GP-B Monthly Report
February 2012

This GP-B monthly report documents the activities in February, 2012 with a focus on the progress towards publishing a set of 24 papers in *Classical and Quantum Gravity*. Four papers are in-work with three additional papers to be started by April 1, 2012. The plan is on-track to complete a total of five papers by July, 2012 with at least 5 KACST, 2 NASA, and 4 Lockheed Martin co-authors. Other activities reported below include the collection of supporting reference documentation and collaboration status with KACST, Lockheed Martin, NASA, and other potential groups.

February Progress:

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

This group had two full team meetings in February as well as smaller sub-group discussions. The current draft comprises 52 pages single spaced. Two active and three retired Lockheed Martin team members have provided vital contributions. A rough draft of the paper will be available by mid-March. A polished draft will be available by end of April, with the writing completed 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 high earth polar orbit. 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 volume of *Classical and Quantum Gravity* 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, provide an analysis of systematic error, and provide the derivation of the final results.

John Turneaure, Francis Everitt, John Conklin, Mac Keiser, and Barry Muhlfelder are continuing work on the first draft of this paper, currently 18 pages in length single spaced. Significant progress has been made on Section 2, Experimental Configuration, and Section 3, Mission Operations. The plan is to put together a draft for the later sections of the paper before addressing Section 1, Introduction. The next group meeting is scheduled for early March.

3) GP-B Attitude Control: D. DeBra, M. Adams, W. Bencze, J. W. Conklin, L. Herman (consultant), J. Kirschenbaum (Lockheed Martin), 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.

There were full team and smaller sub-team meetings during February.
In the most recent full team meeting, held Feb 21, Adams, Bencze, Brandt, Conklin, DeBra, Green, Keiser, Muhlfelder, and Silbergleit reviewed writing assignments, and in a few cases, made adjustments to provide a better fit between the subject matter and writer. John Turneaure, Tom Holmes, and Jie Li were added to the distribution list. Conklin offered to compile input from the co-authors and asked for submissions by 16 March. The next meeting will be held 21 March, at 2:30 PM in Physics and Astrophysics room 232

4) Gravity Probe B Data Analysis Overview I. A. S. Silbergleit1, J. W. Conklin, M. I. Heifetz, G. M. Keiser1, J. P. Turneaure1, 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).

During February revision 4 of DA I was pushed close to its completion. The latest additions deal with one of the most difficult subjects, the patch effect torques, whose full analysis model will be properly derived and explained in the paper. The section on torques in the main body of the text is ready, and a large appendix on the torque theory is at least 80% done. The release of rev. 4 is planned for the second half of March, after finishing the work on torques and carrying out the whole text compression similar to what had been done in rev. 3. Rev. 4 will contain about 90% of the material planned to be included in the finished 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.

Next Three papers:

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

Effort on this paper is ahead of schedule. John Lipa has begun work on a rough draft, and John and Barry Muhlfelder discussed bringing in more people to work on various sections of the paper. During March, the expectation is that Lipa, Wang, Turneaure, Muhlfelder, Sullivan, and possibly Goebel (NASA Ames), Triebes (Lockheed Martin), Huff (Lockheed Martin), and Schweiger (Lockheed Martin) will meet to begin coordinated action on this paper.

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: The Gravity Probe B SQUID Readout Detector and Temp control- 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. Francis Everitt visited MSFC and met with Todd May, the Associate Center Director. Mr. May was the GP-B Program Integration Manager from 2002 to 2005. Personnel at MSFC expressed interest in continued collaboration with GP-B at Stanford. Three Marshall GP-B team members will contribute to the science and technology papers. Marshall was also eager to receive and archive technical reference material.
2. The project to organize the GP-B Ph.D. theses is now complete. A copy of the spreadsheet summarizing this work is included as an attachment. Hamoud Aljabreen, Barry Muhlfelder, and David Cuffy were responsible for this work.
3. Documents were added to Stanford webpage to support the writing of technology papers.
4. There were further exchanges with the office of Dr. Ken Washington, head of Lockheed Martin ATC. Dr. Washington will give a seminar at Stanford April 4, 2012 and to sign a Memorandum of Understanding between Lockheed Martin and Stanford later that month.