to practice in such an experiment, where a hot rocket nozzle was cooled using a two-phase fluid (where the fluid temperature may thus be verified, using the saturation pressure). The measured temperature in the cooling annulus showed good agreement with the method, and the thermocouple became essentially insulated from the wall by setting the hot junction at a distance corresponding to the parameter value of 4.60.

This work was done by Patrick Lemieux, William Murray, Terry Cooke, and James Gerhardt of California Polytechnic State University for Dryden Flight Research Center. Further information is contained in a TSP (see page 1). DRC-010-030

On-Wafer Measurement of a Multi-Stage MMIC Amplifier With 10 dB of Gain at 475 GHz

Imaging applications include hidden weapons detection, troop protection, and airport security.

NASA's Jet Propulsion Laboratory, Pasadena, California

JPL has measured and calibrated a WR2.2 waveguide wafer probe from GGB Industries in order to allow for measurement of circuits in the 325–500 GHz range. Circuits were measured, and one of the circuits exhibited 10 dB of gain at 475 GHz.

The MMIC circuit was fabricated at Northrop Grumman Corp. (NGC) as part of a NASA Innovative Partnerships Program, using NGC's 35-nm-gate-length InP HEMT process technology. The chip utilizes three stages of HEMT amplifiers, each having two gate fingers of 10 μm in width. The circuits use grounded coplanar waveguide topology on a 50-μm-thick substrate with through substrate vias. Broadband matching is achieved with coplanar waveguide transmission lines, on-chip capacitors, and open stubs. When tested with wafer probing, the chip exhibited 10 dB of gain at 475 GHz, with over 9 dB of gain from 445–490 GHz.

Low-noise amplifiers in the 400–500 GHz range are useful for astrophysics receivers and earth science remote sensing instruments. In particular, molecular lines in the 400–500 GHz range include the CO 4-3 line at 460 GHz, and the CI fine structure line at 492 GHz. Future astrophysics heterodyne instruments could make use of high-gain, low-noise amplifiers such as the one described here. In addition, earth science remote sensing instruments could also make use of low-noise receivers with MMIC amplifier front ends.

Present receiver technology typically employs mixers for frequency down-conversion in the 400–500 GHz band. Commercially available mixers have typical conversion loss in the range of 7–10 dB with noise figure of 1,000 K. A low-noise amplifier placed in front of such a mixer would have 10 dB of gain and lower noise figure, particularly if cooled to low temperature. Future work will involve measuring the noise figure of this amplifier.

This work was done by Lorene A. Samoska, King Man Fung, David M. Pukala, and Pekka P. Kangaslahti of Caltech; and Richard Lai and Linda Ferreira of Northrup Grumman Corp. for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47541

Software to Control and Monitor Gas Streams

John F. Kennedy Space Center, Florida

This software package interfaces with various gas stream devices such as pressure transducers, flow meters, flow controllers, valves, and analyzers such as a mass spectrometer. The software provides excellent user interfacing with various windows that provide time-domain graphs, valve state buttons, priority-colored messages, and warning icons. The user can configure the software to save as much or as little data as needed to a comma-delimited file. The software also includes an intuitive scripting language for automated processing. The configuration allows for the assignment of measured values or calibration so that raw signals can be viewed as usable pressures, flows, or concentrations in real time. The software is based on those used in two safety systems for shuttle processing and one volcanic gas analysis system.

Mass analyzers typically have very unique applications and vary from job to job. As such, software available on the market is usually inadequate or targeted on a specific application (such as EPA methods). The goal was to develop powerful software that could be used with prototype systems. The key problem was to generalize the software to be easily and quickly reconfigurable.

At Kennedy Space Center (KSC), the prior art consists of two primary methods. The first method was to utilize LabVIEW and a commercial data acquisition system. This method required rewriting code for each different application and only provided raw data. To obtain data in engineering units, manual calculations were required. The second method was to utilize one of the embedded computer systems developed for another system. This second method had the benefit of providing data in engineering units, but was limited in the number of control parameters.

Other products allow the same end effect, except multiple computers would be required along with multiple software packages. This is compounded by the difficulty in timing the various software products. The software package described here is a combination of gas stream monitoring software products. It combines pressure monitoring and control, fluid flow monitoring and control, and many chemical analysis products, including, but not limited to, mass analyzers, turbo pumps, dew point sensors, oxygen sensors, temperature sensors, and the like. It allows for real-time display of raw data as well as reassigned calibration data. The software is capable of timing events as well as running scripts for semi-autonomous operation. The software also records this variety of data with proper timing.

This complex software package is composed of two primary parts: hardware communications and user interfacing. The hardware interfacing section allows for the computer to transfer data and commands (via digital or analog signals) to a wide variety of system components such as sensors, valves, transducers, analyzers, pumps, etc. The hardware interfacing section also allows for the recording of the transferred data/commands to be stored on the local computer. The user interface section gathers the data from the hardware interfacing section and presents it to the user in various user-configurable methods. The two most common methods of providing data to the user are via time-domain charting and real-time parameter value/status.

This work was done by C. Arkin, Charles Curley, Eric Gore, David Floyd, and Damion Lucas of Kennedy Space Center. Further information is contained in a TSP (see page 1). KSC-13643

Miniaturized Laser Heterodyne Radiometer (LHR) for Measurements of Greenhouse Gases in the Atmospheric Column

Instrument could be used to validate other Earth observing missions.

Goddard Space Flight Center, Greenbelt, Maryland

This passive laser heterodyne radiometer (LHR) instrument simultaneously measures multiple trace gases in the atmospheric column including carbon dioxide (CO_2) and methane (CH_4), and resolves their concentrations at different altitudes. This instrument has been designed to operate in tandem with the passive aerosol sensor currently used in AERONET (an established network of more than 450 ground aerosol monitoring instruments worldwide). Because aerosols induce a radiative effect that influences terrestrial carbon exchange, simultaneous detection of aerosols with these key carbon cycle gases offers a uniquely comprehensive measurement approach.

Laser heterodyne radiometry is a technique for detecting weak signals that was adapted from radio receiver technology. In a radio receiver, a weak input signal from a radio antenna is mixed with a stronger local oscillator signal. The mixed signal (beat note, or intermediate frequency) has a frequency equal to the difference between the input signal and the local oscillator. The intermediate frequency is amplified and sent to a detector that extracts the audio from the signal.

In the LHR instrument described here, sunlight that has undergone absorption by the trace gas is mixed with laser light at a frequency matched to a trace gas absorption feature in the infrared (IR). Mixing results in a beat signal in the RF (radio frequency) region that can be related to the atmospheric concentration. For a one-second integration, the estimated column sensitivities are 0.1 ppmv for CO_2, and <1 ppbv for CH_4.

In addition to producing a standalone ground measurement product, this instrument could be used to calibrate/validate four Earth observing missions: ASCENDS (Active Sensing of CO_2 Emissions over Nights, Days, and Seasons), OCO-2 (Orbiting Carbon Observatory), OCO-3, and GOSAT (Greenhouse gases Observational SATellite).

The only network that currently measures CO_2 and CH_4 in the atmospheric column is TCCON (Total Carbon Column Observing Network), and only two of its 16 operational sites are in the United States. TCCON data is used for validation of GOSAT data, and will be used for OCO-2 validation. While these Fourier-transform spectrometers (FTS) can measure the largest range of trace gases, the network is severely limited due to the high cost and extreme size of these instruments (these occupy small buildings and require personnel for operation). The LHR/AERONET instrument offers a significantly smaller (carry-on luggage size) autonomous instrument that can be incorporated into AERONET's much larger (450 instruments) global network.

This work was done by Emily Steel and Matthew McLinden of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16327-1

Anomaly Detection in Test Equipment via Sliding Mode Observers

Commercial applications of the algorithms exist in the oil, natural gas, and chemical industries for identifying and localizing leaks.

Stennis Space Center, Mississippi

Nonlinear observers were originally developed based on the ideas of variable structure control, and for the purpose of detecting disturbances in complex systems. In this anomaly detection application, these observers were designed for estimating the distributed state of fluid flow in a pipe described by a class of advection equations.

The observer algorithm uses collected data in a piping system to estimate the distributed system state (pressure and velocity along a pipe containing liquid gas propellant flow) using only boundary measurements. These estimates are then used to further estimate and localize possible anomalies such as leaks or foreign objects, and instrumentation metering problems such as incorrect flow meter orifice plate size.

The observer algorithm has the following parts: a mathematical model of the fluid flow, observer control algorithm, and an anomaly identification algorithm. The main functional opera-