The specific communications requirements to support ADS were presented at AMSSP/2.

2.1 FAA REQUIREMENTS.

The FAA requirements that AMSS must support, divided by time-near term requirements up through 1995, are summarized here:

    a. ADS Reports:

Up to 300 aircraft per ocean region	[1, 2]
As short as a 10 second update interval	[1, 2]
Message transit delay equal to 1/2 update interval	[2]

    b. Emergency/Nonroutine Voice Call Setup:

2 second access time	[1, 3]

    c. Service availabilities:

Routine Service - 0.99	[1]
Essential Service - 0.999	[1]
Critical Service - 0.99999	[1]

2.2 PREVIOUS SIMULATION/ANALYSIS EFFORTS.

Several papers provided an initial investigation into the AMSS protocol message transit delay and capacity questions. The "ADS Delivery Time Analysis" information paper described simulations of AMSS with the Automatic Dependent Surveillance Simulation (ADSSIM) model written by Boeing. The results gave average and maximum R-channel delivery times for three-Signal Unit (SU) messages (like ADS reports) on an R-channel randomly loaded to 15 percent [4]. The results provided an initial indication that significant delays could be experienced on a loaded R-channel. The ADSSIM program did not accurately model the protocol of the current T-channel.

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The "AMSS Performance for Automatic Dependent Surveillance (ADS)" information paper stated that on a 15 percent loaded R-channel, delays in excess of 20 seconds would be experienced by 1 percent of the messages [5]. The result was not substantiated in the paper, and the paper calls for further work to quantify the statistical distribution of delays at all R-channel rates.

The "Preliminary Estimates of Data Link Transmission Overhead for ADS Messages" information paper provides initial estimates of the number of ADS aircraft that can be handled on the R-channel. The scenario included only a fixed 5-minute ADS update interval [6].

3. EQUIPMENT.

The AMSS capacity analysis requires the following hardware and software:

    PC computer w/ printer
    BASIC interpreter
    T-channel capacity program
    R-channel capacity program

The T-channel capacity program is attached in appendix A and the R-channel capacity program is attached in appendix B. The message transit delay simulation requires the following hardware and software:

    PC computer w/ printer
    ADSSIM software

4. TEST METHODOLOGY.

This effort will consist of an AMSS capacity analysis and an AMSS message transit delay simulation.

4.1 AMSS CAPACITY ANALYSIS.

The message capacity of an AMSS R- or T-channel can be calculated using equations and tables in the International Maritime Satellite Organization (INMARSAT) SDM. These equations and tables were included in BASIC programs (given in appendix A) and will be used to calculate the number of R- or T-channels required to support ADS. Since there is not a definitive requirement for ADS, a range of parameters will be used. These inputs are:

    a. Number of aircraft earth stations (AES) (10, 25, 50, 100, 200, 300).

    b. ADS update interval (5 minutes (min), 2 min, 1 min, 30 seconds (s), 10 s).

    c. Channel bit rates (600, 1200, 2400, 10500 bits per second (bps)).

    d. ADS message length (1, 2, 3, 5, 7, 10 SUs).

(Note: ADS message lengths up to 3 SUs will be sent over the R-channel. Longer messages will be sent over the T-channel. This reflects the architecture of the current system.)

    e. Channel options (R- or T-channel).

(Note: The loading of timeslot request messages on the R-channel will be calculated for the required T-channel message traffic, and the loading of timeslot assignments messages and acknowledgement messages on the P-channel will also be calculated.)

The number of R-channels will be calculated with the channel loading at 5, 10, 15, 20, and 25 percent. The number of T-channels will be calculated with the T-channel loaded to 80, 90, and 100 percent.

4.2 MESSAGE TRANSIT DELAY SIMULATION.

The Boeing ADSSIM software, written by T. Judd, provides a simulation of AMSS which outputs message transit delay for messages of 1, 2, or 3 SUs over the R-channel under a given loading condition. The model assumes that the channel loading is random, and it provides a Monte-Carlo simulation of the R-channel protocol [4]. The Boeing ADSSIM model will be used to generate the message transit delay time for the AMSS R-channel and will also be used as part of the approximation for transit delay over the T-channel.

4.2.1 R-Channel Simulation Input.

The following parameters will be used to simulate R-channel operation:

    a. R-channel loading (5, 10, 15, 20, and 25 percent)

    b. Channel bit rates (600, 1200, 2400, 10500 bps)

    c. Retransmission timer (5 s, 8 s)

    d. Number of SUs (1 , 2, 3)

    e. Maximum number of retry attempts (5)

    f. Link service (RLS or DLS).

Other parameters which are requested by the ADSSIM model will be given values appropriate for goals of this simulation. These are:

    a. Time to route from ground earth station (GES) to destination (0 s) (to eliminate effects outside the AMSS subnetwork).

    b. Number of SUs in P-channel que (6) (6 is the minimum selectable number which is used to minimize P-channel delay).

    c. Mix of message sizes on channel:

    Mix 1: Balanced - (1 SU - 34 percent, 2 SU - 33 percent, 3 SU - 33 percent).

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Mix 2: Unbalanced - the percentage of the message size which is the same as the ADS report will be set to 80 percent, the other two will be 10 percent each.

d. Link and miscellaneous processing delays (0.25 s) (primarily to account for propagation delay to and from the satellite).

The model will be run to simulate the transmission of 20,000 messages and the transit delay times will be recorded. For cases where the messages are not delivered due to reaching the maximum number of retransmissions on RLS, or because DLS was used, an indication of nondelivery will be recorded.

4.2.2 T-Channel Approximation Input.

The ADSSIM program contains a T-channel approximation which does not take into account the time delay of the T-channel timeslot request message. To account for this delay, a model of the T-channel protocol will be constructed which uses the ADSSIM R-channel model for transmission of timeslot request message in addition to other approximations. The T-channel message transit delay can be approximated by the following simplified formula:

(R-chan req time) + (time to assigned slots) + (Tx time)
= total delay for T-channel

In this approximation, the "R-channel request time" is the time to transmit a 1 SU message on the R-channel; these results are provided in the R-channel simulation described in 4.2.1. The "time to assigned slots" is dependent on the P-channel rate, as described in the INMARSAT SDM, CP34 (expected to become CN34). This is shown in table 1.

TABLE 1. RELATIONSHIP OF T-SLOT DELAY TO P-CHANNEL RATE

P-Channel Rate	Minimum Delay to T-slots
600 bps	3.0 s
1200 bps	2.0 s
2400 bps	1.8 s
10500 bps	1.6 s

The "Tx" time is the time required to transmit the burst at the given channel rate, which can be calculated from table 4 in the INMARSAT SDM [8].

In order to assure that this simulation provides a minimum bound for the performance of the T-channel, the model uses minimum time delay to the T-channel timeslots assigned. This simplification is discussed further in the analysis.

5. DATA REDUCTION AND ANALYSIS.

5.1 AMSS CAPACITY ANALYSIS.

The data generated as a result of the AMSS capacity analysis will be provided in tabular and/or graphic form. The data will be compared to AMSS channel availability.

5.2 AMSS MESSAGE TRANSIT DELAY.

5.2.1 AMSS Message Transit Delay for R-Channel.

The 20,000 transit time delay calculations for each set of input conditions will be stored on a disk and ordered by transit delay time. Messages which were not delivered will be flagged to indicate nondelivery. From this ordered list, the transit delay times which will be output, are shown in table 2.

TABLE 2. MESSAGE TIME DELAY OUTPUT FORMAT

Message Order Number	Representing	Delay Time
1	.99995	_____
2	.9999	_____
20	.999	_____
200	.99	_____
1000	.95	_____
2000	.9	_____
3000	.85	_____
continue by 1000's	continue by .05's	_____
up to 10000	to .50	

Note: The .99999 delay time is not achievable with 20,000 samples of delay time. Also, the sample size is too small for the .99995 and .9999 results to be statistically significant.

The output will also be given in graphic form.

5.2.2 AMSS Message Transit Delay for T-Channel.

The output of the T-channel approximation will be similar in format to the output of the R-channel simulation (discussed in 5.2.1).

5.2.3 Message Transit Delay Simulation Analysis.

The results of the message transit delay simulations will be compared to stated or projected ATC requirements for message transit delay.

The assumptions used in this effort will be documented and discussed. These include:

a. SUs are only lost due to collisions on the R-channel

b. R-channels are loaded with random message patterns

c. T-slots are available after the minimum wait

d. There are no P-channel capacity restrictions.

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<u>5.3 RECOMMENDATIONS</u>.

Based on the results of this effort, recommendations will be made which would help the AMSS subnetwork meet ATC requirements.

Recommendations will also be given for the work required to examine the impact of the assumptions and, if possible, to construct an AMSS subnetwork model which minimizes assumptions.

<u>5.4 REPORT</u>.

The results, conclusions, and recommendations of this AMSS capacity analysis and protocol performance simulation study will be documented in a report prepared in accordance with FAA Order CT 1710.2B.

<u>6. RESPONSIBILITIES</u>.

CTA: Write test
      Write capacity analysis program
      Conduct simulation runs
      Write test report

FAA (ACD-330): Write data reduction program
                Review and approve test plan
                Review and approve report

<u>7. SCHEDULE</u>.

AMSS Capacity Analysis	July 1990
ADSSIM Simulation Runs	July - September 1990
Draft Report	November 1990

REFERENCES

1. <u>Preliminary FAA Requirements for AMSS to Support Air Traffic Services</u>, AMSSP/3-WP/14. Presented by the U.S. Member of the ICAO AMSS Panel, Third Meeting, February 1990.

2. <u>ADS Operational Communications Requirement</u>, AMSSP/2-WP/32. Presented by the U.S. Member of the ICAO AMSS Panel, Second Meeting, March 1989.

3. <u>Aeronautical Mobile Satellite Service (AMSS) Voice Service for Air Traffic Control</u>, AMSSP/3-WP/13. Presented by the U.S. Member of the ICAO AMSS Panel, Third Meeting, February 1990.

4. <u>ADS Delivery Time Analysis Information Paper</u>, AMSSP/3-WP/39. Presented by the U.S. Member of the ICAO AMSS Panel, Third Meeting, February 1990.

5. <u>AMSS Performance for Automatic Dependent Surveillance (ADS)</u>, AMSSP/3-WP/38. Presented by the U.S. Member of the ICAO AMSS Panel, Third Meeting, February 1990.

6. <u>Preliminary Estimates of Data Link Transmission Overhead For ADS Messages</u>,
AMSSP/3-WP/36. Presented by the U.S. Member of the ICAO AMSS Panel, Third
Meeting, February 1990.

7. ADSSIM program writen by T. Judd, Boeing Co., dated 1989

8. <u>System Definition Manual (SDM)</u>, INMARSAT.

APPENDIX A

R-CHANNEL CAPACITY PROGRAM

```
10 CLS
20 PRINT "    "
30 PRINT "this is the R-Channel capacity program"
40 FOR IC = 1 TO 4
50 IF IC = 1 THEN CHANR = 600
60 IF IC = 2 THEN CHANR = 1200
70 IF IC = 3 THEN CHANR = 2400
80 IF IC = 4 THEN CHANR = 10500
100 FOR IUP = 1 TO 6
110 IF IUP = 1 THEN UP = 5
120 IF IUP = 2 THEN UP = 10
130 IF IUP = 3 THEN UP = 30
140 IF IUP = 4 THEN UP = 60
150 IF IUP = 5 THEN UP = 120
160 IF IUP = 6 THEN UP = 300
170 FOR ISU = 1 TO 3
180 IF ISU = 1 THEN SUNUM = 1
190 IF ISU = 2 THEN SUNUM = 2
200 IF ISU = 3 THEN SUNUM = 3
210 IF ISU = 4 THEN SUNUM = 5
220 IF ISU = 5 THEN SUNUM = 7
230 IF ISU = 6 THEN SUNUM = 10
240 FOR IAES = 1 TO 6
250 IF IAES = 1 THEN AESNUM = 10
260 IF IAES = 2 THEN AESNUM = 25
270 IF IAES = 3 THEN AESNUM = 50
280 IF IAES = 4 THEN AESNUM = 100
290 IF IAES = 5 THEN AESNUM = 200
300 IF IAES = 6 THEN AESNUM = 300
310 LPRINT "chan rate = ";CHANR;"      update interval = ";UP
311 LPRINT "number of aircraft = ";AESNUM;"      SUs per ADS msg = ";SUNUM
320 GI = 40
330 IF CHANR = 600 THEN BD = 1000 * SUNUM
340 IF CHANR = 1200 THEN BD = 500 * SUNUM
350 IF CHANR = 2400 THEN BD = 250 * SUNUM
360 IF CHANR = 10500 THEN BD = 125 * SUNUM
370 TCHAN = ((BD/1000) * AESNUM)/UP
380 LPRINT "R-Channels Required at 15% loading = ";TCHAN/.15
385 LPRINT "     "
390 NEXT IAES
400 NEXT ISU
410 NEXT IUP
420 NEXT IC
430 END
```

APPENDIX B

T-CHANNEL CAPACITY PROGRAM

```
10 CLS
20 PRINT "     "
30 PRINT "this is the T-Channel capacity program"
40 FOR IC = 1 TO 4
50 IF IC = 1 THEN CHANR = 600
60 IF IC = 2 THEN CHANR = 1200
70 IF IC = 3 THEN CHANR = 2400
80 IF IC = 4 THEN CHANR = 10500
100 FOR IUP = 1 TO 6
110 IF IUP = 1 THEN UP = 5
120 IF IUP = 2 THEN UP = 10
130 IF IUP = 3 THEN UP = 30
140 IF IUP = 4 THEN UP = 60
150 IF IUP = 5 THEN UP = 120
160 IF IUP = 6 THEN UP = 300
170 FOR ISU = 1 TO 6
190 IF ISU = 1 THEN SUNUM = 1
190 IF ISU = 2 THEN SUNUM = 2
200 IF ISU = 3 THEN SUNUM = 3
210 IF ISU = 4 THEN SUNUM = 5
220 IF ISU = 5 THEN SUNUM = 7
230 IF ISU = 6 THEN SUNUM = 10
240 FOR IAES = 1 TO 6
250 IF IAES = 1 THEN AESNUM = 10
260 IF IAES = 2 THEN AESNUM = 25
270 IF IAES = 3 THEN AESNUM = 50
280 IF IAES = 4 THEN AESNUM = 100
290 IF IAES = 5 THEN AESNUM = 200
300 IF IAES = 6 THEN AESNUM = 300
310 PRINT "chan rate = ";CHANR;"       update interval = ";UP
311 PRINT "number of aircraft = ";AESNUM;"       SUs per ADS msg = ";SUNUM
320 GI = 40
330 IF CHANR = 600 THEN BD = 640+SUNUM*320+GI
340 IF CHANR = 1200 THEN BD = 300 + SUNUM * 160 + GI
350 IF CHANR = 2400 THEN BD = 130 + SUNUM * 80 + GI
360 IF CHANR = 10500 THEN BD = 66.3 + SUNUM * 18.3 + GI
370 TCHAN = ((BD/1000) * AESNUM)/UP
380 PRINT "T-Channel Capacity Required = ";TCHAN
385 PRINT "     "
390 NEXT IAES
400 NEXT ISU
410 NEXT IUP
420 NEXT IC
430 END
```