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Inertial survey applications to civil works

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7. **FERRANTI INERTIAL LAND SURVEYOR (FILS).** The Ferranti Inertial Land Surveyor evolved from the British Military PADS, which in turn evolved from military aircraft systems designed for the British Armed Forces by Ferranti Limited of Great Britain. At present, three FILS-2 and two FILS systems are in operation with Shell Canada Resources, Limited. The system is shown in Figure 16. Smoothing cannot be accomplished immediately after completion of the traverse. During the traverse, all the data is transferred to a digital cartridge recorder for post-mission smoothing at a central processing point. Since FILS-2 is not made in the United States it is not being considered for purchase by the Corps at this time.

8. **USGS AERIAL PROFILING OF TERRAIN SYSTEM (APTS).** The Aerial Profiling of Terrain System is being developed by the Charles Stark Draper Laboratory, Inc., for the United States Geological Survey to provide a precise airborne survey system capable of measuring elevation profiles across various types of terrain from a medium to light aircraft at flight heights up to 1000 meters above the terrain. The systems design accuracy goals are a horizontal position accuracy of 60 centimeters and a vertical position accuracy of 15 centimeters with 90 percent reliability level.

The airborne instrument package, shown in Figures 17 (a), 17 (b), and 17 (c) contains a three-gimbal inertial platform to define the position of the aircraft in three coordinates. A two-axis laser tracker is used to determine long-term drift errors of the inertial platform (the laser tracker will provide the external-aided information similar to the ZUPT data described previously). Three or more positioned retroreflectors over known stations interspersed with several other reflectors (positioned by the laser tracker) will provide ground truth. The inertial platform and laser tracker will provide the position datum and a laser profiler will perform distance measurement from the aircraft to the terrain.

The APTS is one of a kind system and at the present time cannot be considered for use as an inertial survey system for the Corps due to the high cost of purchase and maintenance.

IV. OPERATIONAL RESULTS IN THE USE OF INERTIAL SURVEY SYSTEMS

1. **GENERAL.** The extensive use of inertial navigation systems for surveying purposes started in 1975. Since that time, they have been mounted in trucks, tracked vehicles and helicopters and have operated from the northern slopes of Alaska and Canada, in extreme cold weather, to the hot deserts of Saudi Arabia. The systems have been used to determine land boundaries in the wilderness of Alaska; to position survey markers in cities; to establish basic geodetic control; to provide control for various types of mapping; to assist in route selection of roads, railroads, pipelines and electrical transmission lines; and to obtain positions in geophysical work for gravity and seismic surveys. The following portions of this chapter will deal with the operational results of inertial survey systems by various United States and Canadian Government agencies as well as private companies engaged in inertial survey work.

2. **UNITED STATES ARMY.** The United States Army has awarded a contract to Litton Systems, Inc. for delivery of approximately 102 PADS for use by the Field Artillery. The PADS will greatly enhance the capability for the Artillery to survey positions for various weapons systems. The Field Artillery School used one of the developmental PADS for training purposes for a year. During this period they were requested to do two survey projects. One survey project was at the National Training Center, Fort Irwin, California, and the other project was at Fort Chaffee, Arkansas.

A team of two soldiers, using a 1/4-ton truck-mounted PADS, began the survey at the National Training Center on 15 October 1980, and finished the job on 5 November 1980. During this period, they surveyed 450 miles and established a total of 1250 control points in an actual work time of 17 days. In comparison, a conventional survey party of 7 people would require 100 days to accomplish the same task.

The second survey task was to locate 34 survey control points at Fort Chaffee, Arkansas. A reconnaissance of the area (extensively wooded), indicated that a conventional survey party (7 people) would require about 3 weeks to complete the survey. The PADS was airlifted from Ft. Sill, Oklahoma to Fort Chaffee where it completed the survey mission in less than 6 hours.

3. **DEFENSE MAPPING AGENCY.** Operational testing of the Litton inertial survey system known as the Inertial Positioning System (IPS I) was completed in early 1976, when the system became operational for production purposes. Since that time, the system has accomplished various types of projects, which are listed in Table 1.

The system was used in various carriers from 4-wheel-drive vehicles to helicopters over all types of terrain. An analysis of an MX support survey accomplished in the August-November 1978 time frame, with the system mounted in a helicopter, shows an average daily production rate of 20 stations per day with a high production of 60 stations for one day. The data collected during this period shows horizontal positions accurate to 0.5 meters and elevations accurate to 0.3, meters which satisfied the project requirements. To obtain these accuracies, the helicopter was flown in fairly straight lines between the initial and terminal update points. ZUPTS were done every 3 minutes and traverse lengths were held to distances under 45 kilometers. Each traverse was double run. Greater accuracy could have been obtained by using a shorter time interval between ZUPTS and placing the IMU on the ground when performing ZUPTS and updates.

Table 1. DMA Projects Completed With IPS I - March 1976 - April 1981

PROJECT	LOCATION	POINTS	KILOMETERS	MAN-YEARS SAVINGS
Aircraft Navigation	Southeast U.S.	5	480	0.5
Test Range	California	43	970	1.0
Aircraft Navigation	Wyoming	5	1,210	0.5
Aircraft Points	Michigan	28	80	0.3
Mapping Surveys	Maine	329	2,900	4.0
Aircraft Points	N. Central U.S.	264	645	1.5
Mapping	Yucatan, Mexico	371	4,345	5.0
Test Range	Louisiana	100	300	0.6
Aircraft Navigation	North Dakota	1	80	0.2
Radar Site Survey	Korea	507	1,860	5.0
MX Support	Western U.S.	1,035	6,200	5.0
Weapons Range	Oklahoma	465	400	2.0
Gravity Surveys	California	700	1,010	4.0
Cruise Missile Survey	Missouri	9	350	2.0
MX Support	Western U.S.	1,320	3,000	1.5
TASVAL	California	13	635	1.0
MX Validation	Nevada/Utah	3,200	22,400	24.0
TOTALS		8,395	46,865	58.1

To-date, an estimated total of 58.1 man-years have been saved by DMA with the use of IPS I. The original cost of IPS-I was $605,000 with an additional $400,000 being spent for spare parts and maintenance. An additional $100,000 must be charged to transportation other than the basic vehicle (primarily helicopter time). This brings the cost of the inertial system use to $1,105,000 since 1976. The average total cost (salary, overhead and benefits) of a surveyor for 1 year will conservatively be figured at $35,000. A savings of 58.1 man-years by using the IPS translates to a dollar savings of $2,033,500.

In September 1979, Honeywell delivered their GEO-SPIN system to DMA. Since that time the system has been undergoing extensive test and evaluation. Excellent positional accuracies have been obtained with the system. On courses with a length of 32 kilometers, the system shows an accuracy of 0.5 meters in horizontal positions and 0.3 meters in elevations. The system is undergoing some modifications and further testing.

4. **BUREAU OF LAND MANAGEMENT.** The U.S. Department of the Interior, Bureau of Land Management (BLM) completed testing the Litton Auto-Surveyor in 1975. These tests were conducted to determine if the inertial system could be used to perform cadastral surveys for the United States Government, as well as, being used to monitor contractors doing cadastral surveys. The Litton Auto-Surveyor was sent to Alaska. Since most of the cadastral work to be done in Alaska was in remote areas, the system was mounted in a helicopter.

The primary task to be accomplished was the establishment of section corners every 2 miles on the exterior lines of townships. Normal production for the inertial survey system in Alaska is about 36 section corners over traverse lengths of 70-80 miles. On exceptionally good days, a total of 100 corners over traverse lengths of 200 miles have been obtained. A conventional survey crew would average 4 to 6 points over traverse lengths between 6 to 10 miles.

BLM has been so impressed with the operation of the Auto Surveyor that additional units have been purchased. A total of three sytems are now being operated by BLM. The systems are used in Alaska during late spring, summer, and early autumn. The rest of the year, the units are refurbished and used on projects in the western United States. BLM officials of the Anchorage Office feel that Inertial Survey Systems will decrease the time needed to finish the basic work in Alaska by 50 percent.

5. **CANADIAN DEPARTMENT OF ENERGY, MINES AND RESOURCES.** The Geodetic Survey Division of the Canadian Department of Energy, Mines and Resources (EMR) purchased an inertial survey system from Litton in 1975 for the purpose of producing mapping control faster and more economically. The year 1975 was spent conducting a series of tests to define operational procedures and to train the required personnel. Tests were performed using both vehicle and helicopter mode. The helicopter mode of operation was used for almost all major projects which included establishing basic control as well as mapping control.

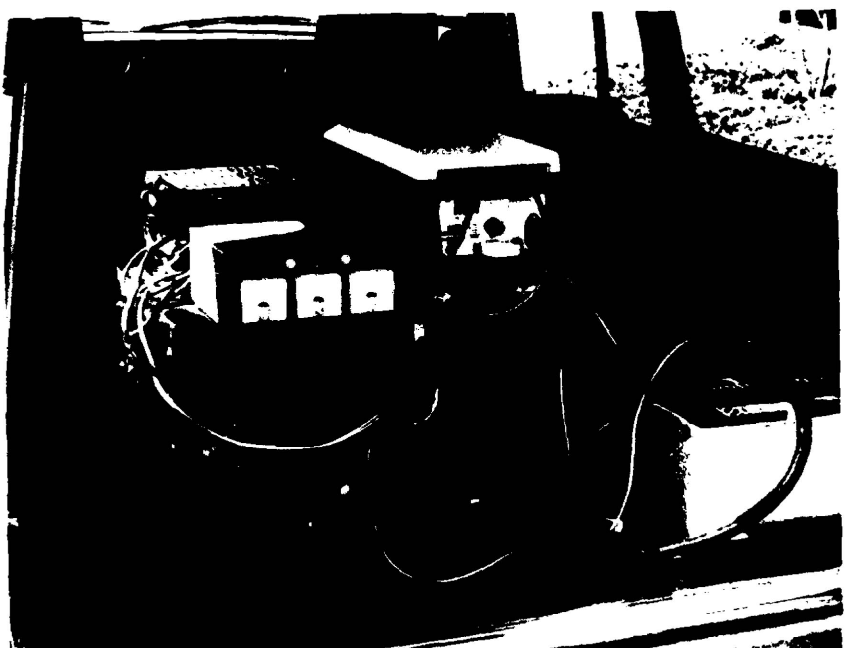

Figure 16. Ferranti Inertial Land Surveyor (FILS)

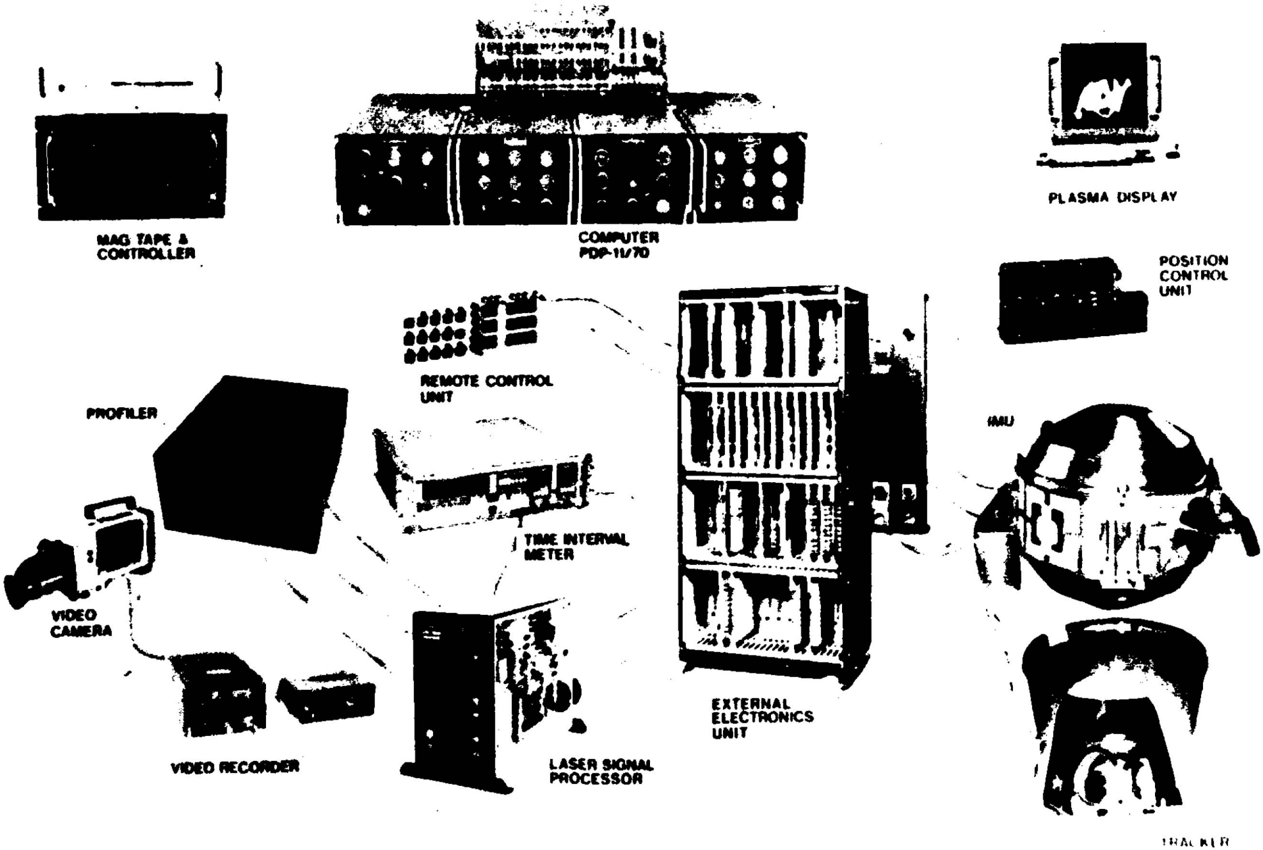

Figure 17a. Aerial Profiling of Terrain System (APTS) Major Assemblies

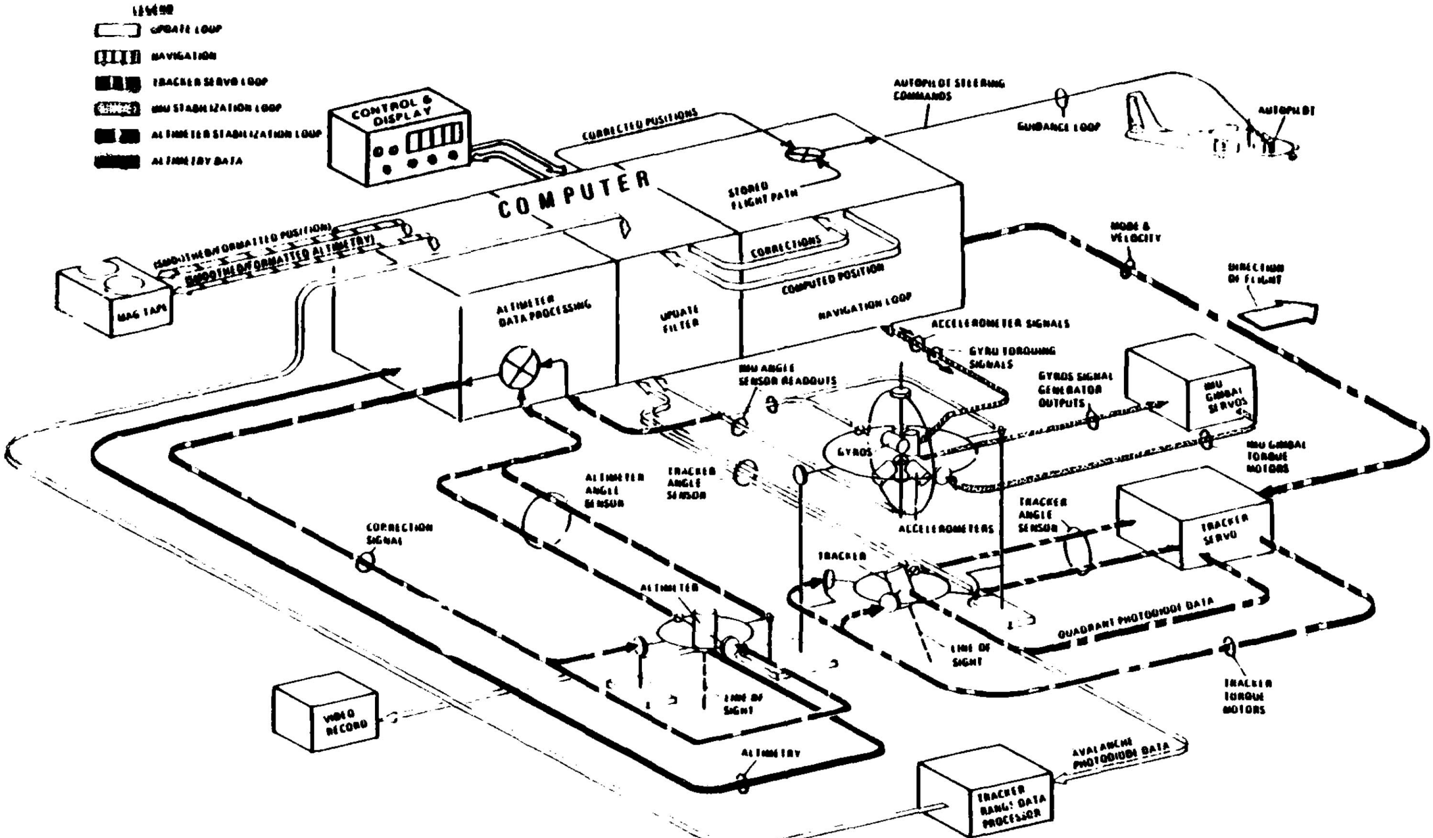

Figure 17b. APTS Functional Diagram

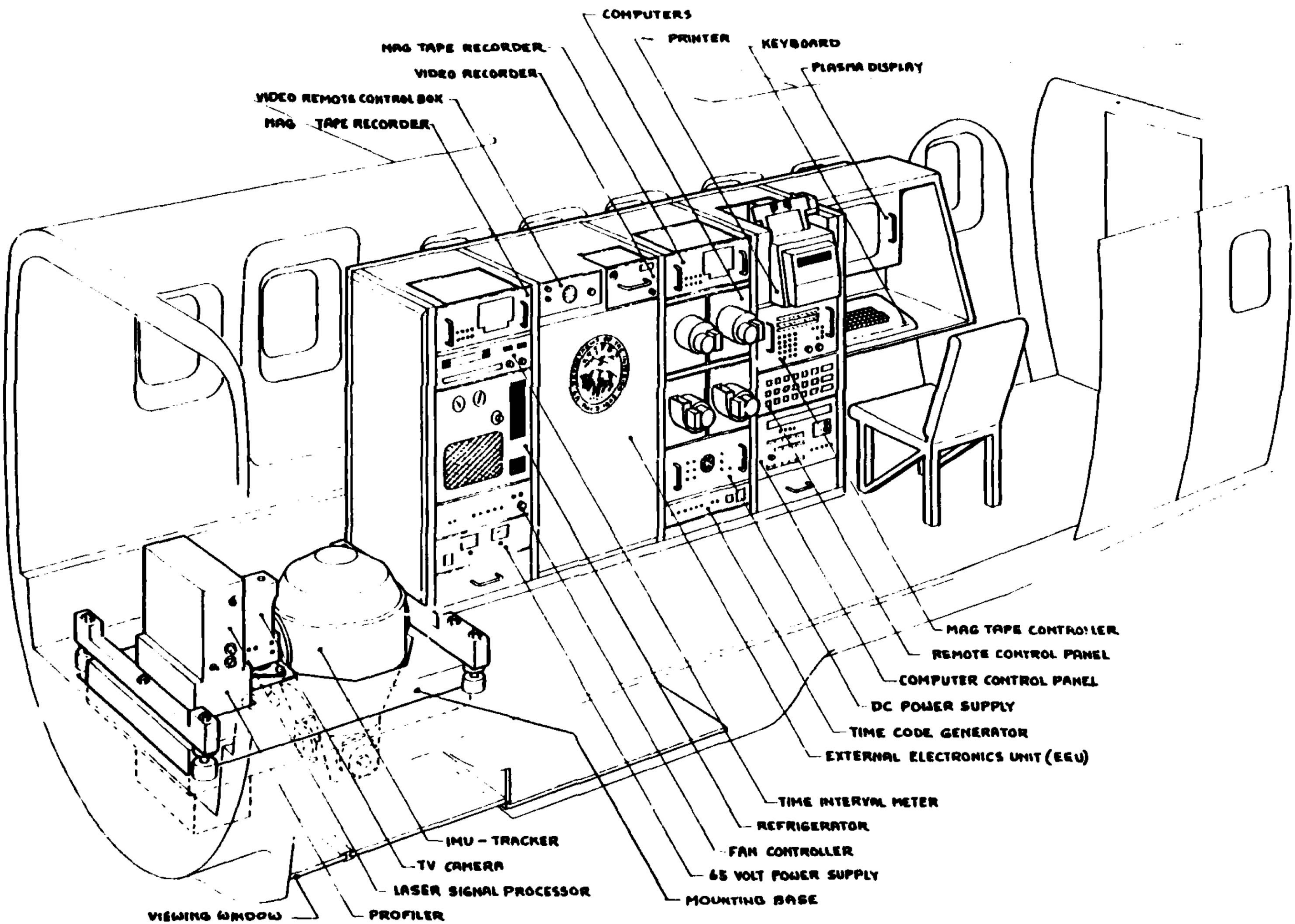

Figure 17c. APTS Installation In Aircraft