DEVELOPMENT OF THE GRAVITY PROBE B PAYLOAD

D. BARDAS, M.A. TABER, J.P. TURNEAURE, S. BUCHMAN, G. KEISER, J. LOCKHART, B. MUHLFELDER, J. MESTER, E. ALCORTA, T. BROSZ, D. DEBRA, P. EHRENSBERGER, C.W.F. EVERITT, D. GILL, C. GRAY, G. GUTT, J. GWO, N. KASDIN, J. LIPA, M. LUO, B. PARKINSON, J. STAMETS, M. SULLIVAN, B. TALLER, J. WADE, S. WANG, C. WARREN, Y. XIAO
W. W. Hansen Experimental Physics Laboratory, Stanford University
Stanford, CA 94305-4085

S. CALHOON, P. DINEEN, D. DONEGAN, T. MUENCH, D. MURRAY, A. NAKASHIMA, R. PARMLEY, G. REYNOLDS, L. SANDS, P. SCHWEIGER, L. SOKOLSKY, J. THATCHER, R. VASSAR, E. WILL
Lockheed Martin Missiles and Space, 1801 Page Mill Road,
Palo Alto CA 94301-1211

The Gravity Probe B Relativity Mission (GP-B), expected to launch in the year 2000, will provide a precise and controlled test of Einstein's General Theory of Relativity by observations of the precession of nearly perfect gyroscopes in Earth orbit. This paper describes some of the key hardware components and their integration into the Science Mission (SM) Payload. We provide an overview of the major prototypical integration tests already completed as well as a description of the upcoming SM Payload integration

1 Introduction

Substantial progress has been made in development of the flight hardware and several integrations and tests of full-size prototypical flight hardware have been successfully completed from 1990 to the present using an incremental prototyping philosophy. Four major hardware assemblies have been successfully tested, each more similar to the flight payload and with correspondingly greater inclusion of flight-type sub-components. Unique facilities and Ground Support Equipment (GSE) have also been concurrently developed with the requirements of the final payload in mind. Through these tests, as well as others, GP-B Science Mission requirements have been systematically demonstrated. Additional information can be found in other papers on GP-B presented at this conference.

2 Major Payload Hardware Components

2.1 Science Instrument Assembly (SIA)

The SIA, figure 1, comprises a fused Quartz Block (QB) bonded to a fused Quartz Telescope inside which are four gyroscopes secured by precision retention hardware consisting of both fused quartz and titanium components. This achieves the gyroscope alignment which is required to be within 10 arc-s of the telescope line-of-sight and within 0.1 mm of the QB longitudinal axis. These requirements, among others, derive from the error budget of the experiment that is apportioned to the gyroscopes. These alignments have been demonstrated in recent assemblies and are achieved as a result of a number of factors: (a) Precision machining of the fused

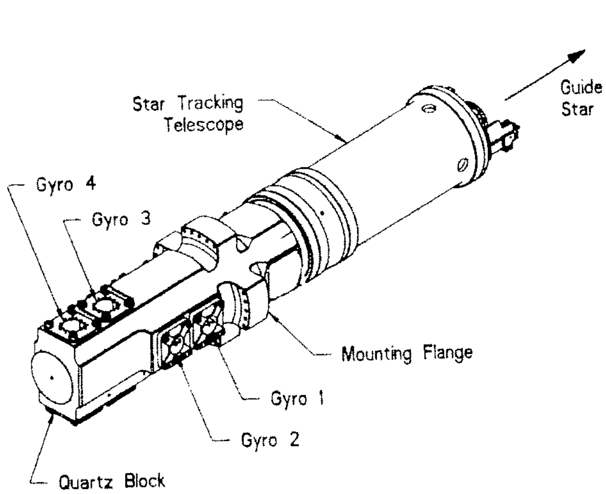

Figure 1: GP-B Science Instrument Assembly

quartz components for the telescope, QB, gyroscopes and retention pieces to maintain parallelism and perpendicularity of critical reference surfaces within 1 arc-s, (b) Surfaces that are be bonded together have an interface wedge angle of less than 1 arc-s through the utilization of a specially developed chemical bonding techniques. These bonds also have the advantage of shear and tensile strength in excess of requirements. Several such bonds are used in the telescope assembly, the joining of the telescope to the QB, and the quartz support assembly for the gyroscope. The gyroscopes are centered to within 0.1 mm dia. in their respective bores within the QB through the use of a precision fused quartz doweling system.

A caging system is integrated with the gyroscope retention system which immobilizes the rotor during launch. This system operates at 1.8 K utilizing pressurized liquid helium to expand a set of diaphragms 0.5 mm thus pushing a polished titanium rod against the rotor with a force of 60 N. A prototype system has been recently demonstrated.

Additional hardware that comprises the SIA are the SQUIDs and the telescope detectors. The former read out changes in the magnetic flux through the readout loops of each gyroscope, while the latter precisely determine the position of the guide star. Structural integrity of the SIA has been verified to an acceleration of 10 g (rms) which is significantly higher than expected launch loads. A more detailed description of the SIA can be found by Turneaure *et al.* [1].

2.2 Science Mission Probe and Dewar

The Probe is a cylindrical vacuum vessel which houses the SIA and provides the support wiring to power and readout the SIA detectors. It also provides gas lines to spinup the gyroscopes. After integration with the SIA the probe is inserted into the Science Mission Dewar which will maintain the experiment at 1.8 K for about 1.5 y. Figure 2 shows the integrated Payload Assembly. The cryogenic tempera-

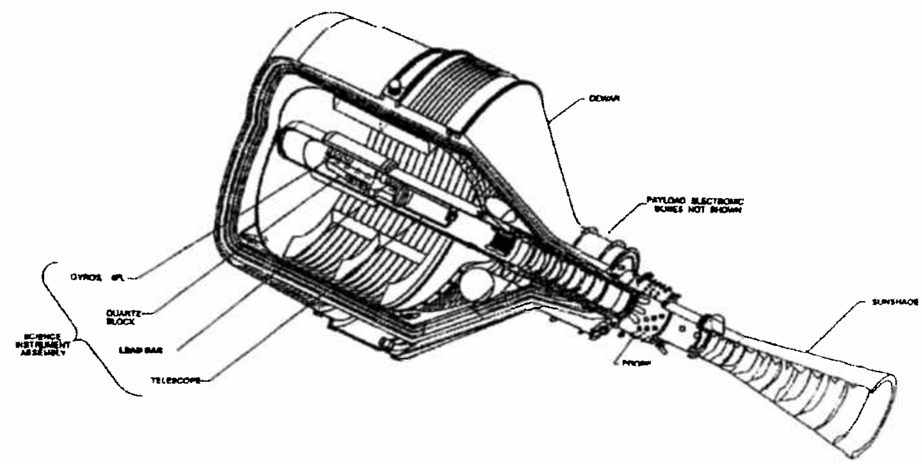

Figure 2: GP-B Science Payload

ture environment ensures that the SIA forms a stable optical platform, enables the superconducting gyro readout system to function, and provides a superconducting magnetic shielding system which maintains an ultra-low ambient field (10^{-11} T) at the gyros as well as a shielding factor of 10^{-12} for external time-varying magnetic fields. Further details of the hardware can be found elsewhere.[1–4]

2.3 Other Payload Subsystems

To support operations and readout, several electronics boxes are mounted on the dewar and the spacecraft. These include the Gyroscope Suspensions Units, the SQUID Readout Electronics, the Telescope Readout Electronics, and the Experiment Control Unit. The latter is one of the main interfaces to the spacecraft computer and its telemetry system. It primarily functions to readout a variety of temperature and pressure sensors throughout the Payload, and also to control operation of spinup and exhaust valves on the probe. In particular, it interfaces to the Gas Management Assembly (GMA), the valves of which control spinup gas to the gyroscopes, exchange gas to the probe, and the gas to the caging units. The GMA is designed with redundancy against failure to open or close the gas flow pathways.

3 Integrated Systems Tests

The development of GP-B sub-components has been ongoing for over 25 years. In 1985 a plan of incremental prototyping of full-sized SIAs, Probes and Dewars was formulated in order to verify functionality of all subsystems under realistic integrated scenarios. These tests and hardware assemblies, with their corresponding completion dates, are known as: The First Integrated Systems Test (FIST), 1991, The Ground Test Unit-0 (GTU-0), 1994, GTU-1, 1995; GTU-2, 1997. The integration and verification of the Science Mission Payload is scheduled to begin in

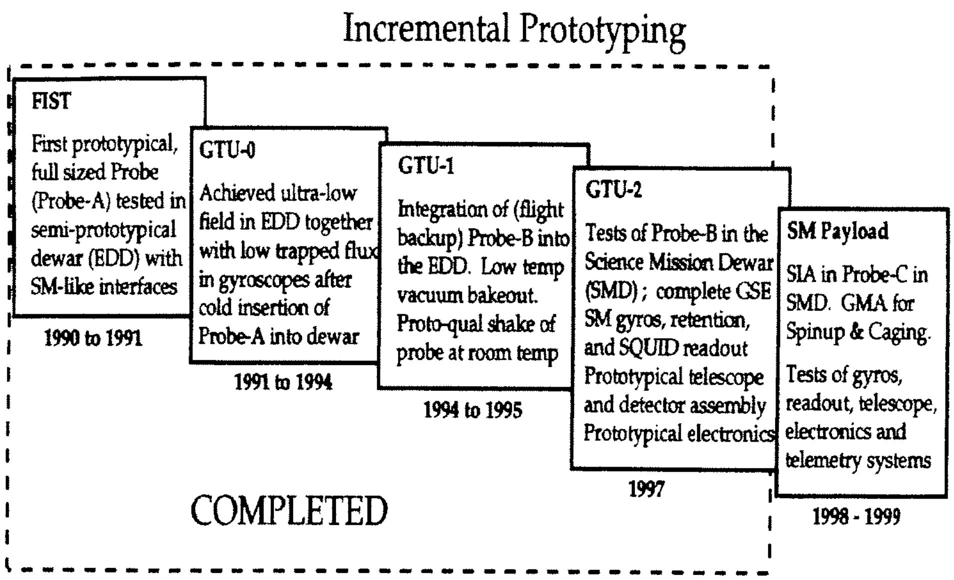

Figure 3: Prototypical Hardware Development

1998. Figure 3 is a block diagram depicting the sequence of these major integration tests and includes a brief description of each system's components and tests. The above series of major integration tests has served to flush out early problems on a system level, and has accelerated progress and minimized risk for the Science Mission Payload integration. This will be the last such integration to take place at Stanford and is then followed by approximately a year of integration and testing with the spacecraft plus pre-launch operations. Further elaboration of the Payload verification and test program and results is given by Taber *et al.*[5].

Acknowledgments

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