the chamber to an absolute pressure of about 3 kpsi (≈21 MPa). In phase 2, valve 2 is opened, allowing the pressurized hydraulic fluid to flow through the hydraulic motor and into the bellows in a second, lower-pressure gas-spring/bellows chamber. Upon completion of this flow, valves 1 and 2 are closed and valve 3 opened in anticipation of phase 3. In phase 3, which takes place upon cooling to <10 °C at depth, contraction of the PCM upon freezing reverses the pressure gradient in the plumbing, causing the hydraulic fluid to flow from the second gas-spring/bellows chamber back to the chamber containing the PCM.

This work was done by Yi Chao, Jack Jones, and Thomas Valdez of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-45404, volume and number of this NASA Tech Briefs *issue, and the page number.*

Reflector Surface Error Compensation in Dual-Reflector Antennas

Real-time detection and compensation of reflector surface errors is enabled for large reflector antennas such as inflatable antennas for Earth and space science applications.

NASA's Jet Propulsion Laboratory, Pasadena, California

By probing the field on a small subreflector at a minimal number of points, the main reflector surface errors can be obtained and subsequently used to design a phase-correction subreflector that can compensate for main reflector errors. The compensating phase-error profile across the subreflector can be achieved either by a surface deformation or by the use of an array of elements such as patch antennas that can cause a phase shift between the incoming and outgoing fields. The second option is of primary interest here, but the methodology can be applied to either case. The patch array is most easily implemented on a planar surface. Therefore, the example of a flat subreflector and a parabolic main reflector (a Newtonian dual reflector system) is considered in this work.

The subreflector is assumed to be a reflector array covered with patch elements. The phase variation on a subreflector can be detected by a small number of receiving patch elements (probes). By probing the phase change at these few selected positions on the subreflector, the phase error over the entire surface can be recovered and used to change the phase of all the patch elements covering the subreflector plane to compensate for main reflector errors. This is accomplished by using a version of sampling theorem on the circular aperture.

The sampling is performed on the phase-error function on the circular aperture of the main reflector by a method developed using Zernike polynomials. This method is based upon and extended from a theory previously proposed and applied to reflector aperture integration. This sampling method provides for an exact retrieval of the coefficients of up to certain orders in the expansion of the phase function, from values on a specifically calculated set of points in radial and azimuthal directions in the polar coordinate system, on the circular reflector aperture. The corresponding points on the subreflector are then obtained and, by probing the fields at these points, a set of phase values is determined that is then transferred back to the main reflector aperture for recovering the phase function. Once this function is recovered, the corresponding phase function on the subreflector is calculated and used to compensate for main reflector surface errors. In going back and forth between sub and main reflectors, geometrical (ray) optics is employed, which even though it ignores edge diffraction and other effects, is shown to be accurate for phase recovery.

This work has direct application to reflector antennas, particularly large spaceborne inflatable antennas at X, Ka, and higher frequency bands. This method can also be effective in scanning or multi-beam reflector antenna systems in which the range of scan can be increased by phase-error compensation on the subreflector.

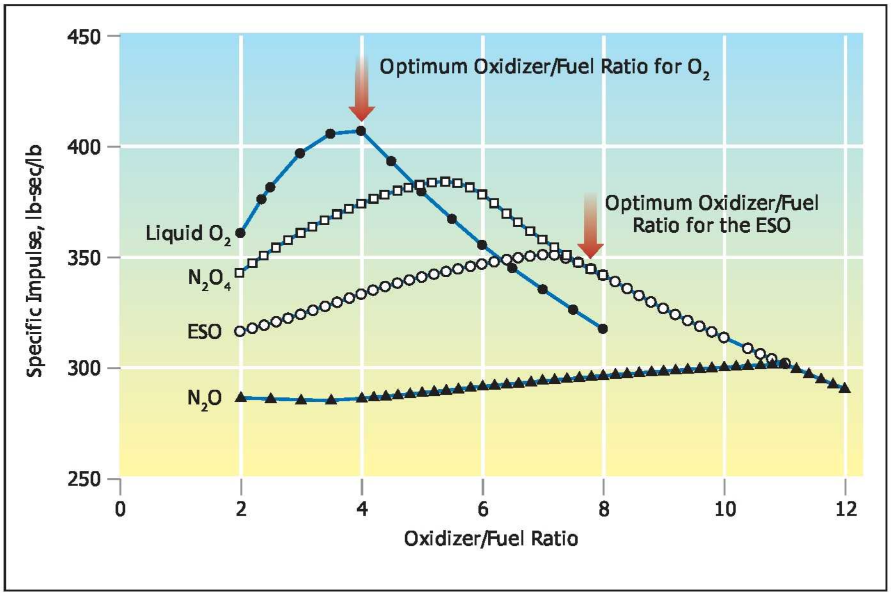
This work was done by Vahraz Jamnejad and William Imbriale of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-45373

Enriched Storable Oxidizers for Rocket Engines

These oxidizers could be stored at room temperature.

Marshall Space Flight Center, Alabama

The name "enriched storable oxidizers" (ESOs) has been coined for a family of optimized mixtures of between two and four oxidizer fluids. For most applications, the constituents of these mixtures would be nitrogen tetroxide (N_2O_4), nitrous oxide (N_2O), and nitrogen dioxide (NO_2); in some applications, the mixtures might include inhibited red fuming nitric acid [IRFN (which consists of red fuming nitric acid to which some hydrogen fluoride is added to reduce its corrosive effect]. The optimum proportions of these constituents would be different for different applications. ESOs were originally proposed for use in spacecraft and launch-rocket propulsion systems: ESOs could be especially useful in advanced spacecraft propulsion systems that could operate in multiple modes. ESOs might also



Specific Impulse Versus Oxidizer/Fuel Ratio was calculated for methane burned with either (1) N_2O_4, (2) an ESO comprising a mixture of 65 mole percent of N_2O with 35 mole percent of N_2O_4, (3) N_2O, or (4) liquid O_2. The combustion-chamber and exit pressures used in the calculations were 1,000 psi (≈6.89 MPa) and 0.05 psi (≈345 Pa), respectively. Stoichiometry favors higher oxidizer/fuel ratios for the ESO than for liquid O_2; this is fortuitous because, as the corresponding plots show, the higher mixture ratio yields higher specific impulse.

be useful in special terrestrial applications that could include ramjet and scramjet aircraft engines.

ESOs would offer an attractive alternative to liquid oxygen and other previously known oxidizer fluids, including the individual constituents of these mixtures:

- Unlike liquid oxygen and fluorine-based oxidizers, which must be stored under cryogenic conditions, ESOs could be stored at room temperature.
- In comparison with most previously known oxidizer fluids other than oxygen, nitrous oxide, and nitrogen peroxide, ESOs would be less toxic.
- In comparison with most previously known oxidizer fluids other than nitrous oxide, ESOs would be less corrosive, and would be more chemically stable in storage.

Calculations have shown that ESOs would offer high energy densities and that specific-impulse levels attainable by use of ESOs would approach those attainable by use of liquid oxygen with two hydrocarbon fuels — RP-1 (rocket propellant 1, which is similar to kerosene) and methane (see figure). ESOs would be hypergolic or nearly hypergolic with methane and RP-1 and with other fuels that include Jet-A (also similar to kerosene), hydrazine, and monomethyl hydrazine. A computational simulation has predicted that only benign exhaust products would result from burning methane or RP-1 with one of the ESOs (a mixture of 35 mole percent of N_2O_4 with 65 mole percent of N_2O): These exhaust products would be primarily CO_2, H_2O, and N_2, plus very small amounts of O_2.

This work was done by R. L. Sackheim of Marshall Space Flight Center and J. R. Herdy, Jr., of Qualis Corp.

This invention is owned by NASA, and a patent application has been filed. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32407-1.

Planar Submillimeter-Wave Mixer Technology With Integrated Antenna

This technology can be used for terahertz radar imagers and in testing of quantum cascade lasers.

NASA's Jet Propulsion Laboratory, Pasadena, California

High-performance mixers at terahertz frequencies require good matching between the coupling circuits such as antennas and local oscillators and the diode embedding impedance. With the availability of amplifiers at submillimeter wavelengths and the need to have multi-pixel imagers and cameras, planar mixer architecture is required to have an integrated system. An integrated mixer with planar antenna provides a compact and optimized design at terahertz frequencies. Moreover, it leads to a planar architecture that enables efficient interconnect with submillimeter-wave amplifiers.

In this architecture, a planar slot antenna is designed on a thin gallium arsenide (GaAs) membrane in such a way that the beam on either side of the membrane is symmetric and has good beam profile with high coupling efficiency. A coplanar waveguide (CPW) coupled Schottky diode mixer is designed and integrated with the antenna. In this architecture, the local oscillator (LO) is coupled through one side of the antenna and the RF from the other side, without requiring any beamsplitters or diplexers. The intermediate frequency (IF) comes out on a 50-ohm CPW line at the edge of the mixer chip, which can be wire-bonded to external circuits. This unique terahertz mixer has an integrated single planar antenna for coupling both the radio frequency (RF) input and LO injection without any diplexer or beam-splitters. The design utilizes novel planar slot antenna architecture on a 3-μm-thick GaAs membrane.

This work is required to enable future multi-pixel terahertz receivers for astrophysics missions, and lightweight and compact receivers for planetary missions to the outer planets in our solar system. Also, this technology can be used in terahertz radar imaging applications as well as for testing of quantum cascade lasers (QCLs).

This work was done by Goutam Chattopadhyay, Imran Mehdi, John J Gill, Choonsup Lee, and Nuria Llombart of Caltech for NASA's Jet Propulsion Laboratory and Bertrand Thomas of Oak Ridge Associated Universities. Further information is contained in a TSP (see page 1). NPO-46880