## **ATS-3 RANGING SUPPORT**

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by

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## TABLE OF CONTENTS

Section		Page
1	INTRODUCTION	1
2	OBJECTIVES	3
3	TONE-CODE RANGING EQUIPMENT DESCRIPTION	5
	<ul> <li>3.1 Tone-Code Ranging Technique</li> <li>3.2 VHF Trilateration Network</li> <li>3.3 Observatory Equipment Configuration</li> <li>3.4 Remote Transponder Configuration</li> <li>3.5 Analytical Techniques</li> </ul>	5 6 7 9 13
4	SUMMARY OF RANGING EXERCISES	15
5	CONCLUSIONS	19
6	REFERENCES	21

## LIST OF ILLUSTRATIONS

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#### Figure

Tone-Code Ranging Waveform	5
Observatory Configuration for Tone-Code Ranging	9
Sample of Typical Tone-Code Ranging Data to ATS-3 Satellite	11
NASA-Goddard Space Flight Center VHF Tone-Code Ranging Transponder Configuration.	12
Initial NASA-Goddard Space Flight Center VHF Tone- Code Ranging Transponder Configuration	12
	Tone-Code Ranging Waveform Observatory Configuration for Tone-Code Ranging Sample of Typical Tone-Code Ranging Data to ATS-3 Satellite

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### LIST OF TABLES

	Page
General Electric VHF Tone-Code Ranging Network	7
VHF Tone-Code Ranging Signaling Parameters	8
Paper Tape Data Format	10
VHF Trilateration Transponder Internal Time Delays.	14
Summary of ATS-3 Trilateration 24-Hour Test, Nov. 3, 1974	<b>1</b> 6
Summary of ATS-3 Trilateration 24-Hour Test, May 4-5, 1975	17
	General Electric VHF Tone-Code Ranging Network



iv

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#### INTRODUCTION

In the advent of the location of remote vehicles (airplanes, ships, satellites and land mobile units) by satellites in geosynchronous orbits, it is of interest to develop a technique for position location and to demonstrate its ease of operation, accuracy and reliability. One technique for the location of remote vehicles is the tone-code ranging system developed by the General Electric Company over the last several years. (1, 2, 3, 4, 5)

The tone-code ranging technique requires the active cooperation of mobile users. A master ground station transmits ranging interrogations to the vehicle via a single communications type satellite. Upon recognition of its unique digital address code, the addressed vehicle will respond to the interrogation (after a precise internal time delay) by transmitting the identical tone-code sequence. The master ground station measures the radio propagation time from itself to the vehicle via the satellite and computes a vehicle line-of-position on the surface of the earth. A vehicle response through a second satellite will result in a second vehicle line-of-position. Crossing of two vehicle lines-of-position yields the vehicle location. Knowledge of satellite position is paramount to accurate vehicle locations.

The tone-code ranging technique has been demonstrated by General Electric at VHF with ATS-1 and ATS-3 and at L-band with ATS-5 and ATS-6. At VHF, it has been used with automatic transponders on aircraft, ships, a buoy, a panel truck and a network of fixed transponders around the world. At Lband, the technique has been used with fixed transponders to locate the ATS-5 and ATS-6 satellites. The tests started in 1968 and were sponsored in part under NASA contracts and have provided data on all factors affecting ranging position fixing accuracy and precision.

The trilateration technique for locating a satellite using range measurements from the widespread network of transponders was first tested in August of 1971.<sup>(1)</sup> Recent experiments by the General Electric Company included the simultaneous near real-time trilateration of the ATS-1 and ATS-3 satellite and the subsequent position location of an Exxon tanker in regular service between Venezuela and US eastern coastal ports.<sup>(3)</sup> The latest experiments included the real-time location of ATS-1 and ATS-3 and the subsequent real-time position fixing of a vehicle at various points within the continental US.<sup>(6)</sup> Simultaneous range measurements to a ground truth reference transponder provided a real-time measurement of the ionosphere and thus, significantly reduced vehicle position inaccuracy.

The purpose of the effort described within this report was to provide NASA-Goddard Space Flight Center with ATS-3 ranging data from ground

stations of the General Electric VHF network and from an additional ground station installed at the NASA-Goddard Space Flight Center. Ranging measurements to the NASA transponder enabled calculation of the transponder's lineof-position. Installation of an S-band transponder (by NASA) at the same site and the conduct of ranging experiments to this transponder and others via ATS-6 (by NASA) provided a second line-of-position. Crossing the lines-ofposition allowed NASA to recover the transponders' location and to evaluate factors affecting the precision and accuracy obtainable. The NASA S-band transponder was specifically designed for installation aboard spacecraft. Consequently, this program provided NASA an opportunity to compare two different techniques using geostationary satellites in the tracking low orbit satellites.

NASA currently tracks the NIMBUS-6 and GEOS-3 satellites at S-band via ATS-6. Tracking is accomplished over a large portion of the satellites' orbit from a single tracking site. More importantly, tracking operations are not limited to the region of space in which the low orbit satellite is visible to the tracking station.

#### **OBJECTIVES**

The objectives of this effort were to provide the materials, facilities and personnel necessary to obtain ranging data to the ATS-3 satellite. Specifically, this included the following items:

- Installation of an automatic VHF remote transponder at NASA-Goddard Space Flight Center. NASA separately provided a VHF circularly polarized antenna with 10 dB gain, an RF cable for the antenna-transponder connection and an RF power meter.
- Conduct of ranging exercises to the NASA based transponder and to the General Electric worldwide network of VHF transponders. The cooperation of the worldwide network VHF transponders was solicited on a voluntary basis. All ranging interrogations originated at the General Electric Radio-Optical Observatory near Schenectady, NY.
- Transmission of accumulated ranging data to NASA. All ranging measurements and the time of ranging interrogations were punched onto paper tape and printed in computer format.

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#### TONE-CODE RANGING EQUIPMENT DESCRIPTION

#### 3.1 TONE-CODE RANGING TECHNIQUE

Range measurements to satellites are made by measuring the radio propagation time of a signal from a ground station to the satellite and return. Following corrections for the propagation delay of the ionosphere and the internal time delays in the satellite and ground station, the ranging time can be converted into a slant range by relating it to the known speed of light. Propagation time is measured by placing a time marker in the form of a tone-code interrogation (Figure 1) on the transmitted signal and observing its two-way transmit time. As used in this experiment, the interrogation signal consisted of a short audio frequency tone followed by a digital synchronization and address code in which an audio cycle was inhibited for a digital "0" and transmitted for a digital "1."



A master ground station can determine the slant range from itself to the satellite by the above mentioned technique. The slant range from the satellite to any number of other remote ground stations can be determined if the ground stations are equipped to acknowledge and retransmit the tonecode interrogation after a precisely determined time delay. The other ground stations may be fully automatic transponders.

A unique digital address code identified each remote transponder. When the satellite-transponder slant range was to be determined, the master ground station transmitted a tone burst followed by the transponder address code. The satellite repeated the tone-code interrogation and all remote transponders within the satellite line-of-sight received the retransmission. Only the transponder which recognized its address code retransmitted the tone-code sequence after a precise delay. The satellite relayed the transponder's response back to the master ground station. Automatic muting prevented the transponder from acknowledging reception upon the response repetition of its address

code by the satellite. The master ground station recognized the address code as the one it sent, and recorded the master ground station-satellite two-way propagation time and the master ground station-satellite-transponder twoway propagation time. To obtain measurements of the slant ranges from the satellite to several transponders, the master ground station interrogated them in sequence.

When a transponder received the tone cycles from the satellite in its receiver, they were applied to the phase matching circuit even though they may have been part of an interrogation for another transponder. A locally generated tone of the same frequency and with a stability of better than one part in  $10^6$  was also applied to the phase matcher, which adjusted the phase of the locally generated tone such that it corresponded to the phase of the received tone. Phase matching was accomplished by averaging over 256 cycles. The averaging process improved the timing accuracy by the square root of the number of cycles averaged.

The phase matched, locally generated tone clocked the received interrogation signal into an address code recognizer consisting of a shift register with summing circuits prewired to correspond to the unique digital address code of the transponder. When the sequence of pulses representing the transponder address code was loaded into the recognizer and acknowledged by the transponder, the recognition circuit produced a single, unambiguous output pulse which simultaneously keyed the transmitter and started a counter which measured out a precise number of locally generated tone cycles. Clock pulses reapplied to the shift register caused the address code to be clocked out to the transmitter following a preset number of tone cycles. In this way, the transponder transmitted its unique address code after a precisely measured time delay following correlation.

At the master ground station, the receiver output was applied to an address code recognizer similar to that in the transponder. Prior to the interrogation of an individual transponder, the taps of the summing circuit were switched to correspond to the address code of the intended transponder. When the address code was received from a satellite, a single output clock pulse occurred at the output of the summing circuit.

#### 3.2 VHF TRILATERATION NETWORK

The VHF trilateration network utilized for ranging measurements to ATS-3 consisted of the master ground station at the General Electric Radio-Optical Observatory near Schenectady, NY and fixed automatic remote transponders in Europe and North and South America. Table 1 lists transponders, their digital address codes and their locations.

At VHF, audio frequency tones of 2.4414 kHz frequency modulated carriers at 149.195 MHz. The downlink signal from the satellite was received

#### Table 1

#### GENERAL ELECTRIC VHF TONE-CODE RANGING NETWORK

GROUND STATION	ADDRESS CODE	STATION LOCATION: GEODETIC LATITUDE EAST LONGITUDE ALTITUDE	LOCATION REFERENCE
Radio-Optical Observatory, Schenectady, NY		42° 50' 53.67" ± 0.10" -74° 04' 13.34" ± 0.13" 414.5 ± 3 m	Aerial survey; USGS topographical map, 1:24000; North American Datum - 1927
NASA-Goddard Space Flight Center, Greenbelt, MD	1	38° 59' 55.58" -76° 50' 22.70" 18.9 m	North American Datum - 1927
US Department of Transpor- tation, Westford, MA	2	42° 36' 32.04" -71° 29' 37.68" 82.3 m	North American Datum - 1927
General Electric Co., Daytona Beach, FA	5	29° 11' 38.04" -81° 4' 23.88" 16.8 m	North American Datum - 1927
US Maritime Administration, Kings Point, NY	6	40° 48' 45.00" -73° 45' 47.16" 30.5 m	North American Datum - 1927
Radio Section, Shannon Airport, Shannon, Ireland	7	52° 46' 55" - 8° 55' 50" 9.1 m	European Datum
Argentine Air Force, Buenos Aires, Argentina	8	-34° 35' 07.00" ± 0.50" -58° 22' 12.69" ± 0.60" 36.6 m	Carta topografica de la Republica Argentina, 1:50000; Argentine Datum
Directorate of Civil Aviation, Reykjavek, Iceland	9	64° 07' 49.1" ± 0.2" -21° 56' 00.1" ± 0.2" 30.5 m	Assumed European Datum

at 135.575 MHz. Demodulated tones passed through tuned circuits with bandwidths of approximately 120 Hz before being compared with the locally generated tones. Table 2 summarizes signaling parameters as used in these experiments and an estimate of ranging performance.

Improved performance at low signal levels would have resulted from the use of phase shift keying. FM was chosen because of the commercial availability of this hardware and compatibility with existing communications equipment. FM also fulfilled the performance requirements for this ranging technique.

#### 3.3 OBSERVATORY EQUIPMENT CONFIGURATION

The Observatory configuration for tone-code ranging is shown in Figure 2. The internal time delay of a ranging tone was measured on every interrogation via the self-calibration loop. A reactive signal sampler on the transmit cable removed a small fraction of the transmitted RF signal. The local

#### Table 2

#### VHF TONE-CODE RANGING SIGNALING PARAMETERS

DESCRIPTION	CHARACTERISTICS
Uplink Frequency	149.195 MHz
Downlink Frequency	135.575 MHz
Modulating Frequency	2.4414 kHz
Type of Modulation	Narrow Band FM
Ranging Signal Duration	430 ms
Signal Format	Preamble Code - 1024 cycles of tone
	Address Code - 30 bits at 2.4414 kb/s
Ambiguity Interval	None (Code is not repeated)
Maximum Interrogation Rate	0.5 Hz
Responder Tuned Circuit Bandwidth	120 Hz
Range Measurement Precision	0.3 $\mu$ s, 50 m, single measurements (improves as square root of number of measurements averaged; thus average of 100 measurements yields approximately 5 m, one sigma resolution)
Range Measurement Bias Uncertainty*	Approximately 15 m (assumes 0.1 $\mu s$ uncertainty in equipment time delay)
Range Measurement Accuracy*	Approximately 30 m
Satellite Position Accuracy*	Latitude, approximately 2 seconds Longitude, approximately 2 seconds Earth Center Distance, approximately 30 meters
Line-of-Position Error*	Less than 100 m, except near sub- satellite point

\*Assumes no error contribution due to the effects of the ionosphere.

oscillator and mixer translated the carrier and modulation as the satellite would have done and a second reactive signal sampler injected the translated interrogation directly into the Observatory receiver. The Observatory thus correlated on the ranging interrogation almost immediately after the completion of the tone-code transmission. With the exception of delays introduced by fixed lengths of the RF cables specified in Figure 2, variations in Observatory delays were eliminated as a degrading factor of range measurement accuracy.

The Observatory correlated on the satellite return of the ranging interrogation after approximately 0.25 second; on the satellite return of a transponder response after approximately 0.95 seconds. All ranging measurements plus the interrogated transponder address code and the time of day passed

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Figure 2. Observatory Configuration for Tone-Code Ranging

automatically in real-time to a computer or to a paper tape punch. Table 3 details the format of the ranging data and Figure 3 presents a sample of the same.

#### 3.4 REMOTE TRANSPONDER CONFIGURATION

A block diagram of the VHF transponder loaned to NASA is presented in Figure 4. Ranging interrogations received on a 10-element crossed Yagi antenna passed to the transponder receiver via a normally closed transmit/ receive relay. Demodulated signals went to both the transponder loud speaker and to the tone-code-data responder unit [the digital logic center of the transponder, previously described<sup>(7, 8)</sup>]. If the responder correlated on a ranging interrogation, it would have keyed the transmitter for a ranging response; the transmit/receive relay would have opened preventing desensitization of the transponder receiver. The self-calibration loop would have translated a fraction of the transmitted signal to the receive frequency for a real-time measurement of the transponder internal time delay. The transponder used a 10-element crossed Yagi antenna for transmission. The transmit and receive antennas were installed within approximately three meters of each other.

The transponder self-calibration circuit operated in a manner slightly different from that at the Observatory. After acknowledgment of its address

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#### Table 3

#### PAPER TAPE DATA FORMAT\*

Format 1: (Found several times near the beginning of data)

Column	Format	Symbol	Description
1-2	12	-	Month of year
3-4	12	-	Day of month
5	I1	-	Last digit of year
6-8	13	-	Observatory data file identification number

Format 2:	(Normal d	lata)	
Column	Format	Symbol	Description
1-8	18	T1	Observatory-satellite-Observatory ranging time, in tenths of micro- seconds
9	-	Blank	Space
10-11	12	IU	Remote transponder address code
12-13	12	IH	Hour of day of interrogation, GMT
14-15	I2	IM	Minute of hour, GMT
16-17	12	IS	Second of minute, GMT
18	-	Blank	Space
19-26	18	Т2	Observatory-satellite-remote transponder and return ranging time, in tenths of microseconds
27	-	Blank	Space
28-35	18	δo	Observatory internal time delay, in tenths of microseconds

Format 3: (Data with transponder self-calibration)

Column	Format	Symbol	Description
1-35	-	-	Same as Format 2
36	-	Blank	Space
37-40	14	δSC	Response of self-calibration circuit in tenths of microseconds. (Note - only user 1 and user 8 generated valid responses.)

\*There are three different formats for the 24-hour ranging data; the first for data identification, the second for normal ranging data, and the third for ranging data with self-calibration response. The paper tape is written in ASCII code, no pairty.

$\begin{array}{llllllllllllllllllllllllllllllllllll$
05045075 02538150 $05072204$ $09324705$ $000039090504507502538154$ $06072206$ $09375418$ $000039100504507502538161$ $07072208$ $0957995$ $0000390802538160$ $0807210$ $09414554$ $0000391002538170$ $09072212$ $09589852$ $0000390902538170$ $09072212$ $09589852$ $0000391002538170$ $09072212$ $09364804$ $0000391102538180$ $0207216$ $09364804$ $0000391102538180$ $02072216$ $09364776$ $0000391102538180$ $05072220$ $09374776$ $0000390802538194$ $07072222$ $09586822$ $0000390802538194$ $07072224$ $09414571$ $0000390802538204$ $09072224$ $09414571$ $0000390802538213$ $02072210$ $09364870$ $000390902538213$ $02072230$ $09364870$ $000390802538213$ $02072230$ $09364870$ $000390802538226$ $07072232$ $09324829$ $0000390802538226$ $06072234$ $09375542$ $0000390802538226$ $05072244$ $09375542$ $0000390802538250$ $05072244$ $09375542$ $0000390802538250$ $05072244$ $09375542$ $0000390802538250$ $05072244$ $09375542$ $0000390802538250$ $05072246$ $09324429$ $0000390802538250$ $05072246$ $09324429$ $0000390802538250$ $05072246$ $09384229$ $0000390802538250$ $05072246$ $09384929$ $0000390802538250$ $05072246$ $09384929$ $0000390802538251$ $00072250$ $09588224$ $0000390802538251$ $01072250$ $09588224$ $0000390802538251$ $01072250$ $09588224$ $0000390802538271$ $09072254$ $09375612$ $000390802538271$ $01072258$ $1096638$ $0000390802538271$ $01072258$ $09384960$ $0000390802538271$ $01072258$ $09384960$ $0000390802538281$ $05072300$ $093284943$ $0000390802538281$ $05072300$ $093284943$ $0000390802538281$ $05072300$ $09328457$ $0000390802538281$ $05072300$ $09328457$ $0000390802538291$ $07072304$ $09580247$ $0000390802538291$ $07072304$ $09580247$ $0000390802538291$ $07072304$ $09580247$ $0000390802538291$ $07072304$ $09580247$ $0000390802538291$ $07072304$ $09580247$ $0000390802538291$ $07072304$ $09580247$ $0000390802538291$ $07072304$ $0958027$ $00$
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$0_{2538154}$ 06072206 09375418 000003910 05045075 02538161 07072208 0950795 000002906 05045075 02538162 08072210 09414554 00003910 02538170 09072212 09569852 06003909 02538180 02072216 09364804 00003919 02538180 02072216 09364804 00003911 02538180 05072218 09324776 00003911 02538190 0607222 09566082 00003911 02538201 0607222 09414571 00003906 02538213 0207223 09364870 00003909 02538213 0207223 09364870 00003909 02538213 0207223 09324829 00003909 02538226 05072236 09588151 00003910 02538226 05072236 09588151 00003910 02538226 05072236 09588151 00003910 02538226 05072246 09359026 00003908 02538250 05072246 0938429 00003908 02538257 06072246 0938429 00003908 02538250 05072250 09588224 00003908 02538251 09072254 09590093 00003909 02538271 09072254 09384926 00003908 02538281 05072300 09388224 00003910 02538281 05072300 09388287 00003908 02538291 07072304 09588287 00003908 02538291 07072304 09580247 00003909 02538291 07072304 09580247 00003909 02538291 07072304 09580247 00003909 02538291 07072304 09580247 00003908 02538291 07072304 09580247 00003908 02538291 07072304 09580247 00003909 02538291 07072304 09580247 00003909 02538291 07072304 09580247 00003908 02538291 07072304 09580247 00003908 02538291 07072304 09580247 00003908
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02538257 06072248 09375612 06003909 02538262 07072250 09588224 06003901 02538264 08072252 09414605 00003909 02538271 09072254 09590093 00003909 02538273 01672256 10096638 00003910 02538274 02072258 09384996 00003908 02538281 0507230C 09324943 06003908 02538281 05072302 09375666 00003909 02538291 07072304 09586287 00003908 02538296 06072306 09414611 00003908 02538303 09072308 09590194 00003908
02538262 07072250 09588224 00003911 02538264 08072252 09414605 00003909 02538271 09072254 09590093 00003909 02538273 01072254 09590093 00003908 02538274 02072258 09384996 00003908 02538281 05072302 09324943 00003908 02538281 05072302 09375666 00003909 02538291 07072304 09588287 00003908 02538296 08072305 09414611 00003909 02538303 09072308 09590194 00003908
02538264 08072252 09414605 00003909 02538271 09072254 09590093 00003909 02538273 01072256 10096638 00003910 02538274 02072258 09384996 00003908 02538281 05072302 09375666 00003908 02538281 07072304 09582827 00003908 02538291 07072304 09582827 00003909 02538296 08072306 09414611 00003909 02538303 09072308 09590194 00003908
02538271 09072254 09590093 00003909 02538273 01672256 10096638 00003910 02538274 02072258 09384996 00003918 02538281 05072302 09324943 06003908 02538281 05072302 09375666 00003908 02538291 07072304 0958287 00003908 02538296 0E072306 09414611 00003908 02538303 09072308 09590194 00003908
02538273 01072256 10096638 00003910 02538274 02072258 09384996 00003908 02538281 05072306 09324943 00003908 02538286 06072302 09375666 00003909 02538291 07072304 0958287 00003908 02538296 08072306 09414611 00003908 02538303 09072308 09590194 00003908
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02538281 0507230C 09324943 06003908 02538286 06C72302 09375666 00003909 02538291 07072304 09588287 00003908 02538296 08072306 09414611 00003909 02538303 09072308 09590194 00003908
02538286 06072302 09375666 00003909 02538291 07072304 09588287 00003908 02538296 08072306 09414611 00003908 02538303 09072308 09590194 00003908
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02538296 08072306 09414611 00003909 02538303 09072308 09590194 00003908
02538303 09072308 09590194 00003908
0.0508005 01080010 1000/(OF 0500000
05239302 01015310 10040038 00003408
02538311 02072312 09385057 00003909
02538315 05072314 09324994 00003909
02538317 06072316 09375736 00003911

#### Figure 3. Sample of Typical Tone-Code Ranging Data to ATS-3 Satellite

code, the responder generated a response consisting of 1024 cycles of audio tone, 30 cycles of synchronization and address code and 144 cycles of data. During transmission of the tone cycles, the transmitted signal was sampled, mixed with a frequency identical to the translation frequency of the satellite and injected into the receiver. The responder compared the phase of the self-calibration looped audio tone cycles with that transmitted and inserted the value of the phase difference in the data stream following the address code. The responder was capable of measuring and transmitting variations in the internal time delay as large as 10  $\mu$ s, representing a variation of about an order of magnitude greater than expected in an operational atmosphere. There was no ambiguity in phase measurement as the 10  $\mu$ s is a small fraction of the 409.6  $\mu$ s period of the ranging tone.

Immediately after deployment of the NASA transponder and during the first several ranging periods, the transponder was configured as shown in Figure 5. During transmission of ranging responses, the close proximity of the transmit and receive antennas resulted in desensitization of the receiver as it was trying to demodulate the self-calibration looped signal. The self-calibration responses were erroneous but transponder correlation was unaffected.

#### GENERAL 🍪 ELECTRIC



Figure 4. NASA-Goddard Space Flight Center VHF Tone-Code Ranging Transponder Configuration. (Self-calibration circuit provides a measure of the transponder internal time delay on every ranging interrogation).



Figure 5. Initial NASA-Goddard Space Flight Center VHF Tone-Code Ranging Transponder Configuration. (The direct receiver-antenna connection allowed receiver desensitization during transmission of ranging responses, preventing self-calibration.)

#### 3.5 ANALYTICAL TECHNIQUES

The Observatory-satellite slant range  $R_0$  is computed by the equation

$$R_{O} = \frac{c}{2} \left( T - \delta_{O} - \delta_{S} \right)$$
(1)

where

- c = appropriate conversion factor from units of time to units of distance,
- T = ranging time, Observatory satellite and return,
- δ<sub>0</sub> = Observatory internal time delay, approximately 388.6 µs; measured on every interrogation by the self-calibration circuit,
- $\delta_{s}$  = satellite internal time delay, approximately 7 µs.

The Observatory transmitter was connected to an 8-turn helix antenna with 100 feet of 1/2-inch foam dielectric cable (0.12  $\mu$ s delay). The same length of 7/8-inch dielectric cable with 0.11  $\mu$ s delay connected the 30-foot dish antenna to the Observatory receiver. The total cable delay of 0.23  $\mu$ s must be added to the measured Observatory internal time delay.

The satellite-remote transponder slant range  $R_i$  for trilateration Stations 2, 5, 6, 7, 8 and 9 is given by

$$R_{i} = \frac{c}{2} \left( T_{2i} - T - \delta_{2i} - \delta_{s} \right)$$
(2)

where

T<sub>2i</sub> = ranging time, Observatory-satellite-remote transponder i and return,

 $\delta_{2i}$  = effective internal time delay of remote transponder station i.

The internal time delays of the remote trilateration transponders are itemized in Table 4 and include delays at the Observatory and delays in the cables.

During a recent set of experiments, <sup>(6)</sup> a fixed transponder was located in Tucson, AZ and a vehicle-borne transponder was driven in the western US from southern California to central Colorado. Both of these transponders had undergone the most thorough internal time delay calibrations. Over some of the greater separations between the vehicle and the fixed transponder, the Observatory, vehicle and fixed transponder formed a satellite trilateration network. Ranging measurements to the parked vehicle (on well identified bench marks) and to the fixed transponder located the ATS-3 satellite. Coincident ranging measurements to the trilateration transponders resulted in measured slant ranges which disagreed with those based on the parked vehiclefixed transponder-Observatory trilateration. This disagreement was interpreted as due to errors in the assumed values for the original trilateration

#### Table 4

GROUND STATION	ADDRESS CODE	ASSUMED INTERNAL TIME DELAY (µs)	RECALIBRATED INTERNAL TIME DELAY (µs)
Observatory		~380.0*	<b>~</b> 380.0*
NASA-GSFC	1	$431714.3^{\$}$ $431470.0^{@}$	
Westford	2	unknown	
Daytona Beach	5	431487.2	431442.7
Kings Point	6	431481.8	
Shannon	7	431500.8	431439.2
Buenos Aires	8	439463.7	439393.3
Reykjavik	9	431505.6	431468.2

#### VHF TRILATERATION TRANSPONDER INTERNAL TIME DELAYS

\*Measured on every ranging interrogation. \$With self-calibration response. @Without self-calibration response.

transponder internal time delays. New time delays, based upon this analysis, are presented in the fourth column of Table 4.

The satellite-NASA transponder slant range  $R_1$  is given by

$$\dot{R}_{1} = \frac{c}{2} (T_{21} - T - \delta_{21} - \delta_{S} - \delta_{SC})$$
(3)

where

 $T_{21}$  = ranging time, Observatory-satellite-NASA transponder and return,

 $\delta_{21}$  = NASA transponder internal time delay, 431714.3 ms,

 $\delta_{SC}$  = response of the transponder self-calibration circuit.

For no returns from the transponder self-calibration circuit or for erroneous returns, set  $\delta_{SC} = 0$  and  $\delta_{21} = 431470.0 \ \mu s$ .

#### SUMMARY OF RANGING EXERCISES

The first 24-hour ATS-3 ranging exercise was conducted on November 3, 1974; Table 5 details the times of individual ranging periods and the active transponders. The transponder in Buenos Aires was not operational during the entire test.

During this particular ranging exercise, other commitments for satellite usage forced NASA to allocate only one-half of the maximum satellite power during several of the ranging periods. Power reduction on ATS-3 implies usage of only one-half of the final output power amplifiers. As each power amplifier drives a separate whip antenna (total of eight) reduction of active output elements decreases antenna gain. Half-power on the spacecraft thus implies a 6 dB reduction of spacecraft effective isotropic radiated power.

In the initial configuration of the NASA transponder (Figure 5), ranging response transmissions desensitized the transponder receiver and prevented proper demodulation of the self-calibration signal. The transponder internal time delay was in no way affected as the transmitter was not keyed until the entire tone-code interrogation had been received from the satellite. This condition was corrected after File 906 (after 1710 GMT) to the configuration of Figure 4. The NASA transponder also suffered intermittent outages (approximately every 90 min) during the daylight hours. The transponder transmitted excellent tone-code signals following depression of the "manual trigger" verifying correct performance of the transmit chain. The problem was diagnosed as Faraday rotation of the linearly polarized transmission from the satellite and a noncircular receive antenna. The antenna was later found to have a poor electrical connection in one plane, resulting in an effectively linearly polarized antenna.

Throughout the November 3, 1974 tests, most of the ranging interrogations were conducted at a rate of one every two seconds. On several occasions, the rate was decreased to one every 2.4 or every 3 seconds. The time of ranging interrogations was recorded to the nearest second generating a maximum 0.5 second error in the recorded interrogation time.

Table 6 contains a summary of the 24-hour ranging exercise of May 4-5, 1975. Range measurements were intended to run from 20 minutes after every odd hour until 40 minutes after the same. These times overlapped the bi-weekly NASA C-band range and range rate measurements to ATS-3. The overlap of the two totally independent ranging techniques allowed for an excellent evaluation of the VHF trilateration.

GENERAL 🍪 ELECTRIC

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#### Table 5

PILE         SIAR         SIAR <t< th=""><th><b>D11 -</b></th><th>TIME (</th><th>GMT)</th><th><del></del></th><th>STA</th><th>TION</th><th>STAT</th><th>us</th><th></th><th>SATELLITE</th><th></th></t<>	<b>D11 -</b>	TIME (	GMT)	<del></del>	STA	TION	STAT	us		SATELLITE	
873       0000       0010       NO       NO       Full       Start of 24 hour test         874       0025       030       "       "       Fixed bad fuse in #7         875       0150       0200       "       "       "         877       0150       0200       "       "       "         877       0250       0300       "       "       "         878       0220       0300       "       "       "         878       0230       0340       "       "       "         881       0400       0410       "       "       "         882       0431       0441       "       "       "         883       0500       0610       "       "       #9 intermittent         884       0530       0640       "       #9 intermittent       #9 intermittent         884       0730       0744       "       "       #9 intermittent         884       0730       0840       "       "       #9 intermittent         884       0730       040       "       "       #9 intermittent         884       0730       040       "	FILE	START	STOP	1	2	5	<u> </u>	<u> </u>	9	POWER	COMMENTS
874       0025       0035       """"""""""""""""""""""""""""""""""""	873	0000	0010				NO	NO		Full	Start of 24 hour test
875       0050       0100       """"""""""""""""""""""""""""""""""""	874	0025	0035				11			11	Fixed bad fuse in #7
876       0.120       0.130       "       "         877       0.150       0.200       "       "         878       0.220       0.230       "       "         879       0.250       0.300       "       "         880       0.330       0.340       "       "         881       0.400       0.411       "       "         882       0.500       0.510       "       "         884       0.500       0.540       "       "         885       0.600       0.640       "       "         886       0.630       0.640       "       "         887       0.700       0.711       "       "       # 9 intermittent         888       0.730       0.740       "       "       # 7, # 9 intermittent         888       0.730       0.940       "       "       # 7, # 9 intermittent         889       0.750       0.800       "       "       # 7, # 9 intermittent         881       0.300       0.940       "       "       # 17, # 9 intermittent         893       1.300       1.010       "       "       # 14 reported cleaned relay c	875	0050	0100				u.			"	
877       0.150       0.200       "         878       0.220       0.230       "         879       0.250       0.300       "         881       0.400       0.410       "         881       0.400       0.410       "         882       0.431       0.441       "         883       0.500       0.510       "         884       0.500       0.610       "         885       0.600       0.610       "         886       0.630       0.640       "         887       0.700       0.711       "       # f9 intermittent         888       0.755       0.805       "       # f7, f9 intermittent         889       0.755       0.805       "       # f7, f9 intermittent         890       0.804       "       "       # f2 repaired cleaned relay contracts         891       1.000       1.010       "       "       # f2 repaired power amplifier         892       0.930       9.44       "       # f2 repaired power amplifier         893       1.000       1.110       "       "         894       1.330       1.440       "       "	876	0120	0130				19			n	
878       0220       0230       "       "         879       0250       0300       0340       "         881       0400       0410       "       "         882       0431       0441       "       "         883       0500       0510       "       "         884       0530       0540       "       "         885       0630       0640       "       "         886       0730       0740       "       # f 9 intermittent         888       0730       0740       "       # f 7, f 9 intermittent         888       0730       0740       "       # f 7, f 9 intermittent         890       0730       0740       "       # f 7, f 9 intermittent         891       0300       0810       "       "         892       0930       0940       "       "         893       1000       1110       "       "         894       1030       1210       "       # f 2 repaired power amplifier         896       1130       1440       "       # f 2 repaired power amplifier         896       1301       1440       NO       "<	877	0150	0200				u			11	
879       0250       0300       """"""""""""""""""""""""""""""""""""	878	0220	0230				н			n	
880       0330       0340       """"""""""""""""""""""""""""""""""""	879	0250	0300				n			n	
881       0400       0410       "       "         882       0431       0441       "       "         883       0500       0510       "       "         884       0530       0540       "       "       #9 intermittent         885       0600       0610       "       "       #9 intermittent         886       0730       0711       "       #9 intermittent         887       0700       0711       "       #7, #9 intermittent         888       0735       0805       "       #7, #9 intermittent         889       0755       0805       "       #7, #9 intermittent         891       0900       0910       NO       "       "         893       10040       "       "       #9 reported cleaned relay contracts         894       1030       1040       "       "       #9         895       1100       1110       "       #1       #1 manual trigger OK         896       1130       1440       "       #2       intermittent         901       1430       1440       "       #2       intermittent         901       1430       14	880	0330	0340				n			n	
882       0431       0441       "       "         883       0500       0510       "       "         884       0530       0540       "       "         885       0600       0610       "       "       #9 intermittent         886       0630       0640       "       "       #9 intermittent         887       0700       0711       "       #9 intermittent         888       0730       0740       "       #7, #9 intermittent         889       0735       0805       "       #7, #9 intermittent         890       0820       0830       "       "       #7, #9 intermittent         891       0900       0910       NO       "       "       #7, #9 intermittent         892       0930       0940       "       "       "       #7, #9 intermittent         892       1030       1010       "       "       #1       #1         894       1030       1040       "       "       #2       repaired power amplifier         894       1230       1340       "       #1       #1       manual trigger OK       #1         901       1400	881	0400	0410				n			n	
883       0500       0510       "       "         884       0530       0540       "       "         885       0600       0610       "       "       #9 intermittent         886       0630       0640       "       "       #9 intermittent         887       0700       0711       "       "       #9 intermittent         888       0730       0740       "       "       #9 intermittent         888       0730       040       "       "       #7, #9 intermittent         889       0730       0605       "       "       #7, #9 intermittent         890       0820       0830       "       "       #7, #9 intermittent         891       0900       0910       NO       "       "         892       0930       0940       "       "       #9 reported cleaned relay contracts         894       1030       1040       "       "       #1 for perported cleaned relay contracts         894       1030       1110       "       "       #2 repaired power amplifier         895       1130       1140       "       "       #1 manual trigger OK         898	882	0431	0441				*			. 11	
884       0530       0540       "       "       "       "       9         885       0600       0610       "       "       #9       intermittent         886       0630       0640       "       "       #9       intermittent         887       0700       071       "       "       #9       intermittent         888       0735       0805       "       "       #7, #9       intermittent         889       0755       0805       "       "       #7, #9       intermittent         891       0900       0910       NO<"	883	0500	0510				n				
885       0600       0610       "       "       # 9 intermittent         886       0630       0640       "       # 9 intermittent         887       0700       0711       "       # 9 intermittent         888       0730       0740       "       # 7, 49 intermittent         888       0730       0740       "       "       # 7, 49 intermittent         889       0820       0830       "       "       "       # 7, 49 intermittent         890       0820       0830       "       "       "       # 7, 49 intermittent         891       0900       0910       NO       "       "       "       # 7, 49 intermittent         891       1030       1040       "       "       "       # 7       # 9 reported cleaned relay contracts         893       1030       1040       "       "       "       # 2 repaired power amplifier         895       1130       1140       "       "       # 2 repaired power amplifier         898       1230       1240       "       # 6 put into respond mode         8991       1330       1340       Full       # 1 manual trigger OK         901       1400	884	0530	0540				n			n	
886       0630       0640       "       "       # 9 intermittent         887       0700       0711       "       # 9 intermittent         888       0730       0740       "       # 7, #9 intermittent         889       0755       0805       "       # 7, #9 intermittent         889       0755       0805       "       # 7, #9 intermittent         889       0750       0800       0910       NO       "       # 7, #9 intermittent         891       0900       0910       NO       "       "       # 7, #9 intermittent         892       0930       0940       "       "       # 7, #9 intermittent         892       1030       1040       "       "       # 7         893       1000       1010       "       "       # 9 reported cleaned relay contracts         894       1030       1140       "       "       # 2 repaired power amplifier         894       130       1140       "       "       # 6 put into respond mode         898       1300       1340       Half       # 1 manual trigger OK         901       1430       1440       NO       "         905 <t< td=""><td>885</td><td>0600</td><td>0610</td><td></td><td></td><td></td><td>п</td><td></td><td></td><td>"</td><td>#9 intermittent</td></t<>	885	0600	0610				п			"	#9 intermittent
887       0700       0711       "       #       # fintermittent         888       0730       0740       "       # fifty intermittent         890       0820       0830       "       #         891       0900       0910       NO       "       "         892       0930       0940       "       "       #         893       1000       1010       "       "       #         893       1000       1010       "       "       #         893       1000       1010       "       "       #         894       1030       1040       "       "       #         895       1100       1110       "       "       #         896       1130       1140       "       "       #         896       1330       1240       "       #       #         991       1330       1340       NO       #       #         901       1400       1410       NO       #       #         902       1500       1510       "       #       #         903       1530       1540       NO	886	0630	0640				n			n	#9 intermittent
888       0730       0740       "       "       #7, #9 intermittent         889       0755       0805       "       #7, #9 intermittent         890       0820       0830       "       "         891       0900       0910       NO       "       "         892       0830       0940       "       "       "         893       1000       1010       "       "       "         893       1000       1010       "       "       "         893       1000       1010       "       "       "         895       1100       1110       "       "       "         896       1130       1140       "       "       #2 repaired power amplifier         898       1230       1240       "       #1       #1         901       1430       140       NO       Full       #1 manual trigger OK         901       1430       1440       NO       "       "         903       1530       1540       NO       "         904       1600       1611       Full       #1 RF rewired; self-calibration operational         906	887	0700	0711				n			11	#9 intermittent
889       0755       0805       "       "       #7, $\frac{49}{9}$ intermittent         890       0820       0830       "       "         891       0900       0910       NO       "       "         892       0930       0940       "       "       "         892       0930       0940       "       "       "         892       0930       0940       "       "       "         892       0930       0940       "       "       "         892       0930       0940       "       "       "         893       1000       1010       "       "       "         895       1100       1140       "       "       #         896       1330       1340       "       #       # fo put into respond mode         899       1330       1340       NO       "       #       # for put into respond mode         990       1400       1410       NO       Full       # inanual trigger OK       #         901       1430       1440       NO       "       "       #         903       1530       1540       NO	888	0730	0740				H.			n	#7, #9 intermittent
880       0820       0830       "       "       "         891       0900       0910       NO       "       "         892       0930       0940       "       "       "         893       1000       1010       "       "       "         893       1000       1010       "       "       "         895       1100       1110       "       "       "         896       1130       1440       "       "       "         897       1200       1210       "       "       #6 put into respond mode         899       1330       1340       "       #16       #1000         900       1400       1410       NO       Full       #1 manual trigger OK         901       1430       1440       NO       "       #2         902       1530       1540       NO       "       "         904       1600       1611       Full       #1 RF rewired; self-calibration operational         906       1700       1710       NO       NO       "         910       1330       1840       NO       "       "	889	0755	0805							n	#7, #9 intermittent
891       0900       0910       NO       "       "         892       0930       0940       "       "       "         893       1000       1010       "       "       "         894       1030       1040       "       "       "         895       1100       1110       "       "       "         896       1130       1140       "       "       "         897       1200       1210       "       "       #2 repaired power amplifier         898       1330       1340       "       "       #2 repaired power amplifier         898       1330       1340       "       "       #2 repaired power amplifier         900       1400       1410       NO       "       #1         901       1430       1440       "       "       #1         901       1430       1440       NO       "       "         903       1530       1540       NO       "       "         906       1700       1710       NO       NO       "         907       1800       1840       NO       "       #1	890	0820	0830				n			11	
882       0930       0940       """"""""""""""""""""""""""""""""""""	891	0900	0910		NO		n			11	
893       1000       1010       """"""""""""""""""""""""""""""""""""	892	0930	0940				Ħ			n	
894       1030       1040       """"""""""""""""""""""""""""""""""""	893	1000	1010		п		п			Π.	#9 reported cleaned relay contracts
895       1100       1110       "       "       " $896$ 1130       1140       "       "       #2 repaired power amplifier $897$ 1200       1210       "       #6 put into respond mode $899$ 1330       1240       "       #6 put into respond mode $899$ 1330       1340       "       #1 manual trigger OK         900       1400       1410       NO       Full       #1 manual trigger OK         901       1430       1440       "       "       #2 intermittent         902       1500       1510       "       "         903       1530       1540       NO       "         904       1600       1611       Full       #1 RF rewired; self-calibration operational         906       1700       1710       NO       NO       "         907       1800       1810       Full       #1 RF rewired; self-calibration operational         908       1930       1940       "       "         910       1930       1940       "       "         911       2000       2010       "       #1         913 <t< td=""><td>894</td><td>1030</td><td>1040</td><td></td><td>н</td><td></td><td>ti.</td><td></td><td></td><td>n</td><td></td></t<>	894	1030	1040		н		ti.			n	
896       1130       1140       """#2 repaired power amplifier         897       1200       1210       ""#6 put into respond mode         898       1330       1340       "#6 put into respond mode         899       1330       1340       Half         900       1400       1410       NO       Full       #1 manual trigger OK         901       1430       1440       "       Half       #2 intermittent         902       1500       1510       "       "         903       1530       1540       NO       "         904       1600       1611       Full       #1 manual trigger OK         905       1630       1640       "       "         905       1630       1640       Half       #1 RF rewired; self-calibration operational         906       1700       1710       NO       NO       "         908       1830       1840       NO       "       #1 RF rewired; self-calibration operational         909       1900       1910       "       "       #1 bad connector on receive antenna         909       1900       1910       "       "       "         911       2000	895	1100	1110		n		P			17	
897       1200       1210       "       #2 repaired power amplifier         898       1230       1240       "       #6 put into respond mode         899       1330       1340       Half         900       1400       1410       NO       Full       #1 manual trigger OK         901       1430       1440       Half       #2 intermittent         902       1500       1510       "       "         903       1530       1640       NO       "         904       1600       1611       Full       #1 Fruit         905       1630       1640       Half       "         906       1700       1710       NO       NO       "         907       1800       1810       Full       #1 RF rewired; self-calibration operational         908       1830       1840       NO       Half       #1 bad connector on receive antenna         909       1900       1910       "       "       "         911       2000       2010       Full       #1 bad connector on receive antenna         919       2300       2140       "       "       "         914       2130	896	1130	1140		Ħ		н			н	
888       1230       1240       " #6 put into respond mode         899       1330       1340       Half         900       1400       NO       Full       #1 manual trigger OK         901       1430       1440       Half       #2 intermittent         902       1500       1510       "       "         903       1530       1540       NO       "         904       1600       1611       Full       #1 RF rewired; self-calibration operational         905       1630       1640       NO       "         906       1700       1710       NO       NO       "         907       1800       1840       NO       "       #1 RF rewired; self-calibration operational         908       1830       1840       NO       "       "         910       1910       "       "       "         911       2000       2010       Full       #1 Receive tone level; may change calibration         913       2100       2140       "       "         914       2130       2140       "       "         916       2230       2400       Half       "         9	897	1200	1210				н			"	#2 repaired power amplifier
899       1 330       1 340       Half         900       1 400       1 410       NO       Full       #1 manual trigger OK         901       1 430       1 440       Half       #2 intermittent         902       1 500       1 510       "         903       1 530       1 540       NO       "         904       1 600       1 611       Full       Half         905       1 630       1 640       Half       Half         906       1 700       1 710       NO       NO       "         907       1 800       1 810       Full       #1 RF rewired; self-calibration operational         908       1 830       1 840       NO       "       "         910       1 910       "       "       #1 bad connector on receive antenna         909       1 900       1 910       "       "         911       2000       2010       Full       #1 bad connector on receive antenna         912       2030       2040       "       "         913       2100       2110       "       "         914       2130       2140       "       "         915	898	1230	1240							11	#6 put into respond mode
900       1400       1410       NO       Full       #1 manual trigger OK         901       1430       1440       Half       #2 intermittent         902       1500       1510       "         903       1530       1540       NO       "         904       1600       1611       Full       #1         905       1630       1640       Half       #1         906       1710       NO       NO       "         907       1800       1810       Full       #1 RF rewired; self-calibration operational         908       1830       1840       NO       Half       #1 bad connector on receive antenna         909       1900       1910       "       "         911       2000       2010       "       "         912       2030       2040       Full       #2 increased receive tone level; may change calibration         913       2100       2110       "       "         914       2300       2240       NO       Half         915       2200       2210       Full       "         915       2200       2210       Full       #1         916 <td>899</td> <td>1330</td> <td>1340</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>Half</td> <td></td>	899	1330	1340							Half	
901       1430       1440       Half       #2 intermittent         902       1500       1510       "       "         903       1530       1540       NO       "         904       1600       1611       Full         905       1630       1640       Half         906       1700       1710       NO       NO       "         907       1800       1810       Full       #1 RF rewired; self-calibration operational         908       1830       1840       NO       "       "         909       1900       1910       "       "       #1 bad connector on receive antenna         911       2000       2010       "       "       "         913       2100       2110       "       "         914       2130       2140       "       "         915       2200       2210       Full       "         916       2230       2240       NO       Half         917       2300       2305       "       Observatory computer down, only 5 minutes of data         919       2350       2400       "       "       #1 only few responses   <	900	1400	1410	NO						Full	#1 manual trigger OK
902       1500       1510       "         903       1530       1540       NO       "         904       1600       1611       Full         905       1630       1640       Half         906       1700       1710       NO       NO         907       1800       1810       Full       #1 RF rewired; self-calibration operational         908       1830       1840       NO       Half       #1 bad connector on receive antenna         909       1900       1910       "       "         910       1930       1940       "       "         911       2000       2010       Full       #2 increased receive tone level; may change calibration         913       2100       2110       "       "         915       2200       2210       Full       #2 increased receive tone level; may change calibration         915       2200       2210       "       "         916       2230       2240       NO       Half         917       2300       2305       "       Observatory computer down, only 5 minutes of data         919       2350       2400       "       "       #1 only few respon	901	1430	1440							Half	#2 intermittent
903       1530       1540       NO       "         904       1600       1611       Full         905       1630       1640       Half         906       1700       1710       NO       NO         907       1800       1810       Full       #1 RF rewired; self-calibration operational         908       1830       1840       NO       Half       #1 bad connector on receive antenna         909       1900       1910       "       "       "         910       1930       1940       "       "         911       2000       2010       Full       #2 increased receive tone level; may change calibration         913       2100       2110       "       "         915       2200       2210       Full       #1         916       2230       2240       NO       Half         917       2300       2305       "       Observatory computer down, only 5 minutes of data         918       2325       2335       "       "       #1 only few responses	902	1500	1510							n	
904       1600       1611       Full         905       1630       1640       Half         906       1700       1710       NO       NO         907       1800       1810       Full       #1 RF rewired; self-calibration operational         908       1830       1840       NO       Half       #1 bad connector on receive antenna         909       1900       1910       "       "         910       1930       1840       NO       "         911       2000       2010       Full       #2 increased receive tone level; may change calibration         912       2030       2040       Full       #2       increased receive tone level; may change calibration         913       2100       2110       "       "       #1         915       2200       2210       Full       #1         916       2230       2240       NO       Half         917       2300       2305       "       Observatory computer down, only 5 minutes of data         918       2325       2335       "       #1 only few responses	903	1530	1540	NÔ						n	
905       1630       1640       Half         906       1700       1710       NO       NO       n         907       1800       1810       Full       #1 RF rewired; self-calibration operational         908       1830       1840       NO       Half       #1 bad connector on receive antenna         909       1900       1910       "       "         910       1930       1940       "       "         911       2000       2010       Full       #2 increased receive tone level; may change calibration         912       2030       2140       "       "         914       2130       2140       "       "         915       2200       2210       Full       -         917       2300       2305       "       Observatory computer down, only 5 minutes of data         918       2325       2335       "       #1 only few responses	904	1600	1611							Full	
906       1700       1710       NO       NO       "         907       1800       1810       Full       #1 RF rewired; self-calibration operational         908       1830       1840       NO       Half       #1 bad connector on receive antenna         908       1900       1910       "       "         910       1930       1940       "         911       2000       2010       Full         912       2030       2040       Full         913       2100       2110       "         914       2130       2140       "         915       2200       2210       Full         917       2300       2305       "         918       2325       2335       "         919       2350       2400       "	905	1630	1640							Half	
907       1800       1810       Full       #1 RF rewired; self-calibration operational         908       1830       1840       NO       Half       #1 bad connector on receive antenna         909       1900       1910       "       "         910       1930       1940       "         911       2000       2010       Full       #2 increased receive tone level; may change calibration         913       2100       2110       "       "         915       2200       2210       Full       #1         916       2230       2240       NO       Half         917       2300       2305       "       Observatory computer down, only 5 minutes of data         918       2325       2335       "       #1 only few responses	906	1700	1710	NO				NO		n	
908       1830       1840       NO       Half       #1 bad connector on receive antenna         909       1900       1910       "       "         910       1930       1940       "         911       2000       2010       Full         912       2030       2040       Half       #2 increased receive tone level; may change calibration         913       2100       2110       "       "         914       2130       2240       NO       Half         915       2200       2210       Full       "         916       2230       2240       NO       Half         917       2300       2305       "       Observatory computer down, only 5 minutes of data         918       2325       2335       "       #1 only few responses	907	1800	1810							Full	#1 RF rewired; self-calibration operational
909       1900       1910       "         910       1930       1940       "         911       2000       2010       Full         912       2030       2040       Half       #2 increased receive tone level; may change calibration         913       2100       2110       "         914       2130       2140       "         915       2200       2210       Full         916       2230       2240       NO         917       2300       2305       "         918       2325       2335       "         919       2350       2400       "	908	1830	1840	NO						Half	#1 bad connector on receive antenna
910       1930       1940       "         911       2000       2010       Full         912       2030       2040       Half       #2 increased receive tone level; may change calibration         913       2100       2110       "         914       2130       2140       "         915       2200       2210       Full         916       2230       2240       NO         917       2300       2305       "         918       2325       2335       "         919       2350       2400       "	909	1900	1910							11	
911       2000       2010       Full         912       2030       2040       Half       #2 increased receive tone level; may change calibration         913       2100       2110       "         914       2130       2140       "         915       2200       2210       Full         916       2230       2240       NO         917       2300       2305       "         918       2325       2335       "         919       2350       2400       "	910	1930	1940							11	
912     2030     2040     Half     #2 increased receive tone level; may change calibration       913     2100     2110     "       914     2130     2140     "       915     2200     2210     Full       916     2230     2240     NO       917     2300     2305     "       918     2325     2335     "       919     2350     2400     "	911	2000	2010							Full	
913       2100       2110       "         914       2130       2140       "         915       2200       2210       Full         916       2230       2240       NO       Half         917       2300       2305       "       Observatory computer down, only 5 minutes of data         918       2325       2335       "       #1 only few responses	912	2030	2040							Half	#2 increased receive tone level; may change calibration
914     2130     2140     "       915     2200     2210     Full       916     2230     2240     NO       917     2300     2305     "       918     2325     2335     "       919     2350     2400     "	913	2100	2110							n	• "
915     2200     2210     Full       916     2230     2240     NO     Half       917     2300     2305     "     Observatory computer down, only 5 minutes of data       918     2325     2335     "       919     2350     2400     "	914	2130	2140							11	
916     2230     2240     NO     Half       917     2300     2305     "Observatory computer down, only 5 minutes of data       918     2325     2335     "       919     2350     2400     "     #1 only few responses	915	2200	2210							Full	
917       2300       2305       "Observatory computer down, only 5 minutes of data         918       2325       2335       "         919       2350       2400       "       #1 only few responses	916	2230	2240	NO						Half	
918 2325 2335 " 919 2350 2400 " #1 only few responses	917	2300	2305							n	Observatory computer down, only 5 minutes of data
919 2350 2400 " #1 only few responses	918	2325	2335							n	· · · ·
	919	2350	2400							11	#1 only few responses

### SUMMARY OF ATS-3 TRILATERATION 24 HOUR TEST (Nov. 3, 1974)

#### Table 6

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#### SUMMARY OF ATS-3 TRILATERATION 24-HOUR TEST (May 4-5, 1975)

		Time (GMT)	
FILE	DATE	START STOP	COMMENTS
075	5/4	072200 074358	· · ·
076	'n	084602 085758	WEFAX in ATS-3 from 0900 to 0945 GMT
077	н	094502 095458	11 11 11 11 11 11 11 11 11
081	tt.	111945 113441	
085	п	132000 133958	
088	. п	151929 154003	
091	ŧ	172000 173532	Computer storage exceeded; data beyond 173532 lost
094	. 11	192001 193957	1
097	n	212000 213959	Occasional problem with Observatory correlator
100	п	232000 233958	Buenos Aires (#8) failed to correlate many times
103	5/5	011954 013959	ATS-3 accidentally turned off by ATSOCC
106	п	032004 034000	
109	11	052001 053859	Shannon (#7) failed to correlate many times

All trilateration transponders operated during this second 24-hour schedule; occasionally one or two of the transponders missed an individual interrogation. The NASA transponder was not operative during this test due to the unavailability of proper antennas.



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#### CONCLUSIONS

The objectives of this contract have all been satisfied. Specifically,

- A VHF tone-code ranging transponder has been successfully deployed at NASA-Goddard Space Flight Center.
- Two 24-hour ATS-3 ranging exercises have been completed.
- Ranging data from all trilateration exercises have been sent to NASA-Goddard Space Flight Center in the form of punched paper tape and computer printout.



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