Books & Reports

Shock Waves in a Bose-Einstein Condensate

A paper presents a theoretical study of shock waves in a trapped Bose-Einstein condensate (BEC). The mathematical model of the BEC in this study is a nonlinear Schroedinger equation (NLSE) in which (1) the role of the wave function of a single particle in the traditional Schroedinger equation is played by a space- and time-dependent complex order parameter $\psi(\mathbf{x},t)$ proportional to the square root of the density of atoms and (2) the atoms engage in a repulsive interaction characterized by a potential proportional to $|\psi(\mathbf{x},t)|^2$. Equations that describe macroscopic perturbations of the BEC at zero temperature are derived from the NLSE and simplifying assumptions are made, leading to equations for the propagation of sound waves and the transformation of sound waves into shock waves. Equations for the speeds of shock waves and the relationships between jumps of velocity and density across shock fronts are derived. Similarities and differences between this theory and the classical theory of sound waves and shocks in ordinary gases are noted. The present theory is illustrated by solving the equations for the example of a shock wave propagating in a cigar-shaped BEC.

This work was done by Igor Kulikov and Michail Zak of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-30593

Progress on a Multichannel, Dual-Mixer Stability Analyzer

Several documents describe aspects of the continuing development of a multichannel, dual-mixer system for simultaneous characterization of the instabilities of multiple precise, low-noise oscillators. One of the documents presents the basic principles and design concept that were summarized in "Oscillator-Stability Analyzer Based on a Time-Tag Counter" (NPO-20749), *NASA Tech Briefs*, Vol. 25, No. 5 (May 2001), page 48. To recapitulate: One of the oscillators would be deemed to be a reference oscillator, its frequency would be offset by an amount (100 Hz) much greater than the desired data rate, and each of the other oscillators would be compared with the frequency-offset signal by operation of a combination of hardware and software. A high-rate time-tag counter would collect zero-crossing times of the ≈100-Hz beat notes. The system would effect a combination of interpolation and averaging to process the time tags into low-rate phase residuals at the desired grid times. Circuitry that has been developed since the cited prior article includes an eight-channel timer board to replace an obsolete commercial time-tag counter, plus a custom offset generator, cleanup loop, distribution amplifier, zero-crossing detector, and frequency divider.

This work was done by Albert Kirk, Steven Cole, Gary Stevens, Blake Tucker, and Charles Greenhall of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-40468

Development of Carbon-Nanotube/Polymer Composites

A report presents a short discussion of one company's effort to develop composites of carbon nanotubes in epoxy and other polymer matrices. The focus of the discussion is on the desirability of chemically modifying carbon nanotubes to overcome their inherent chemical nonreactivity and thereby enable the formation of strong chemical bonds between nanotubes and epoxies (or other polymeric matrix materials or their monomeric precursors). The chemical modification is effected in a process in which discrete functional groups are covalently attached to the nanotube surfaces. The functionalization process was proposed by the company and demonstrated in practice for the first time during this development effort. The covalently attached functional groups are capable of reacting with the epoxy or other matrix resin to form covalent bonds. Furthermore, the company uses this process to chemically modify the nanotube surfaces, affording "tunable" adhesion to polymers and solubility in select solvents. Flat-sheet composites containing functionalized nanotubes demonstrate significantly improved mechanical, thermal, and electrical properties.

This work was done by Thomas A. Reynolds of ReyTech Corp. for **Johnson Space Center**. *For further information, contact the Johnson Innovative Partnerships Office at (281) 483-3809.*
MSC-23428

Thermal Imaging of Earth for Accurate Pointing of Deep-Space Antennas

A report discusses a proposal to use thermal (long-wavelength infrared) images of the Earth, as seen from spacecraft at interplanetary distances, for pointing antennas and telescopes toward the Earth for Ka-band and optical communications. The purpose is to overcome two limitations of using visible images: (1) at large Earth phase angles, the light from the Earth is too faint; and (2) performance is degraded by large albedo variations associated with weather changes. In particular, it is proposed to use images in the wavelength band of 8 to 13 μm, wherein the appearance of the Earth is substantially independent of the Earth phase angle and emissivity variations are small. The report addresses tracking requirements for optical and Ka-band communications, selection of the wavelength band, available signal level versus phase angle, background noise, and signal-to-noise ratio. Tracking errors are estimated for several conceptual systems employing currently available infrared image sensors. It is found that at Mars range, it should be possible to locate the centroid of the Earth image within a noise equivalent angle (a random angular error) between 10 and 150 nanoradians at a bias error of no more than 80 nanoradians.

This work was done by Gerardo Ortiz and Shinhak Lee of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-40395

Modifications of a Composite-Material Combustion Chamber

Two short reports discuss modifications of a small, lightweight combustion chamber that comprises a carbon/carbon composite outer shell and an iridium/rhenium inner liner. The first report discusses chamber design modifications made as results of hot-fire tests and post-test characterization. The modifications were intended to serve a variety of purposes, including improving fabrication, reducing thermal-expansion mismatch stresses, increasing strength-to-weight ratios of some components, and improving cooling of some components. The second report discusses (1) the origin of stress in the mismatch between the thermal expansions of the Ir/Re liner and a niobium sleeve and flange attached to the carbon/carbon shell and (2) a modification intended to relieve the stress. The modification involves the redesign of an inlet connection to incorporate a compressible seal between the Ir/Re liner and the Nb flange. A nickel alloy was selected as the seal material on the basis of its thermal-expansion properties and its ability to withstand the anticipated stresses, including the greatest stresses caused by the high temperatures to be used in brazing during fabrication.

This work was done by Brian E. Williams and Shawn R. McNeal of Ultramet for **Johnson Space Center**. *For further information, contact the Johnson Innovative Partnerships Office at (281) 483-3809.*

MSC-22981/82

Modeling and Diagnostic Software for Liquefying-Fuel Rockets

A report presents a study of five modeling and diagnostic computer programs considered for use in an integrated vehicle health management (IVHM) system during testing of liquefying-fuel hybrid rocket engines in the Hybrid Combustion Facility (HCF) at NASA Ames Research Center. Three of the programs — TEAMS, L2, and RODON — are model-based reasoning (or diagnostic) programs. The other two programs — ICS and IMS — do not attempt to isolate the causes of failures but can be used for detecting faults. In the study, qualitative models (in TEAMS and L2) and quantitative models (in RODON) having varying scope and completeness were created. Each of the models captured the structure and behavior of the HCF as a physical system. It was noted that in the cases of the qualitative models, the temporal aspects of the behavior of the HCF and the abstraction of sensor data are handled outside of the models, and it is necessary to develop additional code for this purpose. A need for additional code was also noted in the case of the quantitative model, though the amount of development effort needed was found to be less than that for the qualitative models.

This work was done by Scott Poll, David Iverson, Jeremy Ou, Dwight Sanderfer, and Ann Patterson-Hine of **Ames Research Center**. *Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Innovative Partnerships Division, Ames Research Center, (650) 604-2954. Refer to ARC-15341-1.

Spacecraft Antenna Clusters for High EIRP

Several documents in a collection discuss a proposal to use clusters of appropriately phased, relatively small microwave antennas to obtain high levels of effective isotropically radiated power (EIRP) for transmission of data from spacecraft to Earth during exploration of distant planets. The advantages of such a cluster, relative to a single larger antenna of equivalent EIRP, would include the following:

- The cluster would have less mass and volume.
- Power densities in amplifiers, waveguides, and other transmitting components feeding the antennas would be lower. Therefore, problems of preventing overheating and high-voltage breakdown would be less severe.
- Phases could be made electronically adjustable for beam steering to increase pointing accuracy.
- Failure of one antenna or its feed system would reduce the EIRP but would not disable the entire transmitting system. Beam-steering capability would remain as long as at least three antennas (and their feed systems) in a triangular arrangement remained functional.

The documents summarize the applicable basic principles of antenna design and requirements that would govern the design of an antenna cluster for a specific proposed mission [the Jupiter Icy Moons Orbiter (JIMO)]. Candidate design concepts for realizing the aforementioned and other advantages for JIMO are analyzed.

This work was done by Robert Clauss, Richard Lovick, Narayan Mysoor, and John Zitzelberger of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

NPO-40729