GP-B Monthly Report
March 2012

This monthly report documents the activities in March, 2012 with focus on progress towards publishing the definitive set of GP-B science and technology papers in *Classical and Quantum Gravity*. Five papers are currently in-work. Two additional papers will be started by May 1, 2012. The plan is complete a total of five papers by July 1, 2012 with KACST, NASA, and Lockheed Martin co-authors. A new, nearly full time volunteer, Laura Brandt, has joined team. Dr. Mac Keiser, the GP-B Chief Scientist, has a new office in the Physics Astrophysics Building. 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 talks at the 13th Marcel Grossmann meeting in Stockholm this coming July in a session chaired by Dr. Turki Al-Saud. A plenary GP-B talk will be followed by GP-B contributed talks including Science, SIA, Payload Cryogenics, ATC, Data Analysis I and Data Analysis II.

Four papers in-progress:

1) Gravity Probe B Cryogenic Payload: B. Muhlfelder, K. Burns (Lockheed Martin), C.W.F. Everitt, D. Frank (Lockheed Martin), D. Murray, R. Parmley (Lockheed Martin, retired), 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.

The current draft of the paper comprises 62 pages. Some additional material needs to be added and some of the existing text needs to be made more concise, resulting in little change to the total length. The two active and three retired Lockheed Martin team members have provided vital contributions. NASA personnel were involved during on-orbit operations and will be involved in the paper with thermal modeling analysis. The plan is to have a complete draft of the paper by the end of April. The paper will be finished by the beginning 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.

John Turneaure is coordinating the effort on this paper and will maintain the electronic copy. The following contributors are currently working on various sections: John Conklin, Mac Keiser, Barry Muhlfelder, and John Turneaure. The next meeting of this group to discuss the progress on the various sections of the paper will be held April 25th.

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 ~ 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.

A detailed outline has been developed and writing is underway. Dan DeBra and John Conklin are co-leading the work. 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).

Paper DA I is well under way. Revision 4 of the paper was released within the previous month. It contains more than 70% of the needed material. The PE torques are discussed in a new section (and a large Appendix C - perhaps the most difficult part of the paper to write). Other than for an introduction and summary, just one section remains to be written (on the telescope, currently in-work by J. Turneaure). Once a complete draft is available, an editing process should result in a reduction in the total length of the paper.

The structure for DA II has been determined, along with an understanding of required specific topics. Writing assignments have been made. One appendix has been completed. DA II is led by M. Heifetz.

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.

A rough draft now exists for this paper, and although incomplete, comprises 28 pages. J. Lipa, S. Wang, L. Brandt, and B. Muhlfelder are involved in this effort.

Two papers to be started by May 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. GP-B team members will be presenting at this summer's Marcel Grossmann meeting in Stockholm, Sweden. A total of 7 talks are planned.
2. Dr. Ken Washington, VP of Lockheed Martin's Advanced Technology Center (ATC) will be giving a HEPL seminar on April 4, 2012. Discussions are planned on the proposed Memorandum of Understanding between Lockheed Martin and Stanford. The intent is to make HEPL the primary party within Stanford.
3. Additional documents were added to the Stanford webpage to support the writing of technology papers.
4. Laura Brandt, has joined the GP-B team. Laura has a Masters degree in work related to space-based research.