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The Personal Computer and Gravity Probe-B Management

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ABSTRACT

The Gravity Probe-B (GP-B) experiment is one of the most sophisticated and challenging developments to be undertaken by NASA. Its objective is to measure the relativistic drift of gyroscopes in orbit about the Earth. In this paper, the experiment is described, and the strategy of phased procurements for accomplishing the engineering development of the hardware is discussed.

The microcomputer is a very convenient and powerful tool in the management of GP-B. It is used in creating and monitoring such project data as schedules, budgets, hardware procurements and technical and interface requirements. Commercially available software in word processing, database management, communications, spreadsheet, graphics and program management are used. Examples are described of the efficacy of the application of the computer by the management team.

GP-B SCIENCE

The Gravity Probe-B (GP-B) will provide two completely new tests of Einstein's General Theory of Relativity. It is designed to measure the non-Newtonian drift of a near-perfect gyroscope in orbit about the Earth. According to Einstein's theory, a perfect gyro in orbit about the Earth will drift 6.9 arc seconds per year because of the earth's mass and will drift about 0.05 arc seconds per year because of the earth's rotation. The two effects are demonstrated in Figure 1. The experiment will utilize near-perfect gyroscopes whose Newtonian drift is less than 0.1 milliarc second per year or about 10^{-11} degrees per hour.

GP-B HARDWARE

The GP-B science mission will consist of a free flying satellite shown in Figure 2. The instrument configuration to accomplish the GP-B science is shown in Figure 3. It consists of an instrument probe inside a liquid helium dewar which is about five and a half feet in diameter and about eight feet in length. The dewar has a cavity in its center of about ten inches in diameter into which the instrument probe fits. The dewar is superinsulated with four vapor-cooled shields which maintain the instrument probe at about 2 Kelvin for one year. Boil-off from the dewar is vented through proportional thrusters to provide control authority for pointing the spacecraft and to provide translational control to produce an acceleration on the gyros of less than 10^{-10} g.

The instrument probe contains a quartz block holding four (quadruply redundant) gyros and a proof mass and it contains a reference telescope that is optically contacted to the quartz block. The telescope is pointed at the star Rigel and the spacecraft is rolled about the line-of-sight with a period of about 10 minutes to eliminate 1/f noise of the readout system and to average out certain gyro torques and thermal distortions. The gyroscopes are very round, very homogeneous quartz spheres coated with superconducting niobium. The gyros are electrostatically suspended and they spin at about 170 Hertz with the spin-up of the superconducting rotor accomplished by means of a helium gas jet. The 1.5 inch quartz rotor will be round to less than one microinch and the variation in the rotor coating thickness is less than 0.3 micro-inches. The readout of drift of the superconducting gyroscope is accomplished by measuring the direction of the magnetic moment that is aligned with the spin axis by use of SQUID's (Superconducting Quantum Interference Devices). In order that the minute magnetic moments associated with the drifts can be detected, the experiment is operated in a magnetic field of 10^{-7} gauss. Table 1 lists the 10 fundamental requirements of the experiment and Table 2 lists some of the resulting "near zero" hardware requirements.

Table 1

Ten Fundamental Requirements

1. Gyro with drift rate below 10^{-11} deg/hr
2. Gyro readout with submilliarc-sec precision over $\pm$ 50 arc-sec range
3. Telescope with submilliarc-sec precision over range greater than $\pm$ 50 milliarc-sec
4. Gyro/Telescope structure stable to less than a milliarc-sec/yr
5. Pointing system able to point within the linear range of the telescope
6. Method of subtracting gyro and telescope signals to submilliarc-sec precision
7. Elimination of null drifts from gyro and telescope readouts
8. Method of separating precession terms in orthogonal planes
9. Absolute scale factor calibration
10. Known absolute motion of guide star

Table 2

"Near Zero" Hardware Requirements

1. Rotor out-of-roundness less than 1 microinch peak to valley
2. Rotor homogeneity of 3 X 10^{-7} $\Delta\rho/\rho$
3. Acceleration less than 10^{-10} g
4. Temperature 1.6 Kelvin
5. Pressure 10^{-10} Torr
6. Magnetic Field 10^{-7} Gauss

PROGRAM CHRONOLOGY

The idea behind GP-B was conceived in the late 1950's by the late Leonard Schiff of Stanford University. Work toward the development of GP-B has been funded at Stanford since 1963, resulting in the accomplishment of major breakthroughs in technology to support the program. In the early 1980's a peer review group found that the individual technologies required for GP-B were sufficiently well understood to justify proceeding to the integration of the technologies into a system. In 1984, the NASA Administrator approved the first of a two stage development--the first stage is engineering development and the second stage is the science mission. The objective of the engineering development is the integration of technologies into a functional instrument which, by use of analytical techniques and test results, can be shown to be capable of achieving the science mission accuracy. The program for the engineering development is called the STORE (Shuttle Test of Relativity Experiment) Program and will result in a Ground Test Unit and the flight of a Shuttle Test Unit. This engineering development of the very sophisticated hardware associated with GP-B is being accomplished by the Principal Investigator Team at Stanford with the support of a subcontract with Lockheed Palo Alto.

PROGRAM MANAGEMENT

The Project is being managed by the Marshall Space Flight Center (MSFC) for the Office of Space Science and Applications (OSSA) in NASA Headquarters. The Principal Investigator Team at Stanford is responsible for delivering the hardware for flight on the Shuttle, and MSFC is responsible for safety and integration of the payload. The STORE program is being procured in phases to provide flexibility in the solution of problems as they arise. The current (first) phase is the Definition Phase which will culminate in a Preliminary Requirements Review (PRR) at the end of 1986. Subsequent phases (Design, Fabrication and Integration and Test) constitute unpriced options, each to be defined and negotiated at the conclusion of the preceding phase. The contract with Stanford is cost reimbursable, and unanticipated cost requirements that may arise during a contract phase will be accommodated by stretching the schedule for that particular phase. During the procurement cycle for a given phase, critical programmatic and technical milestones will be identified that are to be accomplished during that phase. Reporting requirements are primarily focused on management, cost and schedule visibility, safety and interface data and on information about the critical programmatic and technical milestones. The management approach is intended to be constructive in the accomplishment of the program objectives while assuring that MSFC and NASA Headquarters have cognizance of the progress, problems and associated resources to discharge the required accountability for the program.

Currently, the management and administrative staff level at Stanford is at six, Lockheed is at four and MSFC is at three. A key element in minimizing the size of the management teams of GP-B is the personal computer. The three GP-B management offices have standardized on the IBM and compatibles.

COMPUTER APPLICATION

NASA Telemail provides a very convenient and efficient means for informal communication of text files with a maximum size of about a half dozen pages. The Stanford team and the on-site contract administration from ONR (Office of Naval Research) at Stanford have access to NASA Telemail as well as MSFC and Headquarters management personnel. This capability is ideal for exchange of informal text files such as letters, agendas and memos, although it is limited to 300/1200 baud rate. Smartcom (Reference 1) is the communications software package used by Stanford and MSFC. Lotus 1-2-3 (Reference 2) spreadsheet files for budgets can be converted to text files and exchanged on Telemail. This software is also convenient for tracking action items and for tracking the status of procurement approvals on the contract.

Microsoft Word (Reference 3) is a word processing package that has been selected for creating and exchanging experiment requirements and associated experiment integration requirements. The integration activity will involve the interchange of information among Stanford, Lockheed, MSFC project and MSFC engineering personnel.

The database management package dBASE III (Reference 4) is used to automate the search and retrieval of office files. It allows members of the Project to interrogate the database to find the location of files of interest. This program is described in Reference 5. dBASE III has also been used to track the submission of data requirements documents of the contract with the capability to update the due dates as funding profiles and schedules change.

For project management, Primavera (Reference 6) and Primavision (Reference 7) are used by Stanford, Lockheed and MSFC managers. This software is a complete planning and scheduling tool for evaluating and analyzing the time, money and resources that the project requires. Primavera handles critical path scheduling, resource leveling and cost control. The capabilities of Primavera make it well suited for use individually by Stanford and Lockheed for managing their associated tasks and the merge capability of the software allows the total program to be evaluated. The Primavera software package allows summary reports at any level or exception reports to focus on particular information. The GP-B Primavera data files are too large to be transmitted in a cost-effective manner using the 1200 baud modem; therefore, the Stanford/Lockheed data files are sent to MSFC by disk through the mail. The Primavision software is a companion plotter graphics package for producing bar charts and network logic diagrams. It is completely integrated with Primavera and produces very good graphics for use in management reviews and reports.

The penalty associated with the computerization of the management of a project is the time required for training. In the MSFC Project Office, responsibility for a knowledge of the intricacies of each software package is assigned to a member of the team with some cross-training for all members of the team. For an individual with a modest knowledge of microcomputers, three months is a reasonable time to allow before the individual is proficient with the use of a package.

CONCLUSION

Based on the experience of the GP-B management teams, the use of microcomputers significantly enhances productivity and visibility. The time spent in learning the use of the tools is more than offset in the resulting efficiency. Future enhancements will include the use of packet communications to access higher data rates and to facilitate the transmission of graphics between MSFC and Stanford.

References

1. "Smartcom II for IBM Personal Computer" from Hayes Microcomputer Products, Inc. 1983

2. "Lotus 1-2-3 Spreadsheet, Graphics, Database" Release 2, Lotus Development Corporation, 1985

3. "Microsoft Word" Version 2.0 from Microsoft Corporation, 1985

4. "dBASE III" from Ashton-Tate, 1984

5. "Search and Retrieval of Office Files Using dBASE III" by William L. Breazeale and Charlotte R. Talley, (to be published)

6. "Primavera Project Planner", Version 2.50 from Primavera Systems, Inc. 1985

7. "Primavision Plotter Graphics Software", Version 1.6 from Primavera Systems Inc. 1985

EFFECTS OF RELATIVISTIC DRIFT

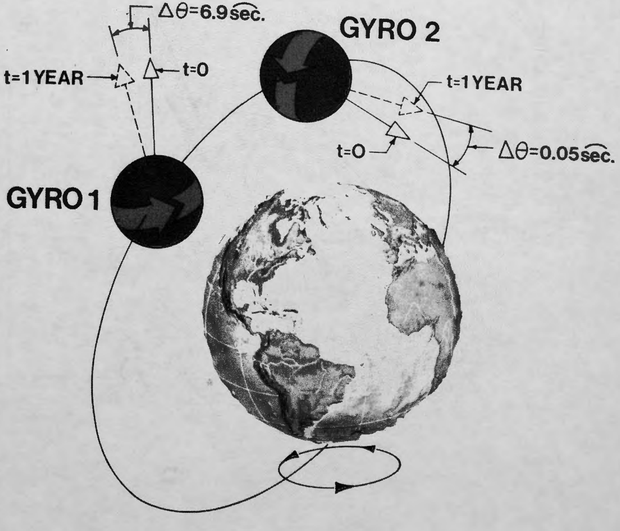


FIGURE 1

GP-B SCIENCE MISSION SATELLITE

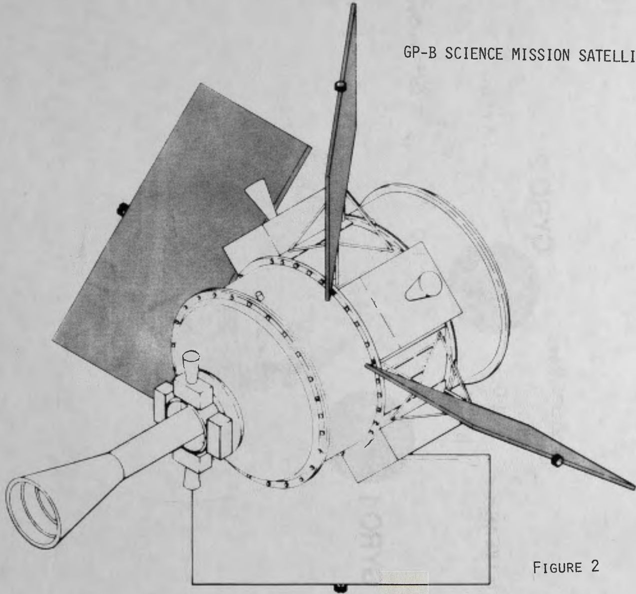


FIGURE 2

GP-B INSTRUMENT MODULE

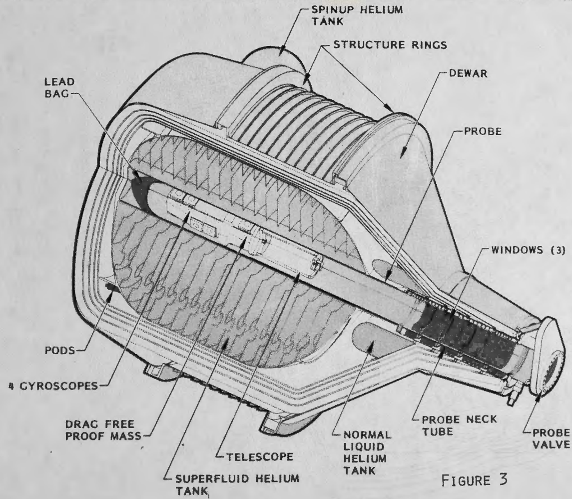
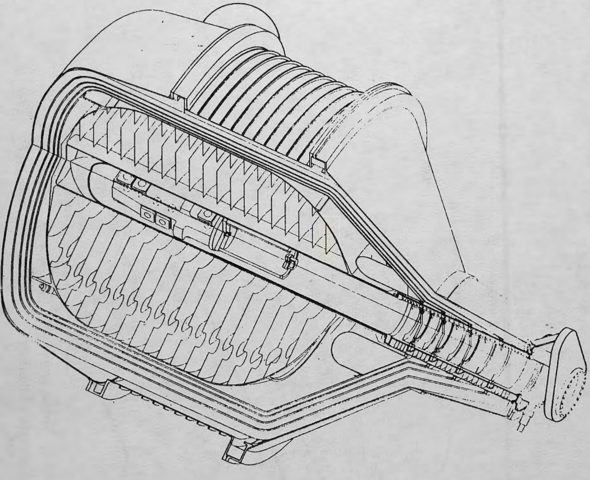


FIGURE 3



CUTAWAY OF EXPERIMENT MODULE

Alternate Figure 3.

GP-B Instrument Module