GP-B Monthly Report
May 2012

This monthly report documents the activities in May, 2012 with focus on progress towards publishing GP-B science and technology papers in *Classical and Quantum Gravity*. Five of these papers are in-work. Co-authored by KACST, NASA, Lockheed Martin, and Stanford personnel, the plan is to complete these first five by August 1, 2012. Other activities reported below include collection of supporting reference documentation and collaboration status with KACST, Lockheed Martin, NASA, and other potential groups.

GP-B team members will be giving a series of eight talks at the upcoming Marcel Grossmann meeting in Stockholm. In addition to these contributed talks, Francis Everitt will give a plenary presentation.

<u>Five papers in-progress</u>:

1) Gravity Probe B Cryogenic Payload: R. Parmley (Lockheed Martin, retired), K. Burns (Lockheed Martin), C.W.F. Everitt, D. Frank (Lockheed Martin), B. Muhlfelder, D. Murray, G. Reynolds (Lockheed Martin), M. Taber, W. Till (MSFC), R. Vassar (Lockheed Martin, retired), KACST personnel.

Abstract: Gravity Probe B mission developed the largest capacity helium flight dewar which provided 17.3 months of cryogenic operations in space. Ground test campaigns and two independent performance models, led by Lockheed Martin and Marshall Space Flight Center, were constructed to ensure that the required hold time of 16 months be met or exceeded. A porous plug device, invented by the GP-B team and subsequently flown on IRAS, COBE, and ISO, successfully constrained the flow of the superfluid cryogen. This paper will present flight performance results and make comparisons with preflight model expectations to inform future space cryogenic systems design.

Work in May has focused on Sections II and III. Francis Everitt has consolidated the existing text and has added additional relevant material. Dave Frank, LM, has added an extended section on mass properties. The plan is to have a complete draft of the paper by the end of June. The paper is planned to be finished by the end of July.

2) Science Paper: Gravity Probe B test of the precession due to general relativity of gyroscopes in earth polar orbit: C.W.F. Everitt, et al.

Abstract: We report the results of an experiment to measure the geodetic and frame-dragging precessions due to general relativity of gyroscopes in a 640 km polar orbit around Earth. The results are in agreement with general relativity: the geodetic precession predicted by general relativity is -6606.1 milli-arcsec/yr, and the result derived from our measurements is -6601.8 ± 18.3milli-arcsec/yr; the frame-dragging precession predicted by general relativity is -39.2 milli-arcsec/yr, and the result derived from our measurement is -37.2 ± 7.2 milli-arcsec/yr. This paper and the accompanying papers in this *Classical and Quantum Gravity* special volume describe in detail the flight instrument configuration, give a detailed description of the data (collected on the ground and during flight) needed for data analysis, describe the data analysis methods used, provide an analysis of systematic error, and provide the derivation of the final results.

In the past month Barry Muhlfelder provided a draft of the Mission Operations section and has updated the section on systematic error. General feedback on organization, etc. has been provided by some of the co-authors. John Turneaure continues to coordinate this paper and is maintaining the electronic copy. The following contributors are currently working on various sections: John Conklin, Mac Keiser, Barry Muhlfelder, and John Turneaure.

3) GP-B Attitude Control: D. DeBra, M. Adams, W. Bencze, J. W. Conklin, J. Kirschenbaum (Lockheed Martin), B. Muhlfelder, M. West (NASA), KACST personnel.

Abstract: We discuss the requirements, design, implementation, and on-orbit performance of the GP-B attitude control system. High precision attitude and roll control, along with a previously described drag-free system, controlled the spacecraft's six degrees of freedom. Novel control features reduced inertially-fixed mispointing to $\sim$ 20 mas. Other techniques allowed the guide star to be locked onto in 1-2 minutes each orbit as the guide star became visible following occultation by the Earth.

Dan DeBra and John Conklin continue to co-lead this paper. A section by J. Li is underway on spacecraft roll control. Detailed contributions have been provided by B. Muhlfelder, J. Kirschenbaum, J. Conklin, and M. Adams.

4) Gravity Probe B Data Analysis Overview I. A. S. Silbergleit, J. W. Conklin, M. I. Heifetz, G. M. Keiser, J. P. Turneaure, P. W. Worden Jr., KACST personnel.

Abstract: We give a detailed description of the analysis of data obtained in the Gravity Probe B Relativity Science mission and its results.

The paper on GP-B data analysis is planned in two parts: Overview I. Coordinate Frames and Analysis Model. (DA I) Overview II. Data to Analyze, Estimation Tools, and Analysis Results. (DA II).

A revised complete draft of DA I and an extended version of DA II was completed this past month.

5) GP-B Tracking Telescope: Lipa, Goebel (NASA), Turneaure, Wang, KACST personnel.

Abstract: This paper will describe the on-orbit performance of the GP-B Star Tracking Telescope. This system provided star tracking measurement to better than 1 mas and served as the reference sensor for the vehicle's inertial guidance system with a mission average mispointing of < 25 mas. A novel hydroxide catalyzed bonding technique, developed to provide robust and high dimensional stability precision quartz bonds has found application in a wide range of optical systems. The telescope cryogenic optical detection system is comprised of matched pairs of blue-enhanced Si photodiodes coupled to Si JFET amplifiers. The photodiodes and JFET circuits are mounted on a sapphire thermal platform maintained near 72K for optimal noise performance. Flight readout electronics drives the cryogenic detector system in a charge-locked loop reset at a 10 hz rate. In this paper we describe the flight performance of the system with an emphasis on future lessons learned for future flight missions.

Work continues towards completion of a rough draft. L. Brandt is now reviewing telescope snapshot data acquired on-orbit. J. Lipa, S. Wang, L. Brandt, and B. Muhlfelder are involved in this effort.

Two papers to be started by July 1, 2012:

6) GP-B Gyroscope: S. Buchman, C.W.F. Everitt, D. Gill, G. Keiser, F. Marcela, P. Peters (MSFC), J. Hayden, KACST personnel

Abstract: The top level rotor requirement states that the Newtonian drift < 0.1 milli-arc-second per year. To achieve this, the rotor has been manufactured to a sphericity of 2e-7 and a mass unbalance of < 20e-9 m. Rotor lapping and polishing of homosil ™ quartz yields 25 nm P-V rotors. Optical measurement of Homosil gives a mass homogeneity of better than 1e-7. A uniform niobium deposition maintains the mass unbalance while allowing electrostatic gyroscope suspension and the London Moment readout. The gyroscope housing encases the rotor, and allows electrostatic suspension, charge control, spin up, and readout.

7) GP-B Gyroscope Readout: B. Muhlfelder, B. Clarke, G. Gutt, J. Lockhart, M. Luo, KACST personnel

Abstract: The London Moment SQUID-based readout system provides milli-arc-sec (~ 3e-7 arc-degrees) measurement of gyroscope spin axis orientation in a 5 hour integration time. Active temperature control provides sub-microKelvin SQUID temperature stability at roll frequency, thereby limiting spurious signals caused by temperature variation.

Other activities:

1. Work was begun preparing for the set of eight GP-B talks to be given at the upcoming MG 13 conference in Stockholm, Sweden.