6746-84

DATE: 4 December 1984

TO: [redacted]

FROM:

SUBJECT: Mission 7300 Overview and System Architecture

1.0 INTRODUCTION.

This memo describes the spacecraft and processing architecture for the Mission 7300 system. The spacecraft section will be covered first, followed by the processing architecture section which will consider three different processing systems: the on-board processing system (OBPS), analog processing, and digital processing.

2.0 SPACECRAFT SECTION.

For the purpose of this study the spacecraft section will concentrate on the FARRAH collection system. FARRAH was chosen for the following reasons. (1) Of the three operational Mission 7300 collectors currently on orbit, the FARRAH collection system is the most complicated and provides a number of measurements not provided by other Mission 7300 systems. (2) The FARRAH I platform has characteristics similar to those of the earlier spacecraft (URSALA and RAQUEL). (3) The older series of 7300 collectors have already far exceeded their life expectancy and are not expected to remain operational far into the future. (4) The FARRAH II spacecraft is now in operation and is a nearly identical copy of the

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FARRAH I spacecraft. (5) Finally, the FARRAH I collector is to be the baseline model for future Mission 7300 collectors which will be launched in the late 1980s and early 1990s.

The FARRAH collection system is a spin-stabilized platform with antenna/receiver combinations capable of acquiring both sidelobe and mainbeam emissions from radar and communication systems of interest operating in the 2 to 18 GHz frequency range. The configuration provides rapid coverage of large geographic regions (horizon to horizon), revisiting each location on the earth at least twice per day at low latitudes and to as many as 16 times at higher latitudes. The spacecraft configuration has been optimized to allow rapid geographic and radio frequency spectrum coverage. Geographic coverage is achieved by either the spacecrafts pencil beam antennas or by its omni directional antennas. The pencil beam or direction finding (DF antennas) intercept emitter sidelobes and provide information to allow computation of emitter location; the omni antennas are designed to collect emitter mainbeam emissions from the spacecrafts local horizon; they are also used in an inhibit mode to protect the DF system from high powered mainbeam energy entering the sidelobes of the DF antennas. Because spin stabilization is utilized, pencil beam motion is a natural consequence of mounting the antennas to the rotating spacecraft. The beams develop overlapping swaths as their footprints move across the earth. The DF antennas intercept duration on an emitter during a spin is short (typically 4 to 25 milliseconds) while omni antennas intercepts can be several minutes in duration. When in the target region intercepted data are typically stored in on-board tape recorders and read-out later to remote ground stations located in various parts of the world.

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Band switching or time sharing of the receiver permits the same receiver (used with either DF or omni antennas) to cover multiple 2 GHz wide frequency bands on different parts of a spin. On a single spin the FARRAH DF receivers will typically be tasked against three bands. On one-third of the spin, the lower frequency antenna called the A antenna which covers the frequency range from 2 to 6 GHz will be facing the earth. During this one-third of the spin the input from the "A" DF antenna is fed into the DF receivers. On the next one-third of the spin the "B" DF antenna (6-12 GHz) will face the ground, and its output fed into the DF receivers. Finally, on the last part of the spin the output from the "C" antennas covering the 12-18 GHz frequency range will be fed into the FARRAH receivers.

In this manner the DF receivers, both pulse and CW, are able to perform "triple duty" and cover three bands, each 2 GHz wide, with one receiver for pulse and one receiver for CW. Typically, on the next spin the frequency bands would be changed to allow additional frequency bands to be tasked with each antenna. Using the concept of switching bands each spin and switching bands three times within a spin it is possible to cover 14 GHz. However, to obtain continuous geographic coverage the spacecraft is typically tasked so that only 10 GHz is covered (five different bands). This provides improved geographic coverage, resulting in higher probability of intercept. The cost for best coverage is that three of the eight frequency bands are not to be tasked within a series of spins.

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Each time a band is changed, be it within a spin or at the beginning of a new spin, the pulse and the CW receivers are changed together so that they cover the same frequency range at the same time and jointly step between the different bands.

3.0 CW RECEIVER OPERATIONS.

Because the primary interest in this study is on CW or COMINT externals, the following sections will be concentrating on the characteristics of the CW receivers as opposed to the characteristics of the pulse receivers. The FARRAH intercept system CW receiver provides two signal parameters. (1) It can measure the frequency of an intercepted signal, and (2) It can provide data to determine the location of the emitter. In addition, the amplitude of an intercepted CW signal is available on the FARRAH and RAQUEL systems. CW amplitude was not measured on the earlier URSALA systems. Information such as modulation type, internals, carrier structure, multi-channel loading, are not available from the Mission 7300 CW search receivers.

CW RECEIVER ARCHITECTURE.

The FARRAH CW receiver is a superheterodyne type receiver which, as mentioned before, operates at an IF of between 2 to 4 GHz. Incoming signals at RF are downconverted to this IF range.

The CW receivers have a nominal dynamic range of approximately 45 dB. The receivers sweep with a slow sweep rate of

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approximately 1.37 MHz per microsecond to improve the sensitivity for the FARRAH and URSALA collectors. The sweep is in the shape of a triangle wave, sweeping up and down across the 2 to 4 GHz IF band. For RAQUEL the sweep was only in one direction forming a sawtooth pattern. Within the CW receiver there is 120 MHz between the real and the image sidebands. The nominal detection threshold is approximately -61 dBm. Both the omni and the DF CW receivers have a nominal 8 MHz instantaneous bandwidth.

ANTENNA CONSIDERATIONS.

The CW receivers on the Mission 7300 spacecraft differ depending on the vehicle series. The URSALA series was designed to perform essentially a DF mission and therefore did not contain a true omni CW receiver. The RAQUEL and FARRAH systems collect both DF and omni data. The emitter location is based on DF antenna monopulse information for the FARRAH system, however, for RAQUEL and URSALA systems the location was based solely on collector antenna boresight information, and geoposition was determined by centroiding on the [redacted] of intercepted CW recognitions. For the URSALA and RAQUEL series centroiding directional accuracy (or half cone angle) was 1 degree or greater. For the FARRAH series collectors the angular accuracy is generally on the order of one-half degree. For the FARRAH collection system there is a plus omni data channel scanning the intercepted frequencies received from the omni antennas mounted on the top of the spacecraft and a minus omni data channel scanning the input from the omni antennas located on the bottom of the spacecraft.

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The DF spinning pencil beam from the high gain parabolic dishes is the sum channel component of a monopulse system. Four supporting channels are used with the sum channel to inhibit pokethrough and provide the monopulse function. These include the two omni channels, the guard channel and the DF delta channel. The sum and the delta channel are used together to provide single [redacted] within the center of sum footprint, which through processing translates to emitter location.

INHIBIT FUNCTIONS.

The inhibit functions of the CW receiver are to remove pokethrough or undesirable signals that are collected through the minorlobes of the spacecrafts high gain pencil beam antennas. The inhibit functions used on the FARRAH spacecraft include a comparison between the omni data stream from the top of the spacecraft, the omni data stream from the bottom of the spacecraft, and the comparison of the output of the guard antenna within the sum channel. If the sum channel is not higher than the three other channels, the input signal is considered spurious or pokethrough and is suppressed. For valid monopulse information the sum channel must always be greater than the delta channel since it is one of the ways of indicating that the emitter is within the DF beam of the antenna. There is an inhibit function called the delta inhibit which will suppress an intercept if its sum channel response is not greater than the delta channel response by a selectable offset.

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DETAILED MONOPULSE LOCATION TECHNIQUE.

The location information provided from the monopulse system is in the form of four payload measurements. The first is the amplitude of the sum channel, the second is the log of the sum divided by the delta channel, and the third and fourth are the outputs of the monopulse combiner called the log A/B and the log C/D. From these values positional information within the DF antenna beam can be reconstructed, allowing greater accuracy than the centroiding technique mentioned earlier. The relationship between the various antenna patterns is shown in Figure 1.

The omni antennas do not output monopulse information. However a comparison is made between the omni input from the top of the spacecraft and the omni input from the bottom of the spacecraft to determine which omni signal strength appears stronger. The omni CW receiver encodes the amplitude of the larger response.

4.0 PAYLOAD DATA FLOW TO THE [redacted]

Data from the CW receiver is routed from the CW receiver to the spacecraft data handler. From there it is placed on tape recorders or transponded either to the remote tracking stations or to the Interim Tractical ELINT Processors (ITEP). The remote tracking stations (RTS) are scattered about the world. The RTS are located in Tule, Greenland; New Boston, New Hampshire; Vandenberg AFB, California; Hawaii; Guam; Scheyelles, Indian Ocean; and Oakhanger, UK. In a similar manner the Army and Air Force ITEP vans are located with different Corps level units. Two ITEPs are located in [redacted]

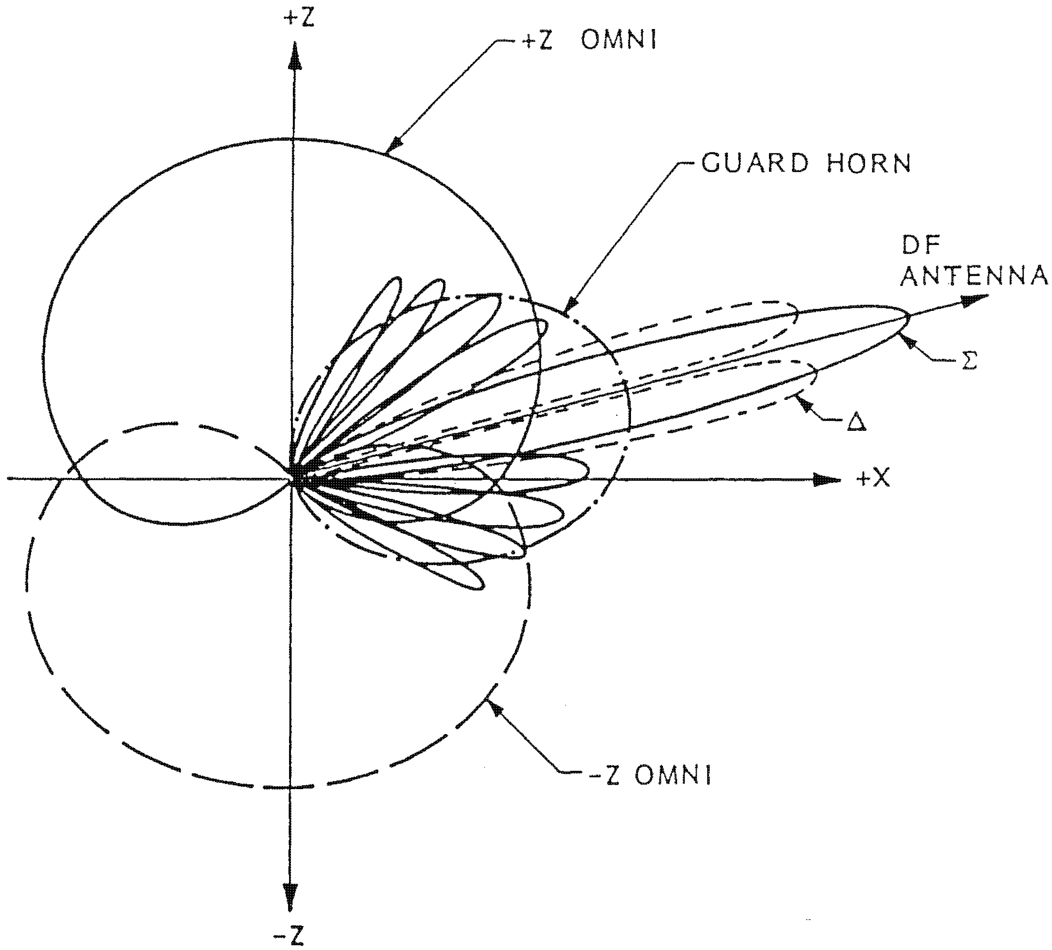

Figure 1. Inhibit Antenna System

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[redacted] Two ITEPs are located in the South Eastern United States, a third is located with the third Corps at Ft. Hood, Texas, and one is located at [redacted] The ITEP processing and handling of COMINT externals is not a part of this report and is being handled elsewhere in the SPADE effort.

Depending on the remote tracking station used, the data is received initially through either a 46 or 60 foot antenna and then recorded. The digital and analog data is separated and the analog data tape [redacted]

Once the digital data is received in the Satellite Control Facility in Sunnyvale, [redacted]

5.0 ON-BOARD PROCESSING SYSTEM (OBPS) DATA FLOW.

The CW and pulse data are also sent from the FARRAH data handler through a digital adapter unit on-board the spacecraft to the advanced spacecraft computer (ASC) which is the heart of the FARRAH I/II OBPS system. In the OBPS part of the signal reconstruction is accomplished. Burst and series formation are done within the ASC. [redacted]

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6.0 PROCESSING CONSIDERATIONS (CW).

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7.0 DATA PROCESSING WITHIN [redacted]

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8.0 UTILITY OF MISSION 7300 DERIVED CW EXTERNALS DATA.

The Mission 7300 CW search receiver can be used for COMINT externals exploitation by using the measurements of RF and geolocation from the CW DF receiver. The parameters that are provided for DF data are the CW signal's RF with a measured [redacted] slant range from [redacted] to 50 nmi.

In addition to identifying signals based on RF transmitted, multiple pass intercepts are required. Normally, first time intercept of a signal from a given location is not reported unless it matches an earlier collection from the site. Without reporting first time intercepts, it would be difficult to use 989 information against mobile emitters or tactical emitters that may relocate with troop movement. This is an [redacted] data processing policy based on current requirements which may be worth re-evaluating for the tactical scenario.

Another attribute is the RF coverage range. The FARRAH and URSALA spacecraft cover from 2 GHz up. RAQUEL IA's frequency coverage is from 4 GHz up. Many of the COMINT emitters of interest to the tactical commander lie below these frequency ranges. The future [redacted]

A third aspect in exploiting COMINT data externals with Mission 7300 is that for the DF data at mid latitudes the

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slant range between the emitter on the ground and the spacecraft in many cases will govern the collectability of CW intercepts. Within a given spin the P989 vehicles will typically task on three different frequency bands. So that on one third of the spin one 2 GHz wide band will be tasked for pulse and CW. On another third of the spin a different 2 GHz segment and on the final third of the spin a third 2 GHz wide band will be tasked. At mid-latitudes this process cuts off signals near the horizon. This is desirable for the tactical user because the geolocation errors would become unacceptably large near the horizon and the horizon signals would add to the data processing load.

Many COMINT or FIS signals are pulsed (PPM or PCM) and will be intercepted by the P989 pulsed receivers. These signals are handled by the pulse DF receiver and are processed on the ground in somewhat different manner. Information which can be derived from pulse intercept includes RF, PRI, pulse duration, location, and cases of staggered or unusual pulse interval variability GPRIs can be determined. Compared to the signals intercepted in the CW system there appear to be relatively few pulsed channel received CW signals of interest. Two of these types of signals that are of interest include Troposcatter links and [redacted] The tropos are in many cases considered a nuisance to pulse collection of ELINT signals and the P989 software is not primarily designed to characterize and exploit tropospheric signal information. The processing system was, however, upgraded to enhance the geopositioning and processing of tropos.

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In the processing of CW data two reference data bases are extensively used. The first is the NSA TOWER file which provides locations of Photo or SIGINT confirmed emitters. The second reference source is the Mission 7300 CW secondary data base. This file contains previous Mission 7300 intercept locations and correlations to known sites. These data bases are used in much the same manner that Electronic Order of Battle information is used in ELINT.

In summary, the future exploitation of the Mission 7300 CW data would be based on the measurements available, RF and location. Today, the reporting of the data collected by the Mission 7300 CW receiver is based on matching the intercepted frequency and/or location with known emitters and known locations. The principal identing parameter used is RF. Due to the coarse tolerance, the RF range of some of the signals of interest intercepted overlap, making it difficult or impossible to sort or ident based solely on RF as is true for any system using just RF. Additional measured parameters related to modulation would provide the ability to better discriminate and develop a more accurate classification.

In a wartime or crisis situation, frequency usage will become dynamic and the accurate measurement of frequency may be of lesser importance when compared to the ability to locate and count the number of emitters in a given region. The ability to measure on an hourly or daily basis changes in the number of emitters present or their operational activity level within the region will also be of value. Mission 7300 can contribute to

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these objectives. The ultimate value of the Mission 7300 CW externals data must of course be specified by potential users who are skilled in situation and battle management. Their review will, no doubt, involve considering multiple source data; the question isn't so much can the Mission 7300 data contribute but, how shall the data be weighted and merged with other information to develop the most complete statement about the intent of hostile forces operating in regions of high interest.

Appendix A contains a list of communication emitters currently intercepted by Mission 7300 from a variety of countries. Many of these emitters are on the SOI lists for several programs and studies. It would be appropriate to give this list detailed attention during the above mentioned user review.