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(U) Utilization of Deactivated Missile Guidance Systems

FEBRUARY 1964

Prepared by J. W. POWERS
Telecommunications and Tracking Department

Prepared for COMMANDER SPACE SYSTEMS DIVISION
UNITED STATES AIR FORCE
Inglewood, California

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(6) [redacted] UTILIZATION OF DEACTIVATED MISSILE GUIDANCE SYSTEMS (U) (8)

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(10) by J. W. Powers ,
~~Telecommunications and Tracking Depart~~ment

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~~El Segundo, California~~

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Inglewood, California

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Report No.
TOR-269(4182)-2

(U) UTILIZATION OF DEACTIVATED MISSILE GUIDANCE SYSTEMS

Prepared by

J W Powers, Jr

J. W. Powers
Tracking and Radar Section

This Technical Operating Report has been reviewed and is approved.

For Space Systems Division Air Force Systems Command	For Engineering Division Aerospace Corporation
	H. R. Anderson
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	M. Goldman, Director Standard Launch Vehicles Office

AEROSPACE CORPORATION
El Segundo, California

CONTENTS

CONTENTS (continued)

TABLES

FIGURES

SECTION 1

INTRODUCTION

With the phasing out of certain ballistic missile squadrons, a number of radio guidance and tracking complexes will be retired to the status of surplus equipment. Since a number of satellite and missile programs are in the planning stage at this time, it was suggested that a brief study be made of the possible uses and applications of these deactivated missile guidance systems.

This report considers applications are considered for two radio command-guidance complexes that are soon to be deactivated: the Atlas D weapons system (GE Mod III), and the Titan I weapons system (BTL guidance system). As the study progressed, it became apparent that some plans had already been made for disposal of the above systems. For example, it was reported by Lt. Bellanca, BTL guidance officer (SSVS), that one deactivated guidance complex was scheduled for installation at Johnston Island for Program 437, and that two more remaining systems, which were to be assembled from available spare parts in the next 18 months, had already been spoken for by the same program office. Thus, when applications for the BTL radars are considered, the time span for obtaining this equipment has been unofficially estimated as three to four years. The Atlas D, GE Mod III equipment, however, appears to be available in the near future (one to two years).* Therefore, most emphasis in this report will be placed on uses for the latter guidance system.

to p. 33

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*In fact, it is reported that a semi-inactive training GE Mod III system exists at the present time at Keesler Air Force Base. It would take approximately nine months to refurbish this system to "R and D" status, and to restore certain missing parts.

SECTION 2

DESCRIPTION OF SURPLUS RADIO TRACKERS

The two radio guidance and tracking systems, described briefly in this section, both operate with track radars and airborne transponders in the X-band region. With regard to obtaining missile velocity data, however, there is a striking difference in the methods employed. The GE MOD III system uses three doppler rate receivers arranged in an L-configuration in conjunction with a separate airborne rate beacon to extract the vehicle velocity, while the BTL tracker differentiates the already obtained radar data, to obtain the time derivative of target position. Details of both tracking techniques, largely taken from References 1 and 2, are presented below.

2.1 GE MOD III Radio Guidance and Tracking

The GE MOD III system contains three major subsystems: track, rate and airborne equipment.

The track radar subsystem, shown in Figure 1, is an X-band precision monopulse radar equipped with a conical scan acquisition mode (nine degree beamwidth).

The radar transmits a coded message which includes steering and discrete commands. The message is received and detected by the airborne pulse beacon and the video message is sent to the airborne decoder which checks the message and, if valid, triggers the pulse beacon to transmit a single pulse reply down to the ground receiver. When this reply is received and certain AGC and error signal criteria are satisfied the radar switches automatically to the monopulse mode of track operation. The output of the track system to the ground computer is RAE data in digital form along with timing and validation signals.

The rate measuring subsystem operates with an airborne rate beacon as shown in Figure 2.

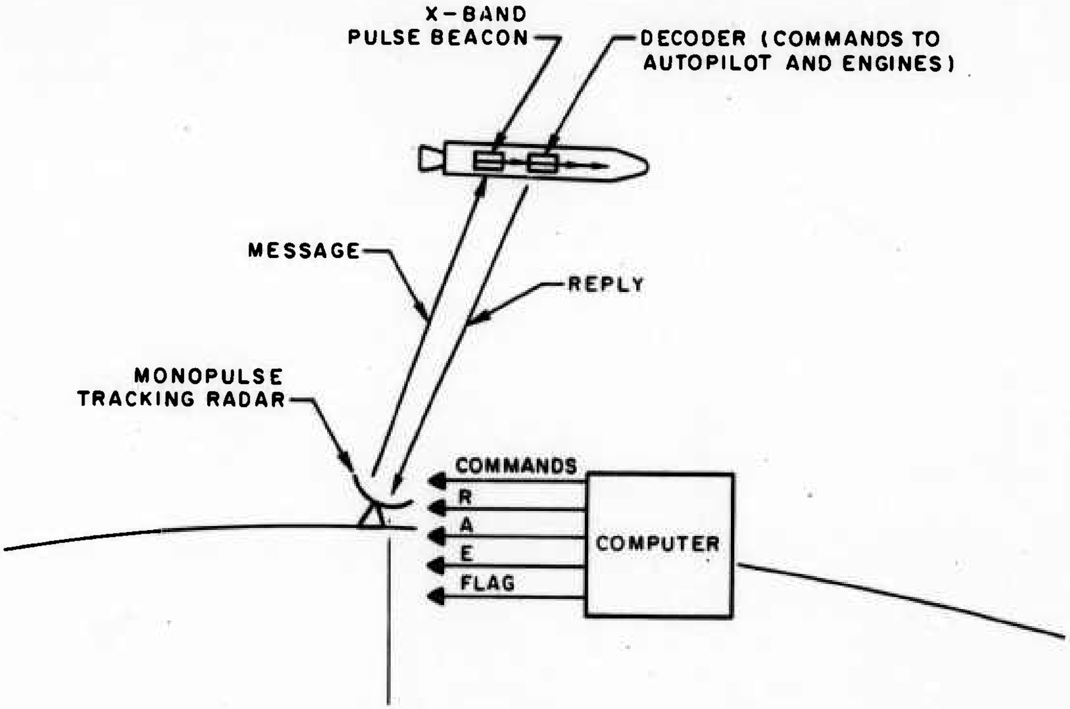

Figure 1. GE Mod III Tracking Operation Subsystem

The central rate station is an X-band CW doppler radar which transmits up to the beacon a double sideband, suppressed carrier signal. The airborne rate transponder receives two phase-coherent signals (both shifted a small amount by the one-way doppler effect). The beacon in turn transmits a return signal to all the ground stations, shown in Figure 2, which is centered in frequency between the up sidebands.

Since a master oscillator serves as a clock for the central antenna and at the two outlying receivers, a two-way coherent doppler shift in the signal is measured at the various ground reference points. The system output to a digital computer consists of r (coherent doppler at the CRS), $\dot{p}$ and $\dot{q}$ – outlying ground station rate differences.

2.2 . BTL Tracker

The BTL guidance and tracking system continuously determines missile position by a precise ground-based automatic tracking X-band radar similar to the system diagramed in Figure 1. Missile position and velocity data so obtained are compared to nominal values, and coded steering commands from the ground computer to the missile are based upon deviations between actual and desired values. However, missile velocity is not determined by separate rate doppler measurements, as in the MOD III system, but calculated in the ground computer by smoothing and differentiating radar position data (RAE). High frequency pulse-to-pulse jitter is filtered out while retaining the more slowly changing characteristics of the desired data. Although this technique inevitably fosters a delay in computed velocity, inertial properties of missile airframe, propulsion and control subsystems are deterministic parameters within reasonable time periods. The term "radio-inertial" is applied to this command guidance system as a result of the combination of radar tracking and inertial updating of velocity.

2.3 Retrospect

Agencies trying to fit either of these "surplus" trackers in their future planning will find it difficult to make a choice between them. Specialized

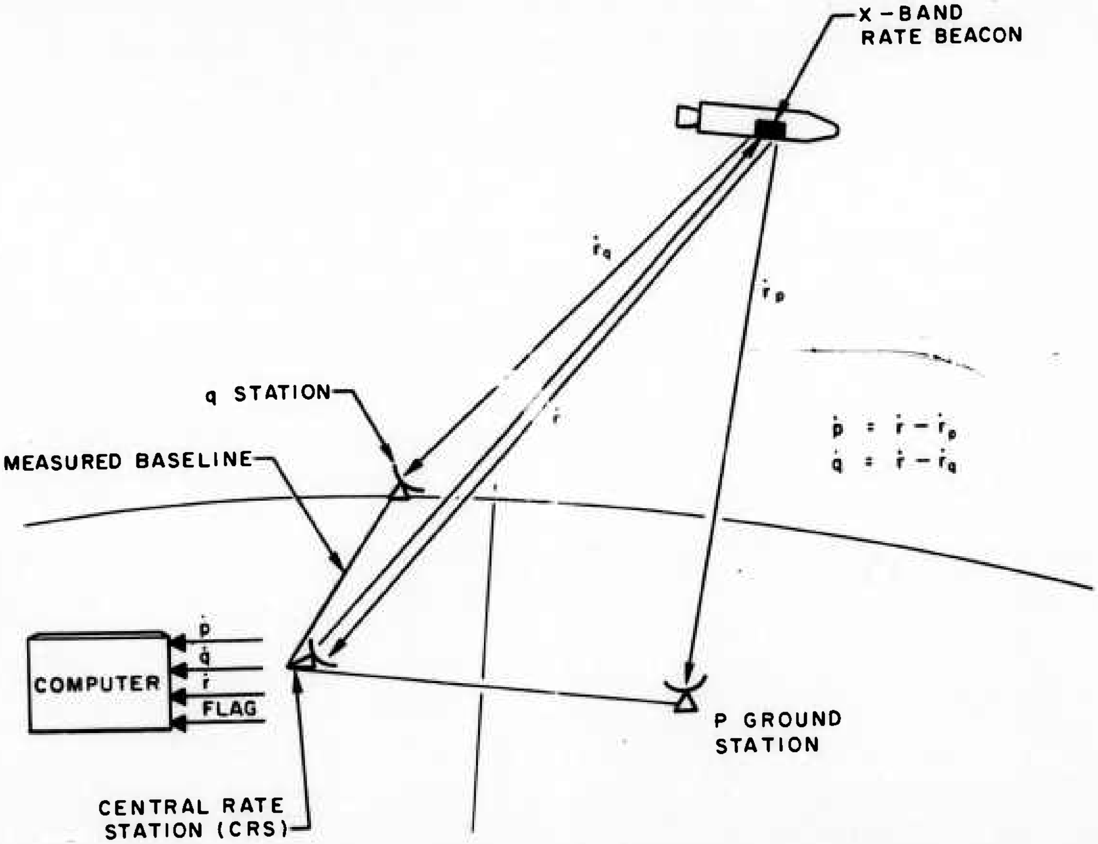

Figure 2. GE Mod III Rate Subsystem

applications may favor one over the other (primary choice of either a Thor or Atlas primary booster) but an important factor may be the time span of availability. The GE MOD III system is favored in this respect (one to two years), whereas use of the BTL system must be planned approximately four years hence.

A brief comparison of the two systems taken from Reference 3, however, is presented for completeness as Tables 1 and 2.

Table 1. Airborne Hardware Comparison

	MOD III F/G	BTL Series "600"
Size	Rate Beacon 12.7" × 8.5 × 3.9" Pulse Beacon 9.8" × 8.8" × 4" Decoder 12.8" × 7.8" × 3.7"	9" dia × 12$\frac{1}{2}$" long
Weight	38 lb (canister) 9 lb (antenna and waveguide)	27 lb (canister) 5 lb (antenna and waveguide)
Input Power	190 watts 25 - 30 vdc	40 watts 29 ± 2 vdc
Antenna Gain		
Track	16 db	15 db
Rate	14 db	
RF Power Output		
Track	1.67 kw peak	3 kw peak
Rate	0.450 watts	
Pulse Width	2 μsec	0.25 μsec
PRF	300	102.4
Frequency Band		
Track	8.6 - 9.6 gc	8.5 - 9.6 gc
Rate	7.5 - 8.5 gc	
Receiver Sensitivity		
Track	-70 dbm	-60 dbm
Rate	-82 dbm	

Table 2. GE and BTL Ground Station Comparison

Parameters	MOD III F/G	BTL
Frequency		
Track	8.6 - 9.6 gc	8.5 - 9.6 gc
Rate	7.5 - 8.5 gc	
Antenna Gain		
Track	43 db	44 db
Rate	39 db	
Power	Track 28 kw Rate 450 milliwatts	250 kw peak
PRF	300 pps	102.4 pps
Pulse Width	0.5μ sec	0.25μ sec
Pulse Code	14	4
Receiver Sensitivity	Track-90 dbm Rate-108 dbm	NF 13 db max BW 8 mc
Angular Accuracy	0.1 milliradians	0.1 milliradians
Azimuth Coverage	324°	360°
Elevation Coverage	-2° to +88°	-10° to 90°
Acquisition Aid	Con-Scan	None
Computer	Burroughs	Remington Rand Univac

SECTION 3

ACCURACIES OF OPERATIONAL SYSTEMS

The quality factor for a radio guidance/tracking system is the ability to inject a payload into a desired orbit. Reliability during operation is also of major importance. The latter property of the Mod III and BTL systems has been compared in References 3 and 4, and both systems seem equal in this respect. A few statistics, however, have recently become available on orbital injection accuracy of the subject guidance systems from experience by SSD in the SCF (Reference 5). Since these numbers quoted are relatively new, and have not been available outside Aerospace, they are reproduced in this section of the report.

3.1 Environment of Orbital Injection Measurements

Before presenting the results of the comparison of the two guidance systems, a few words should be said about the environment in which the "actual" or "true" orbital injection measurements were made. After booster burnout and separation (Thor or Atlas) from the Agena B vehicle, there is a coast phase during the satellite ascent trajectory. During this free-fall interval the radar track of the vehicle is analyzed at the launch point to determine actual performance of the booster; in the case of Thor/Agena future instructions and commands to ignite the engine of the Agena to obtain the necessary velocity increment for correct orbital injection of the FTV are then generated. These radio commands are then executed subsequently for the desired injection point in space. However, since the satellite is then about 1000 miles south, and almost on the horizon from VTS, any auxiliary Verlort tracking data is inadequate to ascertain where injection occurred. Even acquisition at this time by a down-range tracking ship does not solve the measurement problem because of positional uncertainties and shipboard radar equipment inaccuracies.

Thus one is forced to wait for accurate orbital injection parameters until the FTV circles the earth for at least one revolution and a precise best fit ephemeris is calculated from SCF stations. The orbit is then constructed and the coordinates rotated backward in time (noted from Agena on-off timing telemetered commands) until the probable injection point is then reached. Thus the parameter deviations at injection in this report (i. e. planned velocity minus "actual" velocity) are measured only indirectly and may contain errors in fitting of an ephemeris which really should not be charged to the particular guidance system. It is believed, however, that statistical constants in Table 3, computed by Aerospace Corporation from a TRACE routine represent the guidance errors to approximately ten percent of the values listed.

The method of comparison employed here is the computation of the standard deviation of the various orbital parameters at injection over a number of flights. The formula used is

$$\sigma(X) = \left[\frac{(\Delta X - \mu)^2}{N}\right]^{1/2} \qquad (1)$$

where

X = particular parameter (velocity, altitude, etc.)

ΔX = deviation of parameter from planned value (ΔX is positive if the planned value is greater than the "actual" value)

μ = mean value of ΔX

N = number of data samples

3.2 Accuracy Results of Five Atlas Agena B Flights

Data from an Atlas Agena B combination, provided with command guidance by the GE MOD II Radio Tracking System out of PMR, was furnished for this study by the 698BJ Program Office at Aerospace.

The results are listed in Table 3.

Table 3. Orbital Injection Parameter Uncertainties 698BJ Flights

Parameter	Units	Mean	Standard Deviation
Velocity	Ft /sec	+3.1	9.5
Flight Path Angle	Degrees	+0.10	0.10
Altitude	Naut. mi.	-0.50	1.13
Azimuth (Inertial)	Degrees	+0.29	0.14
Longitude	Degrees	+0.28	0.44
Geocentric Lat.	Degrees	+0.42	0.48

Note: Atlas Agena B (GE Mod II Radio Guidance System) Dispersions and means from five flights at injection.

3.3 Statistical Accuracy of Nine Thor Agena B Flights

This data of orbital injection parameters was supplied from the Discoverer satellite series by Mr. Don Krejci of LMSC, Sunnyvale, Calif. The FTV's were as follows: 1107, 1109, 1112, 1113, 1114, 1115, 1117, 1119 and 1123. The results are summarized in Table 4.

Table 4. Orbital Injection Parameter Uncertainties Discoverer Flights

Parameter	Units	Mean	Standard Deviation
Velocity	Ft /sec	-101	178
Flight Path Angle	Degrees	+0.29	0.54
Altitude	Naut. mi.	-0.89	2.87
Longitude	Degrees	-0.04	0.06
Geocentric Lat.	Degrees	-0.15	0.24
Period	Seconds	-70.3	125
Eccentricity	- - -	-0.0105	0.0142
Inclination (orbit plane)	Degrees	0.52	0.62

Note: Thor Agena B (BTL Radio Guidance System) Dispersions and means from nine flights at injection.

3.4 Comments on Statistics

The above results are included here merely as samples of guidance/tracking system accuracy under actual missile launching conditions. One must use these results with caution, since the data sample dispersion may not be representative of spacecraft launched under different environmental conditions or from ranges other than PMR.

3.5 Use of Surplus Equipment in Tracking Mode Only

If an application is considered for radar beacon tracking only, where the rate subsystem of the Mod III is not used, both the BTL and Mod III track radars may be considered approximately equivalent.

Track accuracies for radar beacon tracking alone (Reference 8) are listed in Table 5. It is assumed here that a reasonable signal-to-noise ratio exists for good tracking.

Table 5. Track Accuracy of BTL and MOD III Radars

Measurement	One Sigma Noise Error	One Sigma Bias Error
Angle (Az. and Elev.)	0.05 mr	0.05 mr
Range	50 ft	50 ft

In the next section a number of illustrative examples will be considered for the use of this surplus equipment.

SECTION 4

APPLICATIONS

The applications listed in this section are the result of discussions held with various individuals and program offices within the Aerospace Corporation and SSD, and with the two guidance contractors. Each of the uses of the systems mentioned here has been explored only briefly. Additional detailed cost-trade studies are required to be certain of practical solutions of the many problems entailed. It must also be emphasized that mention of current and future SSD programs in this report is not intended to imply any endorsement by the programs. Individuals kindly furnished the author with information so that some preliminary illustrations could be furnished.

4.1 Down-Range Tracking Station, SCF

Currently, and in the near future, low altitude (100-150 n mi) polar satellites are being launched in a southerly direction from PMR. Program 162, among others, has a number of flights planned such that the completion of the Agena single burn occurs in the vicinity of 22°N latitude and 117°W longitude. This point is approximately 1000 n mi distant from PMR, diagonally off the coast of Baja California, and is not visible to any tracking station in the net. Thus, if the uncertainties in orbital injection position and velocity at the end of the single burn (see Tables 3 and 4) are considered excessive for certain missions, there is presently no way to reduce these uncertainties until the vehicle comes over IOS, TTS, or KTS.* These errors are both periodic and monotonically increasing, and have been plotted for a hypothetical 100 n mi altitude polar vehicle for two orbital revolutions (Figures 3 and 4), assuming no additional tracking. An X-band track/rate beacon aboard the Agena may be warranted in such circumstances.

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*See Section 3.1 for a comment on tracking satellite orbits from ships at sea.

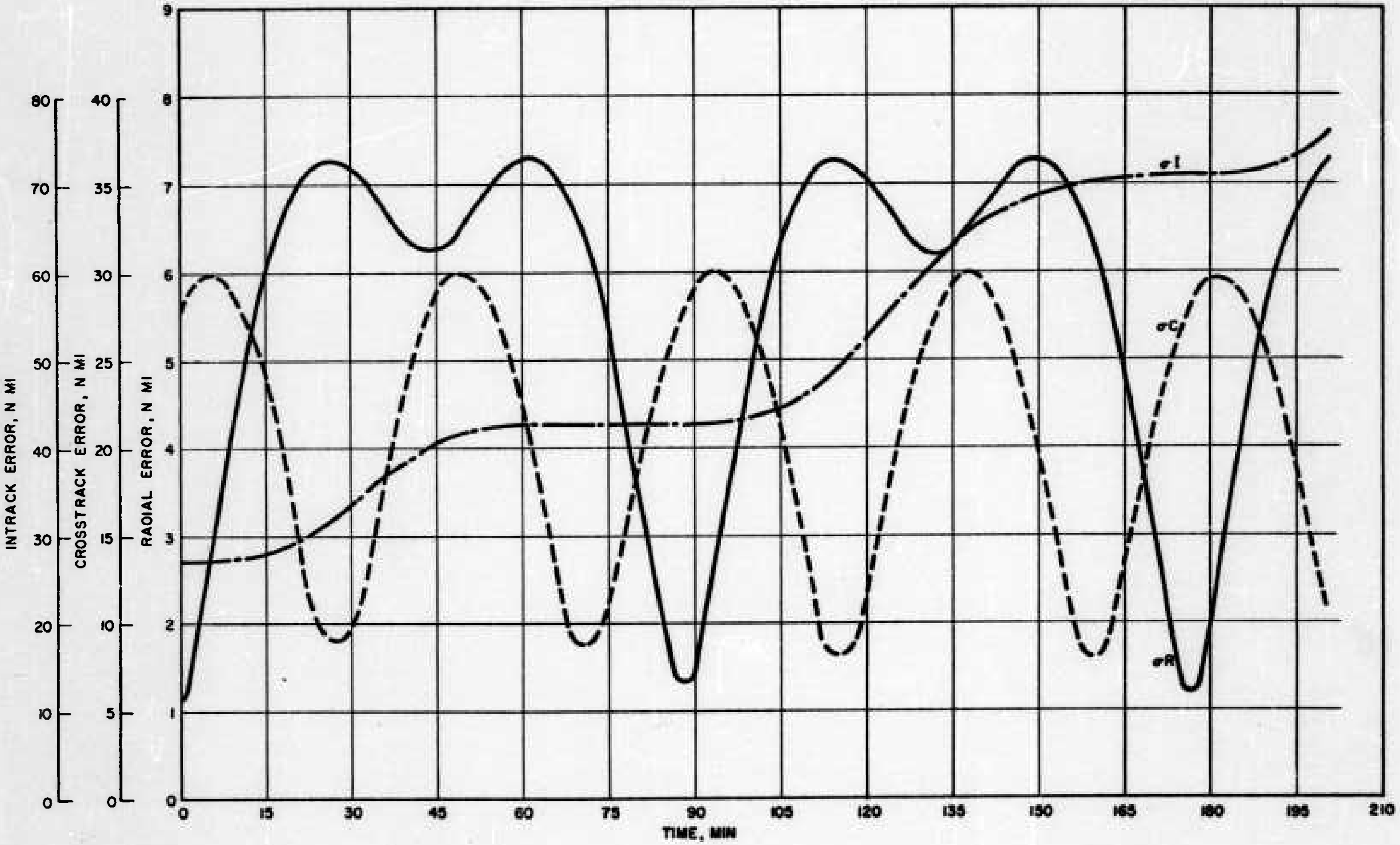

Figure 3. Orbital Errors vs Time for a 100 n mi Altitude Satellite, Injection Configuration - Atlas-Agena B, Program 698BJ

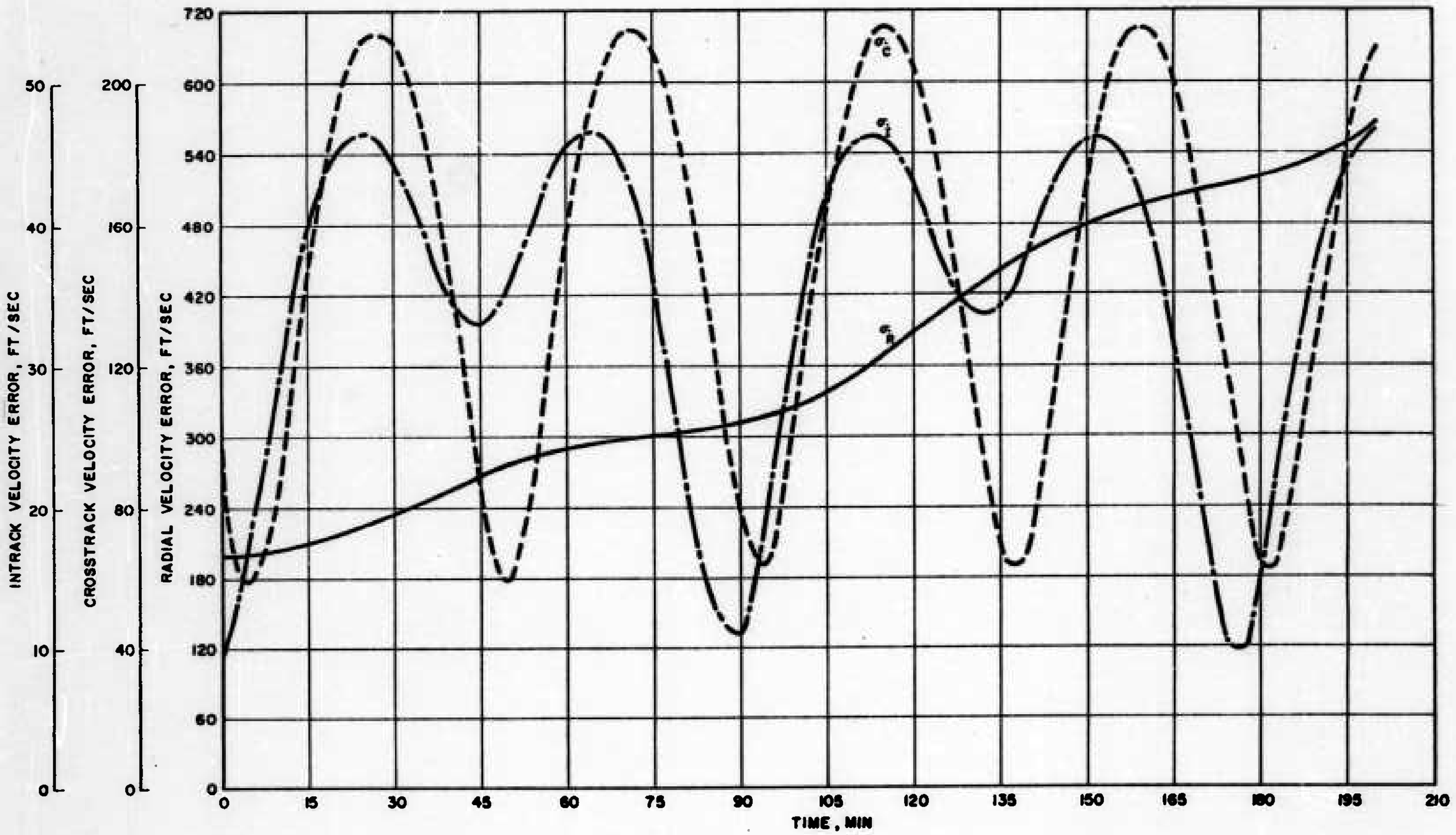

Figure 4. Orbital Velocity Errors vs Time for a 100 n mi Altitude Satellite, Injection Configuration - Atlas-Agena B, Program 698BJ

A recent study, Reference 6, explored the possibility of Clarion Island as a downrange PMR station. Figure 5 shows this island with its local horizon to a 110 n mi polar satellite.

Slant range to the vehicle vs time for a proposed Clarion Island ground station is sketched in Figure 6. Let us examine the effect of installing either of the surplus trackers at this location.

4. 1. 1 Down-Range Tracking Exercise: Target Position Determination Only

Assume the local coordinate system shown in Figure 7.

The tracker, situated at "O", has a data rate of two samples per second; referring to Figure 5, approximately 3 min. of tracking or some 360 data points may be recorded from the end of Agena burn until the vehicle is out of sight. Assuming small radar measurement errors in the intrack, cross-track and radial directions, orbital FTV position errors may be expressed in terms of the standard deviations as follows:

$$\left.\begin{aligned}\sigma^2(x) &= [\cos E \cos A]^2\sigma^2(r) + [r \sin E \cos A]^2\sigma^2(E)\\ &\quad + [r \cos E \sin A]^2\sigma^2(A) \quad .\\ \sigma^2(y) &= [\cos E \sin A]^2\sigma^2(r) + [r \sin E \sin A]^2\sigma^2(E)\\ &\quad + [r \cos E \cos A]^2\sigma^2(A) \quad .\\ \sigma^2(z) &= [\sin E]^2\sigma^2(r) + [r \cos E]^2\sigma^2(E) \quad .\end{aligned}\right\} \qquad (2)$$

[All radar measurement errors of a given type are assumed to have the same standard deviation and all measurement errors are assumed to be independent in Eq. (2).]

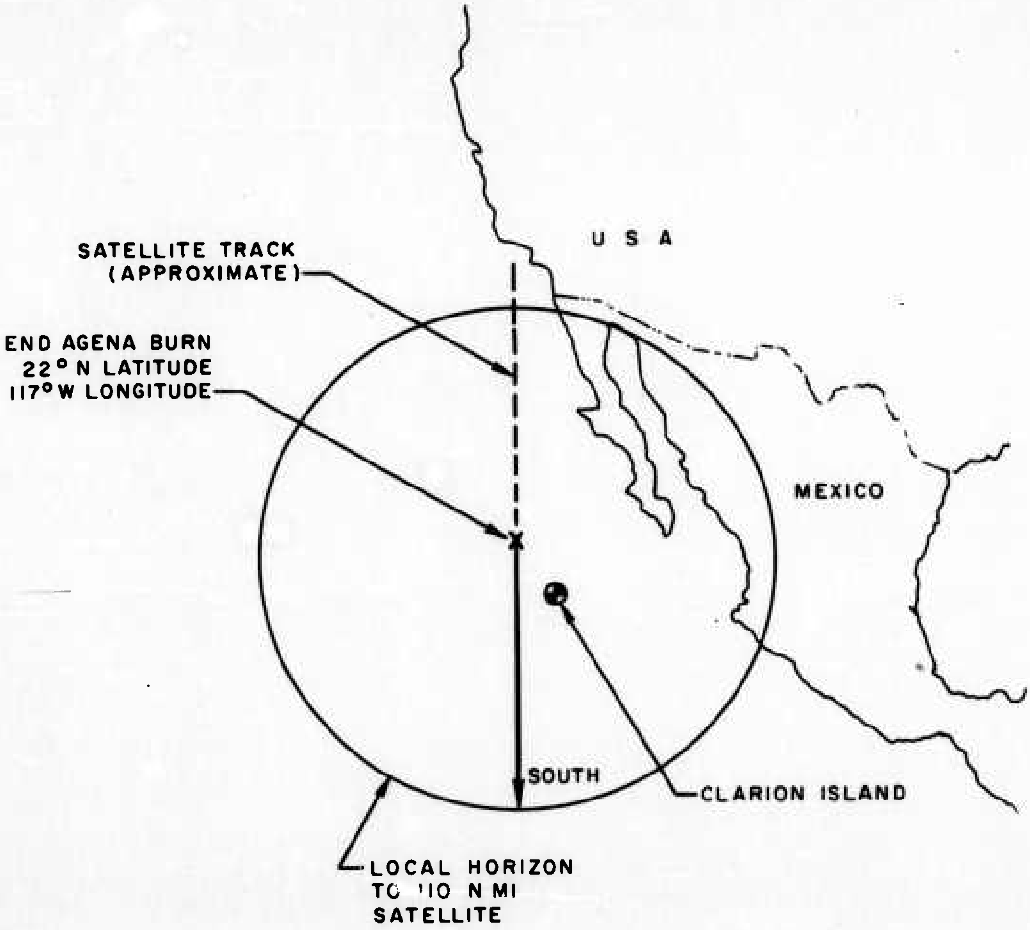

Figure 5. Proposed Downrange Tracking Station

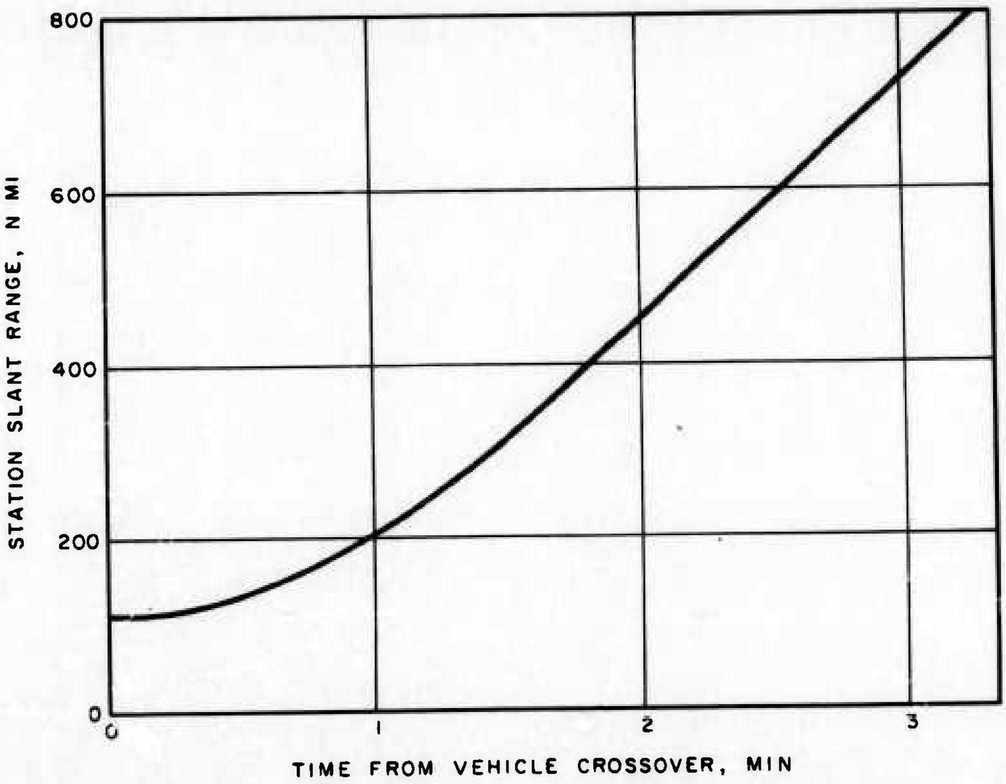

Figure 6. Slant Range to Polar Low Altitude Satellite from Clarion Island

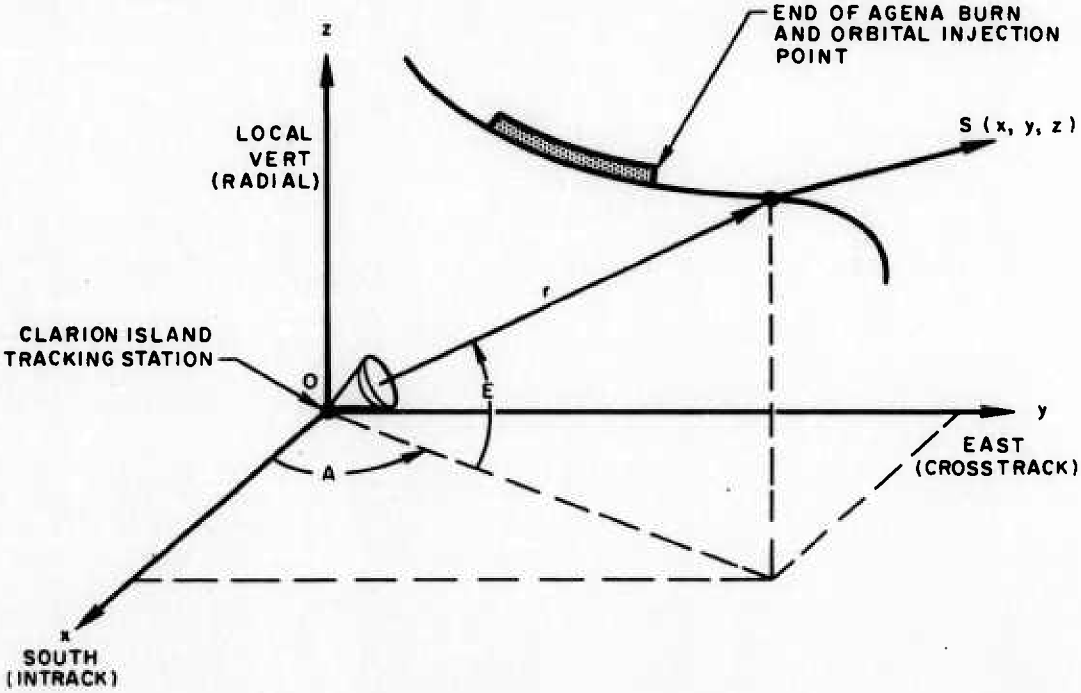

Figure 7. Local Tracking Station Geometry

To generate a typical set of numbers, let $A = 0^\circ$, $E = 45^\circ$ and $r = 400$ n mi; angle noise and bias measurement error (one-sigma) = 0.1 mr; range noise and bias error (one-sigma) = 100 ft. If one inserts these values in Eq. (2), one obtains

$$\sigma(x) = \sigma(y) = \sigma(z) = .28 \text{ n mi} \quad ,^{*}$$

a value two orders-of-magnitude down from the intrack one-sigma uncertainty at time zero from Figure 3 of 27 n mi from present techniques. Thus one uses precision angle and range measurements to make an accurate estimate of the vehicle orbital plane immediately after burnout. The burden of accurate orbit determination from the remainder of the moderately accurate radars of the SCF is thus made less severe.

4.1.2 Down-Range Tracking Exercise: Position and Rate Measurement

In the radar track exercise described above, target position only was measured with a series of redundant measurements. Vehicle velocities ($\dot{x}$, $\dot{y}$, $\dot{z}$) in this case must be considered as parameters which must be estimated from minimizing a weighted sum of squares of errors in functions of the measurements—using an iterative least squares estimation method. Explicitly the trajectory velocity parameters so obtained will correspond to the most probable values, depending on the particular earth model used. If, however, we actually measure the vehicle rates (as well as position) with a high precision system, a more precise BFE[**] will be the result because the rate measurements are not inferred values.

Assume a rate subsystem (as well as the track shown in Figure 7) at Clarion Island. For the idealized geometry of Figure 8, the rate

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[*] It is assumed that reasonable smoothing techniques have been effected on the data and this error is an irreducible residual bias.

[**] Best Fit Ephemeris

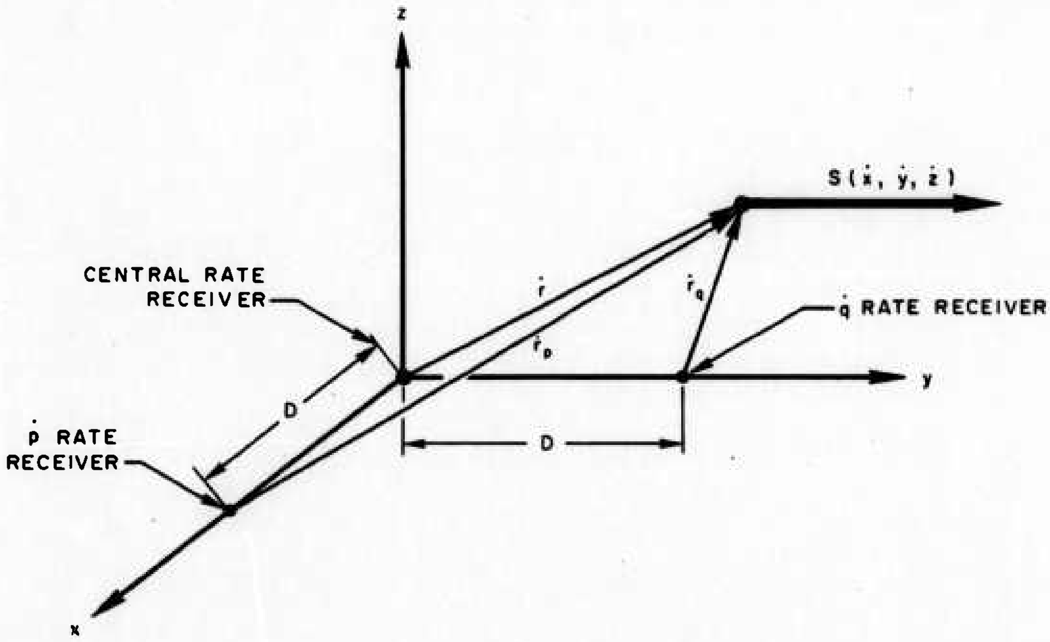

Figure 8. Rate Subsystem at Clarion Island

measurement errors approximately transform into a cartesian coordinate system as follows,

$$\left.\begin{aligned} \sigma(\dot{x}) &\approx \left[\frac{r}{D}\right] \sigma(\dot{p}) \\ \sigma(\dot{y}) &\approx \left[\frac{r}{D}\right] \sigma(\dot{q}) \\ \sigma(\dot{z}) &\approx \left[\cot E \frac{r}{D}\right] \sigma(\dot{p}) \quad . \end{aligned}\right\} \qquad (3)$$

Again to estimate a set of numbers, let

$\sigma(\dot{p}) = \sigma(\dot{q}) = 0.01$
$D = 6000$ ft
$r = 400$ n mi
$E = 45^{\circ}$

and if one inserts these values in Eq. (3), one obtains

$$\sigma(\dot{x}) = \sigma(\dot{y}) = \sigma(\dot{z}) = 4 \text{ ft/sec} \quad :$$

From Figure 4 at time zero, the maximum rate error existing with this data (present SCF Atlas-Agena) is 200 ft/sec in a radial direction.

4.1.3 Acquisition at Clarion Island

In this paragraph we examine briefly the process of locating the FTV coming south from the ground station and initiating automatic angle tracking. Figure 9 gives a locus of antenna elevation rate vs time for this exercise.

The MOD III track system, as an example, will stay in lock at antenna elevation rates up to 9° per sec. Thus, tracking should be satisfactory for elevation angles up to 75°. Azimuth rates in this assumed tracking geometry are much slower as the vehicle will approach the ground station with a ground track that intersects directly with the tracker.

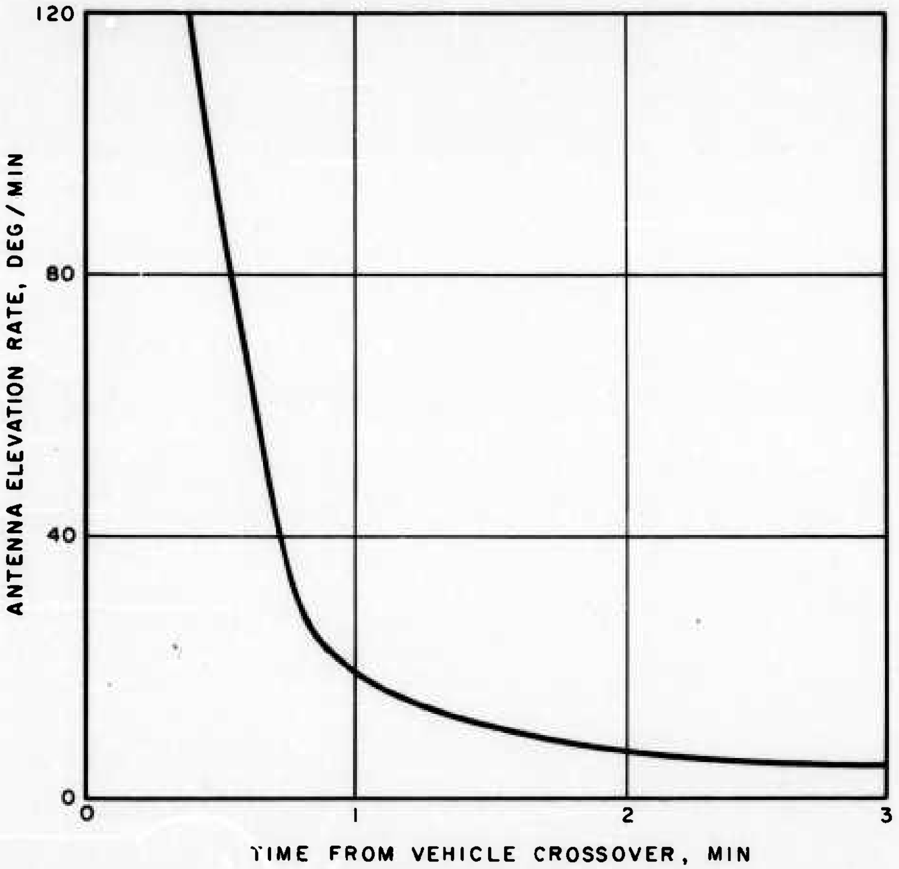

Figure 9. Elevation Tracking Rate

An acquisition technique for this exercise could consist of pointing the MOD III track antenna axis in a northerly direction at the nominal satellite track and waiting for the vehicle to intercept the beam at the horizon, with the track system in a conical scan mode (9° beamwidth). The approximate one-sigma crosstrack error of 28 n mi (Figure 3) each side of nominal is adequately covered by the beam. The situation is diagrammed in Figure 10.

4.1.4 Signal Strength and Link Margin

As a final check of this application, the following power budget is presented for the transponder-to-ground link.

Air-to-Ground Link (Track Mode)

	Gains	Losses
Transmitter power	32.2 dbw	
Transmitter line loss		1.5 db
Airborne antenna loss (slot antenna on Agena)		6 db
Free space loss at X-band		173 db
Ground station antenna gain	43 db	
Antenna line loss		1 db
	75.2	181.5

Net = -106.3 dbw

Ground Receiver Sensitivity = -90 dbm = -120 dbw

Link Margin = -106.3 + 120 dbw = 13.7 db

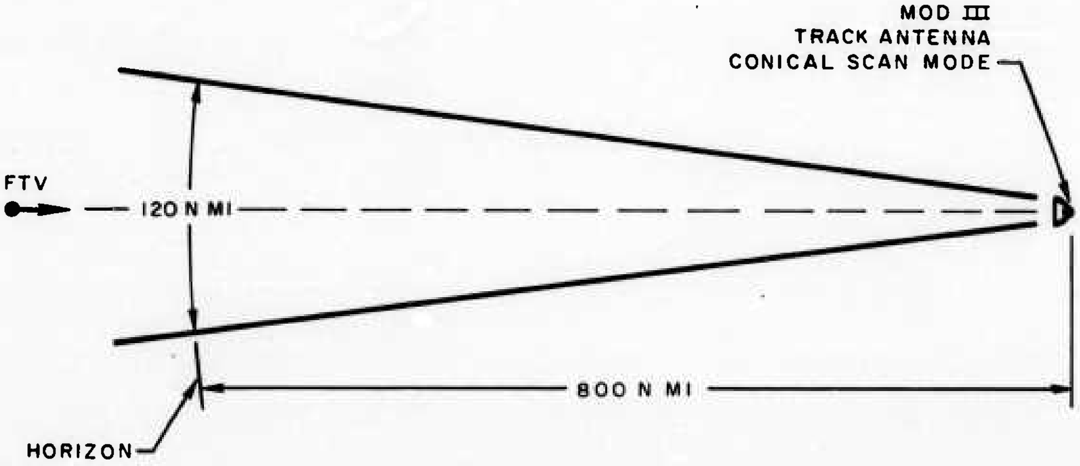

Figure 10. Azimuth Acquisition at Clarion Island

4.2 Manned Orbiting Laboratory (MOL)

4.2.1 On-Orbit Guidance and Tracking

At this time accurate details of the MOL program are not available, since planning is in a very preliminary state. However, the current literature and conversations with the program office at Aerospace have yielded some details, which are presented below to set the stage for a guidance/tracking application of the subject surplus equipment.

Manned Orbiting Laboratory will be launched by a Titan 2 or 3 booster sometime in 1966. The first series of vehicles is planned to be in orbit for approximately two to four weeks. The cylindrical laboratory will be located between the Gemini-X capsule and the launch vehicle. After certain experiments in the laboratory, crew-men will transfer to the original capsule for re-entry.

The particular missions for MOL fall broadly into categories of surveillance, reconnaissance and rendezvous or inspection of unknown space vehicle. These types of missions may require on-orbit guidance/tracking capability, especially when an extreme change in the vehicle orbiting plane (three to five degrees) is contemplated. The use of an X-Band Mod III ground rate and track complex as a subsystem with an on-board MOL navigator (IGS update or ephemeris prediction) would be an advantage in such maneuvers. Existing ground radars (FPS-16) usually require up to two complete orbits to specify position and velocity with sufficient accuracy. The measurement uncertainties could be reduced with one vehicle pass over a Mod III complex. A brief discussion of a midcourse guidance exercise follows, in which a vehicle is subjected to an orbital change-of-plane maneuver.

4.2.2 Orbital Midcourse Maneuver

Many types of space maneuvers or orbit transfers are possible, but only one will be considered here – a change of orbit plane for a vehicle such as MOL.

It is clearly understood that non-gravitational, or thrust accelerations must be applied to the spacecraft for short times to change the vehicle's momentum in inertial space. These accelerations or resulting step velocity increases are in a direction normal to the orbital plane for a change in orbit inclination.

Two curves taken from Reference 7 are presented as Figures 11 and 12, and show the magnitude of velocity increments required for various orbital plane changes for circular orbits. These increments should be considered only representative values, and each case must be determined by detailed study.

As an example, assume that an orbital plane change of 5 deg is desired by a vehicle in sight of a Mod III radio guidance/tracking complex. If the spacecraft (carrying an active X-Band track and rate beacon) is not too far from the orbital line of nodes, the velocity increment, ΔV, from Fig. 12 is approximately (.05) x (24900) or 1245 ft/sec for a 300 n mi circular orbit. The maneuver will take approximately 20 to 30 seconds to execute. The airborne beacons in the spacecraft may be locked on to the signals emanated from the ground complex for true radio closed-loop guidance. The geometry is illustrated in Fig. 13.

Two results may be accomplished by the guidance subsystem: (a) closed loop guidance during the maneuver or powered flight time, and (b) orbit determination after powered flight by precise tracking.

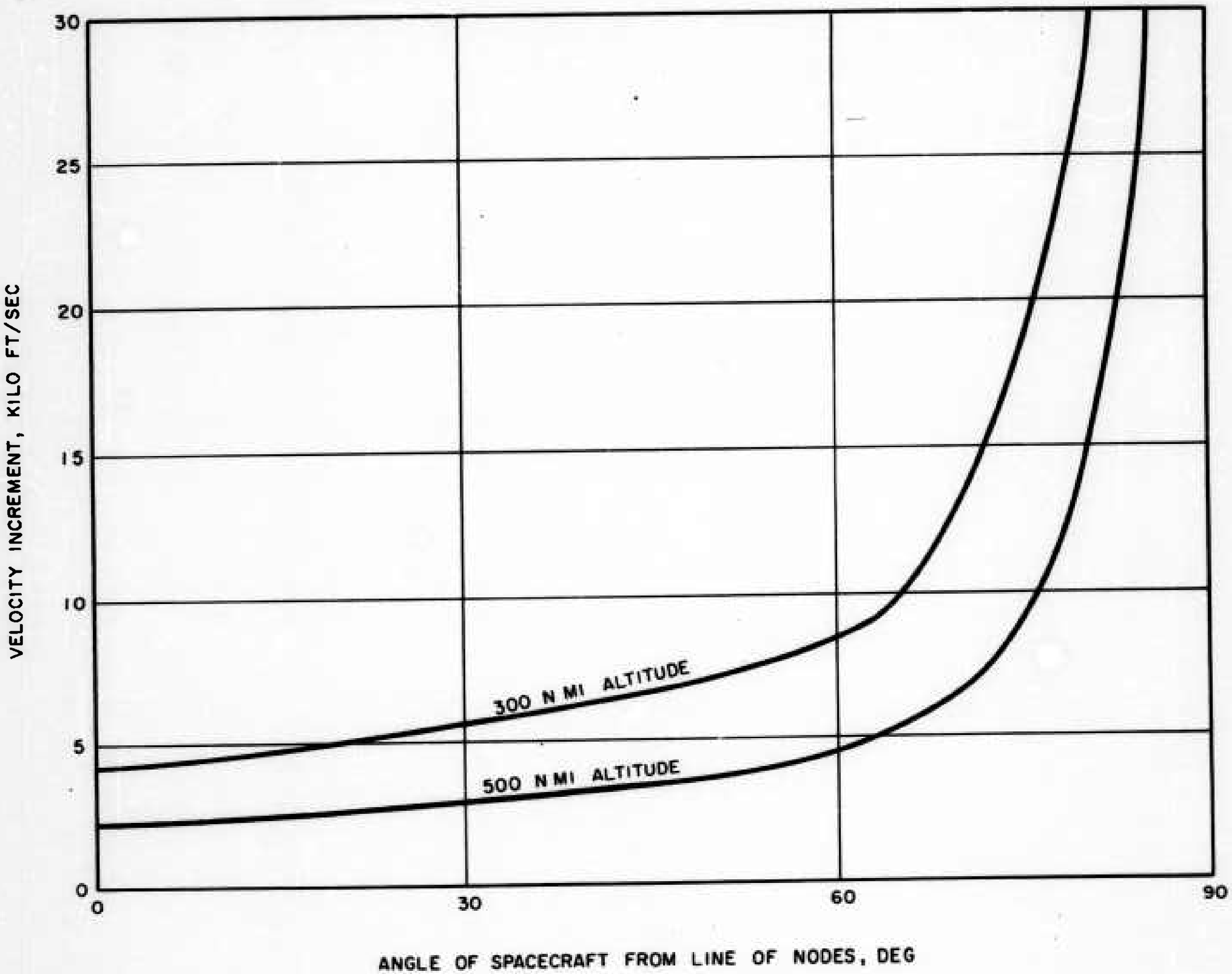

Figure 11. Velocity Increment Required to Change Orbital Plane by 10 Degrees (Source: Reference 7)

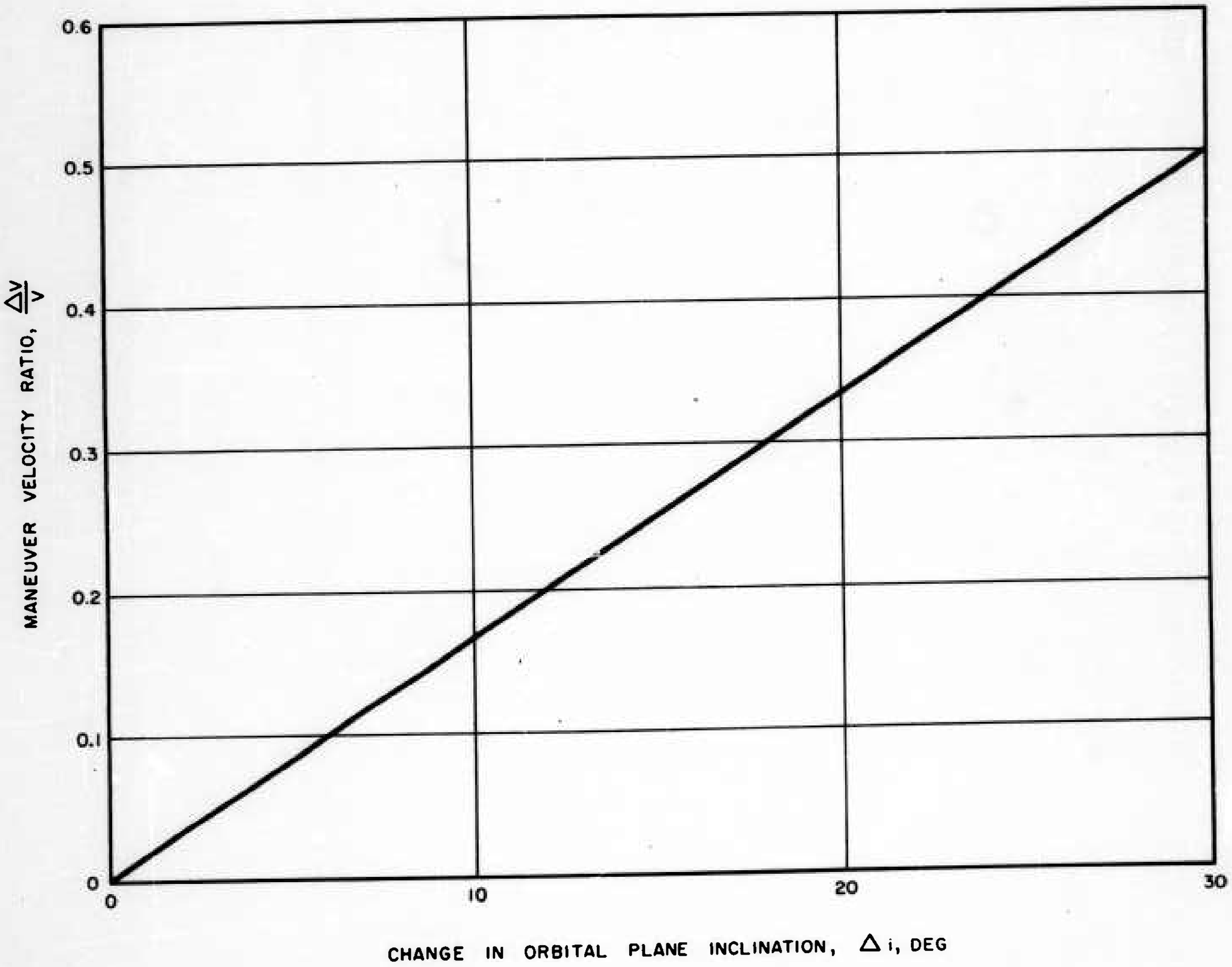

Figure 12. Velocity Ratio Required to Make a Change in Orbit Inclination at the Orbital Node (Source: Reference 7)

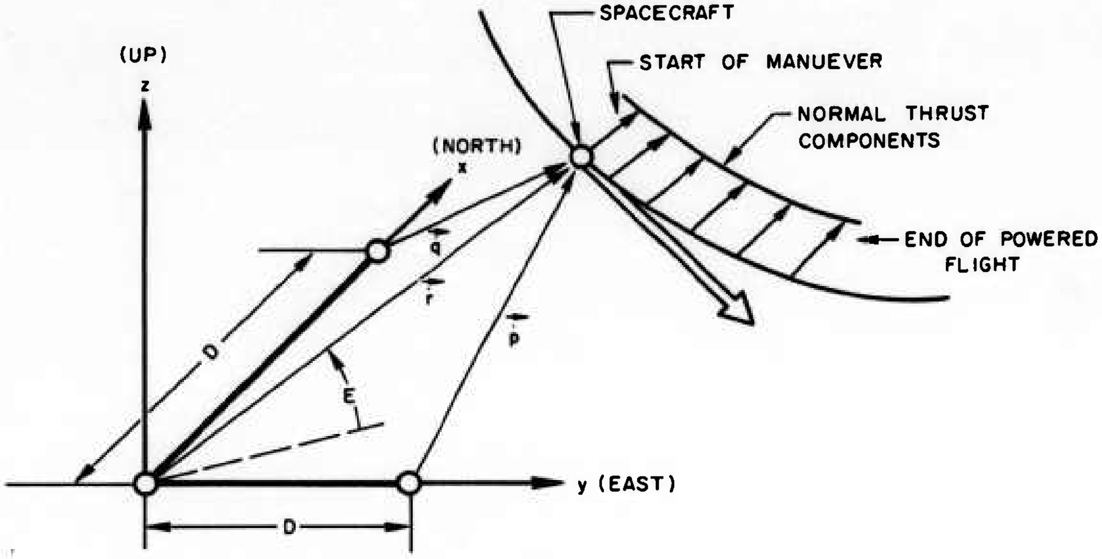

Figure 13. Geometry for Change of Orbital Plane Maneuver

For this case, position and velocity errors at the end of powered flight due to closed-loop midcourse guidance may be approximated from the following table, taken from the study of Reference 8.

Table 6. Radio Guidance Errors

One-Sigma Errors	Altitude, n mi		
	300	700	1000
Altitude (n mi)	0.26	0.36	0.41
Velocity (ft/sec)	2.5	2.6	2.6
Flight path angle (milliradians)	0.094	0.026	0.012

One-sigma orbital velocity errors, after tracking by the Mod III complex, may be estimated from Equation 3, page 21. For a given set of numbers, $\sigma(\dot{p}) = \sigma(\dot{q}) = 0.0014$ ft/sec noise and bias; $D = 6000$ ft, $r = 800$ n mi, $E = 45$ deg. Therefore $\sigma(\dot{x}) \approx \sigma(\dot{y}) \approx \sigma(\dot{z}) \approx 0.8$ ft/sec.

These results may be sufficiently accurate for this type of maneuver. Part of the error (noise) may be further reduced by a longer tracking period after the midcourse maneuver.

4.3 Athena

The Air Force's advanced ballistic re-entry system (ABRES) program is designed to provide trajectory dynamics data from missile re-entry bodies and penetration aids. Missiles will be launched from Green River, Utah, to the impact point at White Sands (470 mi.). Approximate payloads range in weight from 50 to 300 lb. and maximum trajectory altitude is 500,000 ft.

A tracking study (Reference 9) was made by the Telecommunication and Tracking Dept. which discussed optimum sites for the location of FPS-16 C-band ground radars. Early booster stages will be skin-tracked while the ejected payload has an S-band transponder.

The Ballistic Missile Re-entry Systems program office at Aerospace, San Bernardino was contacted regarding the possibility of using a surplus X-band MOD III radio guidance system in the Athena program. Reasons for its use advanced were, (a) possibility of providing radio guidance for future growth of the program at Green River, and (b) using X-band frequency instead of C or S-band for more accurate position velocity tracking thru the booster exhaust plume, and (c) providing redundant data with the present tracking systems. The weight penalty of carrying a set of X-band track and rate beacons on the final stage vehicle is of course a disadvantage.

4.4 Guidance Evaluation Missile (GEM)

A report of the use of a high performance rocket vehicle to evaluate the next generation of ICBM guidance systems at White Sands was recently completed by Space Technology Laboratories (Reference 10). The proposed test program subjects "guidance sensors to certain conditions of acceleration and velocity which will affect guidance error propagation to the degree required to identify and evaluate the multiple and varied error sources inherent to the equipment."*

The report also concludes that "tracking accuracies of 0.05 ft/sec along each of three mutually orthogonal axes are required, but 0.02 ft/sec is desirable." Lastly, survey of WSMR tracking facilities indicates that they are apparently not adequate to perform these measurements.

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*Reference 11, page 4.

Although an interferometer tracking system such as MISTRAM is recommended by STL, it is possible that one of the surplus MOD III systems could be refurbished and revised to meet the above mentioned stringent accuracy conditions. Base legs, for example, may have to be extended to 50,000 ft.

4.5 Miscellaneous

Because of the limited time span of this study, other uses for the surplus guidance equipment can be only lightly touched. Discussions with I. Bekey, 893 Program Office, indicated that a need may exist in the future for radio guidance of boosters at some launching locations other than AMR and PMR. Reference 11 was received from Wm. McKay of General Electric, Syracuse, suggesting certain MOD III applications other than those already mentioned such as tracking the B70 platform, downrange AMR tracking, and use of MOD III in connection with the standard space guidance system program at Aerospace.

It may be noted that deep space applications for the surplus trackers have been mentioned only briefly in this report. Discussions with active space program managers (369, etc) gave the impression that present designs are too specialized to match the X-band tracking equipment of this report. Payload limits are too critical to accommodate the weight of either a rate or track beacon. Since the base legs of the interferometer system also lose their geometric advantage in deep space, the idea was dropped.

It is hoped that programs and agencies to which this report is circulated may have other uses of the surplus BTL/MOD III equipment.

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS

(a) The GE MOD III radio guidance equipment may be deactivated in a one to two year future time span.

(b) The BTL radio guidance equipment may be deactivated in a three to four year future time span.

(c) The chief applications mentioned in this report for the above mentioned surplus equipment are as follows:

1. SCF Down-Range Tracking;
2. MOL Orbital On-Course Guidance and Tracking;
3. Growth radio guidance and supplementary tracking for the Athena Program; and
4. Guidance Evaluation Missile tracking at White Sands.

It is recommended that this report be circulated to the above mentioned agencies to see if interest in the surplus guidance equipment is generated.

SECTION 6

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10. ————, "Final Engineering Report, Design of the Guidance Evaluation Missile", Space Technology Laboratories Document No. MDC-TDR-62-7, Vol I.

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APPENDIX

COST AND DELIVERY DATA FOR USERS OF SURPLUS GUIDANCE EQUIPMENT

The following numbers are presented as preliminary estimates after discussions with Capt. Brown of SSD:

(a)	Cost to refurbish one complex to R and D status	$ 500,000
(b)	Cost to move and install guidance complex equipment only (domestic)	$2,000,000
(c)	Same as (b) but in foreign location	$3,000,000
(d)	No. of MOD III units available in one to two years	9
(e)	No. of BTL units available in three to four years	–

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