

the atmosphere to the target star, suggest that most of the atmospheric turbulence contributing to poor seeing is occurring within about 10 m of the ground. For the Table Mountain Ronchi telescope, signal-to-noise improvements will enable tracking of a visual magnitude 11 star. Demonstrations of this capability will occur this summer after hardware upgrades in the spring.

The above demonstrations will yield 10–50-nanoradian performance, but it has been shown that subnanoradian performance enables many mission enhancements. For example, subnanoradian angular tracking enables detection of Jupiter's spacecraft-relative position about 100 days before encounter. Subnanoradian tracking is largely prevented by atmospheric refractivity fluctuations for both the above mentioned devices. Methods of minimizing atmospheric effects using optimal stochastic estimation and direct calibration will be described.

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 P.1
A TEAM APPROACH TO THE DEVELOPMENT OF GAMMA RAY AND X-RAY REMOTE SENSING AND *IN SITU* SPECTROSCOPY FOR PLANETARY EXPLORATION MISSIONS.

J. I. Trombka¹ (Team leader), S. Floyd¹, A. Ruitberg¹, L. Evans², R. Starr³, A. Metzger⁴, R. Reedy⁵, D. Drake⁵, C. Moss⁵, B. Edwards⁵, L. Franks⁶, T. Devore⁶, W. Quam⁶, P. Clark⁷, W. Boynton⁸, A. Rester⁹, P. Albats¹⁰, J. Groves¹⁰, J. Schweitzer¹¹, and M. Mahdavi¹¹, ¹Goddard Space Flight Center, Greenbelt MD 20771, USA, ²Computer Sciences Corporation, Calverton MD 20705, USA, ³The Catholic University of America, Washington DC 20064, USA, ⁴Jet Propulsion Laboratory, Pasadena CA 91109, USA, ⁵Los Alamos Scientific Laboratory, Los Alamos NM 87545, USA, ⁶EG & G Energy Measurements Santa Barbara, Goleta CA 93117, USA, ⁷Albright College, Reading PA 19612, USA, ⁸University of Arizona, Tucson AZ 85721, USA, ⁹University of Florida, Alachua FL 32615, USA, ¹⁰Schlumberger-Doll Research, Ridgefield CT 06877, USA, ¹¹EMR Schlumberger, Princeton NJ 08542, USA.

An important part of the investigation of planetary origin and evolution is the determination of the surface composition of planets, comets, and asteroids. Measurements of discrete line X-ray and gamma ray emissions from condensed bodies in space can be used to obtain both qualitative and quantitative elemental composition information.

Remote sensing X-ray and gamma ray spectrometers aboard either orbital or flyby spacecraft can be used to measure line emissions in the energy region ~0.2 keV to ~10 MeV. These elemental characteristic excitations can be attributed to a number of processes such as natural radioactivity, solar X-ray fluorescence, and cosmic ray primary- and secondary-induced activity. Determination of composition for the following elements can be expected: O, Si, Fe, Mg, Ti, Ca, H, Cl, K, Th, and U. Global elemental composition maps can be obtained using such spectrometer systems.

More complete elemental composition can be obtained by landing packages that include X-ray and gamma ray spectrometer systems along with X-ray, charged particle, and neutron excitation sources on planetary surface. These *in situ* systems can be used on stationary, roving, and penetrator missions. Both the remote sensing and *in situ* spectrometer systems have been included aboard a number of U.S. and Russian planetary missions [1,2].

The Planetary Instrument Definition and Development Program (PIDDP) X-Ray/Gamma Ray Team has been established to develop X-ray and gamma ray remote sensing and *in situ* technologies for future planetary exploration missions. This team represents groups having active programs with NASA, the Department of Energy (DOE), the Department of Defense (DOD), and a number of universities and private companies. A number of working groups have been established as part of this research program. These include groups to study X-ray and gamma ray detectors, cryogenic cooling systems, X-ray and particle excitation sources, mission geochemical research requirements, detector space radiation damage problems, field simulation studies, theoretical calculations and X-ray and nuclear cross sections requirements, and preliminary design of flight systems. Major efforts in this program will be devoted to the development of X-ray/gamma ray remote sensing systems for the NEAR (Near Earth Asteroid Rendezvous) mission and for *in situ* X-ray and gamma ray/neutron systems for penetrators, soft landers, and rovers for MESUR missions.

References: [1] Fichtel C. and Trombka J. I. (1982) *Gamma Ray Astrophysics New Insight and into the Universe*, NASA SP-453, 19–65. [2] Boynton W. V. et al. (1992) *JGR*, 97, 7681–7698.

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 P.2
MINIATURE LONG-LIFE SPACE CRYOCOOLERS.

E. Tward, TRW, One Space Park, Redondo Beach CA 90278, USA.

Cryogenic coolers for use in space on small satellites require low power and minimum weight. The need for exceptional reliability in a space cooler is made even more critical on small satellites since cooler redundancy is often not an option due to weight constraints. In this paper we report on two reliable, small, efficient low-power, vibrationally balanced coolers designed specifically for use on small satellites.

TRW has designed, built, and tested a miniature integral Stirling cooler and a miniature pulse tube cooler intended for long-life space application. Both efficient, low-vibration coolers were developed for cooling IR sensors to temperatures as low as 50 K on lightsats.

The vibrationally balanced nonwearing design Stirling cooler incorporates clearance seals maintained by flexure springs for both the compressor and the drive displacer. The design achieved its performance goal of 0.25 W at 65 K for an input power to the compressor of 12 W. The cooler recently passed launch vibration tests prior to its entry into an extended life test and its first scheduled flight in 1995.

The vibrationally balanced, miniature pulse tube cooler intended for a 10-year long-life space application incorporates a nonwearing flexure bearing compressor vibrationally balanced by a motor-controlled balancer and a completely passive pulse tube cold head. The maximum cooling power measured at 80 K is 800 mW for an input power to the compressor of 30 W. The cooler is suitable for cooling sensors and optics between 60 K and 200 K, with cooling