A TARGET ACQUISITION SYSTEM FOR TELEMETRY TRACKING SYSTEMS

Henry B. Stephenson, Jr.
Branch Chief
Computing and Software Branch
Instrumentation Directorate
White Sands Missile Range
New Mexico

ABSTRACT

White Sands Missile Range (WSMR) personnel have developed an intelligent, low cost, dual-microprocessor based, Tracking System Interface to be implemented on each telemetry tracking system at WSMR. This interface provides each telemetry tracking system with the capability of acquiring targets based on pointing data from various tracking radars on the Range. The presentation will begin with a historical overview of the WSMR target acquisition system followed by a discussion of the telemetry target acquisition system in particular. The newly developed intelligent interface will be discussed including present attributes. The presentation will conclude with a discussion of future enhancements.

INTRODUCTION

White Sands Missile Range is a large inland missile test range located in south central New Mexico. An outline map is shown in Figure 1, White Sands Missile Range. Remote launch facilities are also provided at Green River, Utah and other areas as shown in Figure 2, Remote Launch Area. To collect missile performance data, WSMR provides various types of mobile and fixed tracking instrumentation along the various missile flight corridors.

To use on-board tracking systems of each instrument, some means must be provided to either dynamically point the instrument at the object-to-be-tracked such the object appears in the tracker field-of-view for acquisition; or to pre-position the tracking instrument at a space point and wait until the object-to-be-tracked passes through the tracker field-of-view and then attempt to establish track before the object leaves that field-of-view.

Until the early 1970's only WSMR radar tracking systems had the capability to slave one radar system to another for target acquisition purposes. Telemetry and optical tracking systems were required to pre-position to a point-in-space for optical systems or sector for telemetry systems with the expectancy that the object would pass through the field-of-view. The pre-positioning was not based on precomputed values in most cases but instead, was based on operator knowledge of past flight paths of the same object.

By the mid 1970's, the first target acquisition system to be implemented on a large scale was completed at WSMR for telemetry and optical tracking systems. A block diagram of the system is shown in Figure 3, Target Acquisition System A. It was based on a new instrument interfaced called the Instrument Data Converter (IDC). This interface was implemented on each instrument and was built using small and medium scale integration technology.

FIRST TARGET ACQUISITION SYSTEM

The IDC was implemented on all radar, telemetry and optical tracking instruments. With this mass implementation a target acquisition system implementation was realized that would allow any radar that was tracking an airborne vehicle to provide point-in-space information at a rate of 20 samples-per-second to a central computer where this data was converted to pointing data for other radars, telemetry tracking instruments and optical tracking instruments. The resulting computed data was transmitted via modems, telephone lines and microwave to the associated tracking instrumentation. The computed output data rate to each instrument was at a 20 sample-per-second rate.

In the figure the radar is shown as the primary tracking system data source and tracks the airborne vehicle using the on-board RF tracking system. Data from the radar range servo system and the azimuth and elevation shaft angle encoders are formed into synchronous serial 120 bit messages and converted to telephone circuit format by a Frequency-Shift-Keyed modem. The computer receives the serial messages, from each of the radars-in-support and synchronizes and strips the data from each message. All data is then converted to point-in-space XYZ data referenced to earth center (geocentric transformation). From this data the computer does a best signal selection to determine which radar data source will be the primary source for target tracking data. The computer performs data smoothing and prediction (of 375 milliseconds). The prediction compensates for the delays in data transmission and data computation paths from the radar to the slave tracking instrument.

After prediction is applied, a coordinate transformation (consisting of translation and rotation) is applied, followed by conversion to RAE data for each slave tracking instrument. This data for each slave instrument is formed into synchronous serial 120 bit messages for transmission to the tracking instrument IDC. A block diagram of the IDC is shown in Figure 4, Instrument Data Converter. At the instrument the IDC synchronizes and strips the data from the mount azimuth and elevation position data. Operator inserted encoder offsets are added to the encoder data to correct for mechanical misalignment of the shaft angle encoder zeros from True North. The corrected shaft angle data is subtracted from the pointing data that was received and stripped by the IDC. The resulting differences are then applied to digital-to-analog converters where an error signal for each axis is derived to drive the respective servo systems of the tracking instrument. Analog filter compensation is used external to the IDC to improve the servo system performance while maintaining tracking system stability. A physical picture of the IDC is shown in Figure 5, IDC Equipment.

THE TRACKING SYSTEM INTERFACE

In 1980 the Tracking System Interface (TSI) became a reality and implementation on telemetry and optical tracking systems began; and is still in process. The unit is shown in Figure 6, TSI Unit. The TSI is a single chassis and replaces three chassis in the IDC. Chassis remaining of the original IDC are the Timing Unit and the FSK modem.

The basic TSI is composed of three S-100 cards contained in a fan ventilated, rack mounted chassis. A block diagram of the unit is shown in Figure 7, TSI Block Diagram. One card contains the master and slave microcomputers including the special arithmetic processor chip controlled by the slave microcomputer. Another card provides the interface between the front panel controls, thumbwheels, and display, and the master microcomputer on the first card. A third card contains the interface between the master microcomputer and the instrument, and modem. The microcomputers are based on the Zilog Z-80. The arithmetic processor is the AM 9511A manufactured by Advance Microdevices, Inc. The basic TS1 costs WSMR approximately $5,000.00 per unit. Design and software for the TSI was and is being performed at WSMR by the Instrumentation Directorate. The manufacturing of the units is contracted to commercial concerns.

SECOND TARGET ACQUISITION SYSTEM

A block diagram showing where the TSI resides in the target acquisition system is given in Figure 8, Target Acquisition System B. Because the TSI was implemented using state-of-the-art microcomputers, many more functions can now be performed at each tracking instrument. First of all, the TSI performs the functions of the IDC. The block diagram showing the present TSI functions is given in Figure 9, Present TSI Process. These are: the synchronization to the incoming messages and the stripping of the data to form the pointing commands; the periodic reading of the azimuth and elevation shaft angle data to correct for mechanical misalignment of the encoder zeros relative to True North; the subtracting of corrected encoder data from the pointing commands to form the tracking errors which are applied to digital-to-analog converters and output to the servo systems as drive signals.

The following functions have been implemented on the telemetry instruments:

a) coordinate conversion
b) static pointing
c) slewing

By accomplishing coordinate conversion at the instrument site, the distribution of pointing data to the site is simplified. Rather than having to provide a unique data circuit to each tracking instrument, XYZ pointing data for one target can be provided to multiple slave tracking systems using a daisy chain distribution approach. This reduces the number of data channels required to acquire or slave track any one target.

The ability to static point the slave tracking instrument with the TSI provides the site operator with the capability to compensate for encoders misalignment and then to check the operator thumbwheel inserted encoder offsets to insure that proper correction has been made to encoder data such that the instrument points to the known landmark. Slewing provisions of the TSI provides a dynamic check of all on-site slave tracking equipment. Another use of the slew is in the determination of the antenna pattern. The telemetry tracking instrument is slewed by the TSI, from +180 degrees to -180 degrees while recording the signal strength of the TM receiving system; as the system looks at a boresight RF source.

From an operational standpoint, the ability to perform static pointing and slewing from the site reduces the amount of coordination between the slave tracking station operator and personnel at the central computer during pre-mission setup. Consequently, the tracking system can be setup faster. The hope is that operator on-site time prior to mission can be reduced.

Additionally, several other functions can be performed at the TSI that were previously performed at the central computer. These are:

a) data smoothing
b) prediction
c) digital servo compensation
d) diagnostics

On many of the optical instruments these functions have already been implemented.

The data smoothing feature provides for less pertibations in the pointing data being provided to the slave tracking system. Prediction capability provides for on-site incremental compensation of data transmission and data processing delays in the acquisition system; thus further reducing the pointing errors due to data delays. Digital compensation provides for replacing the analog servo compensation with digital compensation within the TSI. Figure 10, Typical Servo System indicates where the compensation is located in the servo loop. This replacement offers several advantages. Full adaptive control of each servo system is available. Each servo loop is converted from a Type 1 to a Type 2 servo loop. The equations governing the steady state tracking error (θess) changes from:

Type 1 - to - Type 2

$$\theta ess = \frac{\dot{\theta}}{K_v} + \frac{\ddot{\theta}}{K_a} \; . \; . \; . \; \text{to} \quad \theta ess = \frac{\ddot{\theta}}{K_a} + \; . \; . \; . \qquad (1)$$

Where: K_v is the velocity constant

K_a is the acceleration constant

$\dot{\theta}$ is the steady-state angular velocity constant

$\ddot{\theta}$ is the steady-state angular acceleration constant

It should be noted that tracking error due to the angular velocity component is removed in this transition of compensation approach.

The ability to do more complete diagnostics will be of significant advantage. By including a video plotting capability into the TSI, the tracking system operator will be able to test the tracking system for proper function by plotting such functions as transient response and steady-state tracking error response for each servo loop. This video plotting capability has been included in some optical tracking instruments already and will be included on the telemetry tracking systems in late FY84.

SUMMARY

The incorporation of intelligent tracking system interface as part of the WSMR target acquisition system, provides significant advantages in the areas of servo performance, steady state tracking errors, data distribution, instrument setup and diagnostics. A summary of the present capability of the TSI, an intelligent interface, is given in Figure 11, Capability of the TSI. A more detailed capability summary is given in Table 1, Capability

Summary of the TSI. The TSI performs the basic pointing error computation. Coordination conversion is performed reducing target data distribution complexity. Servo compensation is performed digitally; creating a Type 2 servo system from and Type 1 and providing for adaptive control based on the magnitude and behavior of the pointing error. All of this contributes to better servo performance. Prediction and smoothing capability improves slave system composite pointing error. Last, but not least is the pre-mission evaluation. The ability to have local control over slave track static pointing and dynamic slew contributes immeasurably to setup, evaluation and correction of deficiencies before actual mission support. The video plot capability will further enhance the ability to perform pre-mission evaluation.

The Tracking System Interface provides a state-of-the-art approach to improving the performance of the WSMR target acquisition system. This interface is inexpensive for the capability provided and represents a low complexity approach to tracking system interface operations. This translates into simplified ability-to-maintain and higher reliability; and since everything is controlled by software, the interface is highly adaptable to new and changing requirements.

WSMR has expended considerable effort in the development of this intelligent interface; and would like to share the result with other DoD ranges to get the most out of the investment. The contributory value to WSMR is significant and can offer other ranges similar benefits.

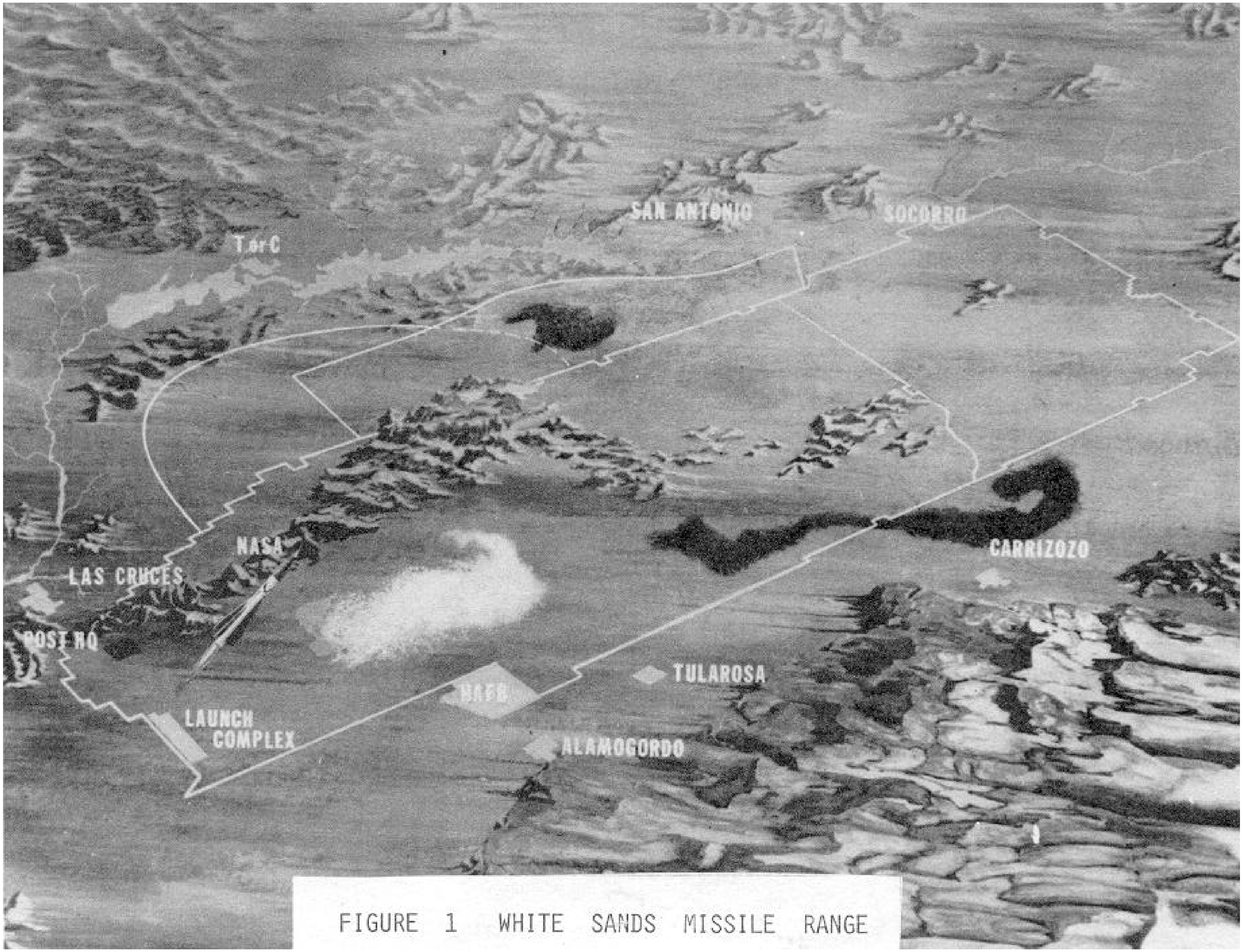

FIGURE 1 WHITE SANDS MISSILE RANGE

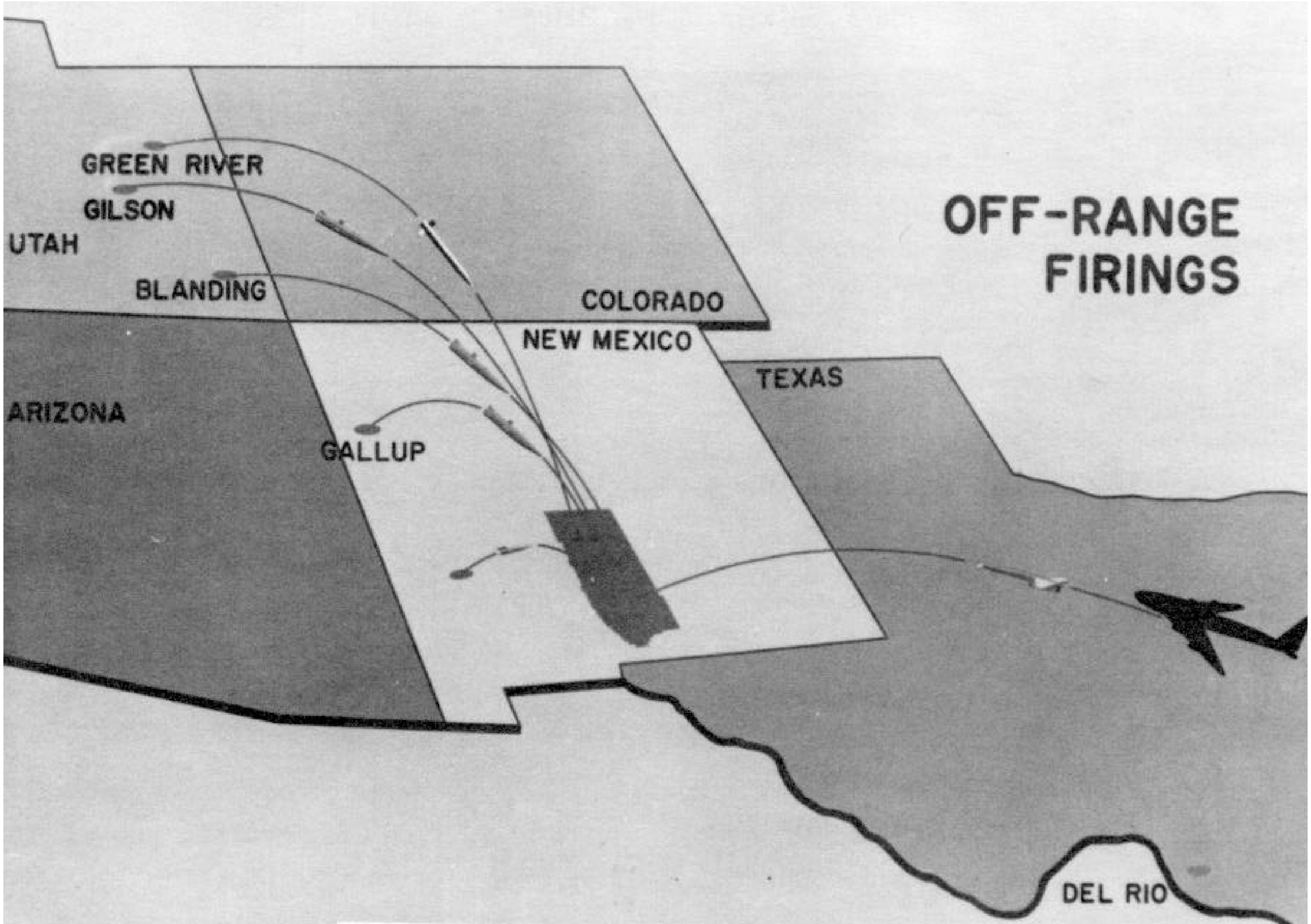

FIGURE 2 REMOTE LAUNCH AREAS

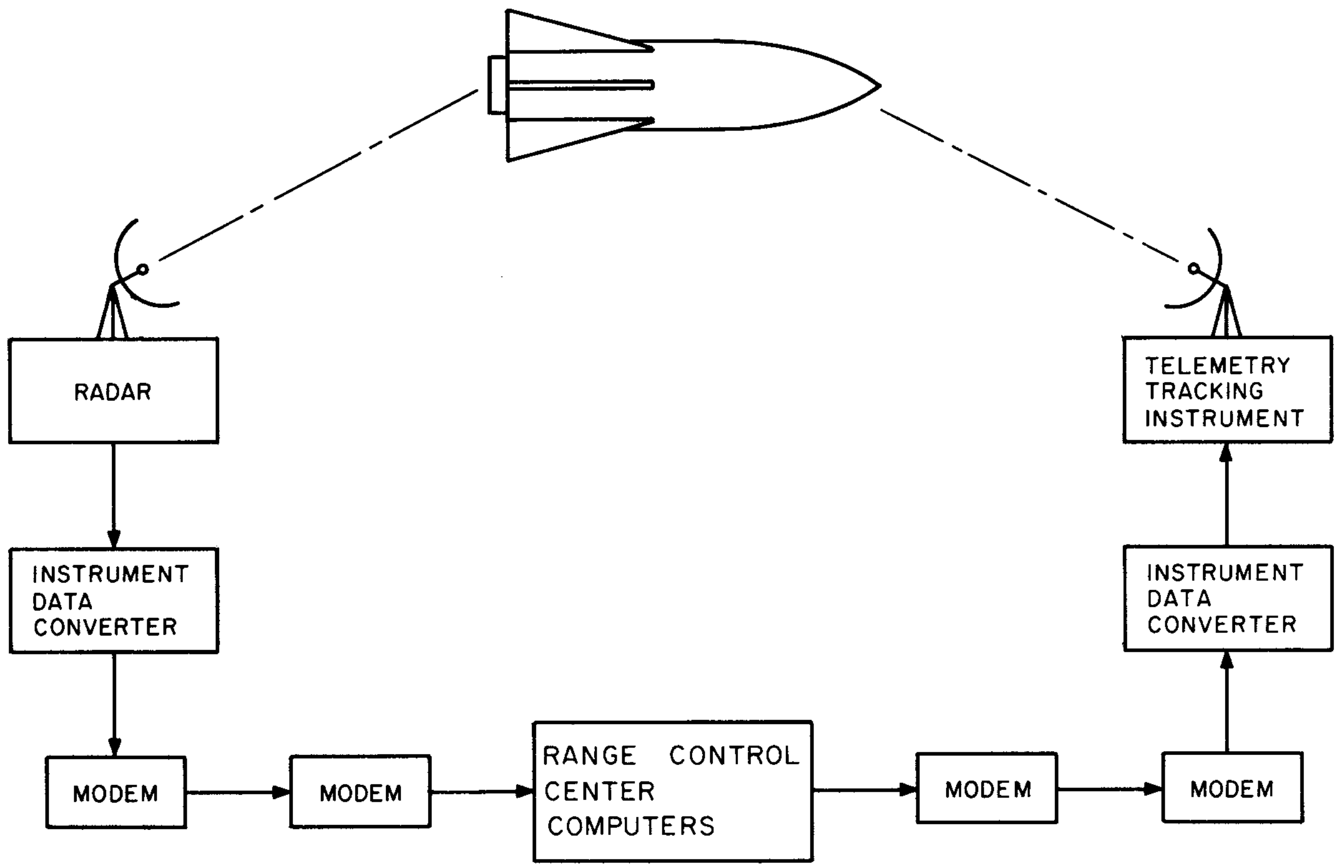

FIGURE 3 TARGET ACQUISITION SYSTEM A

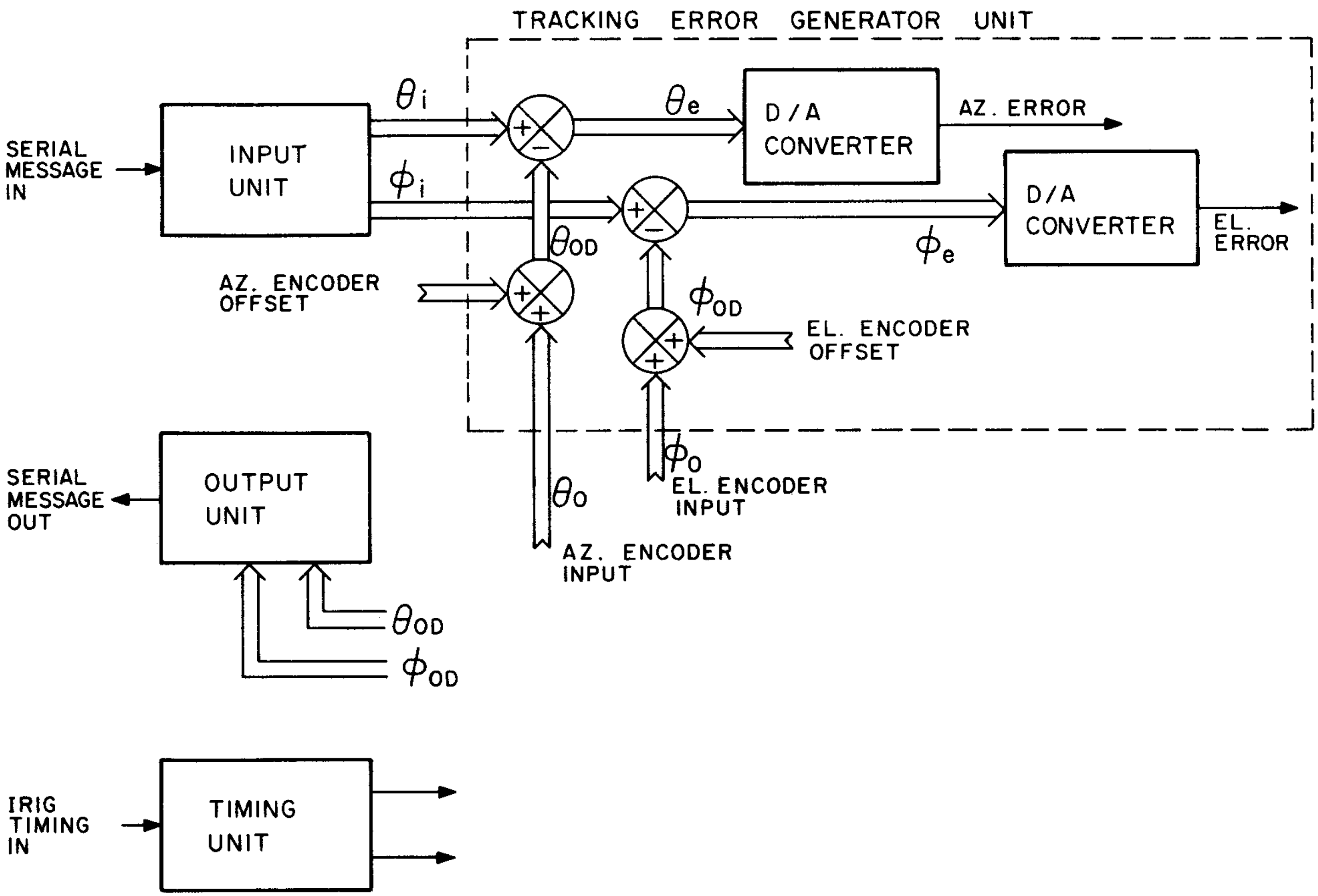

FIGURE 4 INSTRUMENT DATA CONVERTER

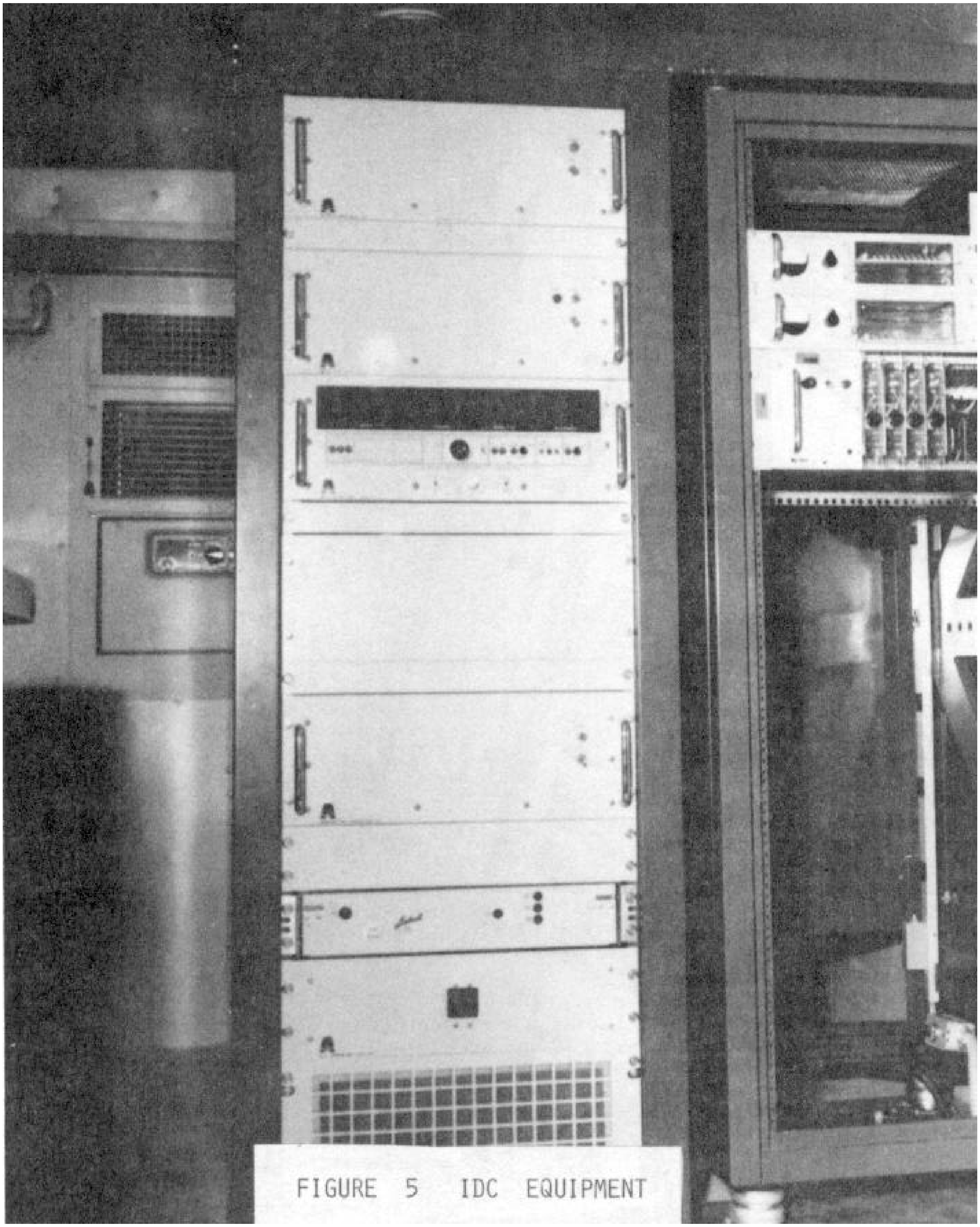

FIGURE 5 IDC EQUIPMENT

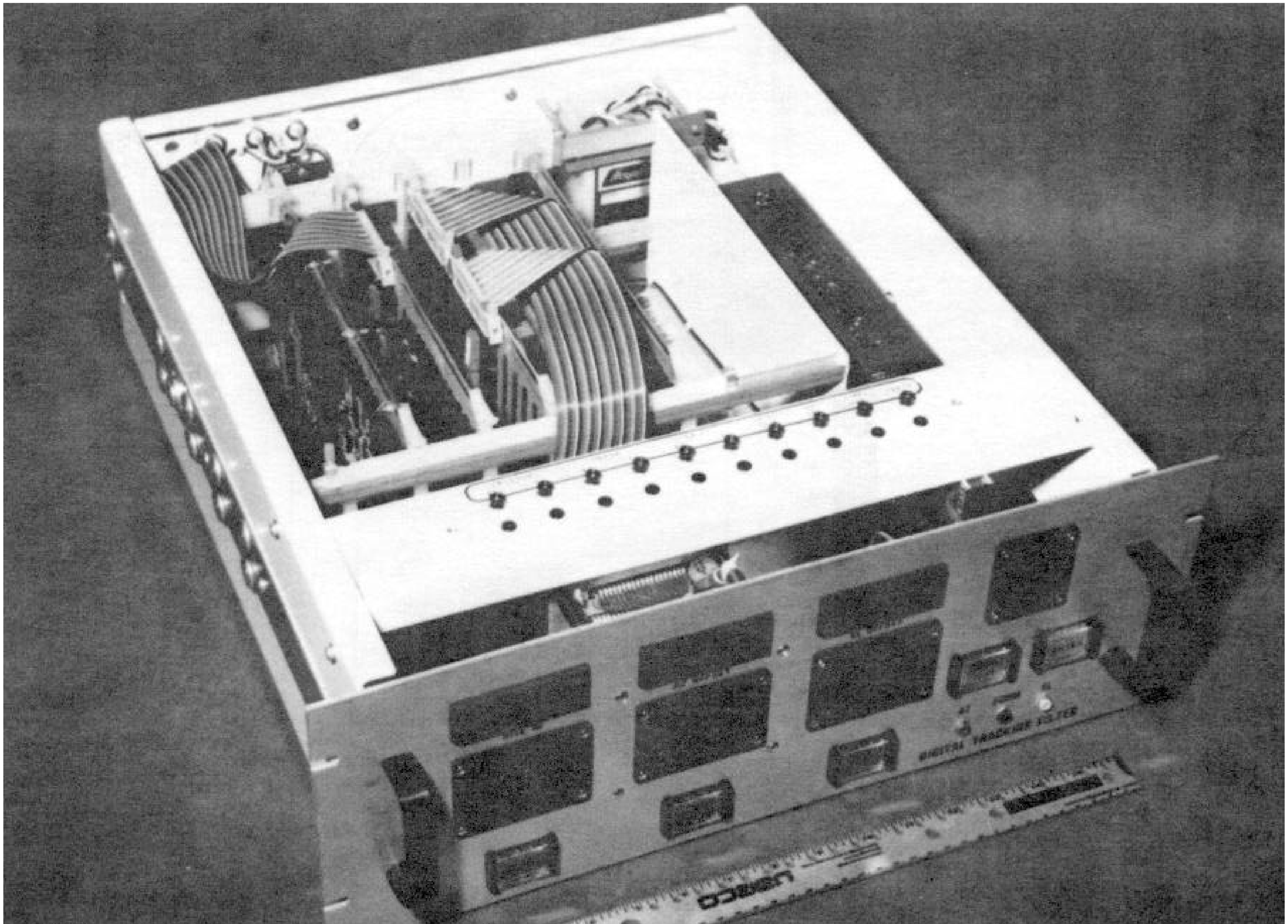

FIGURE 6 TSI UNIT

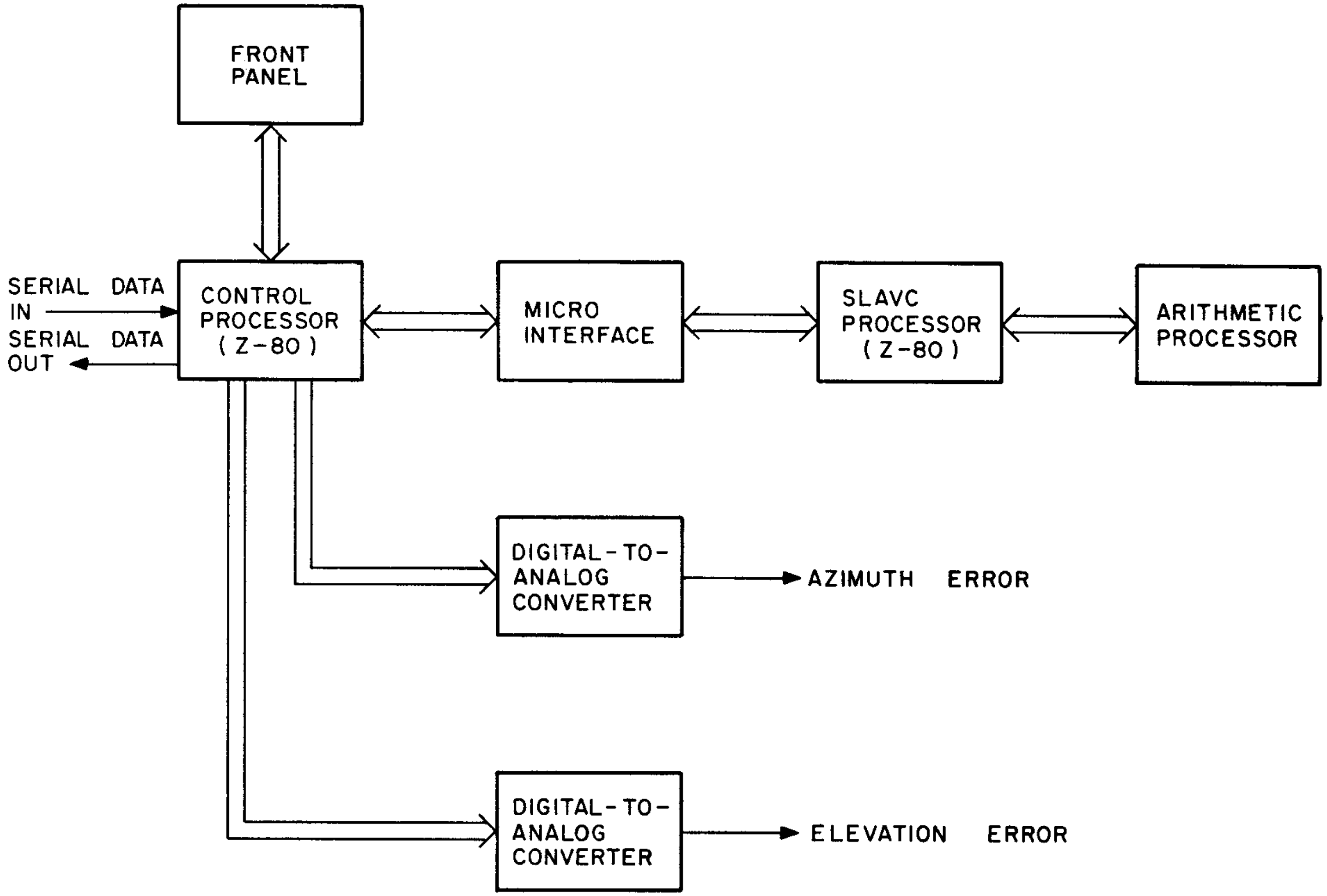

FIGURE 7 TSI BLOCK DIAGRAM

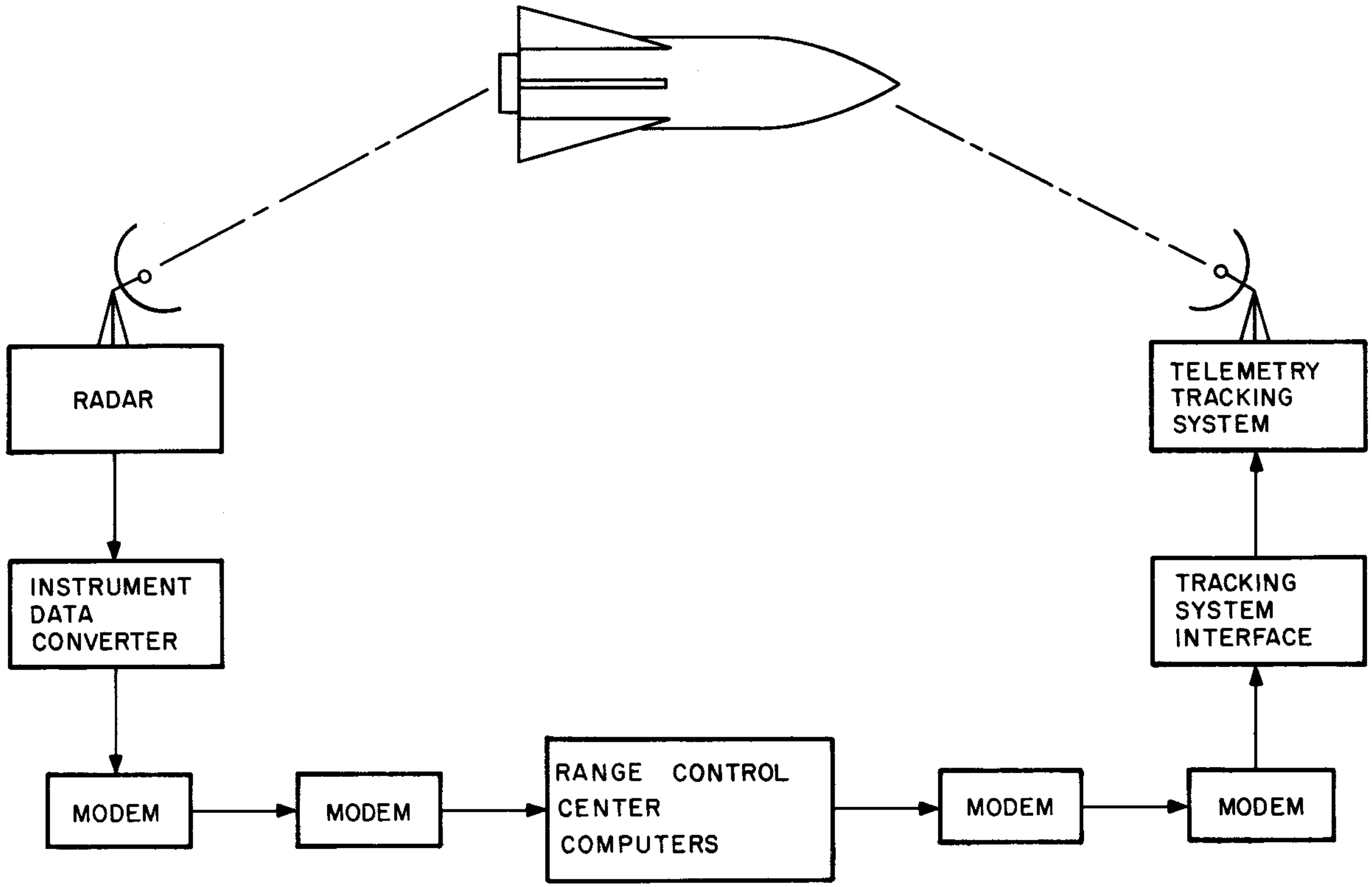

FIGURE 8 TARGET ACQUISITION SYSTEM B

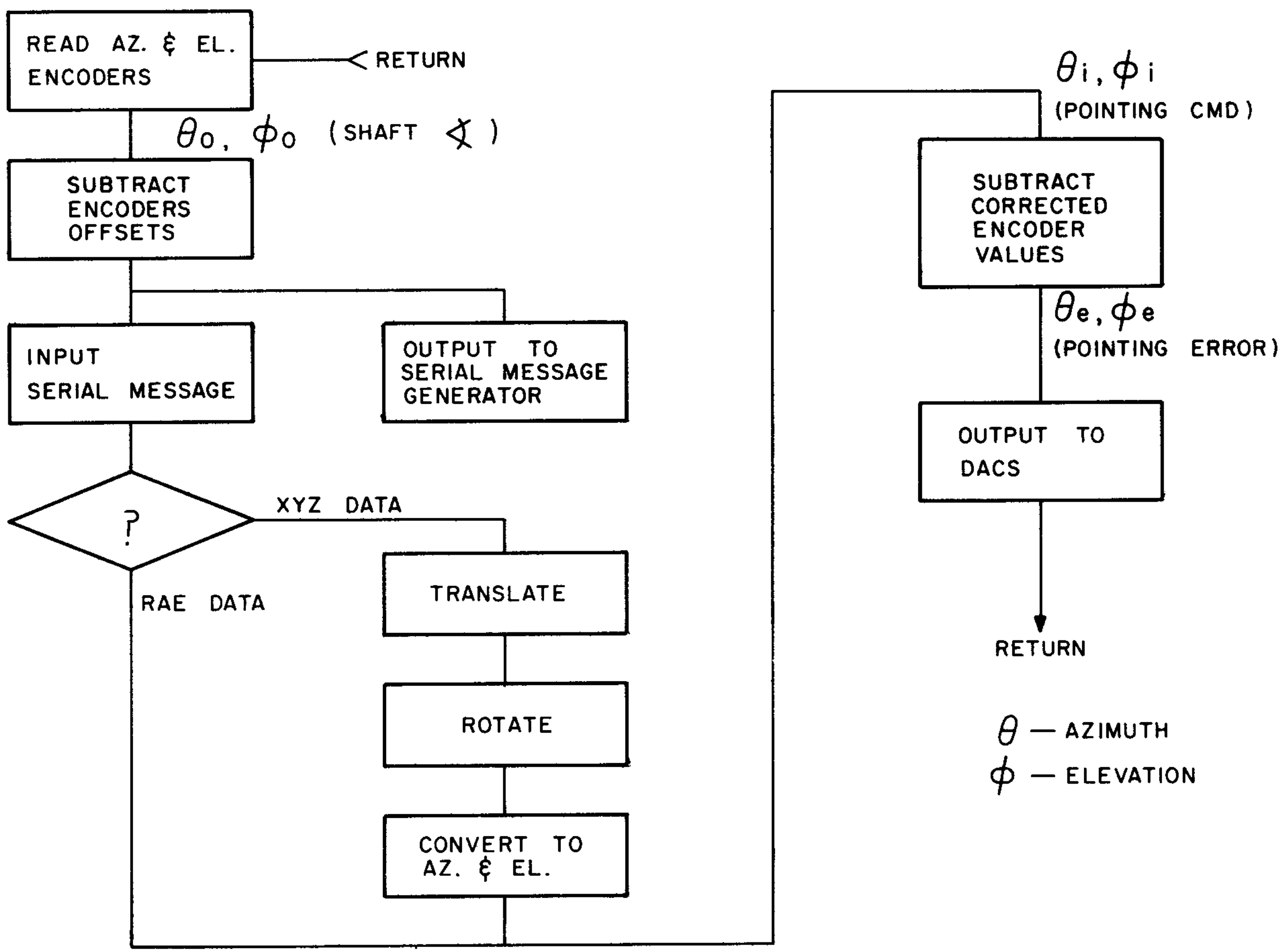

FIGURE 9 PRESENT TSI PROCESS

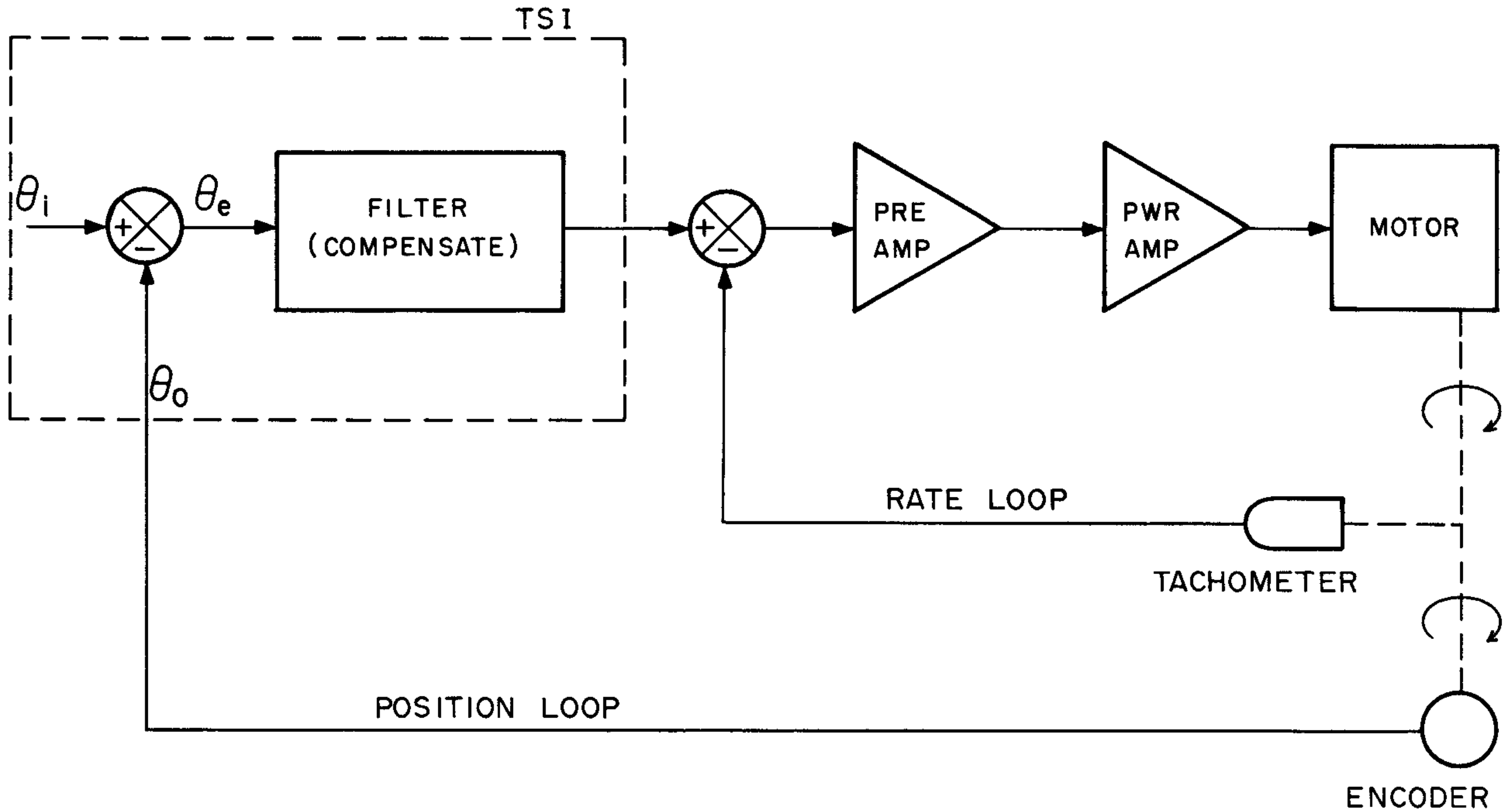

FIGURE 10 TYPICAL SERVO SYSTEM

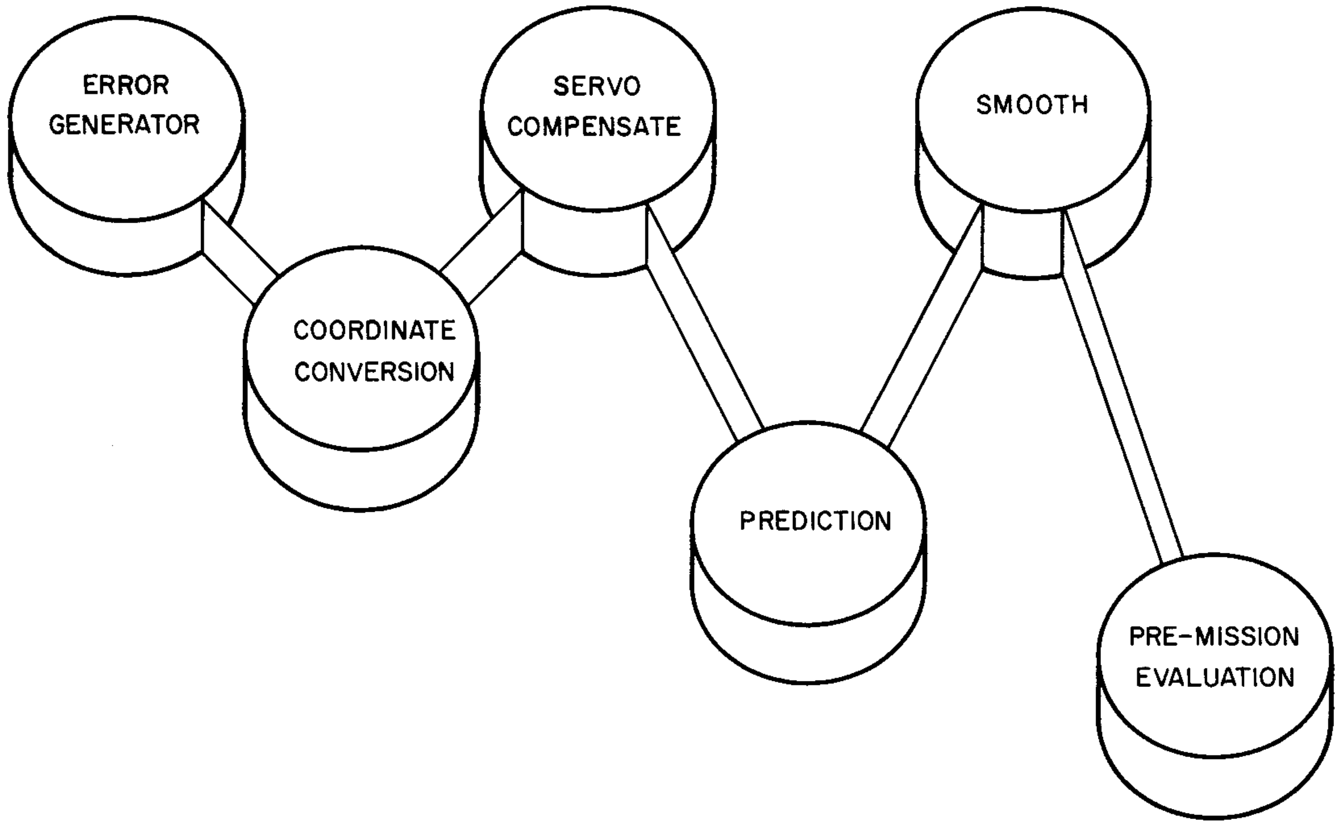

FIGURE 11 CAPABILITY OF TSI

TABLE 1 CAPABILITY SUMMARY FOR THE TSI

ERROR GENERATION:

$$\theta_e = \theta_i - \theta_o$$

$$\phi_e = \phi_i - \phi$$

θ_i, ϕ_i -- POINTING COMMAND

θ_o, ϕ_o -- SHAFT $\measuredangle$ DATA

θ_e, ϕ_e -- POINTING ERROR

COORDINATE CONVERSION:

$$X, Y, Z_{\text{WSCS}} \longrightarrow R, A, E_{\text{SITE LOCAL}}$$

SERVO COMPENSATION:

TYPE 1 $\longrightarrow$ TYPE 2

$$\theta_{ess} = \frac{\dot{\theta}}{kv} + \frac{\ddot{\theta}}{ka} \longrightarrow \theta_{ess} = \frac{\dot{\theta}}{ka}$$

θ_{ess} -- STEADY STATE TRACKING ERROR

$\dot{\theta}$ — $\measuredangle$ VELOCITY

$\ddot{\theta}$ — $\measuredangle$ ACCELERATION

ka -- ACCELERATION CONSTANT

kv -- VELOCITY CONSTANT

PREDICTION:

COMPENSATION FOR TOTAL SYSTEM DELAYS

SMOOTHING:

DATA NOISE REDUCTION

PRE-MISSION EVALUATION:

SERVO PERFORMANCE, ENCODER FUNCTION, ANTENNA PATTERNS