ATS-3 RANGING SUPPORT

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GENERAL ELECTRIC

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Section 1

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 L-band, 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. (1) 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. (3) 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. (6) 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 line-of-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-of-position 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.

Section 2

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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Section 3

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."

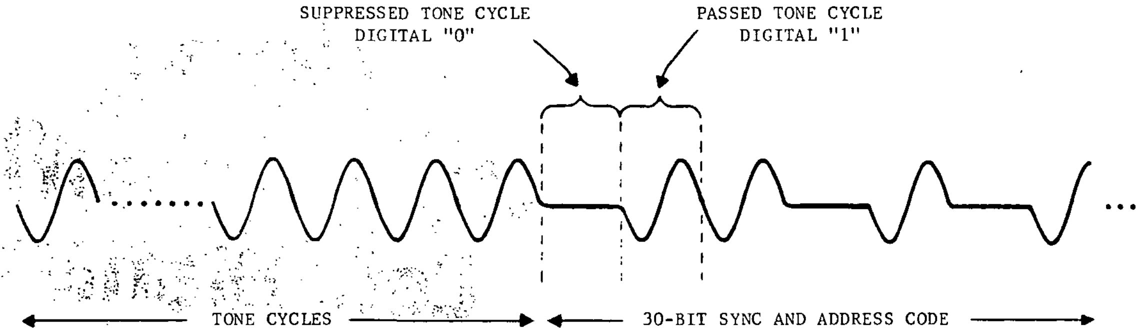

Figure 1. Tone-Code Ranging Waveform

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 tone-code 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 two-way 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 Transportation, 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 μs, 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 μs 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

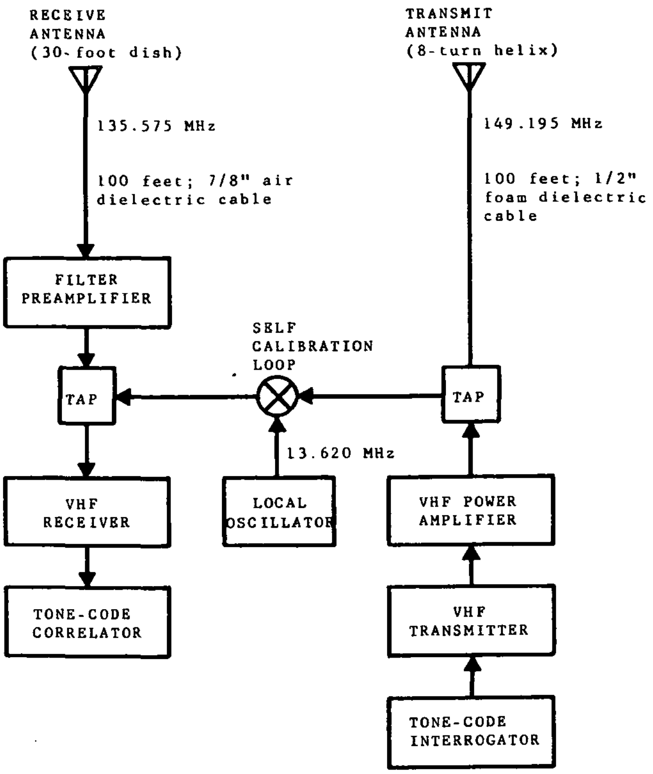

Figure 2. Observatory Configuration for Tone-Code Ranging

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(7, 8)]. 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

Table 3

PAPER TAPE DATA FORMAT*

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

Column	Format	Symbol	Description
1-2	I2	-	Month of year
3-4	I2	-	Day of month
5	I1	-	Last digit of year
6-8	I3	-	Observatory data file identification number

Format 2: (Normal data)

Column	Format	Symbol	Description
1-8	I8	T1	Observatory-satellite-Observatory ranging time, in tenths of microseconds
9	-	Blank	Space
10-11	I2	IU	Remote transponder address code
12-13	I2	IH	Hour of day of interrogation, GMT
14-15	I2	IM	Minute of hour, GMT
16-17	I2	IS	Second of minute, GMT
18	-	Blank	Space
19-26	I8	T2	Observatory-satellite-remote transponder and return ranging time, in tenths of microseconds
27	-	Blank	Space
28-35	I8	δ_O	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	I4	δ_{SC}	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.

```
02538146 02072202 09384742 00003908
05045075
02538150 05072204 09324705 00003909
05045075
02538154 06072206 09375418 00003910
05045075
02538161 07072208 09587995 00003908
05045075
02538168 08072210 09414554 00003910
02538170 09072212 09589882 00003909
02538177 01072214 10096638 00003910
02538180 02072216 09384804 00003909
02538186 05072218 09324776 00003911
02538190 06072220 09375477 00003908
02538194 07072222 09588082 00003911
02538201 08072224 09414571 00003911
02538204 09072226 09589955 00003908
02538207 01072228 10096638 00003909
02538213 02072230 09384870 00003909
02538217 05072232 09324829 00003909
02538224 06072234 09375542 00003908
02538225 07072236 09588151 00003910
02538228 08072238 09414589 00003910
02538236 09072240 09590028 00003910
02538239 01072242 10096638 00003908
02538245 02072244 09384929 00003908
02538250 05072246 09324871 00003908
02538257 06072248 09375612 00003909
02538262 07072250 09588224 00003911
02538264 08072252 09414605 00003909
02538271 09072254 09590093 00003909
02538273 01072256 10096638 00003910
02538274 02072258 09384996 00003908
02538281 05072300 09324943 00003908
02538286 06072302 09375666 00003909
02538291 07072304 09588287 00003908
02538296 08072306 09414611 00003909
02538303 09072308 09590194 00003908
02538305 01072310 10096638 00003908
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 μs, 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 μs is a small fraction of the 409.6 μs 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.

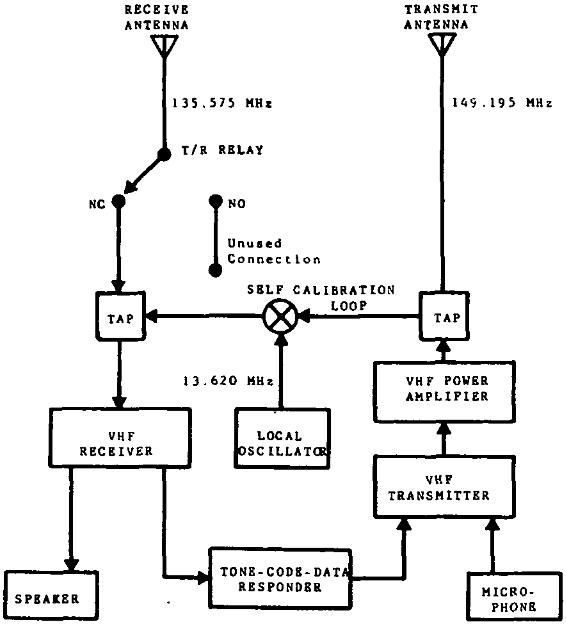

Figure 4. NASA-Goddard Space Flight Center VHF Tone-Code Ranging Transponder Configuration. (Self-calibration circuit provides a measure of the transponder internal time delay on every ranging interrogation).

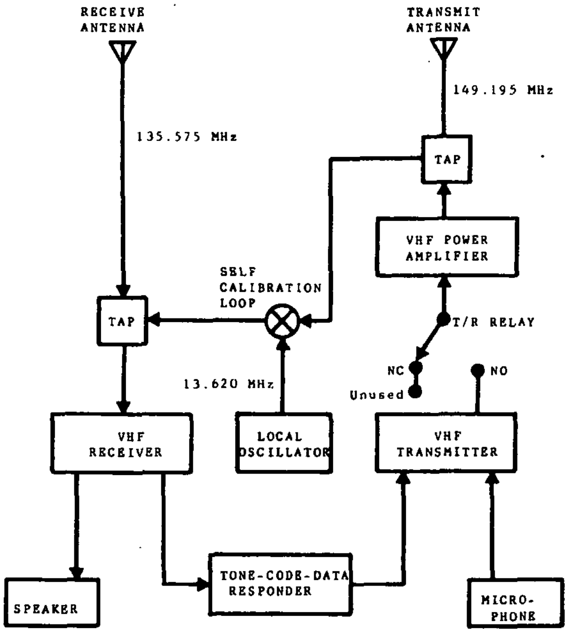

Figure 5. Initial NASA-Goddard Space Flight Center VHF Tone-Code Ranging Transponder Configuration. (The direct receiver-antenna connection allowed receiver desensitization during transmission of ranging responses, preventing self-calibration.)

3.5 ANALYTICAL TECHNIQUES

The Observatory-satellite slant range R_o is computed by the equation

$$R_o = \frac{c}{2} (T - \delta_o - \delta_s) \tag{1}$$

where

c = appropriate conversion factor from units of time to units of distance,

T = ranging time, Observatory - satellite and return,

δ_o = Observatory internal time delay, approximately 388.6 μs; measured on every interrogation by the self-calibration circuit,

δ_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 μs delay). The same length of 7/8-inch dielectric cable with 0.11 μs delay connected the 30-foot dish antenna to the Observatory receiver. The total cable delay of 0.23 μs 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

$$R_i = \frac{c}{2} (T_{2i} - T - \delta_{2i} - \delta_s) \tag{2}$$

where

T_{2i} = ranging time, Observatory-satellite-remote transponder i and return,

δ_{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, (6) 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 vehicle-fixed transponder-Observatory trilateration. This disagreement was interpreted as due to errors in the assumed values for the original trilateration

Table 4

VHF TRILATERATION TRANSPONDER INTERNAL TIME DELAYS

GROUND STATION	ADDRESS CODE	ASSUMED INTERNAL TIME DELAY (μs)	RECALIBRATED INTERNAL TIME DELAY (μs)
Observatory	--	~380.0*	~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

*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

$$R_1 = \frac{c}{2} (T_{21} - T - \delta_{21} - \delta_S - \delta_{SC}) \qquad (3)$$

where

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

δ_{21} = NASA transponder internal time delay, 431714.3 ms,

δ_{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 $\delta_{21} = 431470.0$ μs.

Section 4

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.

Table 5

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

	TIME (GMT)		STATION STATUS						SATELLITE	
FILE	START	STOP	1	2	5	6	7	9	POWER	COMMENTS
873	0000	0010				NO	NO		Full	Start of 24 hour test
874	0025	0035				"			"	Fixed bad fuse in #7
875	0050	0100				"			"	
876	0120	0130				"			"	
877	0150	0200				"			"	
878	0220	0230				"			"	
879	0250	0300				"			"	
880	0330	0340				"			"	
881	0400	0410				"			"	
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	0755	0805				"			"	#7, #9 intermittent
890	0820	0830				"			"	
891	0900	0910		NO		"			"	
892	0930	0940		"		"			"	
893	1000	1010		"		"			"	#9 reported cleaned relay contracts
894	1030	1040		"		"			"	
895	1100	1110		"		"			"	
896	1130	1140		"		"			"	
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	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	
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						Half	
917	2300	2305							"	Observatory computer down, only 5 minutes of data
918	2325	2335							"	
919	2350	2400							"	#1 only few responses

Table 6

SUMMARY OF ATS-3 TRILATERATION 24-HOUR TEST

(May 4-5, 1975)

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

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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Section 6

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