LONG-RANGE POSITION DETERMINING SYSTEM (LRPDS)

by

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The Long Range Position Determining System (LRPDS) is being developed by the Army Engineer Topographic Laboratories. The LRPDS is designed to provide a rapid survey and positioning capability for the Field Army. The basic design goals for LRPDS are :

- The system must be capable of determining 24 positions within one mission.
- The area of operation may be as wide as 200 km.
- The mission should be accomplished in less than one hour.
- The position accuracy may vary from 5 meters to 40 meters depending on where the position is located.
- The weight of one back-pack unit should not exceed 25 pounds.
- The communication links of the system should be jam resistant and difficult to detect.

Some of the significant design characteristics are as follows:

- All signals transmitted during the mission are transmitted on a single carrier frequency which makes simultaneous transmission and reception impractical.
- All data and messages for LRPDS operations are transmitted by the systems communication links.
- The aircraft carrying airborne LRPDS equipment shall not be dedicated only to LRPDS missions.

- The computer shall not be specifically designed for LRPDS.
- The system shall be operational in all weather.
- The system is only controlled by the user.

The range change measurement method has been primarily selected because of the single frequency constraint. The LRPDS hardware is being fabricated by Motorola in Scottsdale, Arizona. The delivery of the equipment is scheduled for December 1972. Although the design has been finalized and engineering prototype equipment has been built, some areas of LRPDS may still be subject to minor changes.

Figure 1 explains the range change measurement concept. The aircraft continuously transmits a coded signal which is received by the unknown station. The receiver compares the phase of the incoming signal with the phase of an identical signal generated by the receiver. As the aircraft moves, the phase of the received signal changes with respect to the phase of the signal generated by the receiver. These phase changes are proportional to range changes as shown in Figure 1. The code of the signal serves as a coarse yardstick with a resolution of 30 meters. The carrier serves as a fine yardstick with a resolution of 11.7 cm. Figure 2 shows a typical operational setup for LRPDS. The aircraft carrying the airborne equipment flies over an area where ground equipment has been deployed. The triangles represent base stations whose positions are known. The crosses represent ground stations whose positions are unknown and must be determined. A position computing center is located in the lower left of the picture. The airborne equipment generates ranging signals and read commands and serves as a relay in the communication, between ground stations and computer center.

There are five basic steps in an LRPDS operation. In the planning phase, all addresses, messages and commands necessary to execute the mission are put together in proper sequence and transmitted to the aircraft. The pilot is advised of the desired flight course. During the second phase,

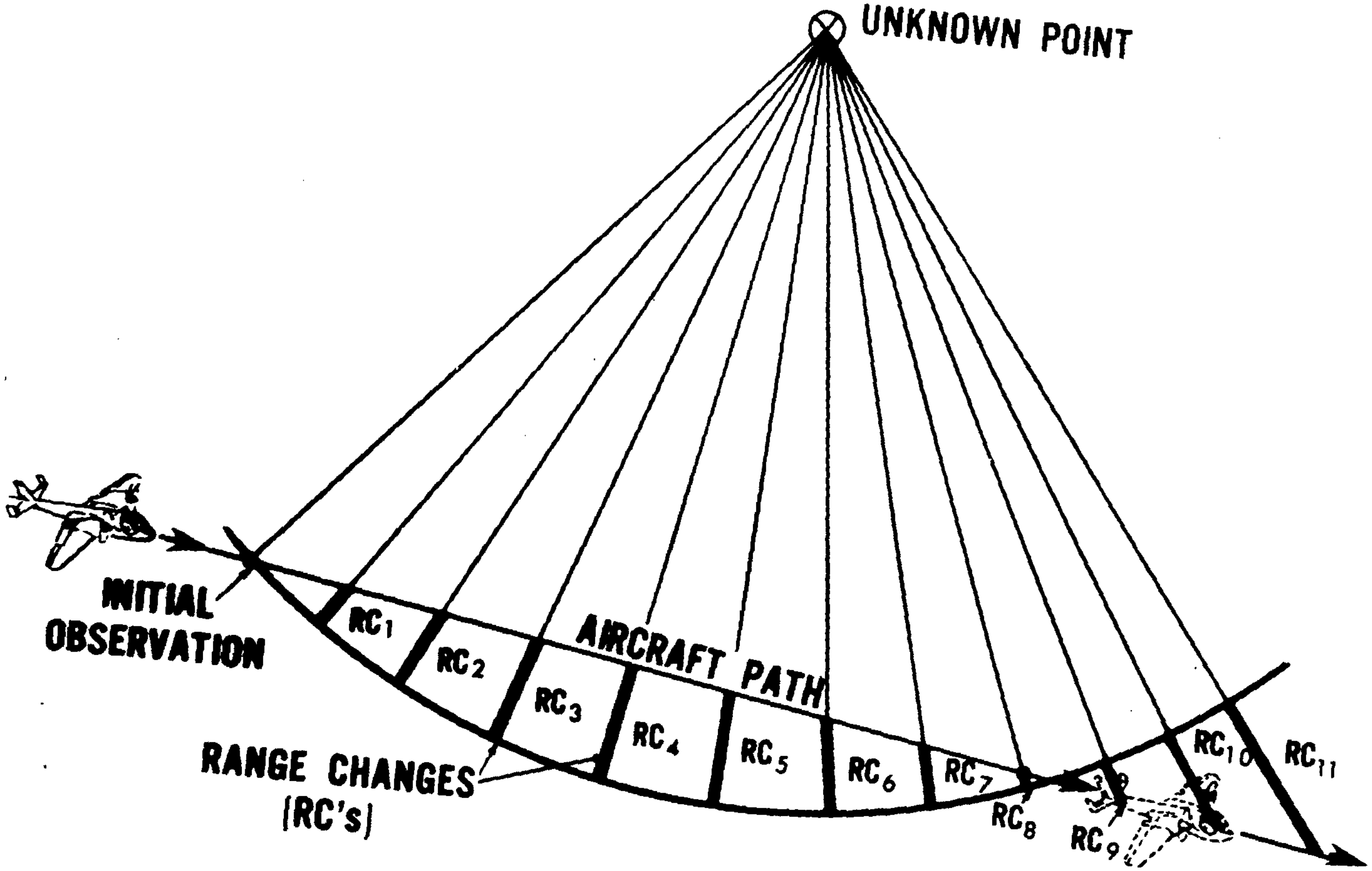

Figure 1. RANGE CHANGE GEOMETRY

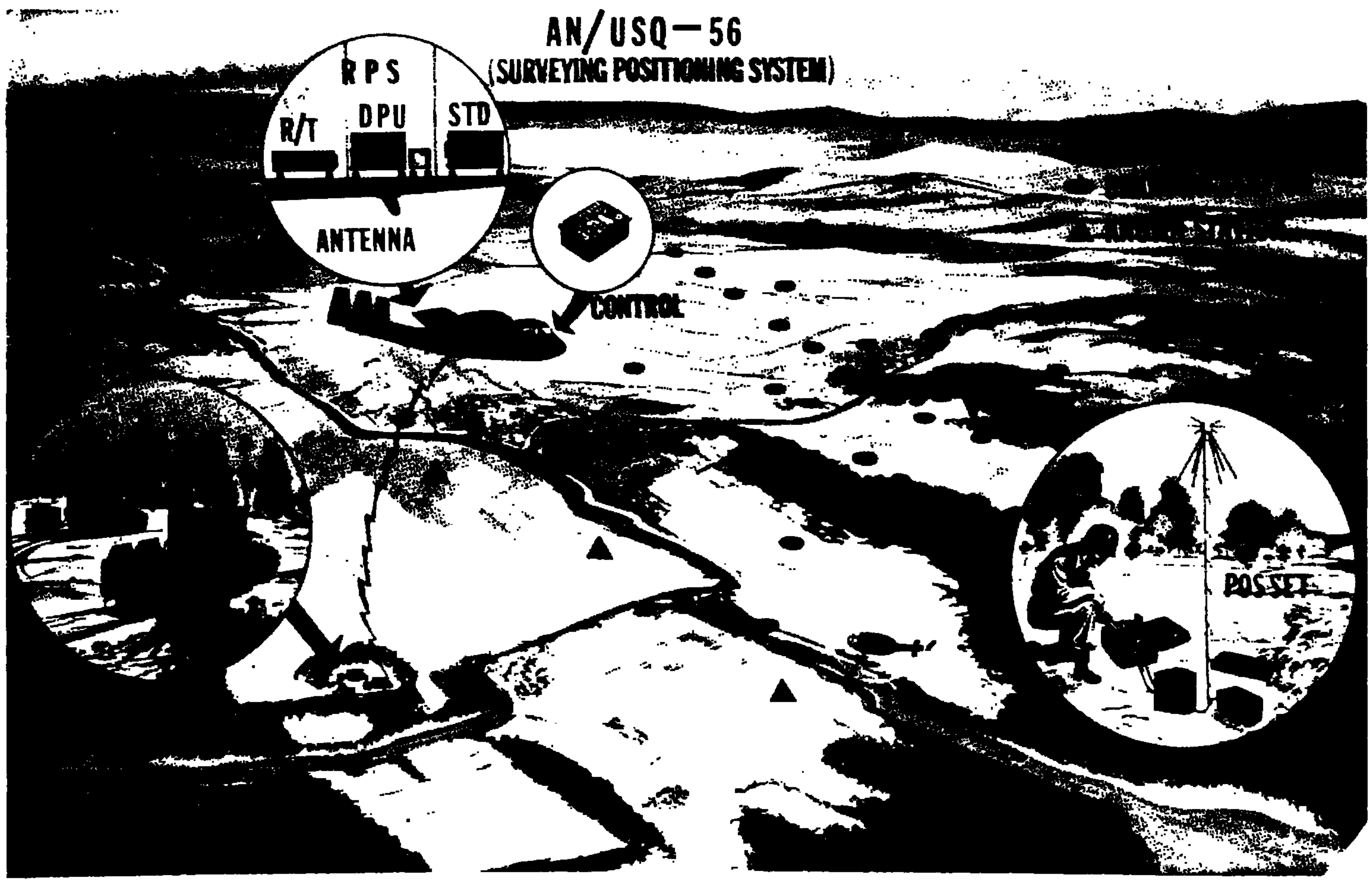

Figure 2. LRPDS CONCEPT

the aircraft transmits ranging signals, messages, and, at scheduled intervals, read commands to the ground stations. The ground stations receive the signals, measure the range changes at read commands, and store them in their memories. Message data are decoded and stored in the memory or displayed. During the third phase the ground stations transmit in sequence the stored range change data back to the aircraft which in turn stores and retransmits all data to the computing center. The positions of the ground stations are computed in phase four. During the last phase of the mission, all necessary information is transmitted to the ground stations via aircraft.

There are four LRPDS subsystems as shown in Figure 3. These are the positioning set, which is carried on two back-packs; the reference positioning set which consists of the LRPDS airborne equipment; the position computing central which contains the computer and serves as the mission control center; and the calibration and maintenance set. The latter two subsystems are housed each in a van and mounted on trucks.

The functional block diagram of the positioning set is shown in Figure 4. The receiver-transmitter unit and the data processing unit are housed in a single case, which is loaded on Packboard "A". Packboard "B" is used to transport the oscillator, battery, antenna, and cables. For certain missions, a digital display unit is included in this package. The receiver-transmitter unit is also a component of the reference position set and the position computing central. The receiver is capable of acquiring and tracking a RF-carrier that is bi-phase modulated with a predetermined pseudo-random code which has been modulo-two added with data symbol bits. The receiver output provides demodulated data and a phase coherent tracking signal representative of the reconstructed RF-carrier. The transmitter is used to transmit data and messages back to the aircraft. The data processing unit stores range change data, decodes messages, and establishes the format for data transmission to the aircraft. Figure 5 is a picture of the positioning set with receiver-transmitter unit and data processing unit in one box, the digital

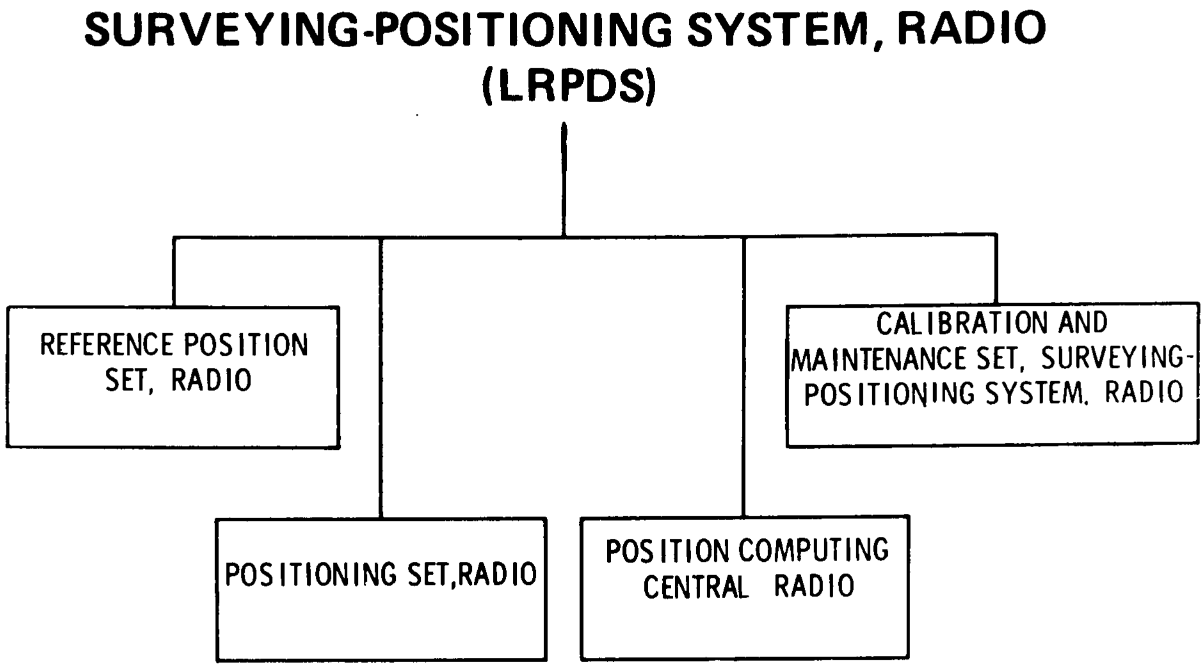

Figure 3. SURVEYING-POSITIONING SYSTEM, RADIO (LRPDS)

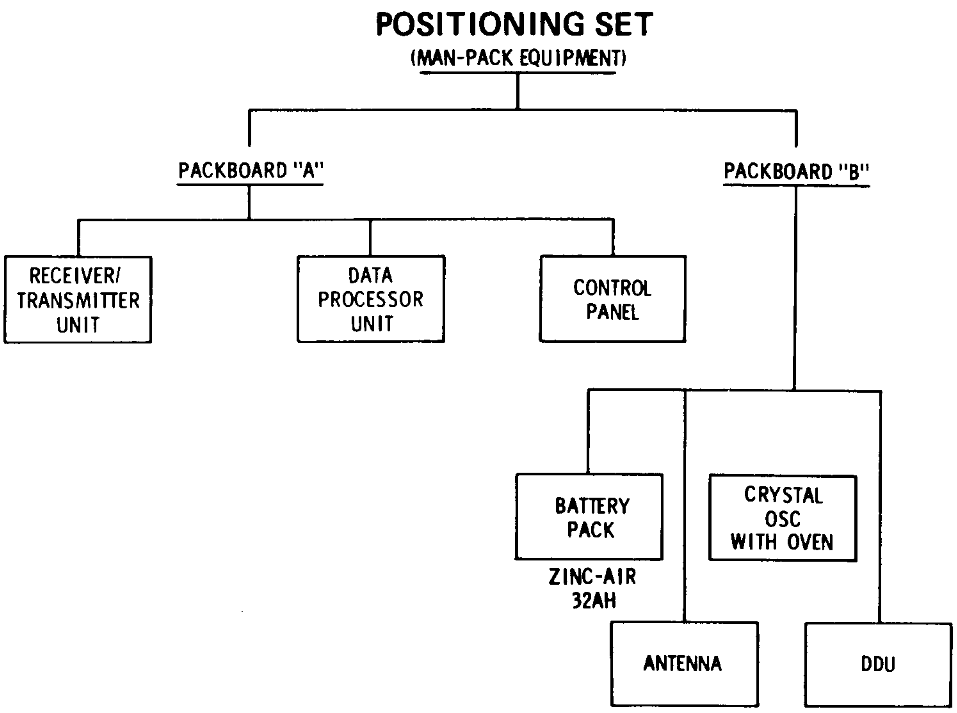

Figure 4. POSITIONING SET (Man-Pack Equipment)

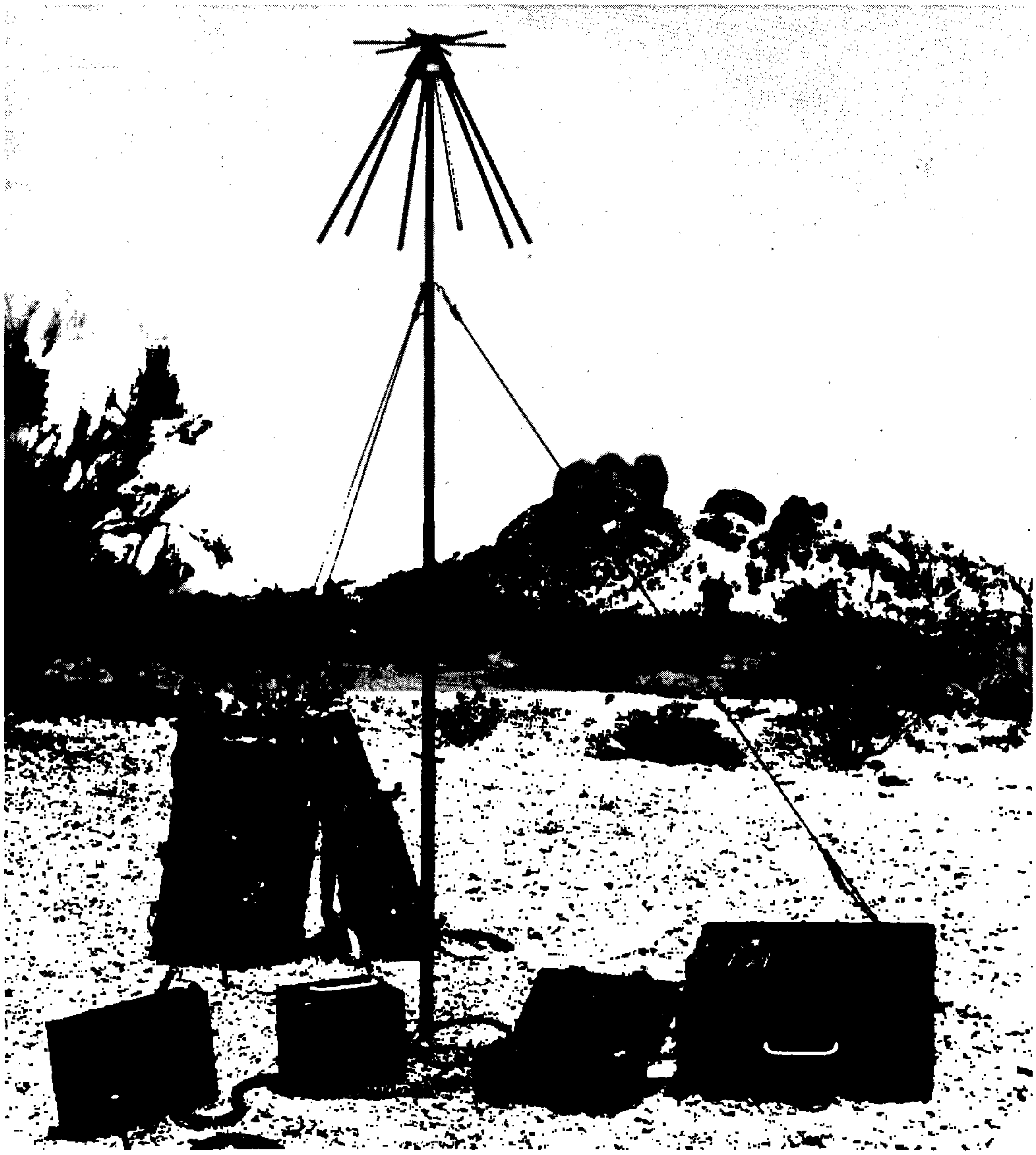

Figure 5. LRPDS POSITIONING SET

display unit, the oscillator package, battery, and antenna. The oscillator is an Austron double oven crystal oscillator which is shock mounted in the case. Figure 6 shows a close look at the unit which contains the transmitter-receiver and the data processor. The switches are used to generate a desired code and to enter data.

The LRPDS signed characteristics are as follows. The carrier is tunable between 260 and 440 megahertz in steps of 10 megahertz. The carrier is pseudo-noise modulated with a code consisting of 8.191 bits. The code is generated in a 13-stage linear feedback shift register. The duration of one bit is 100 nanoseconds. The data are synchronous with the code. One data bit consists of two code lengths and has a duration of about 1.62 milliseconds.

The acquisition of the signal is accomplished in sequential steps. During the first step, correlation between the incoming code and the receiver generated code is established, causing the carrier loop to close. After the carrier loop is closed, the loop will be phase locked. The bandwidth of the carrier loop is then narrowed to about 40 hertz. Finally, the receiver phase-corrected clock is adjusted to zero and the receiver is ready for full tracking. The reference input for the coarse-range measurements is the five megahertz sine wave generated by the Austron oscillator. This frequency is multiplied by two and shaped into a square wave which is counted by the coarse-range register. The coarse-range register is read at the coincidence of a range change measurement command and a unique state of the receiver code generator. The fine-range register is a nine-stage counter with a resolution of 60/512 meters (=11.7 cm). The fine-range measurement is made by measuring the relative phase between the reference wave from the crystal oscillator and the wave of the receiver phase-corrected clock. The receiver phase-corrected clock signal is a square wave at five megahertz $\pm$ doppler. The input to the phase-corrected clock is derived from the received RF-carrier. The relative phase measurement is made by counting cycles that occur

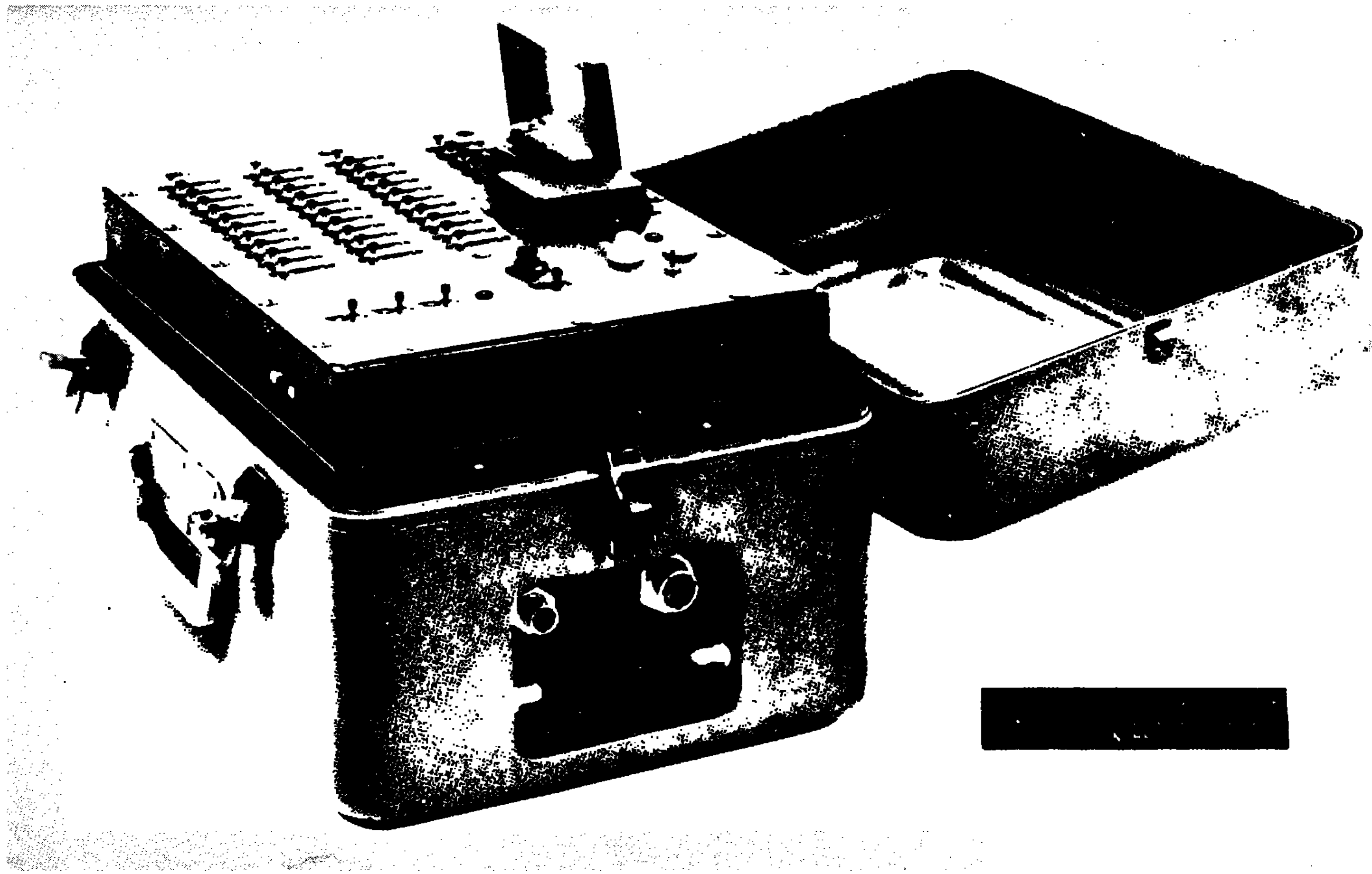

Figure 6. LRPDS POSITIONING SET

between the zero crossings of the reference wave and the translated carrier wave. One full 360° phase rotation at the translated frequency changes the fine range register by 512 counts.

The airborne reference positioning set is shown in Figure 7. The capacity of the data processing unit is considerably larger than that of the positioning set, because more data have to be stored and processed. The master clock is a Hewlett-Packard cesium beam clock which has been designed for airborne applications. This clock has been selected to provide the required stability under dynamic conditions such as aircraft maneuvers. The control and monitor unit provides the observer with control capability over the mission. The meterological data converter unit converts meterological data and altimeter readings in transmissible data.

The computer of the position computing central shown in Figure 8 will be a Datacraft Mod 5 computer with the following characteristics: 24-bit word with 8,192 words in the basic system. The computer capacity can be increased to 65,536 words in 8,192 word increments.

The internal stability of the receiver with respect to range change measurements was determined as a function of dynamic range, ambient temperature, warmup period, supply voltage variation, interference by jamming and adjacent users, shock, and vibration. The internal stability proved to be one to three bits of variation in most cases. Figure 9 shows the effect of a frequency offset and frequency drift of the oscillator on range change measurements. Because frequency effect and frequency drift are practically constant during the range change collecting period, these quantities can be treated as fixed unknowns and solved in the data reduction process. Figure 10 shows requirements and test results for the ground station crystal oscillators. The difference between airborne clock and ground station crystal oscillator is required to be not more than 1×10^{-7}. The drift should not be larger than 5×10^{-10} and phase noise should not exceed 2° RMS at five megahertz. Figure 11 shows the position accuracy which should be attained with LRPDS.

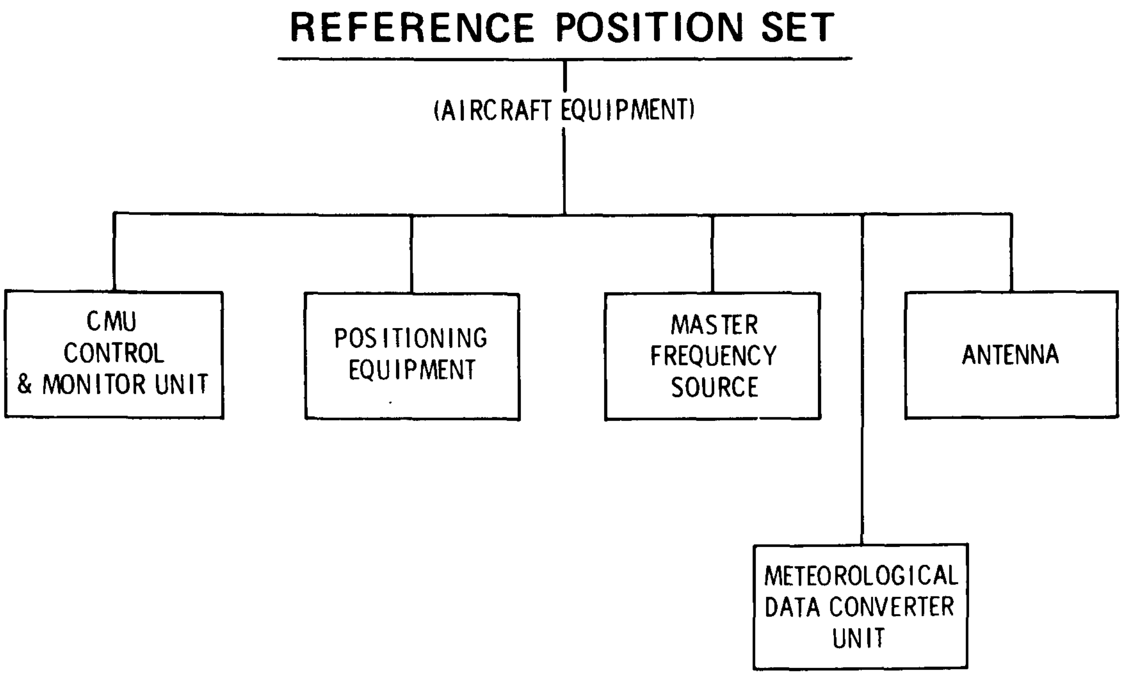

Figure 7. REFERENCE POSITION SET (Aircraft Equipment)

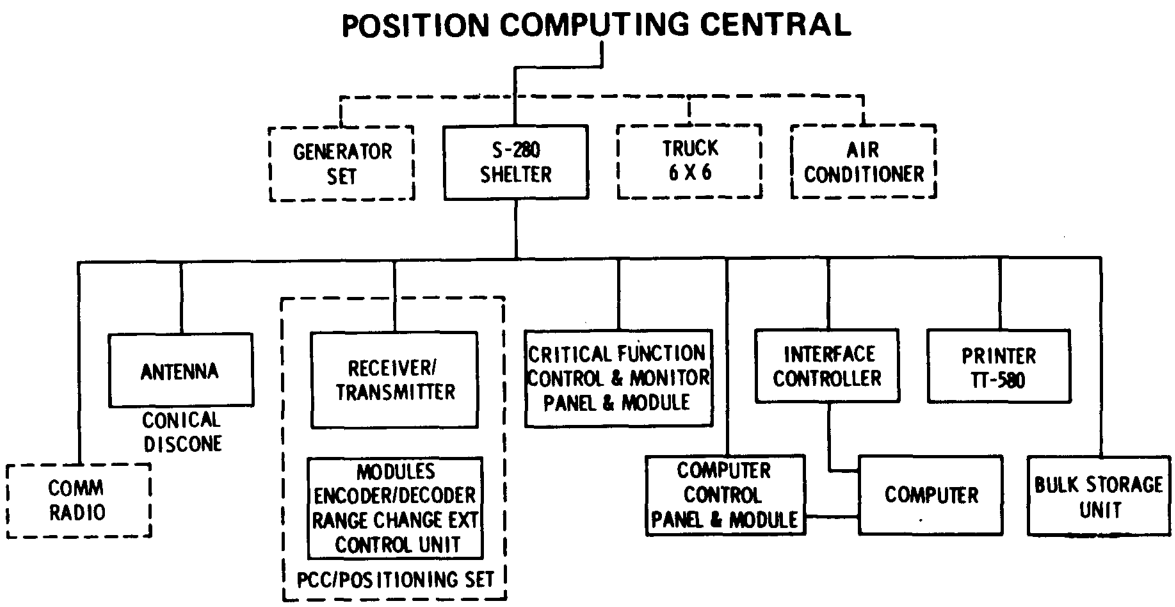

Figure 8. POSITION COMPUTING CENTRAL

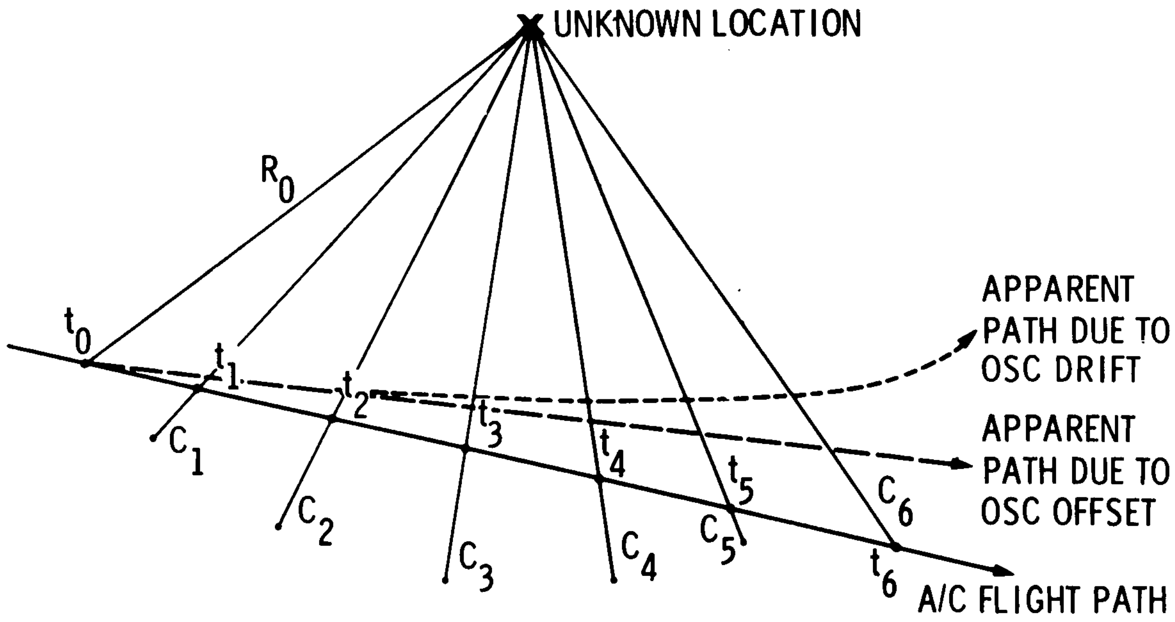

Figure 9. RANGE CHANGE PRINCIPLE AND OSCILLATOR EFFECTS

	REQUIREMENT	TEST RESULTS
OFFSET (f AIRCRAFT −f GND SET)	$\leq 1 \times 10^{-7}$	1×10^{-9}
DRIFT (PARTS/HR AFTER 4 HR WU)	$< 5 \times 10^{-10}$	1×10^{-10} WORST CASE
NOISE (TOTAL PHASE ERROR IN CYCLES AT 5 MHz)	$<$ .005 RMS	.002 TO .005 RMS

Figure 10. LRPDS OSCILLATOR EFFECTS

UNCLASSIFIED

SURVEY AREA	METERS RMS		
	X	Y	Z
30 × 30 KM	5	5	10
60 × 60 KM	8	8	30
LONG RANGE 200 KM	40	40	—

Figure 11. LRPDS ACCURACY