HCl, and HF during thermal ISRU processing with hydrogen or other reducing gases. Removal of contaminant gases is required during ISRU processing to prevent hardware corrosion, electrolyzer damage, and catalyst poisoning. The use of Earth-supplied, single-use consumables to entirely remove contaminants at the levels existing in lunar soils would make many ISRU processes unattractive due to the large mass of consumables relative to the mass of oxygen produced. The LSCS concept of using a primary sorbent prepared from lunar soil was identified as a method by which the majority of contaminants could be removed from process gas streams, thereby substantially reducing the required mass of Earth-supplied consumables.

The LSCS takes advantage of minerals containing iron and calcium compounds that are present in lunar soil to trap sulfur and halide gases in a fixed-bed reactor downstream of an in-ISRU process such as hydrogen reduction. The lunar-soil-sorbent trap is held at a temperature significantly lower than the operating temperature of the hydrogen reduction or other ISRU process in order to maximize capture of contaminants, but is held at a high enough temperature to allow moisture to pass through without condensing. The lunar soil benefits from physical beneficiation to remove ultrafine particles (to reduce pressure drop through a fixed bed reactor) and to upgrade concentrations of iron and/or calcium compounds (to improve reactivity with gaseous contaminants).

*This work was done by Mark Berggren, Robert Zubrin, and Emily Bostwick-White of Pioneer Astronautics for Kennedy Space Center. Further information is contained in a TSP (see page 1).* KSC-13233/615

# Environmental Qualification of a Single-Crystal Silicon Mirror for Spaceflight Use

*Goddard Space Flight Center, Greenbelt, Maryland*

This innovation is the environmental qualification of a single-crystal silicon mirror for spaceflight use. The single-crystal silicon mirror technology is a previous innovation, but until now, a mirror of this type has not been qualified for spaceflight use. The qualification steps included mounting, gravity change measurements, vibration testing, vibration-induced change measurements, thermal cycling, and testing at the cold operational temperature of 225 K.

Typical mirrors used for cold applications for spaceflight instruments include aluminum, beryllium, glasses, and glass-like ceramics. These materials show less than ideal behavior after cooldown. Single-crystal silicon has been demonstrated to have the smallest change due to temperature change, but has not been spaceflight-qualified for use. The advantage of using a silicon substrate is with temperature stability, since it is formed from a stress-free single crystal. This has been shown in previous testing. Mounting and environmental qualification have not been shown until this testing.

*This work was done by John Hagopian, John Chambers, Scott Rohrback, Vincent Bly, Armando Morell, and Jason Budinoff of Goddard Space Flight Center. Further information is contained in a TSP (see page 1).* GSC-16473-1

# Planar Superconducting Millimeter-Wave/Terahertz Channelizing Filter

## The design enables multiple-octave operation with no spurious harmonic response.

*Goddard Space Flight Center, Greenbelt, Maryland*

This innovation is a compact, superconducting, channelizing bandpass filter on a single-crystal (0.45 μm thick) silicon substrate, which operates from 300 to 600 GHz. This device consists of four channels with center frequencies of 310, 380, 460, and 550 GHz, with approximately 50-GHz bandwidth per channel. The filter concept is inspired by the mammalian cochlea, which is a channelizing filter that covers three decades of bandwidth and 3,000 channels in a very small physical space. By using a simplified physical cochlear model, and its electrical analog of a channelizing filter covering multiple octaves bandwidth, a large number of output channels with high inter-channel isolation and high-order upper stopband response can be designed.

A channelizing filter is a critical component used in spectrometer instruments that measure the intensity of light at various frequencies. This embodiment was designed for MicroSpec in order to increase the resolution of the instrument (with four channels, the resolution will be increased by a factor of four). MicroSpec is a revolutionary wafer-scale spectrometer that is intended for the SPICA (Space Infrared Telescope for Cosmology and Astrophysics) Mission. In addition to being a vital component of MicroSpec, the channelizing filter itself is a low-resolution spectrometer when integrated with only an antenna at its input, and a detector at each channel's output.

During the design process for this filter, the available characteristic impedances, possible lumped element ranges, and fabrication tolerances were identified for design on a very thin silicon substrate. Iterations between full-wave and lumped-element circuit simulations were performed. Each channel's circuit was designed based on the availability of characteristic impedances and lumped element ranges.

This design was based on a tabular type bandpass filter with no spurious harmonic response. Extensive electromagnetic modeling for each channel was performed. Four channels, with 50-GHz bandwidth, were designed, each using multiple transmission line media such as microstrip, coplanar waveguide, and quasi-lumped components on 0.45-μm thick silicon. In the design process, modeling issues had to be overcome. Due to the extremely high frequencies, very thin Si substrate, and the superconducting metal layers, most commercially available software fails in various ways. These issues were mitigated by using alternative software that was capable of handling them at the expense of greater simulation time. The design of on-chip components for the filter characterization, such as a broadband antenna, Wilkinson power dividers, attenuators, detectors, and transitions has been completed.

*This work was done by Negar Ehsan, Kongpop U-yen, Ari Brown, Wen-Ting Hsieh, Edward Wollack, and Samuel Moseley of Goddard Space Flight Center. Further information is contained in a TSP (see page 1).*
*GSC-16486-1*

# Qualification of UHF Antenna for Extreme Martian Thermal Environments

## This innovation can be used in aerospace and deep space applications.

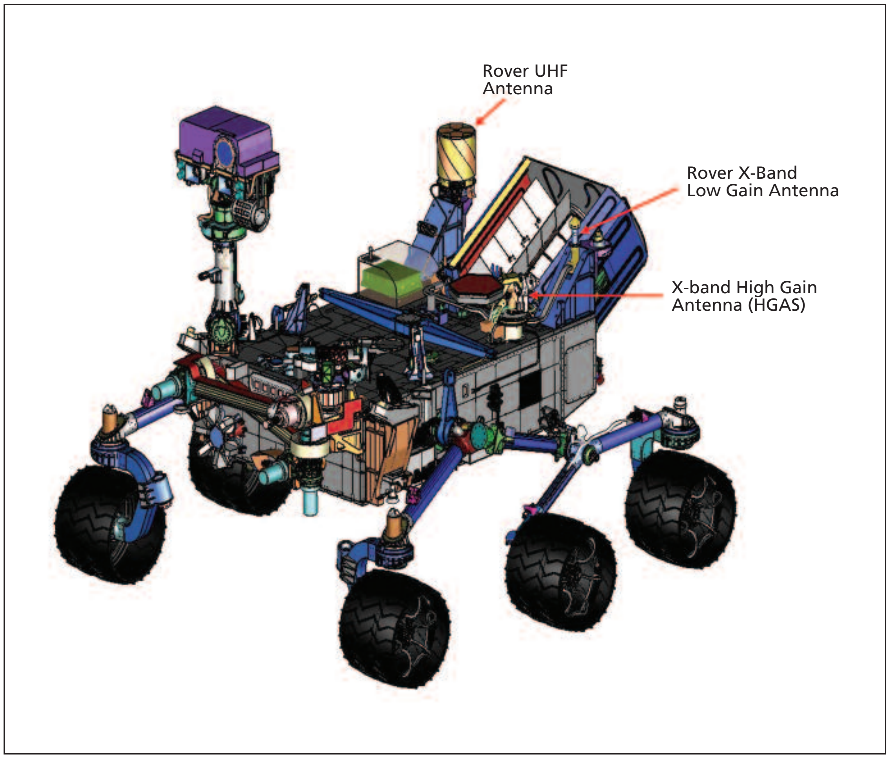
*NASA's Jet Propulsion Laboratory, Pasadena, California*

The purpose of this development was to validate the use of the external Rover Ultra High Frequency (RUHF) antenna for space under extreme thermal environments to be encountered during the surface operations of the Mars Science Laboratory (MSL) mission. The antenna must survive all ground operations plus the nominal 670 Martian sol mission that includes summer and winter seasons of the Mars thermal environment. The qualification effort was to verify that the RUHF antenna design and its bonding and packaging processes are adequate to survive the harsh environmental conditions.

The RUHF is a quadrifilar helix antenna mounted on the MSL Curiosity rover deck. The main components of the RUHF antenna are the helix structure, feed cables, and hybrid coupler, and the high-power termination load.

In the case of MSL rover externally mounted hardware, not only are the expected thermal cycle depths severe, but there are temperature offsets between the Mars summer and winter seasons. The total number of temperature cycles needed to be split into two regimes of summer cycles and winter cycles.

The qualification test was designed to demonstrate a survival life of three times more than all expected ground testing, plus a nominal 670 Martian sol missions. Baseline RF tests and a visual inspection were performed prior to the start of the qualification test. Functional RF tests were performed intermittently during chamber breaks over the course of the qualification test. For the RF return loss measurements, the antenna was tested in a controlled environment outside the thermal chamber with a vector network analyzer that was calibrated over the antenna's operational frequency range.




The locations of the **Rover UHF (RUHF)**, rover X-band low-gain, and rover X-band high-gain antennas on the Mars Science Laboratory rover.

A total of 2,010 thermal cycles were performed. Visual inspection showed a dulling of the solder material. This change will not affect the performance of the antenna. No other changes were observed. RF tests were performed on the RUHF helix antenna, hybrid, and load after the 2,010 qualification cycles test. The RF performance of the RUHF antenna, hybrid, and load were almost identical before and after the complete test. Therefore, the developed design of RUHF is qualified for a long-duration MSL mission.

The RUHF antenna has not been used for long-duration missions such as MSL in the past. The state-of-the-art technology of the RUHF antenna is used to develop the antennas for MSL mission survivability. This developmental test data provides the confidence in using this RUHF antenna for future NASA missions to Mars.

*This work was done by Rajeshuni Ramesham, Luis R. Amaro, Paula R. Brown, and Robert Usiskin of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*
*NPO-48475*