GPS SOLVES THE COMBAT PILOT TRAINING RANGE PROBLEMS

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ABSTRACT

For more than 20 years combat pilot training instrumentation has taken place on Air Force and Navy TACTS/ACMI ranges. The original ranges were designed to instrument a cylinder in space 30 miles in diameter from 5,000 feet to 55,000 feet and to handle up to eight participants. As fighter combat techniques have advanced and battle tactics have been revised to take into account more advanced weapons systems, the capabilities of the existing ranges have become extremely taxed. For example, modifications have been added on to the original systems so that the tracking altitude could be lowered to 100 feet (by adding radar altimeters to the instrumentation pods); the number of participants could be increased to 36 (by lowering the system sample rates), and the range area could be expanded (by increasing the number of ground tracking sites required from seven to a dozen or more). Clearly these were bandaid fixes, and the total capability of the ranges suffered, but since no satisfactory alternate systems were available, these systems continue to be used. During the past twenty years, however, significant advances have taken place in all areas of instrumentation system technology. By the application of modern technology, a new generation of air combat training ranges cm be made available that will greatly enhance the training capability of our armed forces and will be capable of training them in the new tactics required by the fighter weapons systems of the future. Among these training advantages will be the following capabilities:

- Tracking over an entire 25,000-square-mile or larger range area.
- Precision tracking of up to 100 participants.
- Tracking of all vehicles from ground level to 100,000-foot altitude.
- Only a few nonsurveyed portable groundsites will be required.

- An unlimited number of portable unmanned threat emitters can be provided at a fraction of the cost of existing threats.

- The entire range can be made portable.

- Modern display capability will greatly enhance pilot recall ability required for mission debriefing.

By applying GPS, optimizing the datalinks, and restructuring the range design concept, these advantages can be realized. This paper discusses the application of modern range system technology to the design of the TACTS/ACMI ranges of the future.

INTRODUCTION

The use of existing Global Positioning System (GPS) receivers and advanced datalinks provides the capability of unlimited air combat maneuvering area, very low-altitude instrumentation coverage in remote uninstrumented areas, uses fewer groundsites that are portable and not surveyed, and provides enhanced capabilities for the use of low-cost threat emitters for more effective and realistic air combat training. The architecture of this advanced type of air combat training system is an extension of the highly successful air combat maneuvering instrumentation (ACMI) system currently in use [1] but replaces the surface-based multilateration tracking solution with one that is participant-based, utilizing GPS satellite measurements and outboard distributed processing. With the tracking solution thus independent of the air-to-ground datalink, advanced datalink concepts can be used, allowing player-to-player or player-to-high-flyer aircraft relay. In this way, extremely large air combat maneuvering areas can be instrumented with uniformly high tracking accuracy, and very remote low-flying players can be tracked and their data recovered by the relay datalink.

The pod-mounted GPS receivers required are developed, and test results are available [2] showing 6 ft and 1.7 ft/sec horizontal errors and 12 fit and 2.7 ft/sec, vertical position errors. An advanced datalink is also in development [3], which provides the player-to-player relay capability.

With the modernization of air warfare and the resulting sophistication of air weapon systems, the need for combat pilot training has increased significantly during the past 20 years. Advanced air warfare tactics result in the requirement for extensive low-level flying to provide terrain screening against threat systems. Aircrew training in the tactics of modern air-warfare, therefore, requires extensive areas of unrestricted airspace down to ground level. Precision position of the training aircraft must be known at all times over this entire airspace. Modern training requirements now require keeping track of the precise position of up to 100 aircraft over an area of up to 25,000 square miles at altitudes from ground level to 100,000 feet. In addition, environmental considerations for such large range areas demand that this instrumentation be accomplished with a few portable groundsites and still obtain high position accuracy of all of the players. These are the requirements that tax the capability of our existing air combat training systems.

ACMI ARCHITECTURE

The currently used ACMI architecture is illustrated in Figure 1 [1]. A group of surface-based remote stations is deployed on the range area on surveyed and geodetically stable sites. For ground application these are solarpowered and are mounted on towers. Over water, they are also towers, since position location depends upon their being stable and in surveyed locations. Older systems employed these towers typically on a 30-mile-diameter circle, and the instrumented airspace extended from about 5,000 to 50,000 feet in altitude. Newer system have been expanded to cover a 20- by 65-mile area for monitoring aircraft down to 100 feet, and 95 by 40 miles for coverage down to 500 feet above ground level [4]. This was done by adding more ground stations and a radar altimeter in the pod.

The description of the ACMI system operation from reference 1 is as follows:

> The remote stations are controlled by the Tracking Instrumentation Subsystem (TIS) master station, normally located within line-of-sight of all the remote stations to avoid relay stations. The master station measures the loop range from the master to the station selected to be the interrogator, then to the selected pod of the Airborne Instrumentation Subsystem (AIS), and back to remote and master stations. Each remote station receives the pod transmission and returns the signal to the master, providing simultaneous range measurement to all remote stations. The range from each remote to master station is realtime calibrated and subtracted from the loop range to provide slant range from each remote station to the particular aircraft being interrogated. Each participant on the range is interrogated in turn through the remote station most likely to achieve the communication link. All participants are interrogated at least five times per second (this was later reduced to add more players to the system). Digital data is transmitted from the master station to the pod and in turn receives digital data from the pod during each interrogation. The master station formats collected data and interfaces to the Control and Computation Subsystem (CCS) via a microwave datalink. The CCS contains the main data processor for the system and provides executive software for system control. Kalman filtering of all aircraft state vector data and weapon simulation provides the best estimate of state vector, air data, and range status to the DDS at a rate of 10 per second. The Display and Debriefing Subsystem (DDS) is the man-machine interface and provides realtime display and control of the entire system.

Multiple DDS can be interfaced to the CCS to allow control, monitoring, backup, and replay simultaneously.

This system has been extremely successful for combat pilot training. A great number of installations have been made, and it is currently by far the most successful system for combat pilot training ever conceived [4].

Since the multilateration stations are all on the ground, the vertical dilution of precision (VDOP) of the system is very poor at low altitudes up to about 5,000 feet. This characteristic limits the vertical accuracy at low altitude and forces use of a radar altimeter [4] to supplement the vertical measurements.

Also, as explained in the system description, the master station must be in line-of-sight of the remote stations unless relay stations are used. This factor puts limitations on the size range area that can reasonably be covered.

GPS RAP EQUIPMENT [2, 3]

Office of the Undersecretary of Defense for Research and Engineering provides the instrumentation for the Major Range and Test Facility Base (MRTFB). In 1981 this office investigated the use of an orbiting radio multilateration system, the Navstar GPS to meet the time and space-position information (TSPI) requirements of the MRTFB.

A tri-service GPS range applications steering committee contracted with The Analytic Science Company (TASC) to summarize these requirements. The study sampled 22 ranges, including Training Ranges and Operational Test and Evaluation (OT&E) ranges, as well as Developmental Test and Evaluation (DT&E) ranges. The final steering committee report in January 1983 concluded that GPS could satisfy about 95 percent of TSPI range requirements and would be cost effective.

The Range Applications Joint Program Office (RAJPO) was established at the United States Air Force Armament Division at Eglin Air Force Base in 1983. Mr. Tom Hancock was appointed program manager of the Tri-Service GPS-RAP. A Transition Advisory Group was established to create the specifications for the GPS range hardware and system. A contract to perform the full-scale engineering development of the GPS-RAP system was awarded to Interstate Electronics in 1985.

As a result of this development, pod-mounted GPS receivers have been developed and are in test [2]. Also, an advanced datalink is in development [3]. Early test results indicate that the accuracy specifications of Table 1 are being met, providing equipment that exceeds ACMI accuracy requirements. Accuracy improvement, however, is only a minor part of the improved capability afforded by GPS in an ACMI system.

Table 1. Realtime Accuracy Under Dynamic Conditions
HDOP = 1.5, VDOP = 2.5
Differential P-Code
Inertial Aiding
Dynamics to 10g and 10g/sec

		Accuracy
RMS	Position (ft) Horizontal Vertical	 6 12
RMS	Velocity (f) Horizontal Vertical	 1.7 2.7

Two basic techniques must be considered when utilizing GPS for the instrumentation of a flight test vehicle. These are the use of a GPS receiver aboard the vehicle and datalinking its position to a ground station, or recording onboard or the use of a GPS frequency translator aboard the vehicle, which simply receives the satellite signals at L-band and retransmits them to a ground station at S-band. The position solution of the test vehicle is then performed at the ground station. There are many advantages to the use of a GPS frequency translator tracking system. These advantages include small size and weight, low cost, rapid signal acquisition and time-to-first-fix, the ability to predetect record the GPS signals for postflight analysis at the ground station, a 6-dB carrier tracking advantage over an onboard receiver, an inherently differential system and postflight optimization of position determination. The principal advantages of the use of an onboard GPS receiver for position determination are that the position is known aboard the test vehicle, downlink encryption is possible, and there is no theoretical limitation to the number of test vehicles to be tracked simultaneously.

Pictures of the various types of GPS flight test instrumentation hardware are shown in the following Figures. Figure 2 illustrates a GPS instrumentation receiver, while figure 3 depicts a GPS instrumentation pod containing GPS receiver, inertial reference unit, datalink, encryption device, and data recorder. Figure 4 contains a GPS frequency translator, and Figure 5 shows a translator processing system. All of this hardware has been produced and is currently operating at flight test ranges in the United States.

The vertical dilution of precision (VDOP) of the GPS system varies typically from 2 to 4 (with a full-satellite constellation) with 2.5 being typically used for specification purposes, making use of a radar altimeter unnecessary.

GPS IN AIR COMBAT TRAINING SYSTEMS

With the tremendous success of current ACMI systems, why change it? A great many pods are in the inventory. Wouldn't it be best to stay with the current architecture? After all, it has been extremely successful.

To take advantage of the benefits of GPS, major changes in existing system architecture must occur. Simply adding GPS to the existing systems with no other changes does not begin to exploit the available benefits. The potential benefits from full use of the GPS capabilities are outlined in the section Advantages of the GPS Approach.

The required ground systems would be minimized, and some 8 (16 in the Red Flag Measurement and Debriefing System [4] stable and surveyed ground locations for position location would no longer be required. The new datalink could accommodate player-to-player data relay so that the entire enlarged range area could be covered down to ground level with a minimum number of groundsites, depending upon the terrain.

Each GPS pod would also be equipped with a single-card solid-state recorder so that complete replay of the training mission could be performed postflight if data transmission from the vehicles to the ground station were interrupted. The existing mission debrief display systems do an outstanding job. Advantages of advanced display technology, however, could enhance the recall ability of the pilots during postmission analysis and also improve display of terrain screening effects. Fortunately, most of the software would be useful in its present form.

ADVANTAGES OF THE GPS APPROACH

The advantages for the GPS are discussed in the following paragraphs.

Unlimited Instrumentation Area

GPS affords the possibility of greatly expanding the air combat maneuvering area since it is a satellite-based system not requiring that ground-based installations be spread over the entire area. With advanced datalinks (such as the RAJPO datalink) having player-to-player relay, it is even possible to operate at 100-foot altitudes way beyond the instrumented area by using a high-flying aircraft for data relay purposes. This concept of operation is not possible in the current ACMI architecture because player-to-player relay cannot occur with the ranging and data transmission combined into one link. This greatly limits the area of coverage since line-of-sight is required from at least three surveyed ground stations. The result is that the participant aircraft can pass over the instrumented area in a very few minutes. Thus, GPS affords the advantage of instrumenting engagements in a more realistic manner over an unlimited area.

Low-Altitude Coverage In Remote Uninstrumented Areas

Modern air warfare and electronic combat operations rely heavily upon terrain screening to avoid detection by radar-controlled SAM sites. GPS, when used with a modern datalink having player-to-player relay, affords the possibility of instrumenting the participants even when flying in remote valleys to obtain terrain screening. It thus expands the training possibilities.

Fewer Surface Sites, Portable and Not Surveyed

By nature, a GPS approach requires only ground or surface sites for communication purposes and not for location. They do not have to be surveyed, and more significantly, they do not even have to be stationary. When operating over water, they could be tethered buoys with some random motion, making them much more cost effective than the stationary surveyed towers used for over-water ACMI systems. Ground-based communication sites can be portable and unsurveyed, allowing a portable air combat training range. As mentioned before, even high-flying aircraft can be used for relay purposes and could be used as datalink remote stations with advanced datalink architectures.

Makes TSPI Independent of Datalink

By separating the position location function from the datalink, advanced datalink concepts can be used. One mentioned above is player-to-player or player-to-relay aircraft, which allows instrumenting players at low altitude in remote areas. Also, multiple datalink frequencies can be used for the air-to-ground data to greatly increase the number of players.

GPS-Steered Threats

GPS-steered unmanned threat emitters [4, 5] can be used in place of the costly existing manned threats and can be configured to be controlled with less time delay and greater accuracy than through the ACMI system.

Accuracy

GPS position accuracies have been shown in RAP testing [2] already done (and more is now being done) to be on the order of 6 ft and 1.7 ft/sec horizontal and 12 ft with 2.7 ft/sec vertical when differential GPS is used. More is involved than just these accuracy numbers. With GPS, the position, velocity, and acceleration are computed onboard the aircraft; thus the inherent accuracy is not dependent on datalink dropouts caused by terrain or aircraft masking, etc. With ground-based multilateration as used in the ACMI, a radar altimeter must be used to get vertical accuracy at low altitude since the geometry of the tracking stations is in a plane. The altimeter is not necessary with GPS.

CONCLUSIONS

The use of GPS along with advanced datalinks, such as the RAP datalink, opens up many new dimensions in air combat training, such as unlimited instrumentation area, low-altitude coverage even in remote valleys, fewer groundsites, use of only portable unsurveyed groundsites and new possibilities in economical threat emitters.

REFERENCES

1. Eaton, G.W., “Air Combat Maneuvering Range/Instrumentation ACMR/I”, *IEEE PLANS* ’76, Position Location and Navigation Symposium, Nov 1-3, 1976k, IEEE Pub. 76CH1138-7 AES.

2. Kaatz, G., T. Kido,, C. Richmond and R. Snow, “Test Results for the High Dynamics Instrumentation Set (HDIS),” presented to the Institute of Navigation Satellite Division Technical Meeting, *Proceedings of ION GPS-89*, 27-29 September 1989, pp. 87-102.

3. Birnbaum, M., R.F. Quick Jr., K.S. Gilhousen and J. Blanda, “Range Applications Joint Program Office GPS Range Datalink,” presented to the Institute of Navigation Satellite Division Technical Meeting, Proceedings of *ION GPS-89*, 27-29 September 1989, pp. 103-108.

4. Kempf, P.T., “A New Dimension in Aircrew/EW Training, Red Flag Measurement and Debriefing System,” *Journal of Electronic Defense*, Sept. 1986, pp. 51-60.

5. Giadrosich, D.L., “Range Instrumentation for Electronic Combat,” *Journal of Electronic Defense*, Sept. 1986, pp. 65-68

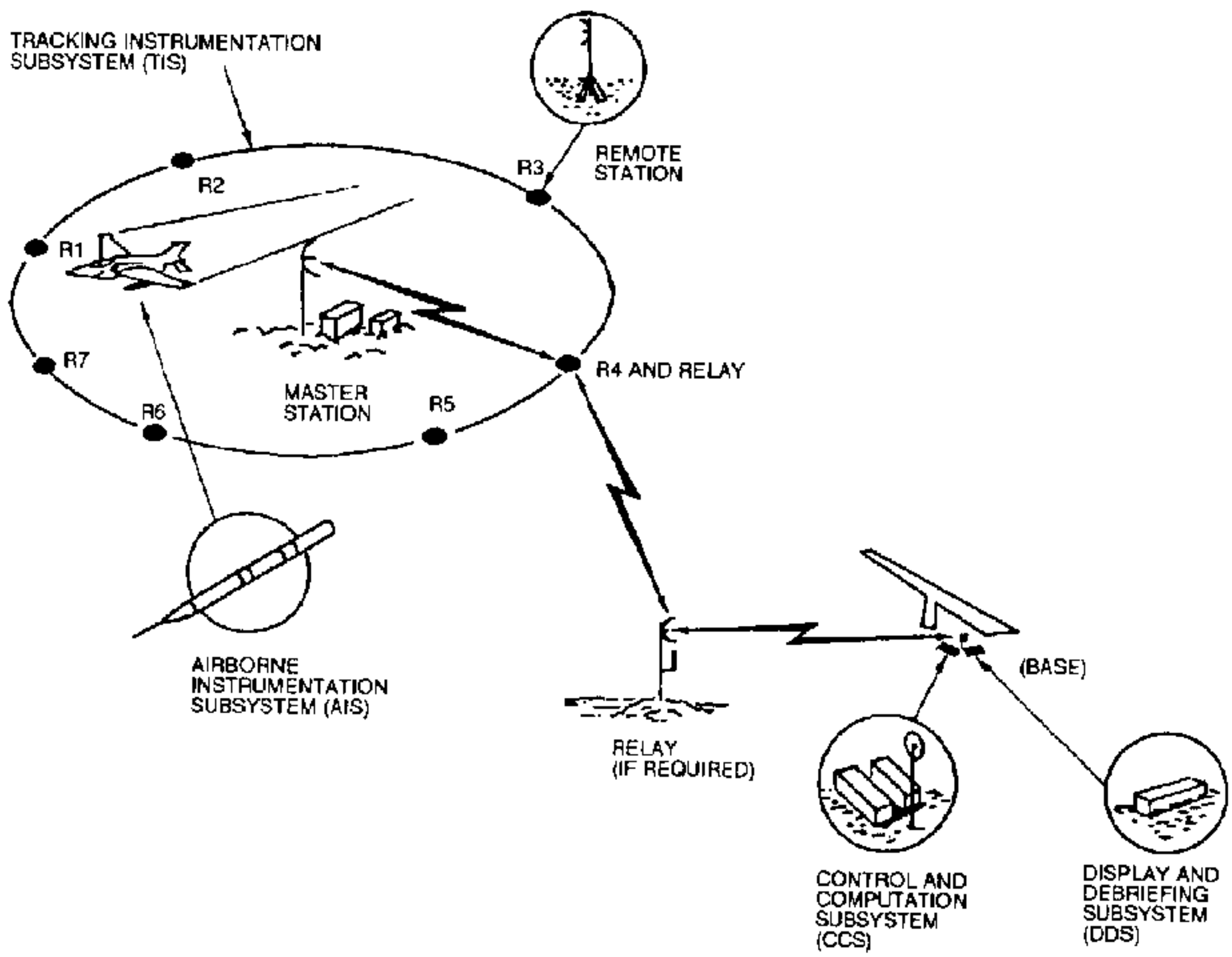

Figure 1. Representative ACMR/I Configuration

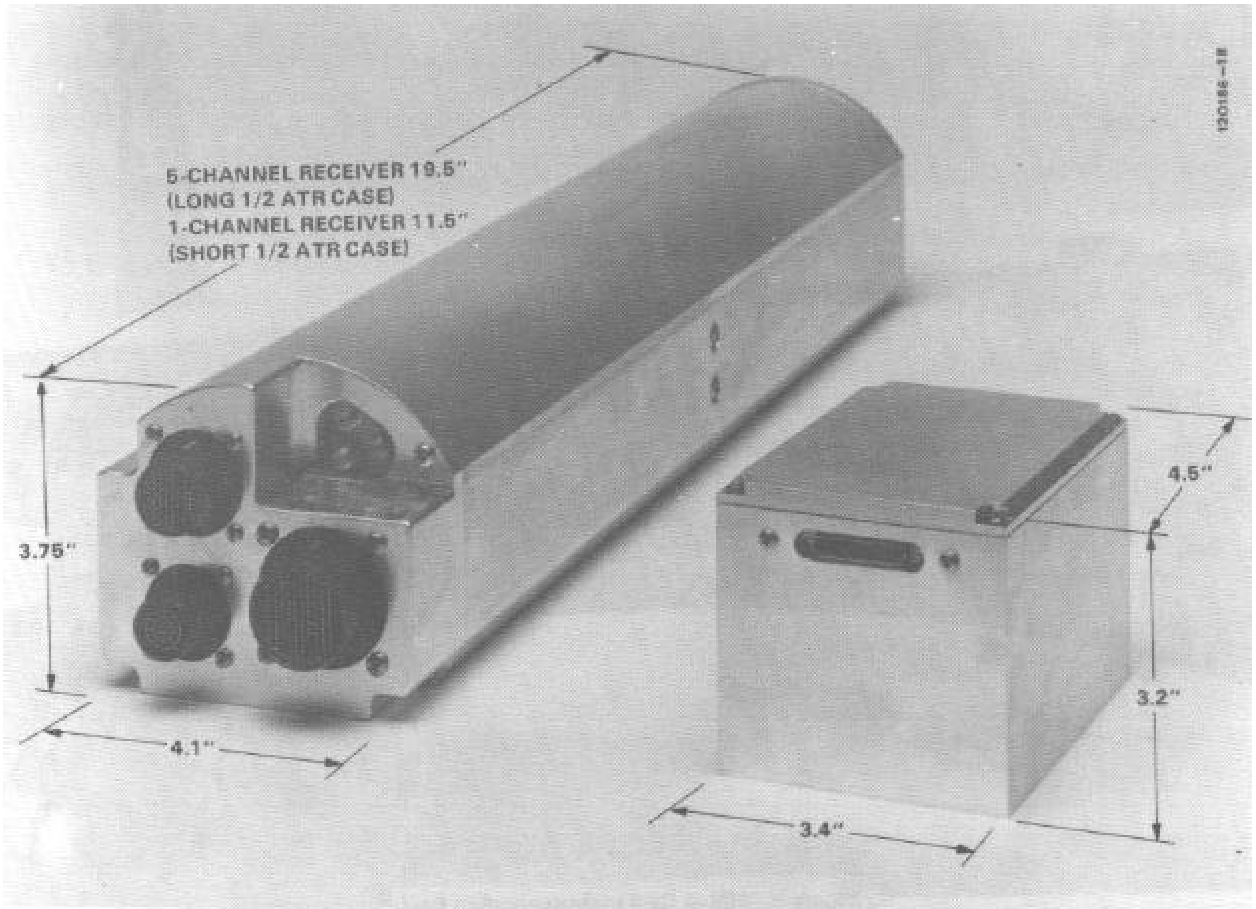

Figure 2. Advanced GPS Receiver

Figure 3. AIM-9 GPS Instrumentation Pod

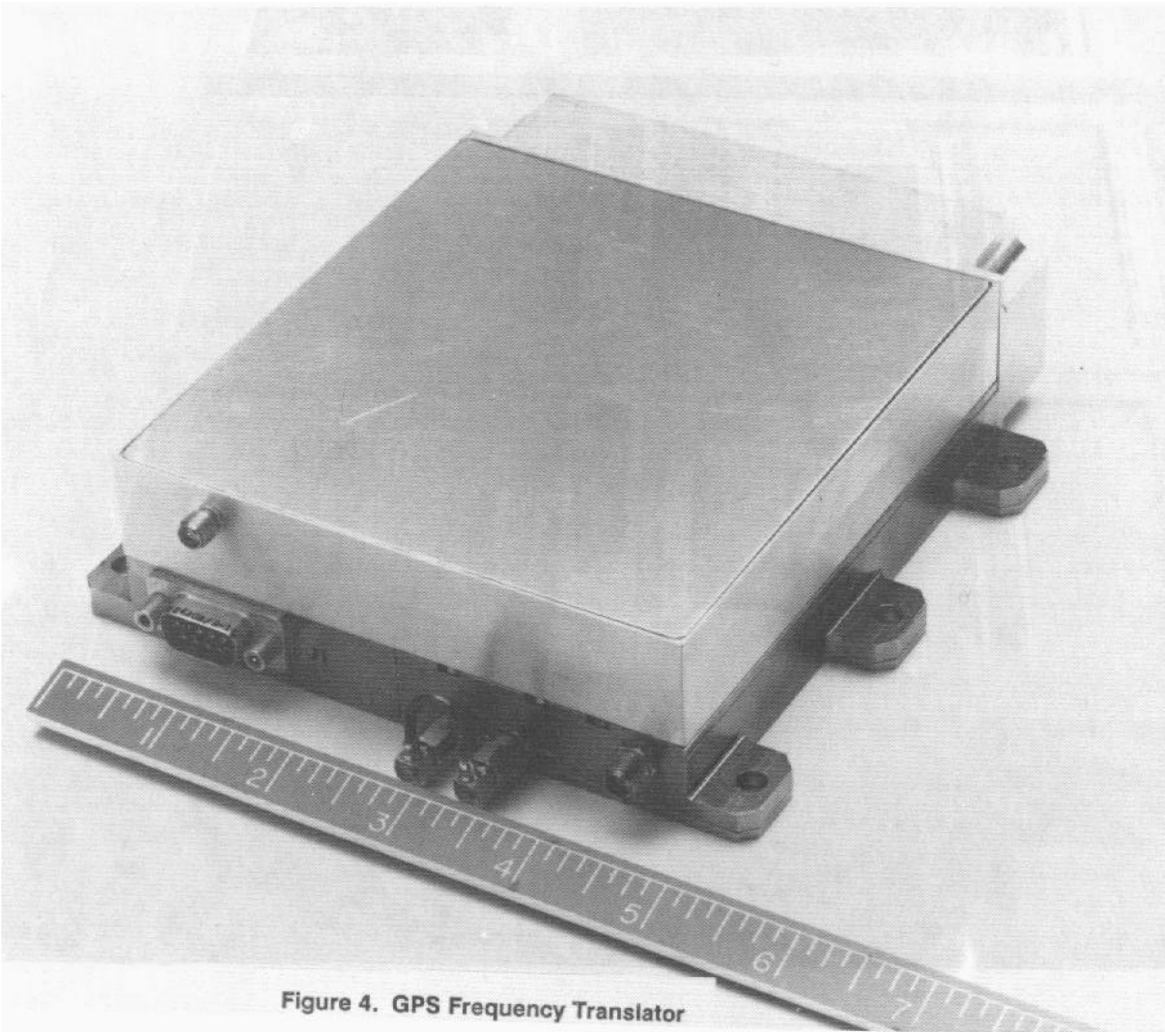

Figure 4. GPS Frequency Translator

Figure 5. Translator Processing System