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eral component interface (PCI) block, making the phasemeter design exportable to a variety of computer architectures. The PCI interface can transfer an entire block of phasemeter registers at a rate of 10 kHz.

- A few hardware components were added to enable measurement of the heterodyne-signal period, to count reference clock cycles during an averaging cycle, and to utilize the resulting data in such a way as to make the phasemeter immune to drift of the heterodyne frequency. These additions also eliminate the necessity of incorporating, into the phasemeter software, a different reference-clock-cycle parameter for every different heterodyne frequency that might be used.

This work was done by Frank M. Loya of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-45484

Loosely Coupled GPS-Aided Inertial Navigation System for Range Safety

Goddard Space Flight Center, Greenbelt, Maryland

The Autonomous Flight Safety System (AFSS) aims to replace the human element of range safety operations, as well as reduce reliance on expensive, downrange assets for launches of expendable launch vehicles (ELVs). The system consists of multiple navigation sensors and flight computers that provide a highly reliable platform. It is designed to ensure that single-event failures in a flight computer or sensor will not bring down the whole system. The flight computer uses a rules-based structure derived from range safety requirements to make decisions whether or not to destroy the rocket.

By combining the inertial navigation system (INS) with Global Positioning System (GPS), the GPS signal can be used to check error growth of the INS and, due to the small, short-term errors of the INS, the system is more accurate than the sensor alone. The fused system helps to solve the common cause failures, and also provides the benefit of graceful degradation of system performance should a failure occur.

This innovation has algorithms developed specifically with range safety applications in mind. The INS and Kalman filter algorithms, including the linearized error model, for integrating the two systems were developed and simulated to determine their performance. The system calculates the errors in the IMU and provides information on the quality of the data it outputs to aid the AFSS system in determining what level of trust to give the data.

The filter is designed in such a way that there is always position and velocity output. Loss of GPS will not cause the INS to go unstable, or to cease information output. Also, covariance estimates and the error states are available to the user for further use in determining data quality.

This work was done by Scott Heatwole and Raymond J. Lanzi for Goddard Space Flight Center. For further information, contact the Goddard Innovative Partnerships Office at (301) 286-5810. GSC-15549-1

Sideband-Separating, Millimeter-Wave Heterodyne Receiver

NASA's Jet Propulsion Laboratory, Pasadena, California

Researchers have demonstrated a submillimeter-wave spectrometer that combines extremely broad bandwidth with extremely high sensitivity and spectral resolution to enable future spacecraft to measure the composition of the Earth's troposphere in three dimensions many times per day at spatial resolutions as high as a few kilometers. Microwave limb sounding is a proven remote-sensing technique that measures thermal emission spectra from molecular gases along limb views of the Earth's atmosphere against a cold space background.

The new receiver will down-convert thermal emission spectra in the 180–300 GHz band using superconductor-insulator-superconductor (SIS) heterodyne mixers. A technique called sideband separation is used to provide 24 GHz of instantaneous bandwidth from a single receiver, enabling many chemical species to be measured simultaneously by a single receiver with accurate calibration. The high sensitivity provided by SIS mixers will enable accurate measurements of chemicals at low concentrations with very short integration times. A novel scanning telescope, also under development at the Jet Propulsion Laboratory, will take advantage of these short integration times to measure three-dimensional maps of the concentration of a large number of key chemical species in the troposphere over nearly the entire planet five to nine times per day. These frequent measurements will enable researchers to both monitor air quality and to understand how pollution is transported by the atmosphere.

This work was done by John S. Ward, Bruce Bumble, Karen A. Lee, Jonathan H. Kawamura, Goutam Chattopadhyay, Paul Stek, and Frank Rice of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-46205