# THE RAJPO GPS RANGE EQUIPMENT FAMILY

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## ABSTRACT

This paper describes equipment to be developed by the GPS Range Applications Joint Program Office (RAJPO) for use on test and training ranges. The equipment is to be modular; the various modules may be assembled in range-specific configurations by the individual range development organizations to perform measurement and communications functions.

**Key words:** Global Positioning System, GPS, Range Applications Joint Program Office, RAJPO, test and training range, test range, training range, time-space-position information, TSPI, differential GPS, differential/relative GPS, transdigitizer, instrumentation pod, data link system, GPS Range System, GPS Range Equipment, High Dynamics Instrumentation Set, HDIS, Low Dynamics Instrumentation Set, LDIS, Position Location Module, PLM.

## INTRODUCTION

The purpose of the tri-service Global Positioning System (GPS) Range Applications Joint Program Office (RAJPO) GPS Range Equipment Program is to develop a family of modules that can be assembled to provide GPS time-space position-information (TSPI) determination functions on test and training ranges. RAJPO GPS Range Equipment is not intended to stand alone but to be integrated with existing and new equipment by individual range development organizations to perform the overall functions of their ranges.

In addition to the generic functional modules, the RAJPO is sponsoring development of specific configurations of the GPS Range Equipment to demonstrate GPS integration concepts on several existing and planned range systems, including the Army Mobile Automated Field Instrumentation System (MAFIS) at Fort Hood, the Air Force Gulf Range Drone Control Upgrade System (GRDCUS) at Tyndall Air Force Base, the Navy Extended Area Test System (EATS) at the Pacific Missile Test Center, the Air Force

Advanced Range Data System (ARDS) at Edwards Air Force Base, and the Navy/Air Force Tactical Aircrew Combat Training System/Air Combat Maneuvering Instrumentation (TACTS/ACMI) at a location to be determined.

## FAMILY OF EQUIPMENT TO BE DEVELOPED BY THE RAJPO

The basic equipment elements to be developed through the RAJPO GPS program are:

(1) A generic GPS High-Dynamics Instrumentation Set (HDIS), based on a GPS receiver able to track four satellites concurrently. The HDIS system includes a generic Range Flexible Modular Interface (RFMI) and an optional generic strapdown Inertial Reference Unit (IRU) interfaced to the basic HDIS GPS receiver.

(2) A generic GPS Low-Dynamics Instrumentation Set (LDIS), based on a GPS receiver able to track two satellites concurrently. The LDIS also includes an RFMI. A special, minimum-cost version of the LDIS, the Position Location Module (PLM), is to be developed for MAFIS. The PLM does not include an RFMI; instead, it has a direct interface with other MAFIS modules.

(3) A generic C/A code GPS Transdigitizer participant set.

(4) A generic GPS Transdigitizer Receiver/Processor (TR/P) system, which includes a Transdigitizer Down Link Receiver (TDLR) or down link converter and a GPS Transdigitizer Receiver (TR). The TR is to be based on a GPS receiver able to track eight satellites concurrently.

(5) A generic differential GPS Reference Receiver/Processor (RR/P) system to support differential/relative GPS functions and transdigitizer system operations. The RR/P system includes a Reference Receiver (RR), a Navigation Correction Processor (NCP), a Pseudorange Correction Generator (PRCG), a Meteorological Sensor System (MSS), and a Control/Display Subsystem (C/DS). The RR is to be based on a GPS receiver able to track eight satellites concurrently.

(6) A generic RAJPO GPS Data Link System (DLS), which includes two segments: a Participant Segment, consisting of the participant transceiver, and a Range Segment, consisting of a Master Station, multiple Remote Stations, and a Data Link Controller.

(7) A RAJPO GPS Range System, which is an integrated system capable of functioning as the TSPI measurement instrumentation facility for a range with aircraft participants. Primary components of the Range System are: (a) an instrumentation pod using a version of the HDIS and containing a GPS DLS Participant Segment transceiver,

(b) a specific configuration of the GPS DLS Range Segment, and a specific configuration of the differential GPS RR/P system.

(8) A set of specific user configurations of the generic RAJPO GPS program elements for the range systems listed previously.

(9) A Control/Display Unit (CDU) that can be plugged into a RAJPO GPS receiver for initialization and checkout purposes.

(10) A suite of Support and Test Equipment to perform test, checkout, and maintenance operations for all the equipment procured by the RAJPO contracts.

Figure 1 illustrates the RAJPO GPS Range Equipment configuration item tree. The Transdigitizer and the Transdigitizer Down Link Receiver have been deferred to a later procurement and hence are not covered in Phase I of the RAJPO program.

## SPECTRUM OF CONFIGURATIONS

GPS Range Equipment modules are intended to be configured in a wide spectrum of forms to suit the needs of individual range applications. Not all these configurations can be defined in advance. The participant equipment is intended to be able to be used on all types of participants that operate on U.S. test and training ranges, including, but not limited to, high-dynamics aircraft (such as fighters and attack aircraft), medium-dynamics aircraft (such as helicopters and tankers), aerial targets (drones), missiles, seaborne targets, ships, tanks and other land vehicles, and infantrymen.

Different applications require GPS Range Equipment modules to be packaged with different form factors. The modules are to be designed to be interoperable, with configurability through plug-in hardware and/or software elements. Table I describes characteristics of the five basic GPS receiver types to be developed through the RAJPO GPS Range Equipment Program. The RAJPO expects that a common set of submodules will be developed that can be assembled as required to form the five major types of Range Equipment GPS receivers. The submodules also are expected to allow assembly of a given type of GPS receiver into different form factor configurations, as illustrated conceptually in Figure 2.

## THE GPS RANGE SYSTEM

The GPS Range System is an integrated system for use by a range that does not already have a TSPI measurement system and/or a range data communication system. Major elements of the GPS Range System are the Range Pod System (RPS), the DLS, and the RR/P. The GPS Range System is illustrated in Figure 3.

## Range Pod System

The RPS is to be an AIM-9-style pod capable of being mounted at any aircraft station that can carry an AIM-9 missile or a TACTS/ACMI P-4 pod. It will consist of the following subsystems:

> HDIS module, including the RFMI and the RAJPO IRU assembly; GPS antenna assembly; RAJPO Data Link participant transceiver, including an optional encryption unit; RAJPO Data Link participant antenna; RAJPO Data Recording Unit (installation optional–may be in place of the Data Link Participant Segment); and other pod equipment such as power conditioning units.

## RAJPO Data Link System

The RAJPO GPS DLS consists of two segments: a Participant Segment and a Range Segment (Figures and 4). The Participant Segment consists of a transceiver assembly and its associated antenna modules. It interfaces with an optional encryption unit using a government-furnished KG-66 encryption device.

**Table I**

**COMPARISON OF RECEIVER TYPES**

| Parameter | Receiver Type | | | | |
|---|---|---|---|---|---|
| | HDIS | LDIS | PLM | TR | RR |
| Number of concurrent satellite tracks | 4 | 2 | 2 | 8 | 8 |
| GPS signals handled | $L_1$ and $L_2$ | $L_1$ and $L_2$ | $L_1$ only | $L_1$ only | $L_1$ and $L_2$ |
| GPS codes handled | C/A and P | C/A and P | C/A only | C/A only | C/A and P |
| Able to use IRU aiding | Yes | No | No | Yes | Yes* |
| Usage/Vehicles | Aircraft<br>Helicopters<br>Large missiles<br>Large drones | Land vehicles<br>Ships | (MAFIS only)<br>Manpacks<br>Land vehicles | Ground centers<br>Range support aircraft and ships | Ground centers<br>Range support aircraft and ships |

| | | | | | |
|---|---|---|---|---|---|
| Form factor alternatives for receiver, IRU, power supply, and interface | • <5-in.-dia. cylinder<br>• ATR box<br>• Rack mount<br>• Others | • <10-in.-dia., 14-in.-long cylinder<br>• Others | MAFIS packaging only | Rack mount | Rack mount |
| Max. (goal) component volume<br>• Receiver with interface and power conditioner<br>• IRU<br>• CDU | 400 (300)in.$^3$<br><br>300 in.$^3$<br>150 in.$^3$ | 350 in.$^3$<br><br>N/A<br>150 in.$^3$ | 250 in.$^3$<br><br>N/A<br>150 in.$^3$ | Not specified<br><br>Not specified<br>150 in.$^3$ | Not specified<br><br>N/A<br>150 in.$^3$ |
| Max. (goal) component weight:<br>• Receiver with interface and power conditioner<br>• Antenna subsystem<br>• IRU | 20 (15) lb<br>1.5 lb<br>12 lb | 15 (10) lb<br>1.1 lb<br>N/A | 6.6 lb<br>1.1 lb<br>N/A | Not specified<br>Not specified<br>Not specified | Not specified<br>Not specified<br>N/A |
| Position accuracy (rms), static conditions | | | | | |
| • Absolute | | | | | |
| - C/A code | | | | | |
| --Horizontal | 40 ft | 40 ft | 40 ft | 40 ft | 40 ft |
| --Vertical | 68 ft | 68 ft | 68 ft | 68 ft | 68 ft |
| - P code | | | | | |
| --Horizontal | 21 ft | 38 ft | N/A | N/A | 21 ft |
| --Vertical | 35 ft | 63 ft | N/A | N/A | 3 5 ft |
| • Differential | | | | | |
| - C/A code | | | | | |
| --Horizontal | 17 ft | 17 ft | 17 ft | 17 ft | N/A |
| --Vertical | 28 ft | 28 ft | 28 ft | 28 ft | N/A |
| - P code | | | | | |
| --Horizontal | 6 ft | 6 ft | N/A | N/A | N/A |
| --Vertical | 10 ft | 10 ft | N/A | N/A | N/A |

* For mobile platform applications (e.g., ship as a reference location).

The Range Segment consists of three primary subsystems: Remote Stations, the Master Station, and the Data Link Controller. In general, physical links between these subsystems will be provided by the range on which the equipment is installed (e.g., via landlines or expansion of existing microwave links), as shown in Figure 4. The elements of the Data Link Controller include the Data Link Controller/Processor (DLC/P), the Encryption System (optional), the DLC/P Control/Display Console, and the DLC/P Recording Unit.

Some key characteristics of the RAJPO DLS are listed in Table II.

**Table II**

**Characteristics of RAJPO DLS**

| |
|---|
| • Time-division multiple access approach<br>• Multiple slot-access modes<br>- Polled<br>- Periodic<br>--Reporting time defined pre-exercise<br>--Reporting time defined in prior command message<br>• Relay capabilities<br>- Participant to participant<br>- Remote station to remote station<br>• Data link frequency selectable by swapping RF front ends<br>• KG-66 compatibility for encryption of downlink<br>• Capability to trade off number of participants, message length, and message repetition rate (Typical resource allocation: 25 participants communicating 400-bit messages each at 10 messages per second per participant). |

### Reference Receiver/Processor

The primary hardware units of the RR/P are the RR, the PRCG, the NCP, the MSS (for tropospherical correction model calibration), and the Control/Display Console (C/DC). The functional operation of the RR/P is discussed in the following section.

## FUNCTIONAL CHARACTERISTICS

### Inertial Aiding

Certain RAJPO GPS sets (particularly the HDIS) are to be able to use inertial data from an IRU to augment the GPS solution. The inertial data can provide additional state vector data (i.e., acceleration, attitude, and attitude rate information), provide "coast-through" capabilities when the GPS solution is lost or degraded (e.g., due to satellite signal loss caused by antenna blockage), increase the rate at which the navigation solution is computed, and aid in code and carrier loop tracking to assist in GPS solution reacquisition.

## Differential/Relative GPS Processing

The RAJPO GPS Range Equipment is to be designed to use differential/relative GPS processing where the necessary facilities are available. Differential/relative GPS processing allows increased GPS accuracy by eliminating common-mode satellite and propagation errors. Four generic methods for differential/relative GPS processing for the RAJPO architectures have been defined, called Methods 1, 2, 3, and 4. However, the characteristics of Method 2 were judged to be undesirable for the identified RAJPO applications and thus are not required to be supported for the deliverable equipment on the initial RAJPO contract.

Differential GPS Method 1 involves uplinking pseudorange corrections and their rate of change for all visible satellites to the participant receivers, which select the appropriate satellite data sets to correct the navigation solution in the GPS receiver. The Reference Receiver must be at a fixed, known location.

Differential GPS Method 3 is similar to Method 1 except that the differential corrected navigation solutions are obtained on the ground in the host range computer. Method 3 thus requires that the participant receiver downlink all GPS raw measurement data (and inertial data if used). Method 3 offers potential for more elaborate post-test processing than the other methods.

Method 4 performs differential/relative GPS corrections to uncorrected participant position data in a NCP that is part of the RR/P on the ground. The participant must downlink its uncorrected navigation solution and the satellites used. The NCP differences the RR/P-measured position with the participant’s measured position to produce the corrected participant position relative to the RR/P. Method 4 allows the determination of relative positions when the surveyed location of the RR/P in GPS coordinates is not known.

## Interfacing

GPS Range Equipment modules are intended to interface to a variety of existing range and platform systems to allow integration into existing ranges. Flexible interface hardware therefore has been included in the system architecture (such as the RFMIs of the various GPS receiver systems and the Flexible Digital Interface Unit [FDIU] in the DLS) to accommodate these interfaces. The selected RAJPO contractor is to establish associate contracts with the vendors of the various range system and platform equipment with which the GPS Range Equipment modules must interface to design the specific customized interface hardware units.

### Transdigitizer Systems

In place of a GPS receiver (such as the HDIS or the LDIS) on the participant, a transdigitizer unit may be installed that receives raw GPS signals, digitizes them, modulates the resulting signal on another frequency, and downlinks this signal to a remote unit. The remote unit downlink receiver reconstructs the GPS information and provides it to a GPS receiver, which computes the GPS navigation solution for the participant. The advantage of using the transdigitizer on the platform is that it is smaller, lighter, uses less power, and costs less than the receiver and thus is more suitable for use on participants that suffer attrition, such as missiles or small target drones.

## SUMMARY

The RAJPO GPS Range Equipment program will develop a set of flexible building blocks to allow exploitation of the GPS for determining TSPI data on test and training ranges. It is likely that many future range systems will incorporate these modules or their derivatives in the post-1988 time frame.


## ACKNOWLEDGMENT

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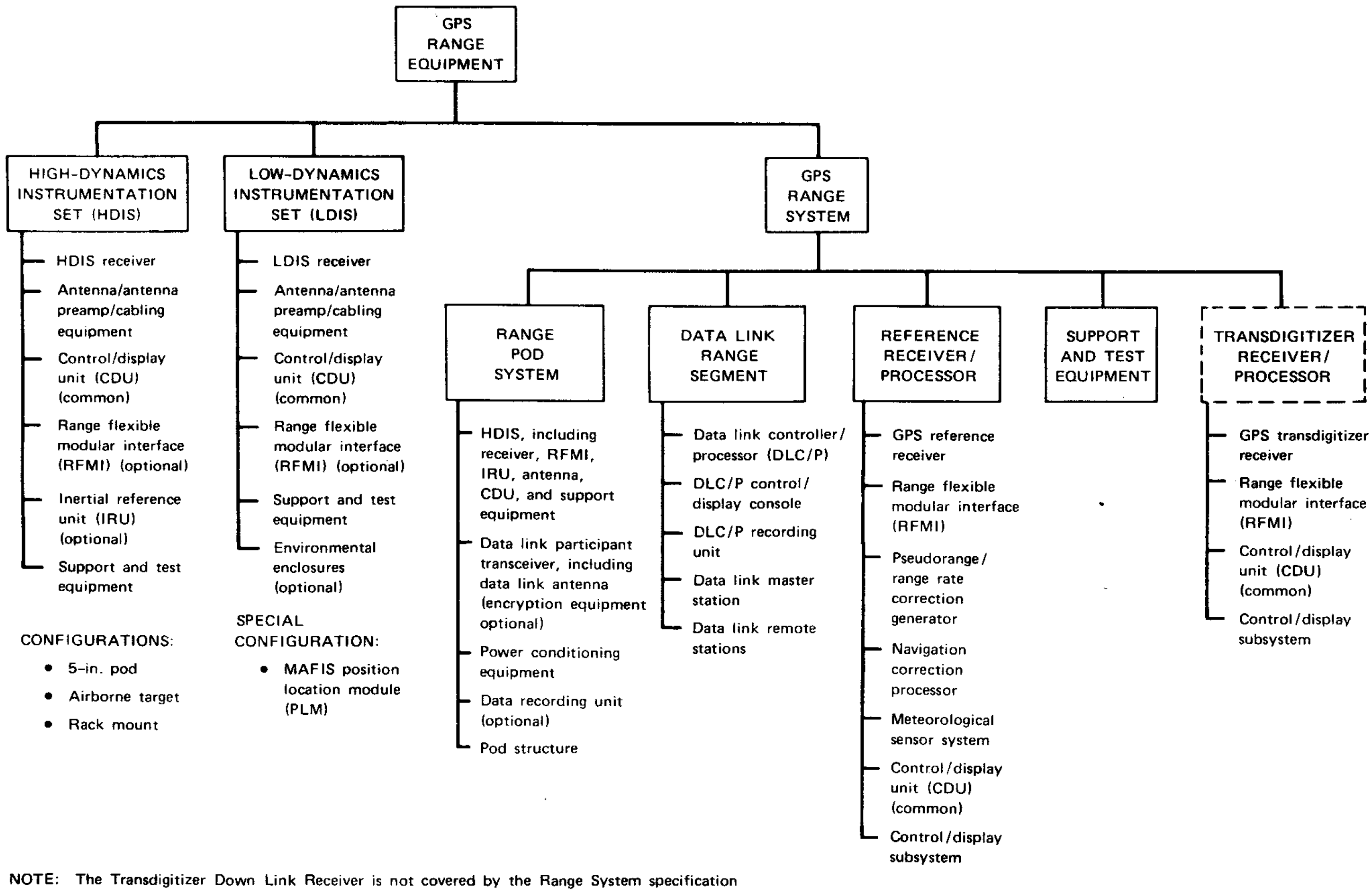


**Figure 1 - GPS Range Equipment Configuration Item Tree (Phase I)**

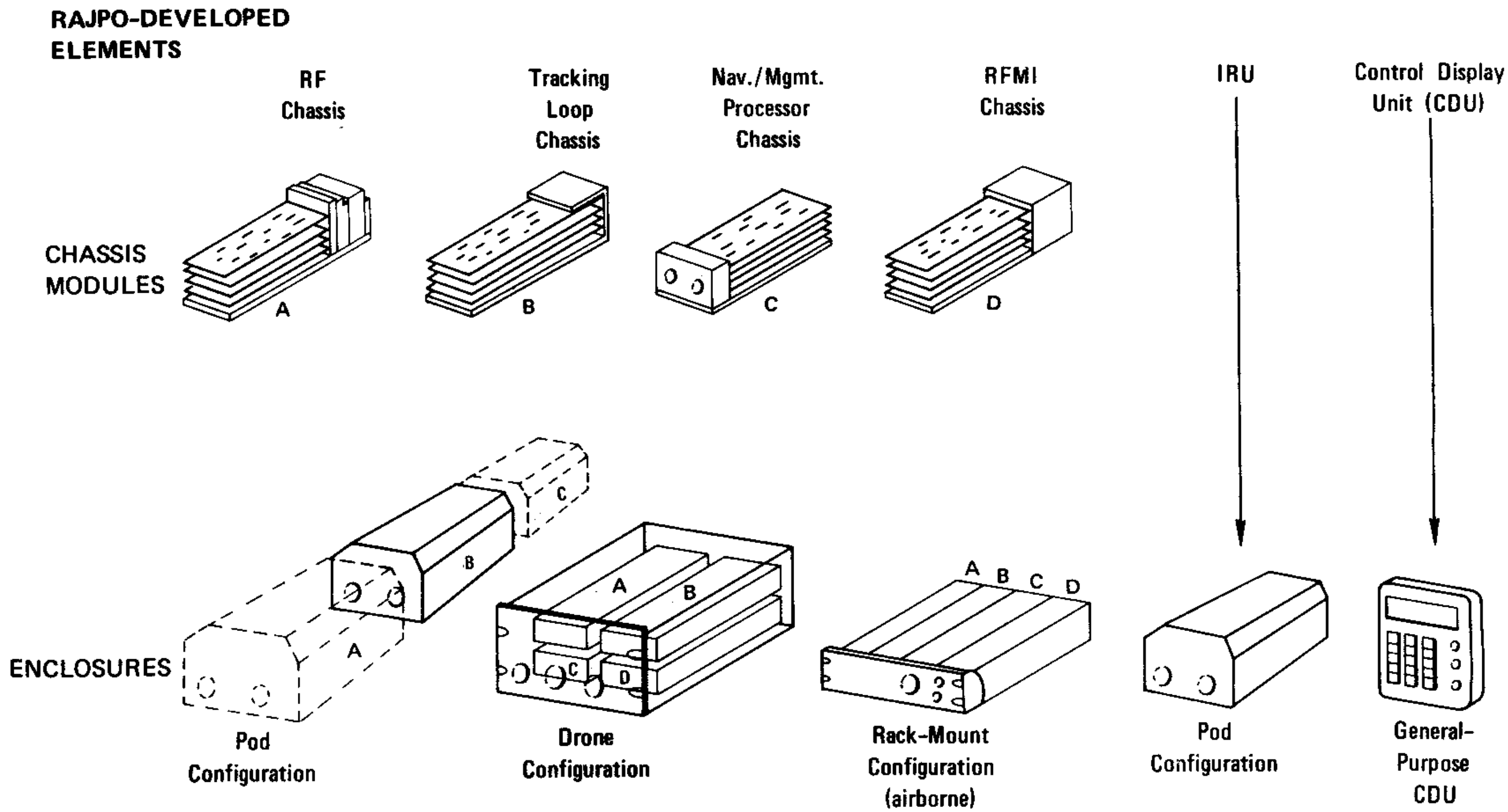


**Figure 2 - Common Elements for the HDIS Configurations**

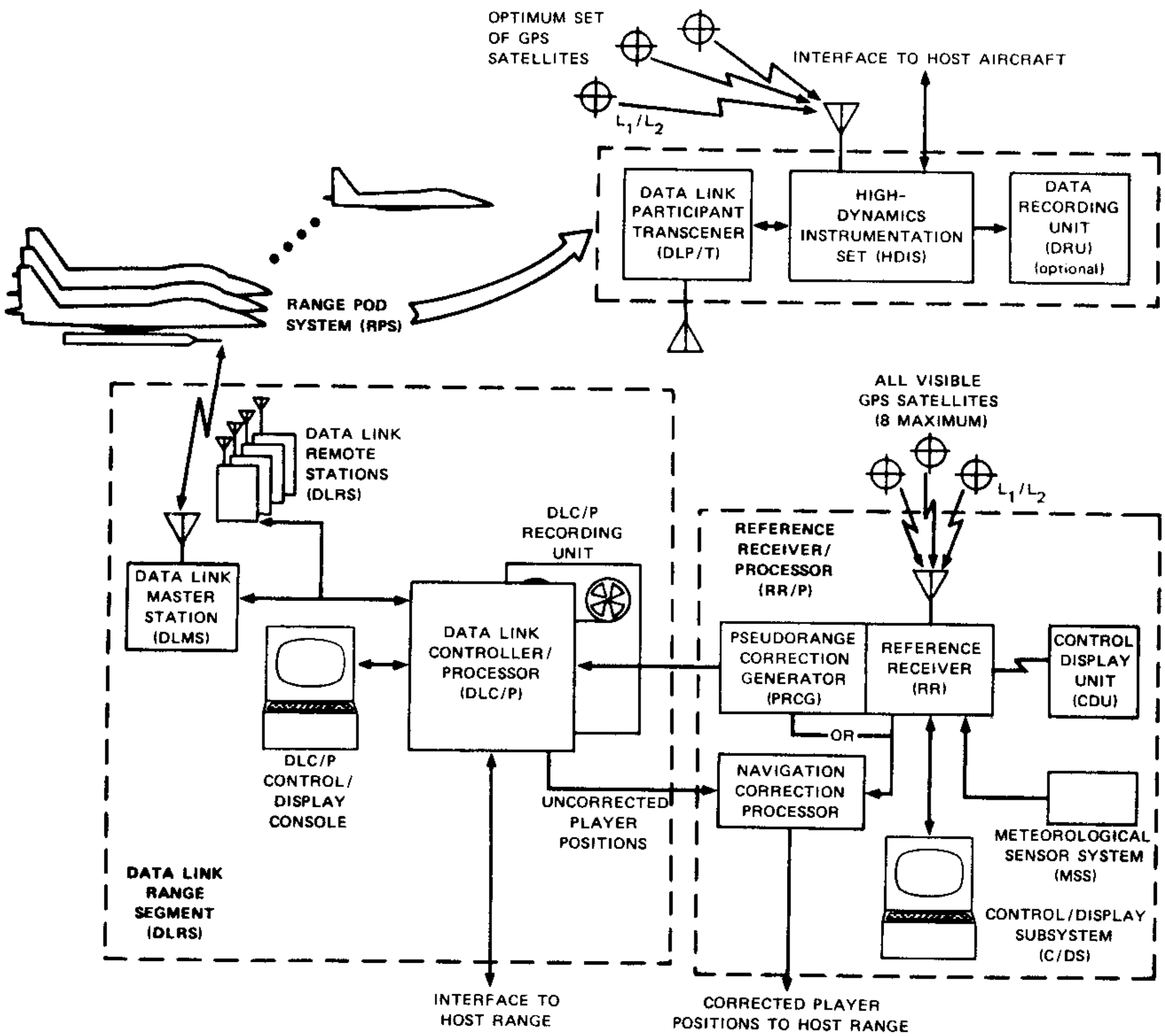


**Figure 3 - GPS Range System Functional Diagram (major systems shown)**

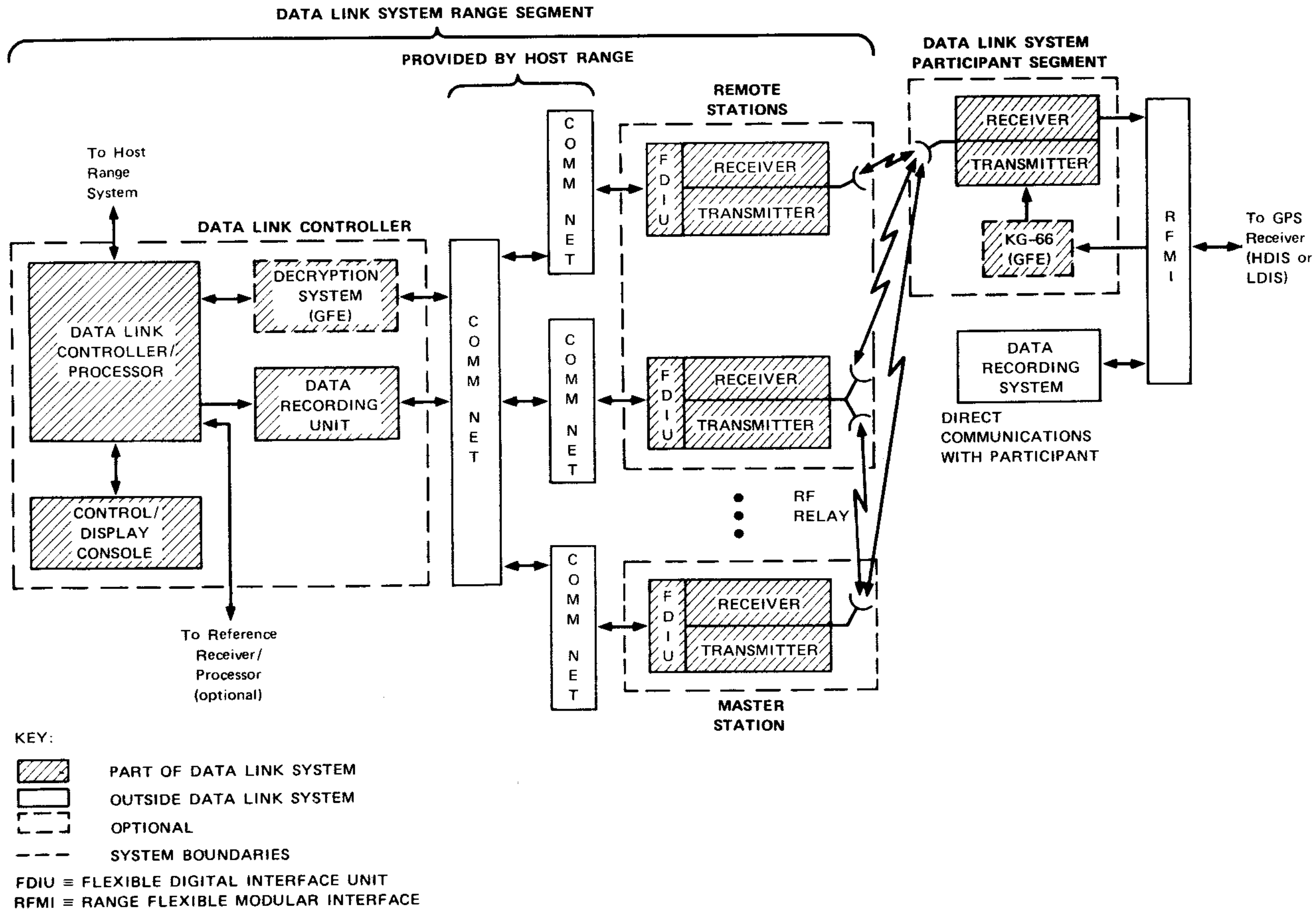


**Figure 4 - GPS Range Equipment Data Link System**