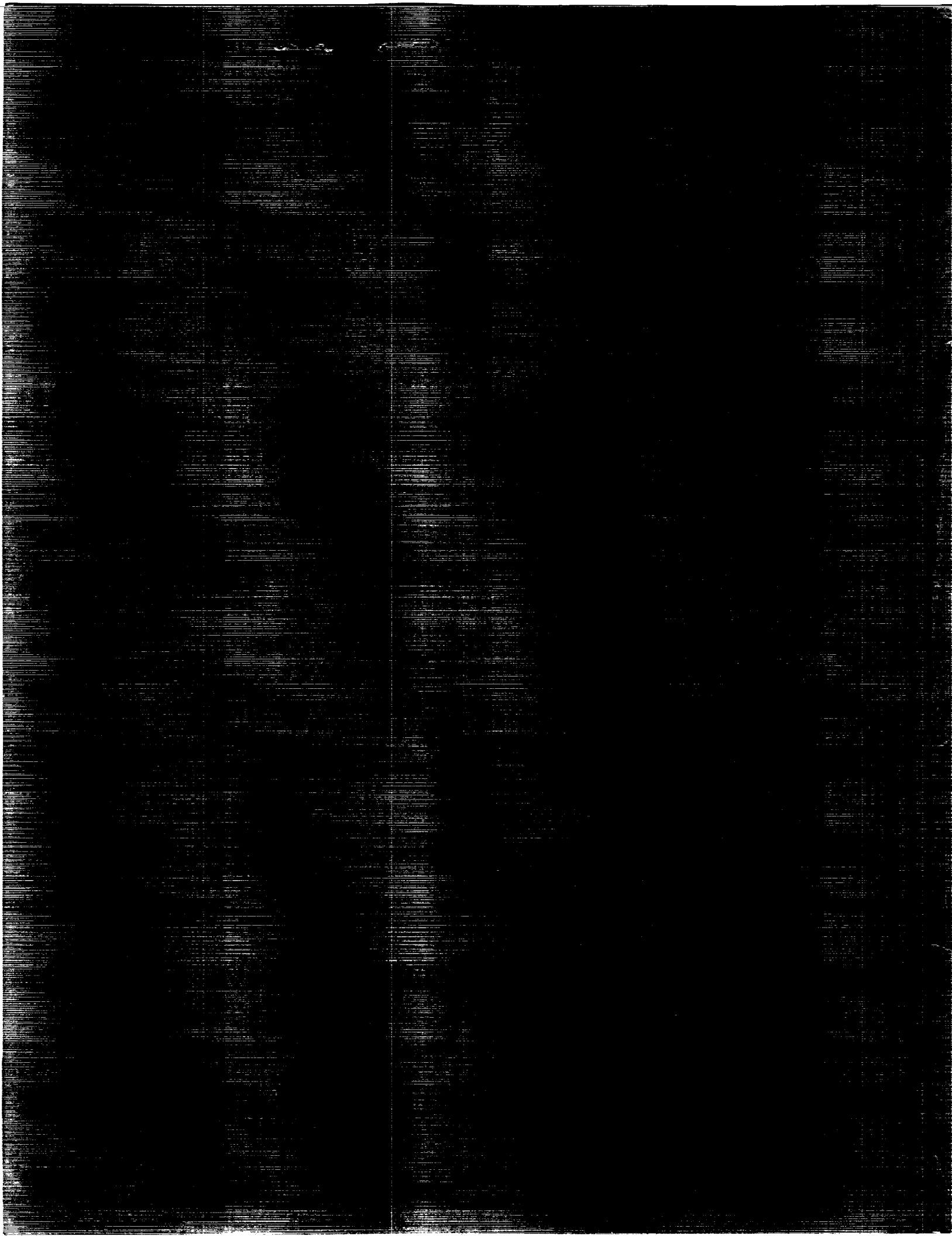
SBIR 87-2

Small Business Innovation Research

Abstracts of Completed 1987 Phase I Projects

December 1989

SBIR PROGRAM
WASHINGTON, D.C.
20546



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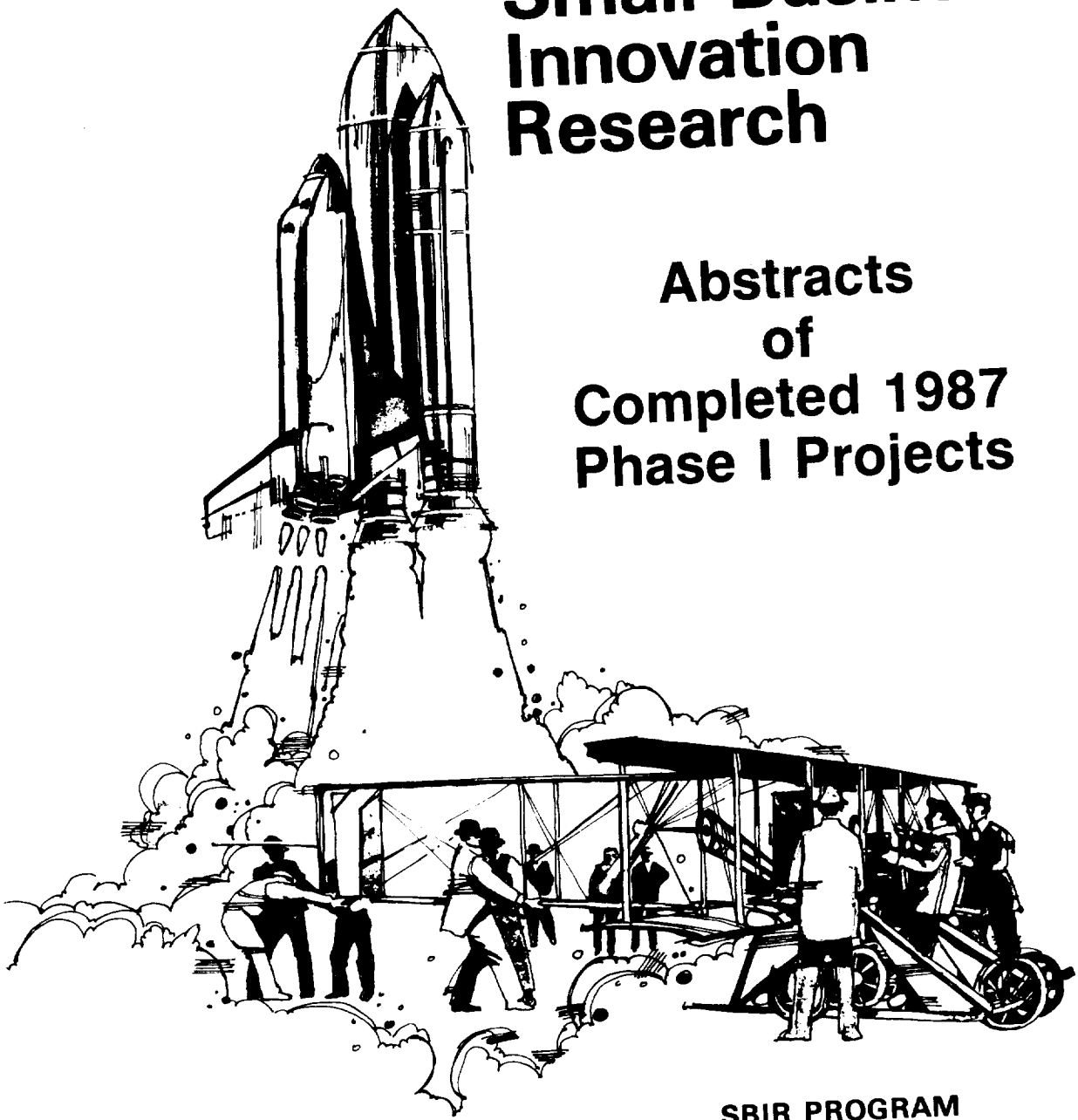

NASA

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Prepared for the Small Business Innovation Research Office, Office of Commercial Programs, National Aeronautics and Space Administration, by F.C. Schwenk and J.A. Gilman of TEM Associates.

INTRODUCTION

This document contains non-proprietary summaries of the results of the set of Phase I Small Business Innovation Research (SBIR) projects supported by the National Aeronautics and Space Administration (NASA) as part of the 1987 Program Year. A Program Year includes all Phase I projects which result from an annual Program Solicitation and the Phase II projects subsequently selected for continuation. The appendices provide background information on the SBIR program, statistics on NASA's program to date, the technical topic and subtopic areas in which proposals were solicited in 1987, and information about the award selection process. The five indexes contain listings through which cross-references may be made for projects, companies, their locations by state, the NASA Field Centers responsible for each project's management, and the principal investigator for each one. For simplicity, each project has been assigned a sequential identifying number, from 001 to 204, in ascending order as found in the body of the report.

The objective of this report is to provide information about the SBIR program to anyone concerned with NASA R&D activities including managers of NASA projects, prime contractors who could benefit from the research conducted through SBIR, industrial concerns and investors who may support further development and marketing of the results of SBIR projects, and small business firms that may wish to submit SBIR proposals and need information on the types of projects of interest to NASA. The information in the abstracts was supplied by the participating small business companies and has been issued by NASA solely for the purpose of information exchange. NASA does not guarantee its accuracy or validity. Readers are encouraged to contact the small businesses for further information or clarification.

The closing date for the 1987 SBIR Program Solicitation was June 19, 1987, at which time NASA had received 1826 Phase I proposals from small business firms. On November 4, 1987, after the evaluation and selection processes were completed, NASA announced that 205 research proposals were chosen to receive six-month Phase I contract awards. Following completion of contract negotiations early in 1988, 204 Phase I contracts had been placed with 170 different small R&D firms located in 29 states.

Of these Phase I projects, all were sent requests to submit proposals for Phase II continuations and 177 Phase II proposals were received. These and two other Phase II proposals (one carried over from 1986 and another recommended to NASA for consideration by the Department of Defense) constituted the group of 179 proposals from which 100 were chosen for Phase II contract negotiations. Phase II projects resulting from these contract negotiations began early in 1989 and most will continue into 1991.

The NASA SBIR program has been supporting research of interest to the agency and the aerospace community since 1983. Since Fiscal Year 1986, as required by law, the funding set-aside for the SBIR program is 1.25 percent of NASA's annual budget for extramural R&D. Since the NASA budget is dedicated, in large part, to the accomplishment of specific mission and R&D goals which provide few options in their use of budgeted R&D, the SBIR program constitutes a significant portion of the agency's discretionary research effort.

Program management is provided by the SBIR Office in the NASA Headquarters Office of Commercial Programs. The proposals are evaluated by nine NASA Field Centers who also let the contracts and manage individual projects. The following Centers are responsible for implementing the NASA SBIR program:

- **ARC** Ames Research Center, Moffet Field, CA 94035
- **GSFC** Goddard Space Flight Center, Greenbelt, MD 20771
- **JPL** Jet Propulsion Laboratory, Pasadena, CA 91109
- **JSC** Johnson Space Center, Houston, TX 77058
- **KSC** Kennedy Space Center, FL 32899
- **LaRC** Langley Research Center, Hampton, VA 23665
- **LeRC** Lewis Research Center, Cleveland, OH 44135
- **MSFC** Marshall Space Flight Center, AL 35812
- **SSC** Stennis Space Center, MS 39529

PRESENTATION OF PROJECT RESULTS

The main body of this document presents the results, as reported by the contractors conducting them, of 204 Phase I SBIR projects arising from the 1987 Program Solicitation. The order of presentation is according to technical topics. Since 1984, each NASA SBIR Program Solicitation has contained the following fifteen Technical Topics:

01 Aeronautical Propulsion and Power
02 Aerodynamics and Acoustics
03 Aircraft Systems, Subsystems, and Operations
04 Materials and Structures
05 Teleoperators and Robotics
06 Computer Sciences and Applications
07 Information Systems and Data Handling
08 Instrumentation and Sensors
09 Spacecraft Systems and Subsystems
10 Space Power
11 Space Propulsion
12 Human Habitability and Biology in Space
13 Quality Assurance, Safety, and Check-out for Ground and Space Operations
14 Satellite and Space Systems Communications
15 Materials Processing, Microgravity, and Commercial Applications in Space.

Each technical topic contains a number of subtopics which specify the problems or opportunities to which the small business firms are invited to address Phase I proposals. The number and content of the subtopics change from year to year depending on the interests of the agency. The SBIR Program Solicitation for 1987 included the 122 subtopics listed in Appendix B.

The information provided for each of the 204 projects (1987 Phase I) includes the name and address of the firm that performed the work, the name of the principal investigator, the NASA Center which monitored the contract, and a brief summary of results of the Phase I contract and the potential commercial application of the proposed innovation identified by the contractor. The 98 projects in this group which were selected in December of 1988 and February of 1989 to receive a Phase II award are identified. Two other Phase I projects were also chosen for Phase II at this time: an 86-1 Phase I project whose circumstances in 1988 prevented its completion and competition with the 86-1 group and a proposal highly recommended by the Air Force which NASA found to be of great value to the NASA R&D program. They are described in Appendix C.

The format for presenting the information for each project is as shown below:

Project Number+ ——>
Project Title ——>
NASA Center ——>
Abstract ——>

* 160 <—— Serial Number (* indicates a Phase II award)
87-1-11.01-3350
Thrust Vector Control
Sparta, Inc. <—— Company Name
3440 Carson Street, Suite 300
Torrance, CA 90503
Irving B. Osofsky (213-542-6090) <—— Principal Investigator
MSFC -- NAS8-37640 <—— Contract Number
This innovation concerns obtaining thrust vector control in a solid-propellant, booster rocket motor by means of...

+ *Note: Project Number is composed of the program year (87), the topic and subtopic numbers (11.01) and an identifying number (3350).*

The data is the most current available. In cases where firms have changed names or rights to Phase I results have been sold, the new name or owner is shown since one purpose of this publication is to enable interested parties to contact the researchers directly.

Table of Contents

ABSTRACTS OF COMPLETED NASA SBIR 1987 PHASE I PROJECTS

01 AERONAUTICAL PROPULSION AND POWER

* 001
87-1-01.01-3800
Multigrid Solution of Internal Flows Using Generalized Solution Adaptive Meshes
Creare Incorporated
PO Box 71
Hanover, NH 03755
Wayne Smith (603-643-3800)
LeRC -- NAS3-25405

In this project, an innovative, interactive, general purpose solver for high-speed compressible flows that uses unstructured, solution-adaptive meshes composed of tetrahedral cells was investigated. Such a computer program will represent a significant advance in the state of the art and will be a powerful tool for the study of inviscid and turbulent three-dimensional transonic and supersonic flows.

The Phase I effort demonstrated that an unstructured, second-order accurate, finite-volume formulation is able to produce accurate, highly detailed flow solutions. The unstructured mesh formulation easily accommodates complex flow features such as shocks and boundary layers. The mesh refinement algorithm provides highly localized mesh refinement while maintaining excellent cell aspect and volume ratios.

Potential Commercial Application: This code will have significant applications for research and design involving high speed flows in turbines, compressors, inlets, aircraft, and hypersonic flight vehicles.

***

* 002
87-1-01.01-5094
Boundary Layer Control Methods in High Speed Inlet Systems
Rose Engineering & Research, Inc.
PO Box 5146
Incline Village, NV 89450
William C. Rose (702-831-5094)
LeRC -- NAS3-25408

The objective of the Phase I effort was to determine the feasibility of using innovative, boundary-layer control arrangements that allow high inlet recovery to be achieved at low bleed rates. This analytical investigation was carried out with the use of a full Navier-Stokes code, and a review was conducted of the relevant literature on recent developments in boundary-layer control in high-speed engine inlets. Of particular interest were inlets intended to operate at flight Mach numbers above 3.0 where viscous effects dominate the behavior of the internal flow.

Various proposed flow control techniques were investigated. The cutback sidewall technique was very successful at minimizing distortion, but an unknown and potentially debilitating amount of the inlet mass flow would, of necessity, be spilled as a result of the lack of the lateral sidewalls. The Phase I effort concentrated on the "design" value for Mach 5; however, it is recognized that flow control methods must work across a wide range of Mach numbers.

Potential Commercial Application: Commercial applications include military aircraft and civilian aircraft used for transportation of people and packages throughout the world.

***

003
87-1-01.02-0236
Advanced Thermal Protection Materials
Ultramet
12173 Montague Street
Pacoima, CA 91331
Richard B. Kaplan (818-899-0236)
LeRC -- NAS3-25411

The objective of this project is to develop a new process for making light-weight, high-temperature, high-performance structural materials for use in hot section components of aircraft propulsion engines through an innovative application of chemical vapor deposition and infiltration (CVD or CVI). The process involves infiltrating a reticulated carbon foam with rhenium, sheathing it with rhenium to form a quasi-honeycomb structure, and overcoating the resultant composite structure with a refractory ceramic for oxidation and erosion protection.

Phase I thoroughly investigated the rhenium infiltration process to form a refractory-metal foam; however, equipment and time limitations did not allow a determination of the effects of a rhenium sheath on the foam properties. Nevertheless, application of a sheath on the foam caused a 2000 percent increase in crush strength from 1000 psi to >20,000 psi, the load cell limit. The drastic increase in strength results from an almost complete load transfer and uniform stress distribution over the stronger "skin" of the structure. One-sided heating tests demonstrated the material's high thermal impedance, stability, and shock resistance. Oxidation protection for the rhenium, using a diffusion barrier and Hf-Si-C deposited on the foam structure, was demonstrated by inspection of the surface after heating with an H_2-O_2 torch to 1800 C.

Potential Commercial Application: Primary applications are for a combustor liner in advanced small gas turbine engines; for other hot section components

of jet engines such as turbine shrouds, exhaust nozzles and nozzle liners, and convergent and divergent flaps; for hot gas valves and rocket nozzles; and for oxidation protection of refractory metals and intermetallics.

***

004
87-1-01.02-7300
Pulse Combustor Driven Recuperated or Regenerated Gas Turbine
Altex Technologies Corporation
650 Nuttman Road
Santa Clara, CA 95054
John T. Kelly (408-395-7300)
LeRC -- NAS3-25404

The goal of achieving minimum-volume, lightweight, efficient and environmentally clean "small" gas-turbine systems for aircraft propulsion may be met with an innovative pulsed-combustor-driven, recuperated or regenerated, gas turbine (PCRGT) concept. It is based upon the fact that pulsating combustion generates velocity fluctuations which propagate throughout the system and increase heat and mass transport. Combustion and diluent air mixing are intensified by the pulsations, thereby leading to greater combustion efficiency and smaller and lighter combustors. Pressure is gained across the combustor, which directly increases cycle efficiency. Heat-exchanger heat transport is significantly improved, leading to smaller and lighter heat exchangers.

Under the Phase I SBIR effort, the concept was analytically evaluated and shown to reduce small gas turbine specific fuel consumption by 22 percent, increase specific power by 32 percent, reduce recuperator volume and weight by 46 percent and 32 percent, respectively, and reduce emissions of oxides of nitrogen by 75 percent. These substantial increases in engine performance were found to require minimal engine modifications beyond replacing the steady flow combustor with a pulsating combustor.

Potential Commercial Application: The PCRGT concept is applicable to a wide variety of commercial and government aircraft propulsion, ground transportation, and power generation applications.

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005
87-1-01.02-9511
Propeller-Wake-Induced Structure-Borne Interior Noise
Dynamic Analysis & Testing Associates
2231 Faraday Avenue, Suite 103
Carlsbad, CA 92008
C. Thomas Savell (619-931-9511)
LeRC -- NAS3-25338

The purpose of this project is to establish a unified model for predicting the portion of the interior, aircraft-cabin noise transmitted through the wing structure and produced by the wake from a wing-mounted propeller. The method used: a velocity defect model representing the viscous wake behind a twisted and leaned prop-fan blade; standard acoustic source modeling methods to describe the wing vibration and pressure loading perturbation resulting from the wake slapping the wing; and finite-element, acoustic-structure interaction analysis to predict the vibration energy transmission through the wing structure, the excitation of the rest of the aircraft structure, and the resulting noise radiation to the interior of the aircraft cabin.

In Phase I several computer codes were developed for analyzing the acoustic-structure interaction problem of the noise experienced in the interior of an aircraft driven by advanced prop-fans. Simplified models of the aircraft wing, fuselage, and cabin interior were used. The wing was modeled as three beam sections of different thickness joined to the fuselage side panels. The fuselage panels were modeled as flat plates attached to stringers at the edges. The cabin interior was modeled as a rectangular cavity. The final computer model was exercised in a parametric study in which the wing and fuselage section properties and joining conditions were varied.

Potential Commercial Application: There is an industry-wide need for a general purpose code to solve acoustic-structure interaction problems for all forms of transportation vehicles, in acoustic fatigue and failure analysis, and in general architectural acoustics.

***

006
87-1-01.03-1520
Simultaneous Temperature, Density, and Flow Diagnostics for Aeropropulsion Systems
Deacon Research
900 Welch Road, Suite 203
Palo Alto, CA 94304
Anthony O'Keefe (415-326-1520)
LeRC -- NAS3-25401

The design of advanced propulsion systems requires simultaneous measurement of the flow velocities and the thermodynamic properties in order to verify the mathematical models based on the time-averaged, Navier-Stokes equations. The coherent anti-Stokes Raman scattering (CARS) technique makes possible the measurement of the temperature and pressure but not velocity. Laser Doppler velocimeters fail at high velocities because the measured dust particles no longer follow the flow lines. The innovation is in combining CARS with a well-known spectroscopic technique, stimulated Brillouin scattering (SBS), which can measure flow velocity from subsonic through hypersonic speeds. By adding a detection system and changing the CARS geometry slightly, one can measure the flow velocity, temperature, and density with a single, stop-motion laser pulse. The Phase I investigation showed that an SBS system can be configured to measure velocities in the range of Mach 0 to 20 and above with an accuracy of Mach 0.02, expanding, thereby, the range of velocity measurements more than an order of magnitude. An SBS technique can also be coupled with a CARS measurement of the temperature and density so that the three critical

variables of the Navier-Stokes equations can be measured independently within 100 ns of each other.

Potential Commercial Application: An SBS velocimeter could find applications not only at ground-based testing facilities but also in flight testing, where the SBS configuration makes these simultaneous flow and thermodynamic measurements possible for the first time.

***

007
87-1-01.03-9030
High-Temperature LDV Seed Particle Development
Physical Sciences Inc.
Research Park
PO Box 3100
Andover, MA 01810
Michael B. Frish (508-475-9030)
LeRC -- NAS3-25284

To perform laser Doppler velocimetry (LDV) in the gas flows of aerospace propulsion systems, light scattering particles able to withstand the harsh ambient environment are needed. This project explored the feasibility of manufacturing mono-disperse, heat-resistant particles having diameters of 0.05 to 0.5 μm which can be seeded into the flow. The technique employs a pulsed, CO_2 laser to decompose gases flowing in a supersonic nozzle, resulting in vapor products which condense, polymerize, or react to form carbonaceous or silicon particulates which are prevented from agglomerating. The particles generated were collected, evaluated for size and shape by electron microscopy, and checked for agglomeration.

In Phase I, a small-scale feasibility study, non-agglomerated, nearly mono-disperse carbonaceous spheres, typically 100 to 500 nm in diameter, were made by pyrolysis of ethylene with a pulsed laser. It is expected that, by pyrolysis of other gases or gas mixtures, this process or a similar one can be made to yield a multitude of different particle compositions and sizes that can be selected as required to suit specific LDV seeding applications.

Potential Commercial Application: Applications include LDV seeding and the commercial ceramics or abrasive materials manufacturing field where mono-disperse, non-agglomerated powders having particle diameters ranging from tens to thousands of nanometers are highly desirable.

***

*** 008**
87-1-01.04-9457
Supersonic Turbulent Reacting Flow Modeling and Calculation
Nielsen Engineering & Research, Inc.
510 Clyde Avenue
Mountain View, CA 94043
Mohammed Farschi (415-968-9457)
LeRC -- NAS3-25285

Accurate modeling and calculation of supersonic turbulent reacting flows depends on a thermochemical model that can account for dominant time scales involved in the reaction and a turbulence model capable of predicting the effects of compressibility and heat release. This project addresses a method of modeling supersonic combustion through the use of a probability-density function (PDF) of scalars in the reaction. The method accounts for the effects of compressibility and heat release in the turbulent kinetic energy and length scales by analysis of exact pressure and vorticity equations. Phase I of the work concentrated on the analysis of the properties of pressure fluctuations and development of a second-order turbulence closure model. Also a specified PDF model was used to relate the local thermodynamic state to a single, conserved scalar for an equilibrium chemical reaction. These models were implemented in a two-dimensional Navier-Stokes solver and applied to several test cases.

Phase I had four significant results. General governing equations for compressible, turbulent chemically reacting flows were developed. The role of pressure-velocity correlations for compressible, turbulent flows was analyzed and used to develop a Reynolds stress turbulence model accounting for compressibility effects. An eddy-viscosity turbulence model for scalar fluxes along with an assumed PDF thermochemical model based only on the mean values was used. A numerical technique was chosen and developed for the solution of the coupled set of governing equations obtained from the above closure models.

Potential Commercial Application: A versatile and efficient computer code with simple but accurate chemical reaction and non-equilibrium turbulence models in supersonic flow regions will be used by aircraft engine companies and defense industries and by researchers and consulting engineers in a variety of other applications such as laser technology.

***

009
87-1-01.05-8500
Shock Waves for Enhanced Mixing in Scramjet Combustors
Flow Research, Inc.
21414 68th Avenue South
Kent, WA 98032
Suresh Menon (206-872-8500)
LeRC -- NAS3-25332

For an efficient supersonic combustion ramjet (scramjet), mixing enhancement between the incoming supersonic air and the injected fuel is essential. However, at hypersonic flight speeds, the short residence time and decreased mixing rate cause deterioration in the combustion efficiency as compared with lower speeds. A configuration recently developed to promote rapid mixing in a supersonic flow is a single-step flame holder with a wedge on the opposite supersonic passage wall to induce a weak shock. The objective of this project is to evaluate the configuration as a means for rapid and thorough

mixing of the fuel with the supersonic air stream through interactions between the shock wave and shear layer.

During Phase I, the interaction between a shock wave generated by a wedge and a supersonic (Mach 2.5) mixing layer was investigated by observing the mixing between two species (nitrogen and helium) downstream of a scramjet flame holder (i.e., rearward-facing step). Schlieren flow visualization and Rayleigh scattering concentration measurements indicate that significant spreading of the mixing layer may be occurring downstream of the shock impingement region. It appears that the shock wave/shear layer interaction allows the helium to diffuse more rapidly across the supersonic nitrogen flow.

Potential Commercial Application: The flame holder design, the experimental data, and the diagnostic instrumentation developed in this project will be provided to NASA for practical evaluation in the scramjet engine.

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02 AERODYNAMICS AND ACOUSTICS

*** 010**
87-1-02.01-0618
Adaptive Schemes for Complex Subsonic 3D-Flow Problems in Arbitrary Domains
The Computational Mechanics Company, Inc.
3701 N. Lamar, Suite 201
Austin, TX 78705
Jon M. Bass (512-467-0069)
MSFC -- NAS8-37621

The innovation explored in this project is in fully adaptive computational schemes with quantitative measures of the accuracy of solutions of very complex problems in fluid dynamics. Particular emphasis is given to the development of models for subsonic, three-dimensional flow problems in arbitrary domains.

Phase I involved detailed studies of the feasibility of the development of new algorithms for subsonic flows. In the area of adaptive methods, some encouraging results have been obtained in the development of a fast, mesh refinement strategy that dynamically allocates cell and node numbers. The method leads to fully unstructured meshes and can automatically refine an unstructured mesh so as to keep cell errors within preassigned limits. In addition, pilot codes on combined mesh refinement and spectral-order enrichment were developed and tested. In the area of error estimation, new and general error estimation techniques were developed which produced results superior to existing error estimation methods. Overall, several new developments in computational fluid dynamics have been made which could improve the reliability and efficiency with which subsonic flow problems are analyzed.

Potential Commercial Application: Numerous commercial applications are possible for design analysis of low-Mach number flows in rocket propulsion systems, pumps, turbo-machinery, ducts, and channels and on aerodynamic surfaces.

***

011
87-1-02.01-3600
Software Package for Solving Large Systems of Nonlinear Equations
Kuck and Associates, Inc.
1808 Woodfield Drive
Savory, IL 61820
Ahmed Sameh (217-344-3600)
MSFC -- NAS8-37633

The numerical simulation of many problems in engineering leads to solving large systems of nonlinear equations. In the past this has required developing a host of specialized codes to solve scientific problems in various applications areas. The goal of this project is a general package for solving nonlinear systems of equations that would include the most recent innovations in solutions of nonlinear and linear equations which have great potential benefits to the scientific community.

In Phase I, a few preliminary kernels of such a package were implemented and tested on a number of sample problems arising mostly from computational fluid dynamics. The numerical methods tested include a nonlinear GMRES (generalized minimal residual) method with point Gauss-Seidel, line, and biharmonic preconditioning and a standard Newton method with the Jacobian system solved by either a direct solver or an iterative solver. All the above techniques gave execution times several orders of magnitude smaller than MINPACK, one of the only existing public domain packages available for solving nonlinear systems of equations.

Potential Commercial Application: A package for solving general, large systems of equations efficiently would provide research groups in industry, government, and universities with a tool that can be integrated into existing codes.

***

012
87-1-02.01-3922
Computational Fluid Dynamics of Store Separation
JAI Associates, Inc.
PO Box 293
Mountain View, CA 94086
Samuel P. Shanks (415-964-3922)
ARC -- NAS2-12779

Development of a three-dimensional, computational fluid dynamics code was studied to provide reliable, economic computations of store separation from an aircraft where the stores have plumes. The purpose of this code is to study plume ingestion and mutual aerodynamic interference between the store and the aircraft. The effort in this project is consistent with and meant to complement the on-going shuttle work at NASA Ames.

Phase I provided a study of the three-dimensional static CHIMERA code to determine how best to modify it for store separation and how best to include a plume. A generic wing was chosen with a generic missile without fins. An algebraic grid generator was written for fighter wings. The codes were modified for the wing and wing-store solutions. Several wing-alone runs were made to test the accuracy of the flow solver. Issues pertinent to store separation were identified and solution theory was formulated.

Potential Commercial Application: The general method may apply to the calculation of ground effects on automobile performance and transient aerodynamic effects of two or more closely moving bodies, e.g., the effects of wing tip vortices from large aircraft on other aircraft.

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* 013
87-1-02.02-9030
Propulsion Simulation for Magnetically Suspended Wind Tunnel Models
Physical Sciences Inc.
Research Park
PO Box 3100
Andover, MA 01810
Prakash B. Joshi (617-475-9030)
LaRC -- NAS1-18616

The purpose of this project is to provide innovative methods for simulating propulsion effects in aerodynamic research conducted with models in magnetic suspension wind tunnels. The feasibility of various techniques of generating exhaust jets of appropriate characteristics was evaluated in Phase I. Judgments of feasibility considered the ability of the selected methods to generate model flow rates and velocities of propulsive jets for a variety of aircraft configurations, flight regimes, and model scales.

Four concepts of remotely-operated propulsion simulators were examined. Three conceptual designs involving innovative adaptation of conventional technologies (compressed gas cylinders, liquid, and solid propellants) were developed. The fourth innovation, namely, the laser-assisted thruster, which can potentially simulate both inlet and exhaust flows, was found to require very high power levels for small thrust levels. This concept needs further research.

Potential Commercial Application: Applications would be in conducting aerodynamic research in wind tunnels equipped with magnetic devices for model suspension.

***

014
87-1-02.03-9778
Modelling of Massively Separated Flows: Renormalization Group Formulation
Spectrex, Inc.
PO Box 707
Gloucester, VA 23061
R. Balasubramanian (804-693-9778)
LaRC -- NAS1-18610

The overall goal of this project is to describe the behavior of massively separated flows using turbulence models based on renormalization group methods and spectral patching elements that easily model complex geometries. Existing turbulence transport models often fail to describe the behavior of non-equilibrium turbulent flows in which there are strong deviations from the law-of-the-wall. This breakdown may be traced to an inadequate treatment of the interaction between eddy and molecular transport in the wall layers. The firm developed a new method based on renormalization group techniques that have been shown to perform well in a variety of situations, including non-equilibrium flows. The success of these techniques originates from the fact that they are differential in character and not based on classical ad hoc algebraic relations.

In Phase I, a new, differential, turbulence-transport model based on renormalization group methods was developed and validated to solve turbulence problems involved in massively separated flows. Issues concerning boundary conditions, numerical stiffness, and wall region modelling with recirculation zones were successfully addressed.

Potential Commercial Application: Many practical commercial engineering problems involve massively separated flows, at both high Mach numbers and low speeds, for which these renormalization group models provide a key new technology.

***

015
87-1-02.04-8450
Three-Dimensional Euler Solver
G.M.A.F., Inc.
PO Box 184
Freeport, NY 11520
Gino Moretti (516-378-8450)
LaRC -- NAS1-18618

The computational technique for two-dimensional, unsteady flows developed by the firm (a combination of the lambda-scheme and shock-fitting) produces excellent results and requires substantially less computational time than shock-capturing techniques. Extending the technique to three-dimensional flows and conducting several feasibility tests, including some with complicated shock patterns in ducts, are the goals of this project.

Phase I showed the feasibility of the project, using both H-grids and Cartesian grids with a special treatment for wall points.

Potential Commercial Application: The method applies to the analysis of intake and nozzle designs for supersonic flows.

***

016
87-1-02.05-1427
Computations of Separated Flows with Two Equation Models
Applied & Theoretical Mechanics, Inc.
4501 Sequoyah Road
Oakland, CA 94605
Joelle M. Champney (415-635-1427)
ARC -- NAS2-12778

This project has resulted in a practical numerical model for use by research personnel to test and develop turbulence models. The selected numerical model was the TURF code (Coakley, 1984). As part of the effort, the code was organized in a user-friendly, modular form and verified on simple test problems for which analytical solutions exist. The innovative turbulence model designed by Mansour, Kim and Moin (1987), called the MKM model, was implemented in the code. The model was successfully tested for channel flow and applied to flows with separation. The experimental flows studied were a backward-facing step and a two-dimensional compression corner at a Mach number of 2.8. The MKM model was compared to the Jones-Launder, Chien, and Coakley (version 1) two-equation models.

Potential Commercial Application: This effort will provide a versatile, easy-to-modify, numerical tool to be utilized by workers in turbulence modeling and aircraft design.

***

017
87-1-02.06-1520
Stimulated Brillouin Diagnostics of Hypersonic Flows
Deacon Research
900 Welch Road, Suite 203
Palo Alto, CA 94304
Anthony O'Keefe (415-326-1520)
JSC -- NAS9-17937

Conventional laser Doppler velocimetry fails for supersonic or turbulent flows. As an alternative, a remote velocity sensor based on stimulated Brillouin scattering (SBS) was investigated. This innovation should operate reliably both at low and high speeds and offer the same scanning capability with better time resolution than the existing technique. Because of the phase conjugation property of SBS resulting in near 100 percent backscatter, this system provides a unique opportunity for measuring supersonic airflows in the vicinity of aircraft in flight. Such a capability will allow a better understanding of the factors limiting the performance envelope of new and existing airframes and provide benchmark information for the simulation codes in a parameter range which cannot be reproduced in wind tunnels.

Phase I work involved scaling of SBS characteristics based upon both the theoretical and the experimental investigations of the SBS process reported in the literature. This study has shown that such a system can be built with commercially available components.

Potential Commercial Application: This new technology is expected to play an important role in the development of new high speed airframes and conceivably in the extension of the performance envelope of existing ones.

***

018
87-1-02.06-5630
A Laser-Based Transition Detector
Complere, Inc.
PO Box 1697
Palo Alto, CA 94302
F. K. Owen (415-321-5630)
ARC -- NAS2-12781

One of the largest sources of uncertainty in proposed hypersonic testing of the National Aerospace Plane will be the measurement of the extent of laminar flow on wind tunnel test models with free and forced transition. In an attempt to alleviate this problem, a novel concept for the remote detection of boundary-layer transition has been investigated. This laser-based turbulent burst detector will enable non-intrusive, microscopic studies of the onset and extent of transition by rapidly scanning boundary layers on wind tunnel models. The potential of this new instrument will be in the capability it provides for the rapid mapping of irregular transition patterns which often occur on complicated wind-tunnel test models. It will also replace the impractically large numbers of surface gages which would be required for transition measurement and so substantially reduce model construction costs and wind-tunnel test time. Completion of this project has been delayed pending the availability of the 3.5 foot wind tunnel at NASA-ARC.

Potential Commercial Application: This innovation would replace the impractically large numbers of surface gages required in rapid mapping of irregular flow patterns on complicated wind tunnel test models, reducing model costs and test time.

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*** 019**
87-1-02.06-7970
Photochemical Ignition and Enhancement of Supersonic Combustion
M. L. Energia, Inc.
PO Box 1468
Princeton, NJ 08542
Moshe Lavid (609-799-7970)
ARC -- NAS2-12782

Significant and revolutionary advances in combustion technology are needed for the new generation of hypersonic flight vehicles. The condition of high-speed flight imposes severe strains on ignition, overall efficiency, and stability of combustion which are risks to the success of the hypersonic program. A novel approach to alleviate these difficulties was proposed

and successfully tested under a Phase I feasibility study. The innovative idea is to irradiate selectively targeted species in the reaction zone. The ensuing photo-dissociation reactions generate highly reactive radicals which significantly modify the kinetics leading to ignition and enhancement via chain branching paths.

The experiments were fully successful in demonstrating that photo-dissociation of sensitizers, e.g. NO_2, can significantly modify combustion processes. Specifically, ignition was demonstrated at conditions where conventional ignition has failed. Explosion limits were also extended. These findings suggest that other combustion properties, e.g. ignition delay time and flame speed, can also be favorably affected by this innovative idea.

Potential Commercial Application: Potential commercial applications include the Aero-Assisted Orbital Transfer Vehicle (AOTV), the National Aerospace Plane (NASP) and the Supersonic Transport (SST).

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* 020
87-1-02.06-9030
Aerothermodynamic Radiation Studies
Physical Sciences Inc.
Research Park
PO Box 3100
Andover, MA 01810
George E. Caledonia (617-475-9030)
JSC -- NAS9-17949

The ability to predict accurately radiative heat transfer from the non-equilibrium bow shock of vehicles operating at hypersonic velocities and elevated altitudes is critical to the design of large NASA vehicles such as the Aero-Assisted Orbital Transfer Vehicle. The extant data base is insufficient to validate models used for this purpose.

In the Phase I effort, this project demonstrated that an optical, multi-channel analyzer can be used to measure accurately the temporal and spectral behavior of non-equilibrium, shock-heated air and that data can be analyzed to deduce temporally excited state population histories even in the presence of overlapping band systems. An innovative technique was also developed for the measurement of $N_2(X)$ vibrational relaxation behind a shock front. The Phase I effort has demonstrated that the integration of modern measurement techniques with a modern shock tube experiment can provide the necessary data for improving the predictive capabilities of computer-based radiation models used to design advanced re-entry vehicles.

Potential Commercial Application: Applications of this facility would be in the study of chemical kinetics and radiative phenomena in high-temperature gases and molecular systems not readily studied by existing techniques.

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* 021
87-1-02.07-8581
Rarefied Gas Aerodynamic Bridging Procedures
Remtech, Inc.
3304 Westmill Drive
Huntsville, AL 35805
E. C. Knox (205-536-8581)
MSFC -- NAS8-37635

Shuttle flight data have shown that the "bridging" relations used to predict the Shuttle reentry aerodynamics in the rarefied-gas portion of its trajectory were inadequate in that twice the predicted body-flap deflection was required to trim the vehicle. Fortunately, there was sufficient margin built into the Shuttle; however, providing such margins on future vehicle designs may render them not viable. For example, the next generation of spaceflight vehicles, such as the Aero-Assisted Flight Experiment (AFE) currently being designed, will require more precise predictions of the vehicle aerodynamics in the transitional flow regime in order to reduce the allowance for propellants in favor of increased payload.

In Phase I the bridging techniques and formulas used to connect the continuum with the free-molecular flow regime in predicting the aerodynamic characteristics of vehicles designed to fly in the rarefied gas regime were revisited. Results from the Phase I study show that some improvements can be made in the bridging techniques, but that further work is needed to account for real-gas effects and molecular-surface interactions. Failure to account for the molecular-surface interactions can cause the drag on a typical vehicle operating in this regime to be in error by as much as 25 percent.

Potential Commercial Application: Applications would be for spacecraft operating between the continuum region near the earth and the free-molecular regime of space.

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022
87-1-02.08-1759
Direct Simulation Monte Carlo of Vacuum Plumes
Ergo-Tech Systems Inc.
6937 Estepa Drive
Tujunga, CA 91042
Jose E. Chirivella (818-352-1759)
MSFC -- NAS8-37623

The overall objective of this project is the development of a three-dimensional, direct-simulation, Monte Carlo (DSMC) code to model the interaction of rocket vacuum plumes with spacecraft structures and the surrounding atmosphere. This work focuses on the complex flow field encountered in the wakes of transatmospheric vehicles operating from an altitude of 75 km to a low earth orbit.

The methods to link the continuum plume with the DSMC molecular description were studied in Phase I. An axially symmetric code (Atlantic 1.3) which can handle an unlimited number of species, structural segments, and molecular sources was developed and

applied in simulating the interaction of the base of the Aero-Assisted Flight Experiment vehicle with its reaction control thrusters. A more advanced version, Atlantic 1.4, tested by simulating the firing of a thruster within a vacuum chamber, features improved accuracy, increased efficiency, multiple region topology, and an architecture that can be readily extended to three dimensions. Phase I has shown the feasibility of direct-simulation Monte Carlo to model and conduct numerical experiments when the flow pattern and geometry are extremely complex.

Potential Commercial Application: Monte Carlo simulation of the dynamics of complex systems may solve a difficult, important problem in space technology and could be reformulated to treat other stochastic systems which appear in nucleonics, robotics, and biotechnology.

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023
87-1-02.08-8150
Numerical Modeling of Fully Viscous Rocket Plume Flows
GT-Devices, Inc.
5705 General Washington Drive
Alexandria, VA 22312
Rodney L. Burton (703-642-8150)
LeRC -- NAS3-25407

The plume produced by the gas flow through the nozzle of a rocket engine or system vent on a spacecraft can contaminate the spacecraft, its sensors, and other nearby apparatus. Current analytical methods patch numerical solutions for the nozzle core flow to those for the boundary layer flow. The resulting continuum solution is then patched to a Monte Carlo calculation for the free-molecular regime. This approach only models steady plumes so that the start-up and shut-down problems cannot be investigated. This project addressed the problem of non-steady plume flows by means of a two-dimensional, fully viscous, non-steady solution for the continuum regime. This numerical method is well-adapted to solving time-dependent flows including viscosity, steep gradients, and even shocks and is, therefore, capable of calculating the fully time-dependent flow of a rocket nozzle during a complete pulse.

Phase I demonstrated the feasibility of using the flux-corrected transport (FCT) algorithm with constant viscosity to model non-steady, axially symmetric flow of CO_2 in a conical nozzle and in the forward plume region. The computations were validated with experimental nozzle data and were shown to give agreement of better than 7 percent for total pressure, exhaust velocity, and boundary layer thickness as far as 1.5 nozzle diameters downstream. Shutdown flow was also modeled.

Potential Commercial Application: PC-based calculation of rocket engine forward and back-flow plumes for axially symmetric nozzles of general shape and simple chemistry in vacuum will be possible.

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*** 024**
87-1-02.08-8581A
Vacuum Plume Impingement Evaluator
Remtech, Inc.
3304 Westmill Drive
Huntsville, AL 35805
Robert L. Bender (205-536-8581)
MSFC -- NAS8-37636

As an Orbital Maneuvering Vehicle or astronauts seated in the Man Maneuvering Unit move externally about the Space Station to perform assembly, maintenance, payload servicing, and other extra-vehicular activities, the plumes from the reaction-control microthrusters may impinge on various structures and payloads and create locally severe environments and surface contamination. The possibilities for potentially severe impingement and contamination are unbounded since mission plans are not final, station growth will occur, and payloads will be constantly changing.

An engineering tool was studied which will geometrically track an arbitrary thruster vacuum plume over an orbiting spacecraft, provide a quick computation of the environment at any nozzle position, and evaluate the criticality of the impingement environment. Phase I research established the feasibility of utilizing a three-dimensional, color graphics display of the impingement zone as the means to evaluate the environment. A quick, visual assessment of the impingement environments is possible even over a complex structure with a variety of components and shapes. The static problem where the plume is fixed relative to the impinged structure was thoroughly exercised in Phase I.

Potential Commercial Application: This development applies to the design of a spacecraft or satellites for simulating and assessing impingement of plumes of gas prior to flight.

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*** 025**
87-1-02.09-0794A
Low-Speed Visualization Studies of Vortex Systems on Chine-Forebody/Delta Wing Configurations
Vigyan Research Associates, Inc.
30 Research Drive
Hampton, VA 23666
Dhanvada M. Rao (804-865-1400)
ARC -- NAS2-12780

Fore-bodies with vortex-generating side edges or chines blending into highly swept leading edges are known to stabilize leading edge vortices through aerodynamic coupling at high angles of attack. However, in post-stall maneuvering flight, chine-vortex interaction with the wing and vertical tails can lead to roll and yaw sensitivity together with reduced or negative damping, making the configuration prone to

departure. This research explored the feasibility of decoupling the chine and wing vortices by applying three alternate geometrical modifications whose effectiveness on a generic, delta-wing fighter configuration were investigated through low-speed, wind-tunnel flow visualizations in a broad angle-of-attack and sideslip envelope.

Smoke visualizations and limited wing-pressure surveys indicated that vortex decoupling could be achieved by introducing a local discontinuity at the chine and leading-edge junction and, even more effectively, by deflecting inboard leading-edge flaps.

Potential Commercial Application: These results will be used by the national aeronautical industry involved in tactical aircraft developments of the U.S. Air Force and Navy.

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026
87-1-02.09-9316
Wing-Rock Dynamics and Control
Eidetics International, Inc.
3415 Lomita Boulevard
Torrance, CA 90505
T. Terry Ng (213-326-8228)
ARC -- NAS2-12787

Modern fighter aircraft operate with increasing demands for maneuverability and controllability in order to track targets accurately for gun or missile shots. A self-induced, limit-cycle oscillation in roll, wing-rock, is sometimes accompanied by coupled oscillations in yaw that occur near the stall angle of attack. The purpose of this project was to develop the capability for performing experiments in a water tunnel to visualize the complex vortex flow fields of aircraft-like models undergoing oscillations in roll. A forced-oscillation-in-roll apparatus was developed. The effects of sweep angle, leading edge radius, oscillation amplitude and frequency, and angle of attack were evaluated. Motion histories of the model and flow response were recorded on video tape.

Phase I has demonstrated the feasibility and usefulness of water-tunnel flow visualization and the forced-oscillation rig in investigating dynamic behavior such as wing-rock. By carefully matching the frequency and amplitude of oscillation, the flow of a forced wing oscillation closely resembles that of natural wing-rock. A forced oscillation rig should also be more convenient to use in many experiments because of the readily available phase reference from the forcing signal. Furthermore, wing-rock frequency and amplitude are dependent on model parameters such as moment of inertia and bearing friction; this often makes comparison between different experiments difficult. With controlled oscillation, matching between two different models or model and actual vehicle is more achievable.

Potential Commercial Application: Applications could be as an alternative control system for new airplanes or, possibly, as a retrofit to existing aircraft. This study also demonstrated the value of water tunnels as a research tool.

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*** 027**
87-1-02.10-9282
Performance Optimization for Rotors in Hover and Axial Flight
Continuum Dynamics, Inc.
PO Box 3073
Princeton, NJ 08543
Todd R. Quackenbush (609-734-9282)
ARC -- NAS2-12789

The rotorcraft community has a continuing need for improved design techniques for hover and axial flight. Such techniques can be employed to best advantage if they are coupled with numerical optimization methods to reduce the trial and error computations when searching for configurations to meet particular design specifications. A new, highly advanced, hover-performance analysis, EHPIC (Evaluation of Hover Performance using Influence Coefficients), recently developed by the firm, seems well-suited to the development of an optimization analysis. As a by-product of the solution method, arrays of influence coefficients relating the rotor loads and wake geometry to the down-wash are generated. These arrays are useful in the development of an optimization scheme.

The Phase I effort demonstrated that a numerical optimization algorithm could be coupled to the EHPIC code to produce rotors with substantially improved performance. The coupling was accomplished by expanding the matrix of linear influence coefficients in EHPIC to accommodate design variables and deriving coefficients for linear equations governing perturbations in power and thrust. Using the rotor power as an objective function and introducing constraints on the design variable perturbations, a sequential linear optimization analysis was formed that was invoked to predict changes in the twist distribution that produced reductions in power at constant thrust for a variety of rotor configurations in hover and axial flight.

Potential Commercial Application: Applications will be by researchers in the government and rotorcraft designers in industry.

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028
87-1-02.11-8060
Zonal Method for Modeling Powered-Lift Aircraft Flow Fields
Amtec Engineering, Inc.
3055 112th Ave NE #208
Bellevue, WA 98004
Donald W. Roberts (206-827-3304)
ARC -- NAS2-12801

The need exists for a cost-effective three-dimensional flow analysis tool for modeling the complex flow fields of powered-lift aircraft. This effort addressed the development of a zonal method that couples a

three-dimensional Navier-Stokes code to a potential flow code based on panel methodology. The Navier-Stokes code is limited to viscous-dominated zones such as impinging jets, ground vortices, separated flows, vectored nozzles, etc. The potential flow code models the inviscid regions. Phase I resulted in a successful coupling procedure. The results indicated that the interzone boundary placement influences the overall convergence rate and that zonal solutions should be converged simultaneously with the boundary conditions as opposed to converging these solutions to a low level during each coupling iteration.

Potential Commercial Application: The results of this work could be applied by aircraft companies to design and evaluate powered-lift aircraft concepts.

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* **029**
87-1-02.12-7070
Direct Computation of Turbulence Noise
AeroChem Research Laboratories, Inc.
PO Box 12
Princeton, NJ 08542
Charles H. Berman (609-921-7070)
LaRC -- NAS1-18622

Direct computation of turbulence noise produced by jet engines is a logical application for advanced computational fluid dynamics (CFD) programs run on supercomputers. Numerical techniques for computing turbulence noise over a range of subsonic and supersonic nozzle exit conditions would eliminate the highly empirical aspects of present noise prediction techniques and enable study of advanced hypersonic propulsion systems. Just as there are many CFD techniques, there are also many ways to determine the acoustic field given the flow results.

Phase I focussed on the connection between CFD and aeroacoustic theory and on modifications and improvements in CFD techniques needed for noise calculations. It evaluated the computational potential for hypersonic flows and recommended specific computational techniques for future development. Procedures were developed for extrapolating near-field numerical pressure computations to the far field. Rules were formulated for the size and shape of the computational domain to obtain accurate acoustic results. Methods for numerically solving the time dependent Lilley equation were developed, and the first known results were presented. A Mach number of 2 or greater was tentatively chosen as the jet Mach number above which compressibility should be considered in the noise source model.

Potential Commercial Application: Applications are in noise control for civilian aircraft such as the High Speed Civil Transport and the National Aerospace Plane. A spinoff of the program will be improved numerical techniques for general, time-dependent turbulent flows.

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030
87-1-02.12-9282
Analysis of Main-Rotor-Wake/Tail-Rotor Interaction Noise
Continuum Dynamics, Inc.
PO Box 3073
Princeton, NJ 08543
Alan J. Bilanin (609-734-9282)
LaRC -- NAS1-18607

The importance of reducing the noise of the helicopter tail rotor has been recognized for many years. However, both the prediction of tail rotor noise and the development of low-noise designs have been impeded by a poor ability to simulate noise-generating interactions between the main-rotor wake and the tail rotor. In many cases, even the flight conditions leading to substantial interactions between the main-rotor wake and the tail rotor have been difficult to determine. Recent advances in the modelling of free-vortex wakes by the firm have generated tools that can generate complete descriptions of the incident-vorticity field in the vicinity of the tail rotor. In light of previous successes, it is anticipated that these tools can produce a computational simulation capable of providing improved definition of interactions between the main-rotor wake and the tail rotor and the resultant unsteady loads that lead to strong acoustic emissions.

The Phase I effort successfully demonstrated that an advanced full-span model of the main rotor wake could be incorporated in a novel scheme that permits high-resolution descriptions of the tail rotor flow field to be reconstructed from preliminary, computationally inexpensive simulations with coarse resolution.

Potential Commercial Application: This analysis would aid rotorcraft designers in meeting noise specifications for both civil and military helicopters and facilitate research by government personnel in helicopter aeroacoustics.

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03 AIRCRAFT SYSTEMS, SUBSYSTEMS, AND OPERATIONS

* **031**
87-1-03.01-8887
Advanced Instrumentation for Aircraft Icing Research
Aerometrics, Inc.
894 Ross Drive, Suite 105
Sunnyvale, CA 94089
William D. Bachalo (408-745-0321)
LeRC -- NAS3-25348

The concern of this project is the need for instruments that can provide reliable data on drop-size spectra and liquid water content in large-scale icing research tunnels and airborne cloud measurements. Advanced laser-based diagnostics is the thrust of this project, which investigated the possibility of utilizing

the recently developed phase Doppler particle analyzer (PDPA) in obtaining these data. Fiber-optic probes are applied in order to make drop size distribution and liquid-water-content measurements within the large scale (6'x 9') icing research tunnel and from aircraft. Although fiber-optic links are compact, robust, and immune from electronic noise, critical questions remain on coupling the laser beams into single-mode fibers and maintaining alignment in a noisy, vibrational environment.

In Phase I, a basic fiber optic probe was evaluated in simulated aircraft icing clouds. Comparisons of the measured drop size and velocity distributions, number-density, and liquid water content made with the standard PDPA and the probe were in excellent agreement. Preliminary testing in the NASA Lewis Icing Research Tunnel produced reasonable results but revealed some problems with vibration and signal quality at high speeds.

Potential Commercial Application: A reliable and tested means for obtaining data on cloud drop sizes will have extensive applications in meteorology and aircraft icing research, monitoring pollutant droplet emissions from power plants, scrubber performance, and numerous other industrial applications.

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* **032**
87-1-03.02-2150
Airborne Advance Warning of Air Turbulence
Turbulence Prediction Systems
4876 Sterling Drive
Boulder, CO 80301
H. Patrick Adamson (303-433-2150)
LaRC -- NAS1-18637

An innovative, operational, airborne, air-turbulence, advance warning system was studied. It is a lightweight, low-power, passive, scanning, infrared optical instrument with a state-of-the-art microprocessor. The basic instrument stems from NASA-sponsored, airborne research on clear air turbulence (CAT) and low-level wind shear (LLWS). The goal is to install the first pre-production system in an aircraft for initial in-service testing. Microbursts and gust fronts, the major causes of LLWS, have a distinctive temperature profile. This profile provides a basis for advance detection. Using multiple IR wave bands, temperature close to the aircraft and up to five to seven miles ahead of the aircraft can be ascertained.

Phase I explored the feasibility of using remote, passive, IR volumetric measurements to provide advance warning of LLWS. The results obtained from testing of the instrument in a simulated atmosphere (computer simulation with NASA-provided microburst LLWS models) and ground testing of the prototype instrument demonstrated that the use of IR represents a feasible method to provide advance warning of LLWS.

Potential Commercial Application: Applications are for commercial and corporate aircraft representing an existing market of more than 20,000 existing domestic units plus foreign aircraft. The technology could also be used to detect other atmospheric conditions, e.g. volcanic ash clouds and the jet stream, as a ground-based sensor either alone or in conjunction with other sensors.

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* **033**
87-1-03.03-0660
Aeronautical Human Factors Research
Decision Science Consortium, Inc.
1895 Preston White Drive
Reston, VA 22091
Marvin S. Cohen (703-620-0660)
ARC -- NAS2-12795

Pilot judgment is a crucial ingredient in almost every aspect of commercial air transport: safety, fuel efficiency, and passenger satisfaction. Effective introduction into the cockpit of systems which support pilot judgments in important decisions will require the development of display and interface designs based on an understanding of pilot cognitive processes.

Phase I involved the development of hypotheses regarding pilot cognitive processes and the design of preliminary cockpit displays that reflect those hypotheses. These displays cater to preferred pilot decision-making strategies with regard both to the balancing of competing objectives and to the handling of uncertainty. Phase I proceeded in four steps: structured interviews of pilots, development of preliminary prototype displays, evaluation and comments by pilots, and revision of the displays.

The aiding concepts developed were designed to help the commercial pilot make decisions regarding potential changes in flight level, routes, or even destination in response to a variety of factors. These concepts try to work with the pilot's preferred methods of decision-making and his values and preferences. However, the aiding concepts attempt to deal with decrements in pilot decision-making performance that could occur under conditions of high stress.

Potential Commercial Application: Commercial airlines are the major potential users of this technology.

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* **034**
87-1-03.03-2975
Electroencephalographic Monitoring of Complex Mental Tasks
Center for NeuroDiagnostic Study, Inc.
275 Hospital Parkway, Suite 530
San Jose, CA 95119
Raul Guisado (408-281-4238)
LaRC -- NAS1-18625

The mental demands created by the increasing complexity of man-machine interactions underline the need for rapid and non-invasive methods of monitoring the ability of the human operator to handle increasingly large amounts of information and make rapid decisions. Reports by others and current work

done in the firm's laboratory suggest that changes in electro- and rheo-encephalographic signals can be correlated to changes in the complexity of a mental task. A study of the changes in electro- and rheo--encephalographic parameters during mental tasks has been initiated in order to define discrete changes predictive of increasing human mental workload.

The Phase I contract permitted development of a non-invasive system of monitoring spatial patterns of neurophysiological changes during cognitive tasks and relating these patterns to cognitive workload. The innovation is based on the integration into a state-space model of neurophysiological and hemodynamic profiles to identify mental state changes that occur during cognition. This approach incorporates electro-encephalographic information from the entire array of electrodes in order to reveal the evolving spatial dynamics of the scalp electropotential field. In addition, it incorporates rheoencephalographic assessment of intracranial hemodynamic changes as an additional dimension of this spatial analysis.

Potential Commercial Application: Potential commercial applications of the innovation include: the development of non-invasive recording units for use in high mental-demand environments; medical diagnostic applications for the assessment of abnormalities of cognitive processing in a variety of disease states, such as brain injury, dementia, neuro-rehabilitation, dyslexia, etc.; an aid in optimizing operator systems and work profiles in private sector human engineering.

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035
87-1-03.04-9024
Integrated Design System for High-Altitude Long-Endurance Aircraft for Micro-Computers
David Hall Consulting
1113 Columbine Avenue
Sunnyvale, CA 94086
David W. Hall (408-248-4800)
ARC -- NAS2-12773

In recent years, increasing attention has been given in the aerospace industry to the integration of aircraft design disciplines. This idea has been applied theoretically to the design of sail planes for solar-powered, high-altitude, long-endurance (HALE) aircraft and, more recently, for microwave-powered aircraft. These attempts at arriving at integrated designs of one class of aircraft used then-existing, state-of-the-art computer capabilities. No attempt was made to use new programming techniques derived from artificial intelligence to develop more flexible systems for the conceptual design of HALE aircraft.

The purpose of this project was to develop a general parametric sizing capability for micro-computers using integrated design methodology. Design of a HALE aircraft was used as a test case. This integrated design methodology incorporates some detailed calculations and many qualitative rules-of-thumb and constraints which are not easily quantified except by the accumulation of design experience. The system is currently running on personal computers at the company, NASA, and the Georgia Institute of Technology.

Potential Commercial Application: This general aircraft sizing methodology, incorporating a knowledge-based system for the design of high-altitude, long-endurance aircraft, has application to other aircraft types. Non-aircraft applications may be possible with further development.

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036
87-1-03.05-2281
Practical Application of Multivariable Robustness Methods to Advanced Aircraft Flight Control
Systems Technology, Inc.
13766 South Hawthorne Boulevard
Hawthorne, CA 90250
Peter M. Thompson (213-769-2281)
LaRC -- NAS1-18634

Much of the motivation for recent developments in general theory for assessing robustness of linear, multi-variable, control systems comes from flight control system (FCS) designs for aerospace vehicles which present the designer with many uncertain and highly variable properties. For the assimilation of the new theories into "real world" design, FCS designers will have to translate the theory into physical understanding.

Taking a distinctly different approach to bridge the gap between theory and practical flight control design, this project combined singular-value and structured-singular-value procedures with a literal (symbolic) development which leads to direct identification of important aircraft dynamic and control system design parameters and their connections with robust performance criteria. The work focused on practical flight control problems expected to be encountered in air-breathing, hypersonic, high-angle-of-attack super-maneuverable vehicles.

All of the project goals were met, and a number of surprises were uncovered. The most notable arose from the comparison of a conventional and presumed highly robust design where the latter exhibited superior robustness for some uncertainties and very inferior robustness properties for uncertainties in aircraft parameters.

Potential Commercial Application: The project outcome could find application in the aircraft industry in the design and testing of advanced, highly integrated, flight control systems. The techniques and procedures would be made widely available as an extension of the firm's existing commercial control system design software.

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* **037**
87-1-03.06-8740
Passive Electro-Optical Sensor Processing for Helicopter Obstacle Avoidance
Space Computer Corporation

2800 Olympic, Suite 104
Santa Monica, CA 90404
William B. Kendall (213-829-7733)
ARC -- NAS2-12774

The purpose of this project is to develop and demonstrate an innovative new computer vision approach for mapping the three-dimensional region surrounding a moving vehicle with passive electro-optical sensors. The primary application is for helicopter obstacle avoidance. Until now, this has not been possible due to the lack of robust processing techniques that can be implemented in real time within practical limitations on hardware size, weight, power, and cost.

During Phase I the firm developed and successfully demonstrated an innovative, velocity filter approach to passive ranging using complex natural-image scenes containing illumination gradients, noise, occlusion, and other real-world artifacts. Furthermore, this approach can be implemented with compact, low-cost hardware, and it is an effective method for the determination of three-dimensional scene information from optical imagery generated by a moving television camera. Those complex, real-world images were processed in a robust manner through an extension of this method involving a combination of image preprocessing and brightness continuity. The accuracy of depth information obtainable with this new technique appears to be substantially greater than that achieved by any other method thus far reported in the literature. For both the lateral and forward motion cases, the experimental accuracy achieved approaches the theoretical maximum as limited by the sensor resolution and the geometry and appears to be more than adequate for helicopter obstacle avoidance and terrain clearance purposes.

Potential Commercial Application: Commercial applications include autonomous navigation of robot vehicles, control of robot arms, detection and tracking of moving objects, and passive ranging and vision for the blind.

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038
87-1-03.07-0821
Miniature Airborne Dew Point Sensor
Niagara Scientific, Inc.
4004 New Court Avenue
Syracuse, NY 13206
Carl F. Fahrenkrug (315-437-0821)
LaRC -- NAS1-18623

The rapid, continuous measurement of relative humidity in fast-flowing gas streams is a matter of a major concern not only for flight requirements, but also for many industrial processes. While many methods exist at present, they all suffer limitations, and there are no truly reliable instruments for measurements at either extreme humidity or temperature. The instrument explored in this project should operate under a wide range of humidity and temperature. It is expected to have a rapid response without hysteresis. It is also expected to be immune to ambient effects such as acceleration and temperature. It will be small in physical dimensions and require little energy to operate.

Potential Commercial Application: There is virtually no major industrial process in which humidity is not an important parameter. The instrument developed under this program will fill an important requirement in many of those processes and activities. It would fit well in this company's interest in sensors and monitors.

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039
87-1-03.07-0905
Smart Angle-of-Attack and Angle-of-Sideslip Sensor
Engineering Development Laboratory
11840 Canon Boulevard, Suite 500
Newport News, VA 23606
Richard E. Campbell (804-873-0905)
LaRC -- NAS1-18662

Virtually all flight vehicles require the accurate measurement of angle of attack (alpha); those undergoing flight testing and some commercial and military aircraft also make use of information on angle of sideslip (beta). Existing angle measurement methods have limitations that make the measurement of alpha and beta impossible under certain flight conditions. Some of these sensors have poor durability and can be sensitive to the environment.

The concept studied in this project is intended to overcome these limitations. It involves the use of miniature, solid-state transducers to detect changes in differential mass flow as the flow angle varies. Included is a microprocessor used as an interface to provide corrections and linearization of the output signal. Phase I consisted of studies and concept verification using a two-dimensional model with a limited number of variations in shape. Low-speed flow testing indicated sensitivity to the shape of the instrument housing that requires further research.

Potential Commercial Applications: The proposed instrument could be used on all types of operational military and commercial aircraft and for aeronautics research and development flight testing.

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* 040
87-1-03.07-0979
Aircraft Flight Testing Techniques and Instrumentation
North American Aerospace Corp.
PO Box 162284
Austin, TX 78716
Larry Bird (512-328-0979)
ARC -- NAS2-12741

The company's air flow analyzer (AFA) measures boundary-layer transitions and pressure lines associated with laminar, transitional, and turbulent air flows associated with airfoil, rotor blade, and propeller

surfaces. The AFA has two distinct advantages over existing flow analysis tools. First, it provides data from thousands of sense points; second, it does not interfere with the natural laminar flow of the airfoil surfaces. In addition, the light weight of the system should make it readily adaptable to a variety of in-flight tests. Instrumentation was the primary emphasis during Phase I, with the incorporation of new types of sensors. A demonstration using a thin-film, ferro-electric, sensor array proved the practicability of using piezo-polymeric devices to study boundary layer transition points and pressure lines. The real problem is to correlate the raw data into meaningful data. This was partially addressed in developing the algorithms for initial filtering of the raw data. It appears that a practical, sensitive, boundary-layer-transition instrument is feasible with refinement of the sensor array tested in this project. This system is now ready to be flight tested to implement a practical new instrument for many air-data-collection applications.

Potential Commercial Application: The applications are as a boundary layer detector for wind tunnel and experimental aerodynamics, an air-data computer, and angle-of-attack instruments.

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* 041
87-1-03.07-3474
Expert Systems for Real-Time Monitoring and Fault Diagnosis
Charles River Analytics Inc.
55 Wheeler Street
Cambridge, MA 02138
Alper K. Caglayan (617-491-3474)
ARC -- NAS2-12725

The major deficiencies in current real-time automatic fault diagnosis applications for aerospace systems are the high rate of false alarms and the maintenance problems caused by intermittent failures. The aim of this project is to demonstrate the use of expert systems technology in improving the performance of current real-time avionics monitoring and fault diagnosis applications and in designing new reconfigurable flight control systems. In particular, the goal is development of a rule-set method allowing a rule-based specification of the domain knowledge in these applications, development of an expert system based on this specification, and integration of this compiled knowledge into existing real-time monitoring and diagnosis solutions implemented in conventional programming languages.

Phase I defined, designed, and developed a rule-set processor which retains the desirable attributes of expert systems during the development state while producing an efficient, conventional embedded code for real-time on-board expert system applications. A prototype of the rule-set processor which allows the specification of topological and procedural knowledge for time-critical applications has been implemented in the Ada language.

Potential Commercial Application: The results of this development of expert systems technology have applications in new, real-time, fault diagnosis and monitoring systems for aircraft and spacecraft.

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042
87-1-03.07-4674
Real-Time Modification of Structural Modes
Systems Technology, Inc.
2672 Bayshore Parkway #505
Mountain View, CA 94043
Wayne F. Jewell (415-961-4674)
ARC -- NAS2-12726

The goal of this project was to improve a method of estimating, in a near-real-time manner, modal frequencies and damping ratios of randomly excited aeroelastic vibrations from flight test measurements. The estimation method operates without knowledge of the random excitation, as well as with knowledge of a deterministic forcing function applied to the aircraft through an excitation system. It is an adaptation of the real-time non-intrusive parameter identification procedure developed by the firm for the NASA Ames Research Center's Dryden Flight Research Facility.

The performance of the estimation method was documented by identifying the modal frequencies and damping ratios of the modelled system both with and without knowledge of the forcing function or input. With knowledge of the input, the method could accurately identify both the frequency and damping ratio of the simulated modes as long as the sampling frequency was properly chosen with respect to the modal frequency. The results of applying the method without knowledge of the input show that it is possible to identify accurately the frequency but the damping ratios were underestimated. The model was applied to a limited amount of flight test data collected by NASA for the F-18 aircraft.

Potential Commercial Application: Real-time analysis of vibration and flutter tests and real-time parameter identification, in general, would find applications in the aerospace industry.

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043
87-1-03.08-0236
High-Performance, High-Temperature Heat Pipes
Ultramet
12173 Montague Street
Pacoima, CA 91331
J. Grady Sheek (818-899-0236)
LaRC -- NAS1-18644

A reliable, efficient means for moving large amounts of heat from the source to a heat sink will be required for thermal management systems in future aerospace applications such as trans-atmospheric vehicles. The heat pipe is just such a device and, through proper selection of the case material and working fluid, can operate nearly isothermally from 5-2300 K. Heat pipes have been produced since the

1960's. This project, however, addresses a unique and innovative method of producing seamless heat pipes utilizing the process of chemical vapor deposition (CVD) and chemical vapor infiltration (CVI). Since the resulting heat pipe will be seamless with the exception of the fill port, it should have a high inherent reliability.

In Phase I, the process for making heat pipes was demonstrated. Vapor passages were drilled through the thickness of reticulated carbon foam which was then infiltrated with tungsten to provide the capillary wick structure. A tungsten wick is suitable for most liquid metal working fluids. The porosity of the foam was then bridged by CVD to create a wall over the part. The heat pipe was successfully tested using methanol as a working fluid.

Potential Commercial Application: This innovative heat pipe design will meet the requirements of thermal management systems for future aerospace applications which will have to be able to move massive amounts of heat and will require materials or devices with high thermal conductivity.

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04 MATERIALS AND STRUCTURES

* 044
87-1-04.01-6000
Oxidation Resistant Ti/6Al/4V-SIC Composite Materials by Ion Implantation
Spire Corporation
Patriots Park
Bedford, MA 01730
James K. Hirvonen (617-275-6000)
LeRC -- NAS3-25326

Lifetime of silicon-carbide-reinforced, titanium-aluminum-vanadium composites at high temperature is presently limited by oxidation and embrittlement to a few hours or less. An oxidation inhibitor could increase this to more than 800 hours at temperature, a time consistent with mission requirements for hypersonic vehicles such the National Aerospace Plane. This project investigated the feasibility of extending the operating temperature of these composites by ion implantation, which has previously been found to significantly enhance the oxidation resistance of titanium.

The Phase I effort explored improving the oxidation resistance of Ti-6Al-4V alloy at 540 C in air by ion implantation processing and using it in SiC-fiber, titanium alloy composite structures. The plan was to use barium and other ions because previous work by the principal investigator showed significantly improved oxidation resistance in elemental Ti after implantation. These choices proved to be very difficult to pursue due to the high secondary electron yield of Ba, which produced high-voltage breakdown on the internal electrodes of the ion implanter.

Potential Commercial Application: Extending the operating temperature of SIC-fiber-reinforced, Ti-6Al-4V composites will open up a large number of applications such as aircraft wing panels for hypersonic flight, compressor blades in advanced turbojet engines, and turbine engine cases, spacers, and turbine disks.

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* 045
87-1-04.01-7070
Embedded Fiber Optic Sensors for Polymer-Matrix Composite Process Monitoring
Geo-Centers, Inc.
7 Wells Avenue
Newton Centre, MA 02159
Ian Aeby (617-964-7070)
LeRC -- NAS3-25337

At present, confidence levels in the integrity of polymer-matrix, composite structures are low due to uncertainties in process control during their manufacture. Control of chemical changes during fabrication will require improved process parameter sensors and control methodologies. The use of fiber optic sensors embedded within the composite structure during fabrication was proposed as a means toward this end. Embedded sensors offer improved data accuracy over remote sensors, and the small physical dimensions of optical fibers minimize their impact on the mechanical properties of the finished composite.

During the Phase I feasibility study, it was established that embedded fiber optic sensors could be used to monitor critical composite process parameters such as temperature and state of cure. Examples of these sensors were successfully embedded in various composite layups. In addition, an interesting new referencing technique for intensity-modulated sensors was discovered. While progress has been made in monitoring polymeric-matrix composite fabrication processes, there is clearly much work to be done before the value of an embedded fiber optic sensor system has been proven in a manufacturing environment.

Potential Commercial Application: Embedded fiber-optic pressure and temperature sensors have applications in the commercial composite industry and, potentially, in medicine for diagnostic instrumentation. Other possible uses are in environmental control and monitoring performance of automobile engines.

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046
87-1-04.01-7747
Micro-Mechanical Model for Prediction of Failure Modes in Ceramic-Matrix Composites
Incubator Technologies, Inc.
800 West 14th Street, Suite 111
Rolla, MO 65401
Li Chai (314-364-7747)
LeRC -- NAS3-25333

The failure of ceramic-matrix composites is a complex phenomenon and differs from the failure behavior of monolithic ceramics and polymeric com-

posites. Prior studies indicate that the growth of existing flaws in ceramic-matrix composites is not self-similar and that substantial frictional slippage occurs at the fiber-matrix interface as evidenced by large pull-outs. The improved fracture toughness for these composites is largely due to these two energy dissipating mechanisms. The objective of this project was to investigate the contribution of these two mechanisms.

A micromechanical analytical model based on the consistent shear-lag theory was developed for predicting the failure modes in a fiber-reinforced, unidirectional, ceramic-matrix composite. The model accounts for the relatively large matrix stiffness, up to 100 percent of the fiber stiffness. The fiber and matrix stresses were established as functions of the applied stress, crack geometry, and, most importantly, the microstructural properties of the constituents and the fiber-matrix interface. The mode of failure was established, and the role of microstructural properties on the failure mode, ultimate strength, and the fracture toughness was assessed. A parametric study was carried out using the model to establish regions of non-steady state cracking (stable crack growth) in a unidirectional, ceramic-matrix composite.

Potential Commercial Application: This work may lead to the optimization of ceramic performance based on matrix and fiber properties for applications in aerospace propulsion and primary structures, for example, on hypersonic transatmospheric aircraft.

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047
87-1-04.01-9785
Controlled Density Composite Carbide Structural Ceramics
Aker Industries, Inc.
952 57th Street
Oakland, CA 94608
Glendon M. Benson (415-658-7248)
LeRC -- NAS3-25406

This project explored an innovative and inexpensive process for producing composite carbide ceramics reinforced with carbide fibers and measured the physical properties of test samples so produced. The goal is to develop a process to tailor the matrix properties through chemical means in order to produce optimum composite properties. It is expected that this process will produce low-cost composite ceramic components that exhibit higher fracture toughness and strength than exhibited by conventional ceramics.

In Phase I, several hundred test specimens were prepared in which formulations and processing parameters were varied according to the findings of previous research to provide a range of physical properties. The processing steps varied were in mixing, blending, aging, dispersing, curing, and pyrolyzing. Five resin formulations were also included in these experiments. From this investigation, choices of the best resins, fillers, dispersing agents, and processing variables can be deduced. Results from Phase I indicate that high strength ceramic composites can be made to net shape at low cost by the proposed process.

Potential Commercial Application: Composite carbide ceramics have potential applications for turbojet engines in the hot sections, heat exchangers, and structural components requiring high hot strengths, wear and fatigue resistance, fracture toughness, benign failure mode, and resistance to corrosive high-temperature environments.

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*** 048**
87-1-04.02-3200
Controlled CTE High-Performance Films for Space Structures
Foster-Miller, Inc.
350 Second Avenue
Waltham, MA 02254
Richard W. Lusignea (617-890-3200)
LaRC -- NAS1-18636

Certain thermoplastic polyimides exhibit a combination of good processability and excellent performance (chemical resistance and high mechanical, adhesive, thermo-mechanical and thermo-oxidative properties) due to groups within the polymer which introduce semi-crystalline character through thermal annealing. The combination of these qualities overcomes the shortcomings of most commercially available high performance polyimides. This program's objective is the development of film processing methods to orient a semicrystalline thermoplastic film to improve and control the coefficient of thermal expansion, fracture toughness, thermo-mechanical behavior, strength, and stiffness.

During the Phase I program, the firm applied innovative film processing and orientation methods to LARC-CPI, a new semi-crystalline thermoplastic polyimide developed at the NASA Langley Research Center. These methods successfully reduced the coefficient of thermal expansion from 38 ppm/C to 16 ppm/C and showed that it could be further reduced to less than 10 ppm/C. The project also showed that LARC-CPI can be processed into high performance thermoplastic films with tensile strength and modulus over 300 mPa (44 Ksi) and 91.6 GPa (1.4 Msi), respectively.

Potential Commercial Application: Potential applications will be for films used for liners, vacuum bags, and encapsulation in the chemical process industry; for electronics where high-density, surface-mounted, multi-chip modules require dimensional stability in thin dielectric layers; and for spacecraft use as reflector substrates, solar cell array panels, and self-deployable structures.

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049
87-1-04.02-5325
Development of Composite Structures with Enhanced Damage Tolerance

Textile Technologies, Inc.
2800 Turnpike Drive
Hatboro, PA 19040
Janice R. Maiden (215-433-5325)
LaRC -- NAS1-18628

The evolution of the aircraft industry has been characterized by a steady growth in the use of lightweight materials strong enough to withstand the increasing demands placed on today's high performance aircraft. However, these materials, such as graphite/epoxy composites, suffer serious compression strength reductions as a result of impact loads. The innovation addressed in this project solves this problem through the use of advanced weave designs that allow for through-the-thickness reinforcement of multi-layer graphite fabrics. This reinforcement provides a capability for the laminate to withstand out-of-the-plane tensile loads induced by impact.

Design verification for small (6" x 36") laminate panels has been completed using a loom to weave laminate plies and to stitch them together at the same time. The next step is to scale-up the process to production size laminates (14" x 100 yards). Alternate stitching materials--glass, Kevlar and graphite yarns--will also be investigated. Multi-layer, through-the-thickness, laminate panels will be woven, infiltrated with epoxy, and tested along side composites made of state-of-the-art laminates. By comparing the damage area and strengths both before and after impact, it will be possible to assess the value of inter-laminar strength and establish a design basis for an efficient through-the-thickness weave. This project was not complete at the time this document was prepared.

Potential Commercial Application: Composite structures with enhanced damage tolerance and reduced costs will be applicable in commercial and military aircraft as well as in sporting goods, boats, automobiles, etc.

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* 050
87-1-04.03-0236A
High-Temperature Turbine Blades
Ultramet
12173 Montague Street
Pacoima, CA 91331
John T. Harding (818-899-0236)
LeRC -- NAS3-25349

Iridium-coated, rhenium thrusters have been fabricated to net internal shape by chemical vapor deposition (CVD) from the inside out. This program proposes to fabricate coated, hollow, niobium turbine blades to net external dimensions by CVD on the inside of a hollow mandrel conforming to the net external shape of the blade: an outside-in process. An oxidation-resistant coating of silica, hafnia, or iridium would be applied first, followed by a thick deposit of niobium or niobium alloy. This process ensures the achievement of net shape for the coated blade; also, contamination of the niobium at the interface, as a result of the coating deposition process and typically involving oxygen, hydrogen, chlorine, or water, would be avoided. The resulting structure should have an uncooled operating temperature capability of 1500 C or higher.

In Phase I, a method for forming iridium-coated, hollow niobium airfoils to net shape by chemical vapor deposition was demonstrated. The iridium coating was shown to provide oxidation protection to the niobium structure up to 1700 C.

Potential Commercial Application: A practical manufacturing process for extending the operating temperature of turbine blades has applications in military and commercial jet engines as well as in spacecraft power systems.

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051
87-1-04.03-6900B
Response of Rapidly-Solidified Ti Alloys to Thermochemical Treatment
Universal Energy Systems, Inc.
4401 Dayton-Xenia Road
Dayton, OH 45432
Rabi S. Bhattacharya (513-426-6900)
LaRC -- NAS1-18620

The objective of this project was to develop titanium alloys with very fine microstructure using rapid solidification and a thermochemical treatment employing hydrogen as a temporary alloying element. In Phase I, the company investigated the microstructure of rapidly solidified alloys of titanium with copper, boron, and carbon (Ti-4Cu, Ti-1B and Ti-1C) before and after thermochemical treatment. This treatment showed significant refinement of microstructure and precipitates in the case of Ti-4Cu. Ti-1B showed promising results; however more work is necessary to optimize the parameters. Ti-1C alloy did not respond positively to thermochemical treatment with hydrogen, as indicated by an observed coarsening of the microstructure.

Potential Commercial Application: A significant enhancement of mechanical properties of Ti alloys would make them attractive for aerospace and other industrial applications.

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052
87-1-04.03-7648
Chemical Vapor Deposition of Ti-Al Foils
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PO Box 865
San Marcos, CA 92069
George H. Reynolds (619-744-7648)
LaRC -- NAS1-18615

Effective use of intermetallic compounds in composite and honeycomb structures will require high-strength, high-quality foils for starting materials. Direct fabrication of titanium-aluminum (TiAl) foils by chemical-vapor deposition onto sacrificial tape sub-

strates was studied as a novel means to produced the desired starting materials.

Two techniques, high-temperature, chemical-vapor deposition from mixed halide vapors and low-temperature, chemical-vapor deposition from mixed organometallic gases, were explored. In Phase I, a cold-wall, chemical-vapor-deposition apparatus was constructed, and TiAl alloy films ranging in composition from essentially pure Ti to approximately $TiAl_3$ and from 5-40 microns in thickness were successfully deposited on molybdenum substrates. As characterized by optical and scanning electron metallographic examinations, X-ray diffraction, microchemical analysis, and micro-hardness testing, the films were found to be chemically homogeneous and generally dense although some films contained isolated porosity and exhibited microcracks. Deposition was in agreement with the predictions of a preliminary chemical process model constructed to describe the chemical-vapor synthesis of TiAl films from halide precursors.

Potential Commercial Application: The product foils could be useful in preparation of thin-gage tapes and complex, honeycomb structures of difficult-to-work materials. Other applications might include intermetallic-matrix composites for hypersonic vehicle structural elements, advanced propulsion system components, and space structures.

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* 053
87-1-04.04-1319
An Expert System for Integrated Structural Analysis and Design Optimization
Structural Analysis Technology, Inc.
4677 Old Ironsides Drive, #250
Santa Clara, CA 95054
Hasan Kamil (408-496-1120)
LeRC -- NAS3-25327

The purpose of this project was to explore the feasibility of an expert system for integrated structural analysis and design optimization by answering questions regarding data and computational requirements, architecture, and cost and by initiating preliminary development.

In the Phase I research and development effort, an architecture and conceptual design were developed for an integrated expert software for the structural design process covering conceptual design work, iterative cycles of finite-element structural analysis and design optimization, and detailed final design. The feasibility of this approach was investigated, and a demonstration package with two expert software modules was developed.

Potential Commercial Application: The resulting expert software could be used by NASA, other government organizations, and their contractors in designing aerospace structures and vehicles with improved efficiency, reliability, and significant savings in man-hours and costs.

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* 054
87-1-04.05-1504
Low CTE, Particulate-Reinforced Metal-Matrix Composite Material
DWA Composite Specialties, Inc.
21119 Superior Street
Chatsworth, CA 91311
Olin Hudson (818-998-1504)
JSC -- NAS9-17938

Joints and couplings for space structures require a low coefficient of thermal expansion (CTE) while remaining light in weight and high in structural integrity. They must also be easy to fabricate and low in cost. No material developed to date adequately meets all of these criteria. The purpose of this project is demonstrating and evaluating various low-CTE, particulate-reinforced, metal-matrix composites for use as the construction material for these components. The approach is to combine ultra-low-CTE reinforcements in selected low-CTE aluminum matrices aimed at producing an isotropic composite material that exhibits a CTE of about 3×10^{-6} in/in/F and an ultimate strength >40 ksi.

Phase I efforts demonstrated that technology is available for producing very low-CTE end fittings and other applications. Wide tailoring of mechanical and physical properties is possible through judicious selection of matrix alloy, particulate composition, size, volume fraction, and matrix reinforcement bond conditions. The relative usefulness of analytical prediction of the CTE was also demonstrated for use as a guide in tailoring key properties.

Potential Commercial Application: The applications are in low-cost, stable (low-CTE), light-weight space structures and components having high strength and stiffness, no outgassing, and increased temperature capability.

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055
87-1-04.05-3200A
Ultra-High Stiffness Net-Shape Tubular Space Structures
Foster-Miller, Inc.
350 Second Avenue
Waltham, MA 02254
Ted E. Kirchner (617-890-3200)
JSC -- NAS9-17940

Net-shaped tubular extrusions of solution-processed, ordered (liquid crystal) polymers can be combined with inter-penetrating networks (IPNs) to produce tubular space structures having ultra stiffness (40 Msi), near zero (less than 1 ppm/deg.C) coefficient of thermal expansion (CTE), and low weight (1.56 gm/cc). The approach taken was to co-extrude biaxially oriented (microfibrillar network), thin-walled poly p-phenyline benzolbisthiazole (PBZT) tubing and, then, introduce a polyimide IPN, Thermid AL-600. The goals were to achieve high axial stiffness through a nearly axial orientation of the PBZT molecules in the inner tube and a low CTE through the combined

effects of the more biaxial orientation of the outer tube and the polyimide IPN. These materials would have superior performance to aluminum and would be cheaper to fabricate than graphite-reinforced, metal-matrix tubes.

The project was successful in extruding PBZT tubing with controlled orientation and volume fractions of polyimide IPN. A zero CTE was bracketed but not achieved. The bonding between the coaxial tubes during the post-cure processing was evident; however, the high modulus was not reached for these tubes as had been demonstrated for PBZT films and tubes in other projects. The difficulty in reaching a high modulus is the result of processing problems.

Potential Commercial Application: The primary application would be for space-based structures fabricated from many tubular struts, truss members, and supports.

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056
87-1-04.05-8900
Filament Winding Process for Thermoplastic Matrix Composites
PDA Engineering
2975 Red Hill Avenue
Costa Mesa, CA 92626
Ronald Allred (714-540-8900)
MSFC -- NAS8-37632

Thermoplastic composites have high impact strength and higher solvent resistance and can potentially be processed much faster than thermoset composites; however, there is a lack of suitable processing techniques. To overcome this, a processing method involving in-situ fusion and compaction during filament winding using an advanced thermoplastic co-mingled with graphite fiber strands was investigated that used heat for fusion from induced currents.

Exploratory experiments have shown that eddy current heating of graphite fibers can be directed and confined to the interface bond line to achieve melt temperature (about 400 C) in a thermoplastic matrix and form a solid structural composite. Compaction of the fiber strands while the resin is molten can be accomplished through proper design of a pressure application device that will conform to cross-overs and other surface irregularities encountered in the filament winding process.

The tests conducted in the Phase I program show that induction heating can be used to process graphite-thermoplastic composites on a continuous basis. Since the research was conducted on the worst case of unidirectional composites, it may be possible to process all types of fiber layups.

Potential Commercial Application: Commercial applications of this technology include manufacture and repair of aircraft skins, aircraft structures, vehicles, boats, spacecraft, rockets, housing materials, and lightweight equipment.

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057
87-1-04.06-8200B
Polymer with Biaxial Strength for Pyroelectric Applications
Chronos Research Inc.
4186 Sorrento Valley Boulevard
San Diego, CA 92121
Randall B. Olsen (619-455-8200)
GSFC -- NAS5-30270

A new method of electrical energy generation called pyroelectric conversion promises to deliver power to spacecraft from a lightweight and inexpensive system. Pyroelectric conversion may enable order of magnitude reductions in future launch and capital costs for power systems.

The Phase I objective of providing a means for forming pyroelectric polymeric films with mechanical properties superior to those of films previously available was successfully accomplished. The enhanced mechanical properties of these films will greatly improve the performance of pyroelectric generators, heat pumps, and refrigerators. An unexpected immediate benefit of reaching the Phase I goal is that the pyroelectric conversion performance of the active polymer was dramatically improved with respect to lifetime. Because of the success of Phase I, the firm now has a method of fabricating durable copolymer films hundreds of meters long, compared to the 3 cm limit of previous technology.

Potential Commercial Application: In addition to their application in space power systems, pyroelectric converters are expected to be an economical means to convert low temperature heat into electrical energy in terrestrial systems at a capital cost of less than one dollar per Watt.

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*** 058**
87-1-04.07-8371
Development of Specialized Floor Coverings for Launch Site Facilities
Springborn Materials Science, Inc.
10 Springborn Center
Enfield, CT 06082
James P. Galica (203-749-8371)
KSC -- NAS10-11455

The existing floor materials at NASA launch site facilities, primarily in shuttle assembly areas, have not been performing satisfactorily. Contamination arises from outgassing of the plasticizers used in vinyl tiles and from chalking and dusting of epoxy floor coverings.

The goal of this project is a conductive floor tiling material that has surface and volume resistivities of 10 million ohm-cm. In addition, the floor covering will be non-contaminating via out-gassing, resistant to hypergolic propellants and other chemicals, non-flammable,

non-dusting, and available in tile form. Other desirable features include a light color, ease of installation, cleaning, and repair, low cost, and resistance to impacts.

The objective of the Phase I effort was to formulate new floor covering compounds that show feasibility for meeting the criteria for NASA's floor application but which may still require further work in Phase II to formulate optimal compounds. Four resins were selected for investigation: polyethylene, polypropylene, polybutylene and polyvinyl chloride. Phase I demonstrated the feasibility of formulating such a suitable flooring material using polymeric plasticized vinyl and flame-retardant polyethylene with selected conductive fillers.

Potential Commercial Application: Applications include floors for hospital operating rooms, electronics laboratories, chemical processing plants, and photo laboratories.

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* 059
87-1-04.08-0960
Robotic Weld Path Programming
Mid-South Engineering, Inc.
3540 Dickerson Road
Nashville, TN 37207
Kristinn Andersen (615-865-0960)
MSFC -- NAS8-37629

For the application of robots to arc welding, constraints of weld position, weld travel speed, and orientation of torch and wire guide (relative to each other and relative to the joint) are considerations that must be dealt with in the path programming task. The objective of this project is to demonstrate the feasibility of developing algorithms for robotic, weld-path programming that are generic to any robot and positioning system capable of accepting the kinematic transformation matrix, positioning system axes, and velocity information from a host computer.

Key components of the proposed system were successfully developed, built, and demonstrated in the Phase I research program. Investigation of commercial systems and other research work was carried out, and the problems of welding using multiple robotic mechanisms and redundant joints were addressed. A theory was developed into a formal algorithm, coded in Fortran, and tested through simulations using equipment and work-piece models from the Materials and Processes Laboratory at NASA-MSFC. The performance of the algorithm was demonstrated by graphical simulations using the ROBOSIM package developed jointly by NASA and Vanderbilt University.

Potential Commercial Application: This innovation will be of significant value to the commercial manufacturing industries for simplifying the task of programming multiple, coordinated, robotic manipulators.

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* 060
87-1-04.08-9955
System Weld Control Through Expert Adaptive Interpretation
International Technical Associates (InTA)
2281 Calle de Luna
Santa Clara, CA 95054
Paul Lovol (408-748-9955)
MSFC -- NAS8-37627

Automated welding has the potential to improve weld quality and reduce the scrap rate. Numerically controlled (NC) welding can be successfully carried out using jigs and fixtures to provide accurate positioning. Alternatively, adaptive, sensor-controlled welding offers the promise of reduced tooling and part preparation costs, improved quality, and reduced scrap rate over manual or NC welding. In addition, on-line quality control of the weld can be implemented using the same sensors.

A rule-based expert system utilizing multiple sensors and a look-ahead capability for real-time, adaptive welding was investigated in Phase I. This investigation conducted welding tests using an available vision system designed to operate in a laser welding environment on dark, nickel-based super alloys. Nonetheless, the vision system performed well on the butt joint samples of the space shuttle aluminum external tank provided by NASA. In almost every case the vision system software algorithms selected the correct seam over near-by scratches. Modifications to the tracking software allowed the system to detect and disregard tack welds and track on the remaining straight seam. The plasma arc torch did not present an electro-magnetic interference problem for the vision system or the electronics, but optical radiation from the arc was significant. Two simple tests proved that more sophisticated filtering on a system designed for plasma arc welding will eliminate any optical interference completely.

Potential Commercial Application: Automated welding systems in automotive, aerospace, and industrial manufacturing and repair environments will be able to use this system. Welding system suppliers will integrate the system into their end products.

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* 061
87-1-04.10-2551
Methods for Evaluating the Predictive Accuracy of Structural Dynamic Models
Engineering Mechanics Associates, Inc.
3820 Del Amo Boulevard, Suite 318
Torrance, CA 90503
Timothy K. Hasselman (213-370-2551)
JPL -- NAS7-1020

Large space structures, such as the NASA Space Station, which cannot be fully tested in a ground test laboratory, require both ground testing and on-orbit identification of as-built structures. This project addressed ground-testing procedures which are critical to the success of on-orbit identification. Innovative

methods for evaluating and improving the predictive accuracy of structural dynamics models were investigated during the Phase I study. This effort identified a new methodology for evaluating uncertainties in mass, stiffness, and damping and how these propagate forward and backward in order to evaluate the accuracy of response predictions and the uncertainty in physical parameters.

Three different methods for propagating uncertainties--first order statistics, fuzzy set theory, and Monte-Carlo simulation--were examined. An approach which combines the first two appears to be an efficient, cost-effective approach for bounding the level of modeling uncertainty. Key elements of the methodology were demonstrated using a realistic model of the NASA Space Station "Block 1" configuration. Experimental error due to substructure and sub-scale testing were simulated and compared using the above methodology.

Potential Commercial Application: Applications exist in all areas where analytical models are relied upon to predict structural performance which cannot be directly verified by testing. Examples include off-shore structures, nuclear power plants, high-rise buildings, and numerous applications in the aerospace industry.

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062
87-1-04.11-3200
Reduced Weight Gondolas for Stratospheric Balloons
Foster-Miller, Inc.
350 Second Avenue
Waltham, MA 02254
Joseph Boyce (617-890-3200)
JPL -- NAS7-1007

Stratospheric and research balloons carrying scientific instruments into the upper atmosphere are very sensitive to payload weight. Reductions in balloon gondola weight will allow a corresponding reduction in balloon volume required to reach a given altitude and result in increased system reliability. Current gondolas are often open frame structures of aluminum with sandwich panel platforms to support the instrument and telemetry packages. Advanced composite materials with their high specific stiffness and strength offer an opportunity to significantly reduce gondola weight. The greatest benefit is derived by developing concepts and design approaches which are tailored for composite materials to take full advantage of their high specific properties while allowing for the unique designs necessary at joints and load introduction points.

The Phase I project has resulted in a lightweight gondola design made from advanced composite materials. Current gondolas typically contribute one fourth of the total system gross weight. This new gondola design is expected to account for one tenth of the total system weight, with a corresponding increase in mission capability.

Potential Commercial Application: The applications of a lightweight balloon gondola are in research in the stratosphere.

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063
87-1-04.11-8900
Lightweight Advanced Composite Gondola for Stratospheric Balloons
PDA Engineering
2975 Red Hill Avenue
Costa Mesa, CA 92626
Donald C. Guichard (714-540-8900)
GSFC -- NAS5-30286

This innovation would provide a versatile, modular gondola for stratospheric balloons that employs a light-weight structural configuration which takes advantage of an improved composite material. The proposed design configuration, validated by the Phase I design assessments, has three primary composite structural components: a payload module, a suspension module, and a payload floor panel, all joined by a pre-loaded, circumferential band clamp.

These modules all employ a sandwich construction locally stiffened in critically loaded regions. Design features provide flanges that can withstand the loads induced when captured by the steel band clamp for assembly of the modules. The proposed joining method was validated by the Phase I assessments.

Potential Commercial Application: Applications are in a variety of balloon flight missions and payloads.

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* **064**
87-1-04.12-8112
Electrostatic Fractionation of Natural and Processed Lunar Solids in Space
Advanced Energy Dynamics
14 Tech Circle
Natick, MA 01760
Donald E. Heyburn (617-653-8112)
JSC -- NAS9-17928

This project explored the application of the firm's ultra-fine coal (UFC) electrostatic separator technology for the separation and concentration of lunar-derived materials. The innovation is in applying technology developed for use on earth to the vacuum of space.

The Phase I effort showed that separation of lunar-derived minerals is technically feasible and that the UFC separator may be a valuable tool in the recovery of minerals from the space environment. Demonstrations included the separation of ilmenite from basalt pulverized to 50% minus 50 micron and the separation of ice from pulverized basalt on a UFC separator operating at -80 C. Theoretical analysis of the UFC separator indicates that vacuum operation could greatly improve separator performance and capacity, perhaps by a factor of 10 or more.

Potential Commercial Application: The UFC separator can be used for dry separation of many diverse solids including coal, talc, fly-ash, wheat flour, calcium carbonate, and others. Vacuum operation is expected to be a space-only application, but the theoretical understanding of the UFC separator in vacuum will greatly enhance terrestrial performance.

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05 TELEOPERATORS AND ROBOTICS

* 065
87-1-05.01-0300A
Control Algorithm for Redundant Degree-of-Freedom Manipulators
Odetics, Inc.
1515 South Manchester Avenue
Anaheim, CA 92802
Steven M. Cohan (714-758-0300)
JPL -- NAS7-1006

Current manipulator control algorithms are often limited by their ability to resolve singularities (when two or more joint rotation axes become aligned) as well as by the inverse kinematics associated with six and higher degree-of-freedom (DOF) manipulators. The goal of this project is to develop a control algorithm to drive a DOF arm while keeping the arm's configuration away from avoidable singularities. The test-bed arm for the project is one possible configuration of a modular, reconfigurable, redundant arm being developed by the firm under an internal research and development program.

In the Phase I program, a control algorithm for a seven degree-of-freedom manipulator was developed. This algorithm transformed six Cartesian command inputs into seven joint command outputs while avoiding the manipulator's singularities. Phase I simulation results also show that the algorithm's singularity avoidance feature improves arm performance. With the singularity avoidance features inactive, the arm will move close to or through singularities resulting in high joint velocity commands that joint servos would not be able to track. With the singularity avoidance feature active, the arm executes the commanded trajectories while avoiding these singularities. This results in lower, achievable, and controllable joint velocities.

Potential Commercial Application: The anticipated seven degree-of-freedom manipulator will have applications in tasks where high strength, low weight, and human-like dexterity are required. Commercial uses include nuclear facility maintenance and manufacturing.

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066
87-1-05.01-0300C
Telepresence Sensor and Control Helmet
Odetics, Inc.
1515 South Manchester Avenue
Anaheim, CA 92802
Timothy R. Larson (714-744-0300)
JPL -- NAS7-1019

The main purpose of this SBIR Phase I was to design a multi-purpose, telepresence helmet that can easily adapt to many applications, including presence for telerobotic control and display of three-dimensional, computer-generated images for "virtual work station" applications. Along with multi-purpose capability, the helmet has a wide field of view (180 degrees) and generates a "true" three-dimensional view by accommodating and focusing to the viewer's area of interest. The helmet also has a high resolution equal to that of the human eye (1 arc minute).

The Phase I study showed that it is feasible to build a helmet-mounted, wide-angle, stereo display system that can match the biological performance of the human eye in acuity, focus, and accommodation. Phase I research indicated that, for flexibility of usage, the helmet system needs to be independent of the image source. This independence was achieved in three steps. First, an intermediate image source was created. A helmet system that uses this intermediate image as its source was designed. Second, transfer equations to translate the real image source to the intermediate image were developed. Finally, the digital electronics were designed to execute the transfer equations at video rates (60 Hz) and then generate the displays to the intermediate image.

Potential Commercial Application: This display system would have commercial applications in the control of remote manipulators for nuclear power plants; underwater exploration and inspection vehicles; and remote surveillance vehicles for security applications.

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* 067
87-1-05.01-0333
Spatial Planning for Mobile Articulated Vehicles and Dendritic Robotic Systems
Scientific Research Associates, Inc.
50 Nye Road
PO Box 1058
Glastonbury, CT 06033
Alexander Y. K. Chen (203-659-0333)
JPL -- NAS7-1012

The new perspective of machine intelligence for multi-link, general-purpose manipulators pursued in this project not only solves the inverse kinematic problem (IKP), but also provides a potential self-correction mechanism to perform the assigned task. The use of an IKP solving mechanism to determine the feasible motion trajectory either by direct solution or with adequate modification is the basis for robot intelligence. The unsolved decision-making procedure can be performed as teleoperation or automatic planning. Due to the advantage of the decomposition technique, the articulation of advanced robotic systems (e.g., redundant degrees of freedom and/or a reconfigurable linkage structure) can be fully utilized.

A technique of implementing the spatial planning skill was developed and analyzed in Phase I. The new IKP solving mechanism was activated on a Harris H700 mini-computer, the computing system available to the company. Because the original software package was incompatible with this computer, a new set of software was developed using FORTRAN 77. Specific emphasis was placed upon extending the original IKP solver to consider mobile, dendritically configured robots.

Potential Commercial Application: Areas such as material handling operations in hazardous environments, outer space or deep sea explorations can take advantage of such advanced robotic systems.

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068
87-1-05.01-2215
Neural Network Controller for Adaptive Movement in Robots
Neurogen Inc.
325 Harvard Street, Suite 211
Brookline, MA 02146
Michael Kuperstein (617-739-2215)
LaRC -- NAS1-18639

The biggest challenges in controlling autonomous robots today deal with self-organization of sensory-motor coordination, novelty in the working environment, and processor faults. To meet these needs, a model of a prototype neural architecture for the dynamic coordination of a multi-joint robot arm and two stereo cameras was investigated by extending the previous static model into a dynamic model which will be able to generate adaptive trajectories. With this system, a multi-joint robot arm could adaptively reach targets in three dimensions in real time. The system would self-organize and maintain visual-motor calibrations and would tolerate internal noise, partial system damage, and changes in the mechanical and optical parameters of the robot as they occur during wear.

Phase I work showed proof-of-concept that a neural-network controller can be simulated on a computer to learn adaptive motor control from its own experience. The adaptive controller can learn to generate accurate stable movements of a robot link without information about link mass, link length, and direction of gravity and requiring only vague information about payload and actuator limits. It can move a link carrying an unforeseen payload from any starting joint angle to any ending point at a specified duration without end point oscillations.

Potential Commercial Application: The controller will find applications in novel working environments because of its ability to deal with unforeseen changes in the mechanical plant and actuators.

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* **069**
87-1-05.01-2878
Telerobotic Rendezvous and Docking Vision System Architecture
Triangle Research and Development Corp.
PO Box 12696
Research Triangle Park, NC 27709
Benjamin T. Gravely (919-467-2878)
GSFC -- NAS5-30292

The innovation defined in this project is a microcomputer-based, vision-system architecture which allows a robot system to identify an object, determine its range and orientation, and access explicit structural data on the acquired object for mating with other objects.

In the Phase I effort, under controlled image conditions, computer algorithms were developed to decode identification markings and to determine the range and orientation of the target object to high accuracy The average execution time of 3.6 seconds was greater than the program objective of 0.25 to 0.50 seconds because of slow data transfer in the prototype system and the use of BASIC programming language. The procedures were used on a robot to demonstrate the capture and placement of objects.

Potential Commercial Application: Applications for autonomous or shared autonomous operations are likely in space station operations, large-scale civil construction, operations in hazardous environments (nuclear, underwater, fire fighting), identification and retrieval of warehoused items and medical samples, and manufacturing components.

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* **070**
87-1-05.01-3319
Telerobotic Digital Controller System
The Navtrol Company, Inc.
9204 Markville Drive
Dallas, TX 75243
Richard J. Brown (214-234-3319)
GSFC -- NAS5-30283

The innovation addressed in this project is a small, light-weight, high capability, multi-processor telerobotic controller system. The system consists of an interconnection of several robotic joint controllers, end effector controllers, and a single master controller communicating through a high-speed, serial communication bus. The master controller controls communication with the various joint controllers in a time-multiplexed manner and synchronizes their activity. Since the system is totally synchronized, the time of occurrence for each measurement and controls application is known precisely all through the system, allowing for compensation for any cross-coupling effects. Both single and dual axis controllers can be developed. A single axis controller would be about 3" x 4.24" and be almost totally self-contained. It will require only 28 V DC and a serial communication link as a tie in with the rest of the system. The controller will control a three-phase, brushless motor requiring up to 20 amps at 15 to 50 V DC. Algorithms utilizing

modern control and estimation theory will be included in the controller

The technical objective of the Phase I effort was to perform a conceptual design of the telerobotic digital controller system and to provide a development plan. The objective was further to demonstrate that the project was feasible. These objectives were definitely met. The system is feasible and can be developed within time and other constraints of this program.

Potential Commercial Application: This telerobotic digital controller system applies to robotics in general and should find many and varied applications in space and on the ground. In addition, the joint controllers are actually very general servo-controllers which could be utilized for pointing, tracking, and other control system applications of all types.

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* **071**
87-1-05.01-3600
Force-Reflecting Joysticks for Manipulator Control
Meridian Corporation
4300 King Street, Suite 400
Alexandria, VA 22302
Mark D. Bryfogle (703-998-3600)
JPL -- NAS7-1024

A need exists for human control of manipulators in highly unstructured environments. The joystick is a key element in the interface between man and machine. A primary objective is to translate forces experienced by the manipulator as directly as possible to the joystick; a direct relationship significantly increases efficiency. Several force reflecting joysticks are in existence. This study dealt with a new, efficient, low-priced, force-reflecting joystick by eliminating the deficiencies noted in the existing mechanisms. This joystick is based upon the six degree-of-freedom Stewart platform. High fidelity in force feedback will be achieved through the installation of a force-measuring cell in the joystick handgrip.

Phase I research demonstrated a kinematic design which allowed translational motion within a 25.4 cm cube and orientational capability of 45 degrees from center about each of three coordinate axes. This motion capability occurs with no leg interference or singularities and with reasonable actuator loadings. Phase I also demonstrated real-time computational control capability.

Potential Commercial Application: Potential applications include the control of manipulators in space, hot labs, hazardous waste sites, and interfacing with computer graphic systems.

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072
* 87-1-05.01-4910
Improvement of Range of Coherent Laser Radar
Digital Signal Corporation
8003 Forbes Place
Springfield, VA 22151
Frank Goodwin (703-321-9200)
LaRC -- NAS1-18640

A need exists for high speed, precise, and long-range imaging sensors for applications to robotics, tele-robotics, and assembly and alignment of large space structures. Precision three-dimensional range imaging with unambiguous range determination has been demonstrated with a scanning, frequency-modulated, continuous-wave, coherent laser radar (CLR) using frequency-modulated laser diodes and heterodyne detection. However, the maximum range of the CLR is currently limited to less than five meters by the coherence length of the laser diode. It is important to improve the maximum range to 100 meters or more. Improvement is possible by narrowing the line-width of the laser source with electronic feedback, thereby increasing the coherence length. The line-narrowing technique has been demonstrated in the laboratory but has not been confirmed with a CLR measurement.

Phase I of this effort demonstrated that line-width reduction of a frequency-modulated laser is feasible once the laser tuning has been made sufficiently linear. An adaptive, signal-processing technique was developed that automatically derives the modulating wave-form necessary to produce a fixed tuning rate. Electronic feedback was used to lock the tuning rate to a reference and to narrow the optical line-width. The line-width was reduced by a factor of three in the Phase I effort. Greater reductions are possible by reducing the time delay in the feedback loop.

Potential Commercial Application: Commercial applications of this work are possible in the following areas: autonomous vehicles, remote measurement, collision avoidance, and robotic control.

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073
87-1-05.01-4910A
Integrated Fiber Optic-Coupled Proximity Sensor for Robotic End Effectors and Tools
Digital Signal Corporation
8003 Forbes Place
Springfield, VA 22151
Anthony R. Slotwinsky (703-321-9200)
JPL -- NAS7-1004

There is a need for fiber-coupled, proximity sensors with high speed and accuracy for application to robot end-effectors and to automated inspection and quality control. Fiber optic sensors have been demonstrated to have geometric flexibility. In the case of phase modulated interferometric-type sensors, high sensitivity is demonstrated as well. However, due to the sensitivity of single-mode diode lasers to back-reflected light and due to the sensitivity of conventional, single-mode fibers to environmental perturbations, problems such as corruption of the laser frequency spectrum and fiber polarization fading are limiting factors.

The Phase I effort designed and demonstrated a fiber-optic sensor system that utilizes multi-mode,

diode lasers as an optical source in a coherent detection configuration that eliminates the problem of environmental perturbations while retaining the sensitivity of phase-modulated sensors. The design has the flexibility to multiplex a number of miniature sensors mounted on robotic end effectors and tools to measure proximity, tactile pressure (touch), force, and torque. The Phase I effort demonstrated the feasibility of this sensor concept and provided a design incorporating three laser sources and three separate sensors.

Potential Commercial Application: Expected applications are in factory automation, machine tool sensors, robot sensors, process control, noncontact sensing, and gauging.

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074
87-1-05.01-5042B
Tactile Telepresence System for Dexterous Telerobotics
Begej Corporation
5 Claret Ash Road
Littleton, CO 80127
Stefan Begej (303-973-5042)
JPL -- NAS7-1015

The objective of this project is to design and fabricate an innovative fingertip-shaped, tactile telepresence system for dexterous robot systems. The principal tasks are: design of various miniature, tactile stimulator elements, construction of a thin, fingertip stimulator unit containing 35 elements, fabrication of an optical, fingertip-shaped tactile sensor containing 35 sensor elements, and construction of an interface unit that will couple the optical output from the tactile sensor to the fingertip stimulation unit. The performance of the resulting tactile stimulation system will be qualitatively evaluated using a simple, single-finger teleoperator test device.

Phase I demonstrated the feasibility of fabricating small tactile stimulator elements and resulted in the construction and satisfactory demonstration of a low-resolution, 37-element tactile telepresence system for a single finger.

Potential Commercial Application: Primary application would be in the control of dexterous robotic devices in space. Terrestrial applications include remote handling operations in the nuclear, chemical, and ordnance industries.

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075
87-1-05.01-5649
3-D Laser Imager
Daedalus Enterprises Inc.
PO Box 1869
Ann Arbor, MI 48106
Scott L. Strodtman (313-769-5649)
GSFC -- NAS5-30275

The goal of this project is to establish the feasibility of a new technique to obtain three-dimensional imagery. The innovative concept is the implementation of a non-mechanical optical scanning technique consisting of a modulated laser and a compact, high-frequency video camera with no moving parts. The resulting three-dimensional imager would be about one-tenth the size and weight and consume much less power than comparable mechanically driven laser scanners. It would also be more rugged and have higher reliability and lower production costs.

The Phase I feasibility study has shown that the design of an electronic scanning sensor, using an image dissector photodetector, is possible and has provided a preliminary optical, electronic, and mechanical design concept. Preparation of a system design concept provided the means for predicting the performance of the sensor as well as the size, weight, and power consumption estimates. This three-dimensional imaging scanner would have performance suitable to satisfy the requirements of the NASA Goddard Space Station Orbital Replacement Unit grasping task.

Potential Commercial Application: Applications of the three-dimensional sensor are in enhanced autonomous robotic assembly and bin picking, quality control, mensuration, vehicle guidance, and teleoperated robots used in hazardous environments including hazardous waste, nuclear-contaminated sites, and bomb disposal.

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*** 076**
87-1-05.01-5860
Development of Telerobot Hand Joint
Ross-Hime Designs, Inc.
1313 5th Street S.E., Suite 221
Minneapolis, MN 55414
Mark E. Rosheim (612-379-3808)
MSFC -- NAS8-37638

Telerobotic hands provide the grasping ability needed for telerobot arms designed to replace or assist astronauts in the hazardous task of extravehicular activity. This project deals with the construction and development of a highly anthropomorphic, zero-backlash, telerobot hand-joint for use as knuckles and a wrist. A patent is pending for this innovation. Applied as a wrist and knuckles, the telerobot hand-joint features circumduction identical to the human hand. This pitch-yaw motion increases dexterity, simplifies computer control, and is not found in other robotic hands.

In Phase I, a telerobot hand-joint was built and tested in the configuration of a wrist and finger-head knuckle. An interconnecting palm was built as a bonus. The project achieved the following results: a four inch-diameter telerobot hand- joint having a 25-pound payload capacity with 90 degrees of pitch and yaw motion for use as a wrist with very low backlash; a one-inch-diameter teleoperator hand-joint having a 5-pound payload capacity with 90 degrees of pitch and yaw motion for use as a finger and thumb

knuckle; and a servo computer control for telerobot operation.

Potential Commercial Application: Applications include advanced, high-dexterity telerobot for handling nuclear and chemically hazardous materials. Undersea robots would benefit from this advanced telerobot hand technology by making them more dexterous and thus more versatile.

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*** 077**
87-1-05.01-8500
High-Performance, View-Generated Database for World Model Definition and Update
KMS Fusion, Inc.
3853 Research Park Drive
PO Box 1576
Ann Arbor, MI 48106
Jerry L. Turney (313-769-8500)
JPL -- NAS7-1009

Geometric knowledge of the environment must be incorporated in both NASA's and commercial applications. This knowledge is often referred to as a world model. Because NASA intends to use this knowledge in CAD-based applications, a system is needed that can create a CAD-compatible, world-model database from digital views of an object.

During Phase I, the firm determined the design specifications for a high-performance, view-generated database that will allow the combining of multiple camera images of an object to capture an accurate geometric computer model of the object complete with surface detail. Specifically, innovative approaches were developed for combining stereo images to reconstruct an object's surface and for determining the relationship between different camera views of an object. A CAD-compatible, hierarchical database for storing the surfaces of an object that will allow rapid access to surface data at a variable level-of-detail was developed.

Potential Commercial Application: Significant commercial potential is possible in at least three areas: in three-dimensional computer vision, in CAD/CAM systems, and in commercial graphics.

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078
87-1-05.01-9570
Telerobot Collision and Obstacle Avoidance Based on Real-Time Proximity Sensors
Robotics Research Corporation
5400 DuPont Circle
Milford, OH 45150
Jack M. Thompson (513-831-9570)
LaRC -- NAS1-18629

A critical technology required for future space telerobots is a practical, sensor-based, real-time, obstacle avoidance system capable of preventing unplanned collisions between the appendages of a telerobot and objects in the machine's working envelope. This project sought to prove the concept of using arm-mounted proximity sensors and new motion control algorithms to control the pose of a kinematically redundant manipulator in such a way that the arm steers itself around objects encountered in the work space while the operator "flies the hand."

In Phase I, proximity sensor technology was surveyed and evaluated for both earth and space applications. The firm's K-2107HR dexterous manipulator and Type 2 motion controller were outfitted with arm-mounted proximity sensors, and the control algorithms were modified to cause the robot to steer its elbow around objects in the work space. As a result of Phase I work, it was determined that surface mounted silicon photodiodes, packaged with solid-state lasers operating in the near-infrared range, were the most promising sensor candidates for space applications. A versatile mathematical approach was developed for synthesizing sensor inputs which can be employed for redundant robot systems of any kinematic configuration.

Potential Commercial Application: Applications of dexterous robots incorporating 20 to 30 degrees-of-freedom may play important roles in future space operations and may also be used on earth in applications such as fire-fighting, forestry, and construction.

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079
87-1-05.02-3912
Adjustable Autonomy for Hazardous Robotic Operations
Advanced Decision Systems
1500 Plymouth Street
Mountain View, CA 94043
Marcel Schoppers (415-941-3912)
JSC -- NAS9-17926

For many tasks, partial automation is desirable but complete automation is out of the question. Partial automation of robots raises this question: "How can robotic software be made intelligent and flexible, yet subject to human control, without becoming dependent on human input?"

Phase I has demonstrated a solution to this problem. Using universal plans technology, the robot's control plan can be assembled automatically as needed, and human input can be reduced to supervision of the planner's decisions about the current instant. The prototype robot planner can accept and remember advice about what to do, what criteria to use in deciding, how to decide what criteria to use, whether or not to decide autonomously, whether to act or be controlled, etc. These pieces of advice allow operators to adjust the robot's level of autonomy without having to reprogram the robot. Phase I demonstrated software embodying this approach and left no major problems outstanding.

Potential Commercial Application: This work will be beneficial in all robotic applications involving significant intelligence and risk or where human trust in a robot's competence must be built up gradually.

Examples are the extra-vehicular-activity retriever, deep-space missions, nuclear reactor maintenance, and military uses of artificial intelligence.

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* 080
87-1-05.02-3912A
Architectures for Semi-Autonomous Planning
Advanced Decision Systems
1500 Plymouth Street
Mountain View, CA 94043
Daniel Shapiro (415-941-3912)
JSC -- NAS9-17927

The innovation addressed in this project is a computational architecture for reactive planning, which is the task of controlling robot execution in unrestricted, or "real world", environments. The domain of the problem is the task of NASA's EVA (extra-vehicular-activity) Retriever: to find and return astronauts, tools, and other objects that may lose tether to the Space Station. This problem involves a range of physical situations which cannot be predicted in advance, multiple agents, natural processes which will alter the environment outside the retriever's control, and actions that may fail or introduce unwanted side-effects. In order to function reliably and safely in this context, the retriever's control system must involve reactive planning.

In the Phase I, scenarios for EVA Retrieval were examined, reactive plan generation and EVA Retriever problems were defined, and a high level architecture to solve these technical problems was designed.

Potential Commercial Application: This work has application in the EVA Retriever program and in the development of all robot control systems for natural environments.

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* 081
87-1-05.02-5172A
Toward Intelligent Control of Robotics for Space Station Maintenance
UFA, Inc.
335 Boylston Street
Newton, MA 02159
Arthur Gerstenfeld (617-964-5172)
MSFC -- NAS8-37641

The purpose of this project was to show the feasibility of adding intelligence to a telerobot. It builds on the firm's prior research done with the National Bureau of Standards in having a robot use lettered blocks to spell certain words. During that research, it was shown that a learning model can be built.

This project takes the step of robotic inspection and maintenance of the Space Station. Its purpose was to demonstrate a system that could handle unexpected events. In Phase I, the project simulated a satellite floating through space with an attached robot performing a maintenance or replacement task. In the simulation, the satellite part that needed replacement is not exactly where it was expected to be. Intelligence in the robot is needed to guide the robot to the correct location. Through a demonstration at the NASA MSFC, it was shown that the robot could use reasoning to direct itself to a new location, illustrating how a robot could use intelligence and heuristics to replan and find an alternate approach to locate the part.

Potential Commercial Application: Intelligent telerobots could be used for inspection and maintenance of nuclear reactors and associated equipment. They could also be used in the aircraft industry for maintenance.

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082
87-1-05.02-5272
New Solution Method for Robot Kinematic Equations
Advanced Control Technologies, Inc.
182 Edgewater Circle
Gallatin, TN 37060
Mary S. Waggener (615-256-5272)
MSFC -- NAS8-37616

All robots differ from their idealized mathematical models because of parametric errors, link flexion, environmentally induced errors, etc. Because the resulting equations are too complex, analytically derived models cannot include compensation for such errors. Numerical models, however, can easily provide compensation.

During Phase I, the feasibility of providing compensation in a quasi-static situation was demonstrated by deriving multi-dimensional, B-spline models of inverse kinematic equations for a robot. These models were shown to be immune to certain parametric errors, measurement noise, and the dimensionality of the functions. The partial derivatives of the models also seem accurately to represent the true joint partial derivatives. Some errors (payload induced link flexion, axes misalignment, etc.) are too complex to simulate. However, if models are derived from measured end effector and joint data, which include the effects of such errors, error compensation will implicitly be included in the models.

Potential Commercial Application: Robot models that include error compensation can be substituted for existing models in operational robots and are particularly appropriate for controllers marketed for use with various robots. The modeling algorithm will also make it possible to use flexible or imprecisely manufactured robots for precision tasks.

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* 083
87-1-05.03-1391A
Roller-Gear Drive for Robotic Manipulators
Transmission Research, Inc.
Division of NASTEC, Inc.
10823 Magnolia Drive
Cleveland, OH 44106

William J. Anderson (216-231-6570)
LeRC -- NAS3-25282

Multi-roller, planetary traction drives offer a unique combination of compactness, high efficiency, and high torsional stiffness in high ratio drives. They have the added advantages of back-lash-free operation, low noise and vibration, no gear cogging, and smooth torque transfer in bi-directional operation. Combining traction rollers and gears yields further benefits in compactness (high torque capability) without the sacrifice of the inherent advantages of roller-gear drives. A typical drive employs a planetary arrangement of gears and rollers consisting of a sun roller gear, two concentric clusters of stationary, roller-gear planets, and a ring gear. The low torque, high speed input is supplied to the sun gear, and the high-torque, low-speed output is taken from the ring gear.

Preliminary designs of three roller-gear and two roller drives were completed in Phase I to assess their feasibility for use in a laboratory telerobotic manipulator. These include a dual-input, pitch-yaw joint drive utilizing cone rollers and zerol bevel gears, drives for a wrist-roll and hinge joint utilizing cylindrical rollers and spur gears, and planetary roller drives for the wrist-roll joint and large gearhead. The five roller-gear and roller drives examined in this program are technically feasible for robotic positioning devices.

Potential Commercial Application: Roller-gear drives are ideally suited for both terrestrial and space applications, for servo positioning devices, actuators, and high-speed, compliant-motion robots being developed for manufacturing assembly tasks, and in speed changers for office and other light duty commercial machines.

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084
87-1-05.05-1167
High-Resolution, Avalanche-Diode X-Ray Spectrometer for Planetary Exploration
Radiation Monitoring Devices, Inc.
44 Hunt Street
Watertown, MA 02172
Gerald Entine (617-926-1167)
JPL -- NAS7-1018

The selection of the best samples to bring back to earth from the Mars planetary exploration mission will require the development of analytical techniques compatible with the unusual mission environment. X-ray fluorescence analysis techniques are particularly attractive, and the new, avalanche-diode, x-ray spectrometer could help provide the performance needed to make this technique applicable.

The Phase I project demonstrated the feasibility of making high resolution, avalanche- diode detectors capable of the sensitivity and resolution needed for the Mars Lander mission. Studies conducted to determine the underlying phenomena presently limiting the spectral resolution of these devices under reduced temperatures clearly identified the two primary limiting factors. Both of these factors were successfully addressed during this project.

Phase I also resulted in the first reported X-ray fluorescence spectrum taken with an avalanche photodiode of an element as light as sulfur. Furthermore, the noise level of these diodes was lower than any previously reported for a non-cryogen-cooled semiconductor detector.

Potential Commercial Application: The applications are in X-ray fluorescence analysis, an important analytical technique with many industrial, military and research applications. This technology will reduce the cost significantly and also make portable field units much more practical.

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06 COMPUTER SCIENCES AND APPLICATIONS

085
87-1-06.01-4131
Asynchronous, Multi-Level, Adaptive Methods for Partial Differential Equations on Navier-Stokes Computer
Colorado Research Development Corporation
621 17th Street, Suite 1620
Denver, CO 80293
Daniel J. Quinlan (303-293-8633)
LaRC -- NAS1-18606

NASA is currently supporting a project for development of a high-powered multi-processor system, the Navier-Stokes Computer (NSC). While multi-level algorithms are being studied for solving the elliptic discrete, incompressible Navier-Stokes equations, no research has yet focused on locally adaptive schemes for this purpose. Having such schemes is important because very large scale physical problems usually demand local resolution to account for such things as boundary singularities, shocks, and transition regions.

This Phase I project studied some promising multi-level methods developed recently by the company. These methods exhibit a very high degree of parallelism and computational efficiency and couple well with an effective load balance which was also developed by the company. The plan was to develop a simple prototype and study its performance on Poisson's equation, first in the NSC simulator, then on the NSC itself. Phase I demonstrated the effectiveness of asychronous, multilevel methods for aerodynamic model simulations involving both static and dynamic refinements. These methods were coupled with a dynamic load balance that demonstrated marked effectiveness in efficient management of the program tasks.

Potential Commercial Application: The software produced by this project for solution of aerodynamic simulation problems on the Navier-Stokes Computer

should be important to any business or institution that acquires this computer.

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086
87-1-06.02-3900
Structured Analysis and Generation of Requirements
Applied Logic Systems, Inc.
PO Box 90
University Station
Syracuse, NY 13210
Kenneth A. Bowen (315-471-3900)
KSC -- NAS10-11465

This project addressed the construction of an automated support system for development, verification, and maintenance of computer software. Its purpose was to overcome problems created by an inadequate understanding of the target problem which often leads to incorrect requirements and specifications for programming projects, especially for distributed systems. Specifically, Phase I explored the feasibility of a system which would generate a program to support experimentation with a model of the problem so as to develop formal specifications for the desired software package.

The research in Phase I was carried out on Sun workstations. A windowing system was used to provide a front-end to the firm's Prolog program to enable construction and annotation of diagrams that represent a problem. Prolog captures an abstract representation of the diagrams and transforms these into a set of Concurrent Prolog clauses. The multiple window environment traces the execution of the Prolog program together with animation of the structured analysis diagram. The prototype system generated in Phase I demonstrated the feasibility of the proposed system.

Potential Commercial Application: The proposed software development and support system would be applicable for large-scale programming projects which occur widely in governmental, commercial, and military activities.

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087
87-1-06.02-7701
An Automated Database Design Methodology
Datawise, Inc.
1915 E. Colonial Drive, Suite 22
Orlando, FL 32803
Kathryn C. Kinsley (305-894-7701)
LaRC -- NAS1-18621

Databases form the basis for computer-based applications by providing the structure on which to maintain and manipulate data. The effectiveness of the application is dependent, to a large extent, on the design of the database. The innovation addressed in this project is an automated design tool for creating data bases which will reduce the problems caused by poor design and loss of data integrity. This software tool is a knowledge-based automated database design engineering tool (KADDET).

Phase I produced a prototype implementation of KADDET, a system that automates the firm's database design methodology. This prototype supports the design methodology through a knowledge base and an automated designer. The knowledge base contains a number of common database designs. The automated designer enforces design rules and merges database objects into a minimum set of entities and relationships.

Potential Commercial Application: KADDET represents an important advance in the tools that are necessary to produce valid, logical, database designs for increasingly complex software applications.

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* **088**
87-1-06.03-3635
Distributed Artificial Intelligence Representation Language Language
Symbiotics, Inc.
875 Main Street
Cambridge, MA 02139
Bruce H. Cottman (617-876-3635)
KSC -- NAS10-11464

Distributed Artificial Intelligence (DAI) deals with the solution of complex problems by networks of cooperating, autonomous computational processes, called agents. Development of production-quality DAI applications has been impeded more by practical limitations in current software development platforms than by serious theoretical difficulties. During Phase I, the critical design requirements were investigated for a general DAI development framework. It was found that they turn primarily on issues of integration: of agents into logical organizations, of multiple, heterogeneous logical organizations, and of existing heterogeneous database and knowledge base systems. The work resulted in the design of SOCIAL, a development framework that will simplify the design, implementation, and integration of DAI applications. SOCIAL's architecture partitions distributed communications, agent and agent organization control, and knowledge and reasoning into clearly separated building blocks. SOCIAL will allow non-intrusive integration of existing database and stand-alone knowledge-base systems into DAI applications responding to a real-world design constraint that is not addressed by most current DAI research tools. In addition, SOCIAL's architecture conceals the mechanics of implementing distributed communications and control in a modular and extensible language.

Potential Commercial Application: SOCIAL represents a potential commercial product that would greatly facilitate the development, maintenance, and enhancement of deployable DAI applications.

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* 089
87-1-06.03-8265
Fault-Tolerant Distributed Knowledge Bases
ISX Corporation
501 Main Street, Suite 214
Thousand Oaks, CA 91360
Scott Fouse (805-495-8265)
ARC -- NAS2-12777

As organizations have increased their dependency on computers, many databases have been developed, and the computers containing the databases have been linked together via networks. The innovative aspect of this project is to extend the capabilities of a formalized, knowledge-representation substrate, which is capable of supporting existing and developing knowledge representation techniques, to handle distributed data storage and information processing. The project objectives are to create algorithms to perform remote procedure calls, to access distributed databases, to maintain consistency of distributed databases, and to balance the load of the processing activities of a computer network.

Phase I has shown that the use of data-driven programming techniques is appropriate for distributed processing applications. The proper method for maintaining both the consistency and redundancy of information in a distributed environment is by using demons that encapsulate a "behavioral law" which reacts to changes in the database. There is no single appropriate method for distributing information in a network. The use of a rule-based system is a good way to implement the load-balancing strategy for a distributed database.

Note: ISX Corporation has acquired the rights to continue Phase II of this project from Teknowledge Federal Systems, who received the Phase I award.

Potential Commercial Application: A general software tool for the management of distributed, fault-tolerant, intelligent systems is in wide demand for applications where reliability is crucial and intelligent behavior is needed, e.g., Space Station and autonomous systems.

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* 090
87-1-06.05-1165
Intelligent Evaluation System for Simulator Training
Global Information Systems Technology
1800 Woodfield Drive
Savoy, IL 61874
Thomas T. Chen (217-352-1165)
JSC -- NAS9-17942

Flight simulation is a primary and critical form of training; however, simulators have not been integrated with the technology of computer-based training. This project proposes to integrate an existing computer-based training system with current flight simulators. As a first step, an expert system will be applied to the evaluation of a Shuttle Mission Simulator lesson using that simulator's capability to store data.

The results of the Phase I work demonstrated the feasibility of an intelligent, computer-assisted instruction system to evaluate lesson performance on simulators. The evaluator would be quite useful to improve the overall training operations especially for complex lessons like rendezvous that require a great deal of instructor expertise or for lessons that include specialized assessment as in fuel usage for maneuvering spacecraft. Phase I produced the following: a procedural-network, knowledge structure for representing both an expert and a student model of the simulator lesson; a strategy for evaluating a student or crew's performance based on (mocked-up) data generated by the simulator; and an initial methodology to explain student errors. Furthermore, a great deal was learned about knowledge engineering in this domain and the most pertinent issues for the NASA simulator environment and training.

Potential Commercial Application: A list of potential commercial applications includes: airline and aerospace simulators, military operations using simulators (e.g. missile simulators), and commercial space operations.

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091
87-1-06.05-2383
CLIPS-Vbase Feasibility Study
Ontologic Inc.
47 Manning Road
Billerica, MA 01821
Michael J. Vilot (617-667-2383)
JSC -- NAS9-17946

This project focuses on applying expert system technology to software systems for mission planning and flight control by combining two state-of-the-art approaches: an object-oriented database management system and an expert system. In Phase I, two specific systems, the Vbase object-oriented database and the CLIPS C Language Production System, were integrated. Vbase, a commercial product produced by the firm, addresses the complex modeling and high performance needs of the CAD\CAM\CAE market. It is portable (UNIX and VMS operating systems), has high performance, and is flexible. CLIPS, an expert system tool developed at NASA-JSC, was designed to provide high portability, low cost, and easy integration with external systems. Both are implemented in the C programming language, giving them advantages in portability and performance over traditional, LISP-based expert systems.

The Phase I study examined several ways to combine these two systems and concluded that such an integration is feasible. The preferred approach adds hierarchical object descriptions to the fact base and declarative rules as constraints to the database. It also enhances the existing Vbase facilities, which provide an expressive, yet efficient, software engineering platform for expert system development.

Potential Commercial Application: The combined CLIPS-Vbase system could provide an efficient and

powerful expert system support tool and could substantially improve the techniques for complex planning, monitoring, and process control tasks.

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* 092
87-1-06.06-0929
A Knowledge-Based Expert System to Coordinate CAD\CAE with Integration and Test
Coherent Research, Inc.
100 E. Washington Street
Syracuse, NY 13202
Charles D. Stormon (315-426-0929)
JPL -- NAS7-1014

During computer-aided-design and computer-aided-engineering (CAD\CAE) phases of spacecraft and mission development, a large and valuable database is created by the design engineers and mission planners. This database may include system specifications, schematic diagrams, simulations, and software. Currently, this data is seldom used during the system integration, test, and operational phases. Instead, much of the same information is manually reconstructed by engineers, adding many hours of effort and many opportunities for error to each mission and system.

Alleviation of many of these problems may be possible by constructing a knowledge-based expert system to coordinate the data produced using CAD\CAE tools and to make that data suitable for use during system integration, test, and operation. The completed Phase I study determined the feasibility of such an expert system and has resulted in a working prototype which aids in fault diagnosis and operational simulation for digital systems. This innovation makes use of state-of-the-art techniques in language translation, expert system building, symbolic simulation, and diagnosis to provide an end-to-end capability demonstrating the automatic transformation and effective use of CAD knowledge through integration and test.

Potential Commercial Application: While the specific system addresses aerospace uses, the techniques are applicable to any large-scale engineering task where CAD tools are used.

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* 093
87-1-06.06-4610
CAD\CAE Knowledge-Base Development Tool
Prospective Computer Analysts, Inc.
1800 Northern Boulevard
Roslyn, NY 11576
R. Glenn Wright (516-484-4610)
KSC -- NAS10-11458

CAD\CAE is commonly used in many aspects of spacecraft design and development. However, once an assembly or system is designed and manufactured, the information contained within the CAD\CAE files is no longer of use. This project investigated a CAD\CAE knowledge-base development tool. Its purpose is to enable data contained within the CAD\CAE files to be translated into a knowledge base for use throughout the life cycle of the product. In addition, the tool will contain provisions for knowledge capture to expand the knowledge base throughout the design, development, simulation, testing, and deployment phases of the product. Natural-language processing will be utilized to obtain knowledge from design, test, and operating personnel in areas for which automated translation of a CAD\CAE file to the knowledge base is not possible.

During Phase I, research was performed to define a software tool which would utilize CAD\CAE files to develop a knowledge base for use the life cycle of the product. The results of Phase I included a design specification for a CAD\CAE knowledge-base development tool which incorporates model building and design knowledge capture provisions.

Potential Commercial Application: Commercial applications of the CAD\CAE knowledge base development tool are many since such a product would provide a means for developing knowledge-based systems for product support, diagnoses, repair, simulation and other applications for any CAD\CAE-designed product.

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094
87-1-06.07-2555
System to Create Models of Fluid Flow Phenomena
Mathematical Research, Inc.
1120 NASA Road One, Suite 210
Houston, TX 77058
C. Lamar Wiginton (713-333-3912)
ARC -- NAS2-12796

Data representing certain fluid flow phenomena are frequently presented as three-dimensional graphics displays on a computer screen. Such displays are inherently two-dimensional and graphics techniques for visually portraying three-dimensional features are limited. For example, depth perception, precise measurement, and data comparisons pose difficulties. The objective of this project was to determine the technical feasibility of developing a system that will produce a faithful three-dimensional model from a three-dimensional graphics display of fluid flow data. Such a system would truly be an innovation in that there is no currently available, inexpensive technique for model production directly from a computer display.

This effort centered around the use of a standard personal computer with graphics capabilities, an electronic control subsystem, an output mechanism, and control software. The results involve both good and bad news. The good news is that the system constructed models; the bad news is that the accuracy needs to be improved for precise measurement of fluid flow parameters.

Potential Commercial Application: For applications where accurate modeling of functions is not required, the system may find a wide range of applications,

e.g., education in mathematics and engineering, architecture, and commercial display and advertising.

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* 095
87-1-06.07-4109
Digital Storage Device Using Thin-Film, Shape-Memory Alloy
TiNi Alloy Company
1144 65th Street, Unit A
Oakland, CA 94608
A. David Johnson (415-658-3172)
ARC -- NAS2-12797

The need for high-volume, high-speed digital data recording, storage, and retrieval systems is growing rapidly. Magnetic media technology is approaching its practical limits of capacity while existing work on optical media seems to be limited to magneto-optical and WORM (Write Once, Read Many times) technology. There is a clear need to increase the speed and capacity of mass storage systems, not only for routine science, engineering, and business systems, but for existing and future supercomputers.

This innovation applies a thin film of shape-memory alloy such as Nitinol (nickel-titanium alloy) as a medium for high-density, non-volatile, read-write digital information storage. Small domains (approaching one micron in diameter) of shape-memory alloy are selectively heated by fast, high-intensity, light pulses, causing the domains to change their angle and/or amount of reflectance. Readout is accomplished by detection of reflected pulses of light of lower intensity from the small domains.

Phase I clearly demonstrated the feasibility of sputtering micron-thick Ni-Ti film which can be annealed to induce the shape memory property. Free-standing beams of Ni-Ti film down to 5 microns thick displayed the mechanical shape memory effect when bent in the cold state and allowed to warm. Experimentation with loads on the end of the beam indicate recovery stresses of approximately 70 ksi. In effect, this work has shown conclusively that the shape memory effect can be produced in sputter-deposited films of nickel-titanium.

Potential Commercial Application: If successful, this technology will be widely used by defense, space, and commerce. "Spin-off" to the growing field of micro-mechanical actuators will generate a secondary market.

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07 INFORMATION SYSTEMS AND DATA HANDLING

* 096
87-1-07.01-0888
Hardware for Parallel Asynchronous Focal Plane Image Processing
Microtronics Associates, Inc.
4516 Henry Street, Suite 403
Pittsburgh, PA 15213
Darryl D. Coon (412-681-0888)
LaRC -- NAS1-18645

The project involves development of high performance systems which combine the functions of image acquisition and image processing. The systems are based on a highly novel, parallel, asynchronous processing approach which permits concurrent two-dimensional image acquisition and two-dimensional image processing. The systems and algorithms studied possess many features of natural vision systems. Silicon devices--which provide a natural basis for parallel, asynchronous, focal-plane, image preprocessing--are the innovation addressed in this project. The simplicity and novel properties of these devices would permit an independent analog processing channel to be dedicated to every pixel. Multi-spectral processing is possible because of compatibility with the cryogenic environment of high performance infrared detectors.

Phase I results showed that the novel means of information coding to be employed permits unusually high dynamic range (up to 10^7 with visible light) and very low power dissipation (4 pJ/mm^2/pulse). Information coding is accomplished through the use of an integrate-and-fire mechanism in silicon diodes. The theory of the device and network dynamics was also developed.

Potential Commercial Application: The market is associated with industrial, robotic, scientific, military, space, and other applications of interest to companies which operate wholly in the private sector as well as NASA contractors and other government contractors.

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* 097
87-1-07.01-5600
Optimizing the Camera and Positioning System for Telerobotic Work Station Viewing
TeleRobotics International, Inc.
8410 Oak Ridge Highway
Knoxville, TN 37931
Paul E. Satterlee (615-690-5600)
LaRC -- NAS1-18627

A necessary component of tele-operated robotic manipulation is visual feedback. The goal of this project is to provide an improved remote viewing capability by simply moving the optical elements of the camera system rather than orienting the entire camera. The elimination of mechanical components and motion sensing devices should increase reliability while significantly reducing size, weight, and maintenance costs--all key elements to future NASA implementation of telerobotic viewing systems.

In the Phase I effort, a miniature, omni-directional, prototypical camera was produced. Considerable reductions in size and weight were realized in this feasibility demonstration. A theoretical analysis was performed to develop a mapping algorithm to convert a fisheye image into an undistorted object plane representation for use with digital electronics. The

resulting algorithm allows pan, tilt, and zoom functions to be accomplished with a fixed camera and was validated experimentally in Phase I. An electronic hardware concept was also created.

Potential Commercial Application: Applications are in the field of remote manipulation in space missions, radioactive materials handling needs, remotely operated military vehicles, and private sector surveillance and security systems.

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* 098
87-1-07.02-1700
Concept-Oriented Distributed Expert System for Spacecraft Control
Omitron, Inc.
6305 Ivy Lane, Suite 500
Greenbelt, MD 20770
David E. Simm (301-474-1700)
GSFC -- NAS5-30284

The innovation in this project is a prototype, distributed, concept-oriented, expert system for application to spacecraft analysis, monitoring, and control. System functions will be performed by semi-autonomous expert modules working together under the coordination and control of a supervisory expert. Concept-oriented representations of both knowledge-base and logical processes will be employed throughout the expert system, providing a capability for abstract reasoning considered necessary to the feasibility of a distributed system of this scope.

Phase I efforts demonstrated the feasibility of the concept-oriented approach by the development and integration of a knowledge-base concept, processing kernel, and supervisory expert functions with a software bus. This initial work also demonstrated a method for effective representation and utilization of generalized knowledge. This methodology was implemented in a system architecture specifically designed to support a long-term strategy for development of large-scale, distributed-expert-system applications. The completeness of the methodology was verified by implementation of a prototype spacecraft analysis, monitoring, and control system.

Potential Commercial Application: Distributed expert systems will provide increased capability and autonomy for analysis, monitoring, and control facilities based both on earth and in space and will reduce both manpower requirements and operator errors.

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* 099
87-1-07.03-0081
Discrete Fourier Transform Algorithms for Bit-Serial, GaAs Processor Architectures
Systems and Processes Engineering Corp.
1406 Smith Road, Suite A
Austin, TX 78721
Gary B. McMillian (512-385-0082)
GSFC -- NAS5-30291

An innovative array processor architecture for computing Fourier transforms and other commonly used signal processing algorithms is under development. During Phase I, an architecture was designed to extract the highest possible array performance from state-of-the-art, gallium arsenide (GaAs) technology. The architectural design features a high-performance, reduced-instruction-set-computer (RISC) processor implemented in GaAs, a floating-point coprocessor, and a unique array communications coprocessor also implemented in GaAs.

The architecture includes very high speed, low-gate-count, bit-serial arithmetic, and communication units in the floating-point and communication coprocessors, respectively. Utilizing the very high speed of GaAs, currently with clock rates in excess of 1 GHz, bit-serial units can be used to form the core of complex arithmetic and communication units. A bit-serial architecture is, in fact, ideal for implementation of the communication links between processors.

Potential Commercial Application: Potential applications are mainly in signal processing, with possible application to computational physics and artificial intelligence. The GaAs RISC processors will also find application in high-performance graphics work stations.

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100
87-1-07.03-8442
Rapid Readout System for Solar Pointing Sensors
Applied Research Corporation
8201 Corporate Drive, Suite 920
Landover, MD 20785
Andrew S. Endal (301-459-8442)
GSFC -- NAS5-30267

The purpose of this project was to investigate a system for rapidly reading and processing photometric data from linear charge-coupled-device (CCD) arrays used as solar tracking sensors. For applications to pointing payloads, the system must determine solar aspect angle with an accuracy of 0.4 arc-seconds with updates available at 4 millisecond intervals. Since tracking functions typically use a small subset of the sensor pixels and the approximate location of this subset can be determined from the previous scan, the read time can be reduced by clocking the unwanted pixels at a very rapid rate. Therefore, circuits were designed to read the CCD array at two rates: at a slow rate (13 kHz) for pixels near the solar edge and at a high speed (3.3 MHz) for the remaining pixels.

The dual read-out rate scheme was tested during Phase I using a linear CCD array illuminated by a helium-neon laser with a knife edge in the beam to simulate the solar edge. These tests demonstrated the feasibility of the dual-rate, read-out technique for solar edge tracking and show that the required update rate can be achieved with low-power levels for control and data acquisition.

Potential Commercial Application: The immediate application of this design is to a fine-pointing system

for spaceborne solar telescopes. It can also be applied to tracking systems, robotic vision systems, and surveillance.

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* 101
87-1-07.04-2800
High Speed Packet Switching
Proteon, Inc.
Two Technology Drive
Westborough, MA 01581
Nathan K. Salwen (617-898-2800)
GSFC -- NAS5-30287

The growth of data networks has resulted from the ability to interconnect dissimilar computers and workstations on a single network and to connect dissimilar networks. The former is made possible by standard protocols, notably the Internet Protocol Suite (also known as TCP/IP). Networks are interconnected by a packet switching element called a gateway, which permits unified packet transport. A significant problem is the throughput of gateways. The goal of this innovation is the development of an Internet gateway that can process packets at a rate to match the capabilities of an advanced LAN (local area network) or higher speed phone lines without compromising the architecture of Internet.

The Phase I SBIR effort explored the character of LAN and wide-area-network traffic to be expected in the early 1990's. Existing LAN hardware and software architectures were investigated in detail to determine where bottlenecks and performance limitations exist. Next, the added performance expected from new technology such as high-speed RISC (reduced instruction set computer) microprocessing was evaluated for porting critical sections of router code to these devices. Possible software modifications were also analyzed for their potential effect on performance. The results of the Phase I effort are embodied in a hardware and software methodology for implementing a packet switch which can achieve performance in excess of 25K packets per second and 300 Mbps.

Potential Commercial Application: Effective interconnection of high-speed networks using a well-proven, existing protocol suite (e.g., TCP/IP) will greatly expedite their deployment for high- data-rate applications.

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102
87-1-07.05-3223
Intelligent Data Abstraction and Analysis
L.N.K. Corp.
6811 Kenilworth Avenue #306
Riverdale, MD 20737
Barbara A. Lambird (301-927-3323)
GSFC -- NAS5-30280

An innovative, ground-based, data management system is required for intelligent, automatic, data cataloging and characterization that will combine several computer technologies, including third-generation expert system tools, advanced data structures, and spatial, graphical, and multiple scientific databases. Past and current science research is generating enormous amounts of many different kinds of data that are presently stored primarily on magnetic tape. Often, each data set is largely inaccessible to all but the few scientists who designed and built the original instruments, and even for them the data may be cumbersome to use.

The data management system investigated has two general purposes: first, to screen the data to form an archive that is useful in terms of scientific goals and, second, to provide a scientist with the ability to browse the archive in near real-time in a domain-specific manner for potentially useful data sets. Its core is a planning system which is used to initiate and operate the data archiving and characterization, to plan the interactions with the scientists, and to monitor the state of the archiving procedures. A rudimentary planning system and simplified versions of the required knowledge bases were implemented and tested in Phase I.

Potential Commercial Application: The planning aspects of this project are applicable to a wide range of archival data retrieval problems and intelligent user interfaces.

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* 103
87-1-07.06-3759
Viewcache: An Incremental Database Access Method for Distributed Library Systems
Advanced Communications Technology, Inc.
1209 Goth Lane
Silver Spring, MD 20904
Hyunchul Kang (301-384-3759)
GSFC -- NAS5-30265

One of the problems facing NASA today is to provide scientists efficient access to a large number of distributed databases. A pointer-based, incremental database access method, Viewcache, provides such an interface for accessing distributed data sets and directories. Phase I proved the suitability of Viewcache by means of a demonstration employing three astrophysics databases (IRAS, IUE, and Einstein) and a master directory. The compactness of the pointer structures formed during database browsing and the incremental access method allows searching and inter-database cross-referencing with no actual data movement between database sites. Once the search is complete, the set of collected pointers indicating the desired data is cached. Extending Viewcache to include spatial access methods for accessing image data sets was shown to be very useful. It eased query formulations by referring directly to the image and provided efficient search for objects contained within a two-dimensional window.

Potential Commercial Application: Viewcache will be a stand-alone software product running on personal computers, work stations, and mainframes. It will

provide an inexpensive access to heterogeneous and distributed databases.

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* 104
87-1-07.07-0094
EOS Workstation
Vexcel Corporation
2905 Wilderness Place
Boulder, CO 80301
Franz Leberl (303-444-0094)
JPL -- NAS7-1026

Development of an image processing and graphics work station is needed to support remote sensing research prior to and during the era of NASA's Earth Observing System (EOS) to assist scientific users of multiple image and collateral data sets. This work station is defined as an integrated platform for using geographic and collateral information with imagery and image processing functions. The work station would serve to integrate the numerous existing software packages for image processing with a geographic information system via a convenient user interface. The specific innovation is in the domain of image processing for geometry and visualization of multiple data sets, areas that require specific attention in the EOS era.

Phase I included a survey of user requirements concerning both functions and performance combined with performance analyses of the major computationally intensive functions. The result is a top level design.

Potential Commercial Application: Applications of this research will be by the scientists using EOS data. It could lead to a widely available, novel, integrated, remote-sensing work station suited mostly for land studies.

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105
87-1-07.08-8430
Symbolic Imagery Management System
Consultant's Choice, Inc.
8800 Roswell Road #130
Atlanta, GA 30350
Paul D. Lampru, Jr. (404-992-8430)
GSFC -- NAS5-30271

The innovation pursued in this project is a symbolic, imagery-management system (SIMS) for use initially by NASA scientists and, subsequently, by remote-sensor scientists external to NASA. Integrating image data with graphic data structures and feature information is very difficult using traditional digital representations. Separate image and feature information data bases are commonly used, but the analyst is required to maintain two or more databases and to perform mentally the integration of the information. This project applies an innovative digital-to-symbolic transformation algorithm (DSTA) to NASA-supplied imagery. This innovation employs a technique that represents gray-scale images symbolically in Lisp to develop software that allows smooth integration of image data, graphic data structures, and feature information. The user will be able to create and maintain such an integrated database, to embed feature information directly into images, to integrate graphic data structures with images, and to query the image database based upon information content.

Phase I successfully demonstrated the feasibility and potential of both DSTA and symbolic image-analysis and, in addition, found that the use of artificial neural systems provides a substantive increase in the efficiency and accuracy of image segmentation and classification .

Potential Commercial Application: Commercial applications may be for satellite imagery and imagery dealing with manufacturing productivity and robotics.

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106
87-1-07.09-2140
Continuous-Wave Signal Detector for SETI
Silicon Engines, Inc.
955 Commercial Street
Palo Alto, CA 94303
Jerome F. Duluk (415-967-5544)
ARC -- NAS2-12808

The SETI (search for extra-terrestrial intelligence) approach for finding extra-terrestrial artificial signals includes the detection of weak, narrow-band, continuous-wave (CW) signals among a large number of noisy narrow-band channels. The CW signals may drift slowly in frequency, and the many choices for frequency and drift make computation an arduous task and CW detection difficult. A special computer architecture is proposed as a solution to the CW signal detection problem in the SETI.

A key part of the innovation is a minimal-precision, matched-filter processor that is ideally suited for custom, very large scale integration. This computer incorporates a new concept in the design of a minimal-precision-filter (MPF) integrated circuit devised in Phase I. A single MPF chip will contain approximately 200 filters and perform 10 complex multiply-accumulate operations every 50 ns. A system using 2000 of these chips in parallel will perform 8 trillion complex multiply-accumulate operations per second. Using this device as the CW detector computation engine alleviates the computation bottleneck and replaces all competing alternatives in performance, size, and cost.

Potential Commercial Application: This technology may apply to radars capable of providing simultaneous, ultra-high resolution in both velocity and range; digital coding and encryption; and recovery and detection of spread spectrum transmissions.

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08 INSTRUMENTATION AND SENSORS

* 107
87-1-08.01-7513
Image-Quality Ultraviolet Interference Filters
Barr Associates, Inc.
2 Lyberty Way
Westford, MA 01886
Thomas A. Mooney (617-692-7513)
JPL -- NAS7-1021

Present ultraviolet filters can have very high spectral performance, but the best spectral performance generally requires materials and filter construction which are not well qualified for use in space and have marginal image quality. The objective of this effort is to improve this situation by reducing to a minimum the number of substrates used and totally eliminating cement and color glasses. In order to do this, more robust and spectrally stable filter coatings must be developed which can be employed as open, unprotected filter elements. The bulk of this work involves developing these coating materials and deposition processes and applying them to space-qualified substrates. The primary deposition techniques are ion-assisted deposition and reactive sputtering. Oxide and nitride materials are the prime coating material candidates, with fluorides used where necessary at the shortest wavelengths. Aluminum is expected to be the primary metal used.

Phase I results proved the feasibility of the proposed technique. Durable, stable, unprotected filter coatings were produced on a single substrate.

Potential Commercial Application: Commercial applications exist in the clinical instrument market where extremely long-life, service-free, stable filters are needed. Other applications exist in process control or analytical instruments used in harsh environments where servicing is difficult or expensive.

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* 108
87-1-08.01-8211
HYMOSS™ Signal Processing for Pushbroom Spectral Imaging
Irvine Sensors Corporation
3001 Redhill Avenue, Bldg 3 #208
Costa Mesa, CA 92626
David E. Ludwig (714-549-8211)
JPL -- NAS7-1008

Pushbroom spectral imaging (PSI) systems are frequently capable of generating much more data than can be transmitted to the ground. Furthermore, extensive ground calibration often impedes the full utilization of the data. These problems may be solved by application of commercial, focal-plane-array technology which provides massively parallel processing of each detector's signals. This processing can be programmable, occur in real time, and include non-uniformity (gain and offset) calibration, digitization, and buffering. The proposed innovation is a signal-processing, integrated circuit (IC) which will enable PSI systems to generate higher data throughput and to be self calibrating.

The Phase I effort consisted of requirements definition, electronics specification, IC design, control unit specification, and planning of future work. This work showed the feasibility of placing gain compensation, offset correction, and automatic detector and readout electronics calibration circuitry, anti-aliasing filtering, and analog-to-digital conversion on the focal plane on a per-channel basis to provide high performance remote sensing capabilities for PSI systems. Preliminary designs for the critical integrated circuit components have been completed and were tested using computer simulation software.

Potential Commercial Application: Applications are high-resolution IR spectrometers, thermal imaging systems, environmental monitoring and analysis, forest fire detection, and power line monitoring.

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109
87-1-08.02-0071
High Sensitivity Active Cavity Radiometer
The Radiometrics Corporation
PO Box 215
Altadena, CA 91001
Richard C. Willson
GSFC -- NAS5-30288

The Activity Cavity Radiometer Irradiance Monitor experiment on the Solar Maximum Mission has demonstrated the state-of-the-art accuracy and precision for solar observations of active cavity radiometer (ACR) sensors in space flight. The design and operational advantages of the solar ACR sensors have been successfully applied to wide and medium field of view earth-viewing sensors on the Earth Radiation Budget (ERB) experiments. If the sensitivity of the solar ACR sensors were increased by between one and two orders of magnitude, the advantages could be applied to the narrow field of view observations of future ERB-type experiments, replacing the inaccurate and unreliable scanning systems in current use. The objective of this project was to modify the ACR solar sensor cavity design and electronics to achieve such an improvement in performance without sacrificing accuracy.

During Phase I (not complete at this writing), the cavity of a new detector was designed and procured, the electronic boards for the detector and the electronics for testing were fabricated, and the software for test and analysis was developed.

Potential Commercial Application: Applications would include any optical radiation measurement tasks that require state-of-the-art accuracy and precision at the irradiance levels corresponding to 1 to 100 percent of the total solar irradiance (1368 watts/square meter).

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110
87-1-08.02-1512
Low-Cost Doppler Micro-Radar Rain Gauge
Ophir Corporation
3190 S. Wadsworth Blvd., Suite 100
Lakewood, CO 80227
Loren D. Nelson (303-986-1512)
GSFC -- NAS5-30285

New NASA satellite remote sensing programs such as the Tropical Rainfall Measuring Project, which intend to measure global precipitation, require "ground truth" calibration. The overall goal of this project is a practical and inexpensive precipitation gage based on miniature, frequency-modulated, continuous-wave Doppler radar technology. It would be suited to shipboard or land use.

The Phase I effort was aimed determining which frequency band provided the best overall characteristics for measuring rainfall. At X-band frequencies, conditions for scattering are better met, and the water vapor in the atmosphere absorbs less. On the other hand, droplet reflectivity is greater at K-band, making stronger Doppler signals possible. Prototype equipment included both X-band and K-band transceivers which permitted simultaneous observation of performance under identical environmental conditions. Test results indicate that K-band offers the greatest overall advantages. The stronger Doppler signal and lower error rate tip the scales in its favor.

Potential Commercial Application: Commercial uses would be to measure rainfall at sea in order to improve the National Weather Service data base and to support the NASA Tropical Rainfall Measuring Project to measure droplet-size distributions, cloud ceiling height at airports, and present weather conditions.

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* 111
87-1-08.02-9388
Monolithic GaAs Digitizer for Space-Based Laser Altimeter Pulse-Spreading Effect
Amerasia Technology, Inc.
620-1 Hampshire Road
Westlake Village, CA 91361
Binney Y. Lao (805-495-9388)
GSFC -- NAS5-30266

An innovative, miniature, low-power, GHz waveform digitizer system for analyzing space-based laser altimeter pulse spreading is under development. The system consists of a 6-bit, monolithic gallium arsenide, flash analog-to-digital converter using enhancement and depletion mode technology with latching comparators, a de-multiplexer to reduce the output data rate, a surface acoustic wave 1 GHz oscillator-clock, and a random-access buffer memory for interfacing with the 8-bit parallel bus of the altimeter system computer. The advantages of the approach are the following: low power consumption of the 6-bit converter (less than one watt), low voltages, component production using existing foundry processes, ability to interface with low-speed system processors, and a GHz surface-acoustic-wave clock that provides a stable reference with low power consumption and small size.

In Phase I, the digitizer was designed to analyze the pulse spreading effects in a space-based altimeter. This design is unique because it uses only inverters and NOR gates for the converters and the encoder; hence, it can be fabricated by means of existing, state-of-the-art processing techniques for gallium-arsenide.

Potential Commercial Application: Potential commercial applications are in high-speed signal processing, medical electronics, scientific research, and microwave astronomy. The firm intends to develop the digitizer system as a commercial product interfacing with personal computers.

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112
87-1-08.03-4080
High-Resolution Remote Sensing for Earth Observation
TS Infosystems, Inc.
4200 Forbes Blvd, Suite 100
Lanham, MD 20706
Warren A. Hovis (301-731-4080)
ARC -- NAS2-12815

The proposed effort was to design an optical sensor that would demonstrate the capability of linear detector arrays, coupled with a suitable telescope, to provide 2.5 meter spatial resolution from spacecraft altitudes. The two most difficult problems in building such a sensor are to arrange several detector arrays so that they appear to be contiguous and aligned and to design a collector telescope to image a reasonably wide swath width on the arrays with optical quality to match the required resolution. The Phase I effort was to carry out the design, including the positioning of the filters that will define the spectral bandpass, and to produce plans that could be used to fabricate a breadboard for aircraft testing of the concept. Off-the-shelf arrays, now being manufactured in the US, were to be used, and it was planned to explore several options for the telescope. This project was terminated upon the departure of the principle investigator from the company.

Potential Commercial Application: The technique of butting several arrays could be of use to industrial applications of detector arrays.

***

113
87-1-08.04-9500
Ruby Crystal Chlorophyll Fluorometer for Measurements of Photosynthesis Rates
Aerodyne Research, Inc
45 Manning Road
Billerica, MA 01821
Paul Kebebian (617-663-9500)
ARC -- NAS2-12776

The goal of this project was to establish the feasibility of a spectral-line discriminator for the measurement of chlorophyll fluorescence from plants. The spectral-line discriminator operates on the oxygen absorption line at 693.6 nm, using the R_1 line of ruby as a tunable, narrow-band filter.

The line discriminator built to test this concept was able to detect the presence of the absorption line in sunlight reflected from a non-fluorescent natural surface. However, the signal-to-noise ratio of this particular instrument was not large enough to detect, by reduction of the depth of the absorption line, the expected level of fluorescence from plants. The signal-to-noise ratio could be improved by more efficient collection of light from the crystals and by the use of crystals having a less strain-broadened R_1 line. Theoretical calculations predict a signal-to-noise ratio greater than ten for an observing time of one second.

Potential Commercial Application: The potential applications could be for large area measurements of photosynthesis rates for NASA global biology studies, in the plant biology and atmospheric research communities, and in commercial agricultural enterprises for crop monitoring purposes.

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114
87-1-08.05-5049
Software Package to Compute the Incoming and Net Solar Irradiance at the Surface from GOES-VISSR Data
Earth Space Research, Inc.
3840 Sequoia Street
San Diego, CA 92109
Frederick C. Mertz (619-273-5049)
JPL -- NAS7-1005

The objective of this work is to develop a commercial software system with the capability of computing daily, short-term, mean incident, and net solar irradiance at any location on the surface of the globe with a spatial resolution of 1 to 50 km. These computations will be based on existing methods and new techniques developed within the scope of this project.

During Phase I, the firm converted the Gautier et al. (1980) shortwave algorithm into a prototype, image-processing system for mapping earth-surface, solar irradiance and photosynthetically active radiation from GOES/VISSR satellite data. The project's major accomplishments were the design and construction of an integrated software system under the NASA-developed Transportable Applications Executive and the Land Analysis System image analysis package. This work included development of GOES data ingestion and manipulation functions, enhancement and integration of shortwave processing functions, and construction of display functions for Raster Technologies display systems. The technical feasibility of the prototype solar energy mapping system was established in Phase I.

Potential Commercial Application: Applications can be broadly placed into five areas: agriculture, land management, weather services, energy production and land and ocean research. These have markets both nationally and internationally.

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115
87-1-08.06-2035
Imaging Altimeter Using Imaging Doppler Interferometry
Novatech, Inc.
1745 East 1350 North
Logan, UT 84321
Bruce R. Peterson (801-750-2035)
JPL -- NAS7-1016

This Phase I activity examined the feasibility of using imaging Doppler interferometry (IDI) as a method of obtaining three-dimensional, high-resolution images of the earth's surface via radar from aircraft. Although the IDI technology has been applied successfully to other applications, this is the first attempt to use the technology for imaging of the earth's surface. The radar technology which has been used until now for creating images is called synthetic aperture radar (SAR). SAR provides very good resolution in one dimension and moderate resolution in a second direction provided that the surface being imaged is horizontal. The third dimension is not obtainable with SAR. Briefly stated, this research coupled IDI technology with radar technology to produce three-dimensional images.

At the end of Phase I, the technology investigated has been shown to be feasible for providing three-dimensional representations of geological surfaces down to approximately one meter of resolution in each of the three directions.

Potential Commercial Application: Applications of three-dimensional imaging of the earth's surface include studies in geomorphology and earth resources, military reconnaissance, cartography, weather observation, night-time and foul weather vision for pilots, and planetary surface studies.

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*** 116**
87-1-08.06-5649
Portable Multispectral Thermal Infrared Camera
Daedalus Enterprises, Inc.
PO Box 1869
Ann Arbor, MI 48106
Frederick G. Osterwisch (313-769-5649)
JPL -- NAS7-1010

The project investigated a field-portable, multispectral, thermal infrared camera for use in the NASA Geology Program to characterize the compositional and textural heterogeneity of undisturbed surfaces. The results are the preliminary design and performance specifications for an instrument that will provide data which will greatly expand the knowledge of spectral properties of heterogeneous natural surfaces. This information will aid efforts to perform geologic mapping and mineral exploration through the use of

airborne and space-based, multi-spectral, thermal infrared instruments.

The effort in Phase I included the investigation of alternative techniques for dispersion and detection of the thermal infrared spectrum, field-of-view optics, field display techniques, and digital data recording. A significant portion of the effort addressed packaging design and power limitations necessary to provide a rugged, field-portable instrument. The results of the Phase I research have established that it is feasible to design and fabricate a portable multispectral thermal infrared camera. Moreover, the research predicts that the performance of this instrument will meet the desired performance parameters and will have the capability to be improved by substituting new components as technological advances occur.

Potential Commercial Application: In addition to geological investigations, the multi-spectral, thermal infrared camera could have commercial applications in industrial process control and quality analysis for the deposition of thin films on substrates.

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* 117
87-1-08.07-2627
Stabilized Lasers as Spectro-Radiometric Standards for Ultraviolet Electro-Optic Detectors
Cambridge Research and Instrumentation, Inc.
21 Erie Street
Cambridge, MA 02139
Peter V. Foukal (617-491-2627)
GSFC -- NAS5-30269

The innovation pursued in this project is an improvement in the calibration accuracy of ultraviolet spectrometers through use of intensity-stabilized UV lasers as precise illumination sources and a helium-cooled cavity radiometer as an absolute irradiance standard. A calibration system using a stabilized continuous-wave UV laser to alternately illuminate the detector under test and an absolute radiometer will allow a radiometric measurement to be made at the laser's wavelength. An absolute accuracy of 0.1 percent is achievable with this method.

The main objective of Phase I was to determine the feasibility of constructing an automated facility for the calibration and testing of electro-optic detectors in the UV spectral region (200-400 nm) based on stabilized lasers. Phase I resulted in the successful stabilization of a laser beam at 257 nm, the first time that laser light in the UV region has been stabilized. Phase I also produced a computer-controlled facility for the characterization of electro-optic detectors. Various test sequences capable of determining a detector's linearity, hysteresis, etc. were implemented.

Potential Commercial Application: The firm plans to introduce the laser-based facility to the electro-optics industry as a new tool for more accurate automated and convenient characterization of detectors and optical instruments.

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* 118
87-1-08.08-0438A
A Method to Provide Lower-Cost Crystal Properties Study Samples
Scientific Materials Corp.
P.O. Box 786
Bozeman, MT 59715
Ralph L. Hutcheson (406-585-3772)
LaRC -- NAS1-18639

There is need for crystal samples in studies of new laser materials. Current crystal growth systems are expensive, and hence the experimenter normally limits the test variables. The flame-fusion crystal growth process was investigated as a means to provide lower-cost study samples as compared to currently available commercial sources.

The Phase I work demonstrated a method to produce lower-cost spectroscopic study samples and a method to provide accurate analytical data on these samples. It also has shown the need to investigate four areas: causes of cracking and frothing in YAG (yttrium-aluminum-garnet), improvements in the analytical methods to determine accurately the deposition coefficient for dopants in common laser host materials, extension of the growth methods to advanced laser materials, and the influence of highly purified raw materials.

Potential Commercial Application: The applications would be in providing lower-cost, higher-perfection laser rods, new laser design data, and a source of new laser-rod study samples at a reasonable cost.

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119
87-1-08.08-7528
New Four-Level All-Solid-State Laser Source Within the 1.5 to 4 Micron Range
Solidlite Corporation
16150 N.E. 85th Street #217 V
Redmond, WA 98052
Larry G. Deshazer (206-882-7582)
LaRC -- NAS1-18619

A novel, four-level, solid-state laser based on a new combination of rare-earth ions was proposed for use in remote atmospheric sensing and space-based lidar systems that require radiation sources in the near infrared (NIR). Operation of current NIR lasers involves quasi-three-level lasers with associated problems of strong temperature dependence with increased thresholds and reduced efficiencies at room temperature. In the new four-level laser, one ion acts as the sensitizer selectively absorbing the diode pump light. The sensitizer ion transfers the pump energy to the other rare-earth ion which performs as the laser-active ion.

Phase I studied two oxide crystals co-doped, for the first time, with the selected ion pair. Fluorescence, absorption, and excitation spectra were investigated.

It was learned that the host should be a crystal with low-energy phonons, such as yttrium-lanthanum-fluoride (YLF), for the laser-diode-pumped NIR laser. In addition, YLF is an uniaxial crystal giving polarized emission which would enhance by two-fold the laser gain coefficients perpendicular to the optical axis and would reduce the problems concerning thermal loading of the laser crystal.

Potential Commercial Application: Commercial applications would be in remote sensing of atmospheric constituents and pollutants, sensing industrial leaks and spillage, and providing new wavelength coverage for scientific and medical instruments. An efficient eye-safe laser could be used in wind sensing, low power materials processing, and remote bar code reading.

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* 120
87-1-08.09-1894
Automatic Scanning Lidar System to Map Upper Tropospheric Aerosols and Clouds
Science and Technology Corporation
101 Research Drive
Hampton, VA 23666
Geoffrey S. Kent (804-865-2065)
LaRC -- NAS1-18631

An innovative lidar system which will provide three-dimensional mapping of upper tropospheric aerosols and clouds was studied. Its application would be for altitudes up to about 15 km and ranges of 30 km. The instrument would provide alternative forms of color-coded, real-time displays of aerosol backscatter and cloud position as well as storage of data for subsequent study and analysis. The system would scan the complete sky using either a bi-directional scanning or a unidirectional scanning technique employing a multiple beam system. This dedicated, multi-wavelength lidar system for the study of upper tropospheric aerosols and cloud employs state-of-the-art technology for its scanning and electronic data processing systems as well as little-used techniques for the optimization of detector performance. The design is modular and flexible, permitting easy modification for alternative studies.

Phase I of this project was concerned with the establishment of the science requirements, interpretation of these in terms of system parameters, a study of available technology, and detailed conceptual design for a prototype system. In addition, a menu-driven simulation program was written, and simulations of the anticipated performance of alternative system designs were carried out. It was found that certain design conflicts arose in the achievement of the science objectives, and compromises were required. The final design, a flexible state-of-the-art system capable of making a wide range of measurements, employs the latest available technology and has been shown to be capable of achieving the project goals.

Potential Commercial Application: This instrument applies to the scientific study of upper tropospheric phenomena.

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* 121
87-1-08.10-2214A
Miniaturized Tandem Mass Spectrometer for Manned Space Missions
Viking Instruments Corporation
103-B Carpenter Drive
Sterling, VA 22170
Russell C. Drew (703-689-2214)
MSFC -- NAS8-37643

Advances in electronics, microcomputers, computer-aided instrument operation and data analysis, and the science of mass spectroscopy have all combined to make possible the development of a new, powerful, and versatile analytical tool that is suitable for manned spacecraft use. The innovation addressed in this project is an advanced spacecraft tandem mass spectrometer (ASTMS) that combines the miniaturized, space-proven, Viking mass spectrometer with a small, space-qualified second stage, an electro-optical detector system, and a unique approach to interstage fragmentation to yield an instrument with unprecedented performance in an extremely lightweight, rugged package.

The components of the system, defined and tested in Phase I, provide for the first time an opportunity to bring the high selectivity of tandem mass spectrometer systems to bear on the analytical tasks that will be required on advanced manned missions. The ASTMS uses a highly automated operating system and performs multiple functions. It will be capable of routine monitoring of the spacecraft atmosphere for trace contaminants, providing rapid warning of hazardous conditions. In addition, it functions as a general purpose analytical device using an alternate sample inlet to support the analytical testing requirements of space biomedical, life sciences, micro-gravity, and scientific investigations.

Potential Commercial Application: A compact, portable, highly integrated system can be used for field environmental monitoring, industrial process control, explosives detection, and on-site biomedical testing.

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* 122
87-1-08.10-8211
On-Focal-Plane Processing for Atmospheric Measurements
Irvine Sensors Corporation
3001 Redhill Avenue, Bldg 3 #208
Costa Mesa, CA 92626
David E. Ludwig (714-549-8211)
MSFC -- NAS8-37628

A commonly used approach to the measurement and monitoring of atmospheric contaminants is spectral finger printing of the suspect gases and other contaminants. A Fourier transform infrared (FTIR)

spectrometer simultaneously modulates each wavelength of the transmission spectrum at different frequencies, which are superposed in the detector output. Conventionally, a computer performs fast-Fourier transforms to generate the spectra which are then analyzed. One of the major problems associated with this approach is the large amount of data involved when the measurements are continuous and frequent. The proposed innovation is to process spectra "on-the-fly" using signal processing electronics integrated with the IR detector.

Successful completion of Phase I demonstrated that Z-plane technology for focal plane architecture provides the space needed to implement on-focal-plane signal processing and data reduction circuitry for a variety of atmospheric measurement instruments. A baseline design was developed which includes a trans-impedance amplifier, band-pass filter, threshold comparator, and event-driven multiplexer for each detector pixel. The Phase I analysis indicates that realizing the level of circuit integration required to achieve the original goals is low risk and within standard, commercial, radiation-hardened foundry capability.

Potential Commercial Application: Applications may be found in security systems and intrusion alarms, rapid-scan Fourier transform spectrometers, thermography, and robot vision systems.

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123
87-1-08.10-9054
Automated Atmospheric Analysis for Manned Space Missions
Mosaic Industries, Inc.
1260 L'Avenida, Suite B
Mountain View, CA 94043
Paul K. Clifford (415-961-9054)
MSFC -- NAS8-37630

A rugged and compact instrument is needed for identification and measurement of contaminants in cabin atmospheres for manned space missions. Metal oxide semiconductor (MOS) chemical sensors are well suited to the development of reliable, automated, multi-gas analysis instruments. They are sensitive to a wide variety of toxic and combustible gases and vapors at parts-per-million levels and are small, stable, rugged, and long-lived. The principal drawbacks of presently available sensors are their non-linear response and lack of selectivity; these have prevented their use in low-level contaminant monitoring.

The Phase I effort took a chemometric approach to overcome these limitations by augmenting arrays of semiconductor sensors with pattern recognition software. The feasibility of pattern recognition techniques to identify selectively one of eight representative contaminants based on measurements from arrays of as few as three semiconductor sensors was demonstrated.

Potential Commercial Application: Commercial applications include multi-gas leak detection, industrial hygiene monitoring, comprehensive in-plant chemical hazard detection, hazardous waste management, indoor air quality assessment, and fuel spill detection.

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*** 124**
87-1-08.11-3888A
Free-Space Particulate Contamination Sizing and Counting System for Space Applications
SKW Corp.
1901 North Moore Street, #1204
Arlington, VA 22209
Scott J. Bartel (703-243-3888)
GSFC -- NAS5-30290

Spaceborne particles from either man-made or natural sources can cause undesirable effects on spaceborne optical systems and micro-gravity manufacturing systems requiring a "clean" vacuum. A system capable of making multiple, particle size and count measurements in free space would be an asset for establishing the particulate contamination on the STS Orbiter, the Space Station, and other spaceborne systems.

The innovation explored in this project, a particle imaging measuring system (PIMS), will provide real-time engineering data regarding the size and frequency distribution of particulate contaminants in the micro-gravity and vacuum environment of space. The PIMS requires the following elements to perform this function: an illumination source, a solid-state imager, and image processing hardware and software. The technique investigated used a gated xenon strobe, macro-optical systems, a solid-state video imager, and signal processing electronics to correlate back-scatter with known particle sizes. Additional work indicates that far better size correlation will be achieved by using a scanned laser as an illumination source. What makes this approach interesting is that it would be a relatively compact, low-cost instrument capable of continuous monitoring of the particulate environment.

Phase I efforts successfully demonstrated the imager and image processing elements by measuring back scatter from a test target. Phase I also revealed test and illumination techniques which lead to the solutions proposed for possible future efforts.

Potential Commercial Application: The instrument described in this abstract has the potential to become a standard feature for space-borne optical and manufacturing systems where absolute knowledge of the contamination environment is required.

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*** 125**
87-1-08.12-3708A
Three-Stage Linear Split-Stirling Cryocooler with 1 to 2K Magnetic Cold Stage
APD Cryogenics, Inc.
1919 Vultee Street
Allentown, PA 18103
Ralph C. Longsworth (215-481-3708)
ARC -- NAS2-12643

This project is aimed at developing a cryocooler for space-borne, infrared astronomical telescopes which require 50 mW or less cooling at 1 to 2 K. It consists of a linear-drive, three-stage, split-Stirling cryocooler which will produce refrigeration at 8 K to cool a niobium-tin, alternating-current, superconducting magnet and a magnetic cold stage. During Phase I, the design of the refrigerator was studied to determine the size, weight and power input. Specific areas of innovation include: warm and cold, flexible, suspension means; a concentric, three-stage expander with clearance seals; a new, cold regenerator geometry; cold heat switches; and a conduction-cooled 8 K ac superconducting magnet.

The design studies confirmed the feasibility of the refrigerator concept to achieve the desired goals in a practical design capable of achieving long life in space with low noise and vibration levels. Results of the analysis show the cold end to have a volume of about 6 liters and a weight of 22 kilograms while the compressor volume is about 20 liters and weight is 64 kilograms. Total system power input is about 720 watts. Weights and power include magnetic shielding but not power supply components.

Potential Commercial Application: Applications are in cost effective refrigeration systems for cryo-pumps and cryo-electronic devices, including computers. With the magnetic cold stage, the refrigerator will offer a competitive way of liquefying helium (e.g., cooling magnets) and providing low temperatures for basic research.

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* **126**
87-1-08.13-4567
Microanalytical Characterization of Biogenic Components of Interplanetary Dust
Charles Evans & Associates
301 Chesapeake Drive
Redwood City, CA 94063
Filippo Radicati Di Brozolo (415-369-4567)
ARC -- NAS2-12818

This project investigated the analysis of interplanetary dust particles (IDP) using several microanalytical techniques. The analysis requires the development of non-contaminating techniques for particle preparation and analysis, especially with respect to the distribution of the biogenic elements H, C, N, O, P and S. Quantitative microanalysis of the biogenic elements and of the organic molecules in IDP is necessary to improve the understanding of the organic chemistry in the early solar system and in the interstellar medium. Consistent with the ultra-fine grain size of IDP, quantitative analytical methods with submicrometer lateral resolution were explored using Auger electron spectrometry, secondary ion mass spectrometry with ion imaging, and laser microprobe mass spectrometry. Improvements of these techniques were addressed for the chemical, textural, and isotopic characterization of selected standard materials and IDP.

The Phase I research demonstrated the feasibility of producing microtome cross sections of IDP analogs from particles embedded in non-contaminating metallic media and of acquiring hydrogen-isotope-ratio images from an IDP. These are the first isotope-ratio images ever produced for an IDP. Various organic microanalytical procedures using a laser ionization microprobe were also tested, and new analytical methods for the organic analysis of IDP were identified.

Potential Commercial Application: A commercial particle characterization facility with a complete range of analytical instrumentation will serve clients from the semiconductor, magnetic storage media, biomedical materials, environmental analysis, and government sectors.

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127
87-1-08.15-2960
A Magnetically-Controlled Power Distribution and Control System
C. T. K. Enterprises
PO Box 17879
Anaheim, CA 92817
Charles T. Kleiner (714-974-2960)
GSFC -- NAS5-30274

The innovation investigated involves the use of a vector-controlled magnetic power distribution technique which promises the following benefits: high reliability, low noise, inherent short-circuit limiting, ease in scaling for differing voltage and current loads, circuit isolation, radiation hardness, producibility and repeatability, and relatively low cost.

The Phase I results showed that the vector-controlled magnetic power distribution technique operated as predicted. A breadboard was demonstrated at the NASA Goddard Space Flight Center in May of 1988 followed by a demonstration of a combination of a breadboard-brassboard version of the "point design" in July of 1988. Although these were both preliminary versions, they nevertheless gave a strong indication that the basic principles were sound and could be further perfected.

Potential Commercial Application: This innovation is applicable to any power system where weight, efficiency, reliability, and relatively low cost are key requirements.

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128
87-1-08.16-0660
PE-CVD Diamond Thin Film for UV Detectors
Crystallume
125 Constitution Drive
Menlo Park, CA 94025
J. Michael Pinner (415-494-0660)
GSFC -- NAS5-30273

The innovation addressed in this project involves the use of thin diamond films as high-performance

ultraviolet detectors, where the films are produced by an inherently low-cost technique of plasma-enhanced, chemical vapor deposition (PE-CVD). The wide band gap, exceptional thermal conductivity, superior corrosion resistance, and high immunity to radiation damage makes diamond an ideal semiconductor material for devices that can operate at high temperatures in hostile environments. The superior physical properties of diamond can be economically exploited due to the ability to synthesize thin polycrystalline films of diamond over large areas using PE-CVD processes.

In Phase I of this program a similarity between the photoconductive properties of CVD diamond films and single crystals of natural diamond has been established, and a new approach to the nucleation and growth of high-quality, thin diamond films suitable for electronic applications has been developed. Photoconductivity has been observed in PE-CVD diamond films, and measured carrier lifetimes are similar to lifetimes in natural diamond single crystals. The factors that determine the nucleation and growth characteristics of diamond films have been addressed. A correlation between the grain size of the diamond films and their intrinsic photoconductivity has been obtained.

Potential Commercial Application: Diamond-based semiconductors will find use in uncooled electronic devices for test and control purposes in aircraft, rockets and spacecraft.

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129
87-1-08.16-0888
Infrared Detector Systems for High Dynamic Range Radiometry and Imaging
Microtronics Associates, Inc.
4516 Henry Street, Suite 403
Pittsburgh, PA 15213
Darryl D. Coon (412-681-0888)
GSFC -- NAS5-30282

The goal of this project is a new radiometric and imaging technology based upon cryogenic, extrinsic-silicon, infrared detectors which perform intensity-to-frequency conversion at the focal plane via simple circuits with very low power consumption. Incident infrared intensity controls the repetition rate of output pulses of short duration. Pulse heights are typically greater than one volt so that preamplifiers are not required. Each detector can drive a separate light-emitting diode so that pulse-coded image data can be optically transmitted out of the cryogenic environment. This would eliminate the need for multiplexers in the cryogenic environment of focal plane arrays. Pulse timing or counting provides an accurate means of signal digitization.

In Phase I, a dynamic range of about 10^6 was demonstrated. Measurements of pulse rate as a function of intensity over this range were carried out and found to compare reasonably well with a theoretical model. Other Phase I considerations and results deal with noise issues, detectivity, power requirements, and recovery after severe overexposure. The detector systems would be useful in many infrared radiometric and imaging applications, including simultaneous measurement of multiple infrared sources or images with luminosities ranging over many orders of magnitude.

Potential Commercial Application: This new radiometric and imaging technology could result in a commercially exploitable edge over older radiometry systems and imaging systems, especially in connection with space-related, scientific, thermographic, military, and other cryogenic infrared system applications.

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*** 130**
87-1-08.16-1188
High Performance Indium-Gallium-Arsenide Detector Arrays for the 1.0-to-1.7 Micron Spectrum
Epitaxx, Inc.
3490 U.S. Route 1
Princeton, NJ 08540
Vladimir S. Ban (609-452-1188)
GSFC -- NAS5-30278

The purpose of the Phase I project was to improve the material properties of indium-gallium-arsenide (InGaAs) crystals grown by vapor-phase epitaxy such that ten-element, linear arrays of room-temperature photodetectors can be fabricated with +10 percent uniformity. In Phase I, this project successfully produced a multiplexed, 256-element, detector array for the spectral range of 0.8 to 1.7 μm. These arrays were based on epitaxial layers of lattice-matched $In_{0.53}Ga_{0.47}As/InP$ alloys.

Specifically, a complete, 256-element linear array of 30 x 30 μm detectors was packaged in a Reticon multiplexer package and demonstrated with a commercial optical multichannel analyzer unit. The far-field pattern of a 1.3 μm semiconductor laser was also monitored (with 100 μm spatial resolution) using this array. The frequency response of this instrument was extended to a wave length of 1.7 μm using an InGaAs array.

Potential Commercial Application: Potential applications include satellite imaging and remote sensing for detection of water vapor and foliage, fiber optic receiver arrays, and optical multichannel analyzers for spectroscopy at wave lengths approaching 2.6 μm.

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131
87-1-08.16-2589
Scintillating Optical Fiber Trajectory Detectors
Fibre Optics Development Systems, Inc.
125 South Quarantina Street
Santa Barbara, CA 93101
Harry L. Watts (805-965-2589)
GSFC -- NAS5-30279

The objective of this project was to develop large area, low mass, high resolution, scintillating-optical-

fiber trajectory detectors. These would be suitable for use in experiments such as the Particle Astrophysics Magnet Facility (Astromag) which is presently being considered for flight on the Space Station. This detector requires development of fiber ribbons which are straight on the scale of the spatial resolution required by instruments being considered for Astromag. During Phase I, techniques for making ribbons with improved straightness were developed. The deviation from a straight line was about 500 microns over a length of 70 cm. Large area fiber ribbons (The largest were about 15 cm in width by 70 cm in length for the straight portion.) were fabricated and supplied to Washington University for tests to determine the spatial resolution. Attempts to increase fiber efficiency by using a cladding material of a lower refractive index on the fibers were unsuccessful.

Potential Commercial Application: Likely commercial applications are in high resolution, low mass, trajectory detection of charged particles in cosmic ray physics, nuclear physics, and high energy physics experiments. The techniques and detectors developed as a part of this program may also have applications in nuclear medicine.

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132
87-1-08.16-4645
Position-Sensitive CdTe Detector Using Improved Crystal Growth Method
San Diego Semiconductors, Inc.
7408 Trade Street
San Diego, CA 92121
E. Raiskin (619-549-4645)
GSFC -- NAS5-30289

The overall goal of this project is to demonstrate that a novel process developed by the firm can grow large-volume crystals of cadmium-telluride that are suitable for fabricating large-area, two-dimensional, gamma-ray detector structures.

Phase I demonstrated that a new, high-pressure, vertical Bridgeman approach can be used to grow crystals of CdTe of sufficient size, quality, and uniformity for the fabrication of large-area detector arrays. The crystals produced were characterized with respect to materials properties and detector operating characteristics. Single-element detectors were fabricated and investigated in detail. A 10 x 10 array of 1 mm^2 (nominal) detectors was fabricated and evaluated under various conditions.

The primary conclusion, thus far, is that detector-quality crystals suitable for large area arrays can be produced by the new crystal growth method. Utilization of a scaled-up new furnace now under construction should make it possible to produce array structures with areas exceeding the overall program goal of 50 cm^2. The particular sawing method used to produce the Phase I array led to problems in area definition and performance. A completely different approach to segmentation based on photoresist processing is recommended for future development.

Potential Commercial Application: A new class of position-sensitive detectors for use in gamma-and X-ray astronomy, medical diagnostic imaging, and industrial inspection is a potential result of this work.

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133
87-1-08.17-8961
A High-Resolution Multi-CCD, Time-Delayed-Integration Camera System
Photometrics Limited
2010 North Forbes Boulevard #103
Tucson, AZ 85745
T. W. McCurnin (602-623-8961)
JPL -- NAS7-1022

The Phase I effort evaluated the feasibility of constructing a high-resolution, multi-charge-coupled-device (CCD) camera system (MCCS) for use in a time-delayed-integration (TDI) imaging mode for wide-field astronomical imaging. The MCCS will employ five CCDs with 1024 by 1024 pixels arranged in a staggered format to provide a resolution width of over five thousand detector pixels. The MCCS will increase ten-fold the imaging field of view over a conventional TDI camera system that employs a single CCD with 1024 by 1024 pixels.

The MCCS provides a more practical solution to the TDI resolution problem than camera systems relying on a single large format (2048 by 2048) CCD. The MCCS makes use of small-format, commercially available CCDs, which are produced in higher yields than large CCDs. Because it is based on an expandable number of CCDs (five CCDs is simply a convenient number for this phase of the development), the MCCS can be altered to satisfy the desired degree of resolution. The readout of several CCDs in parallel results in a higher readout rate per scan line even in slow-scan cameras.

The Phase I SBIR project has been successfully completed. The firm designed and built an MCCS with two detector elements; a pair of .PM512 CCDs (512x512 pixels) were arranged in a single camera head according to the staggered and overlapped concept to give a resolution width of about 1000 pixels. Major technical achievements include: a method of aligning the CCDs, image correction for the staggered CCD concept, and an optimal electronic design for camera head operation.

Potential Commercial Application: In addition to the astronomy applications, a large-field-of-view TDI camera could be used for radiological non-destructive testing or inspection, e.g. the inspection of large scale aircraft sections.

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* **134**
87-1-08.18-0669
Microwave Network Analyzer for Superconductor-Insulator-Superconductor Mixer Research
MetriWave, Inc.
77 N. Oak Knoll Avenue #114
Pasadena, CA 91101

Wyman L. Williams (818-795-0669)
JPL -- NAS7-1025

Thesuperconductor-insulator-superconductor(SIS) mixer is a revolutionary new device which is used in sensitive millimeter- and sub-millimeter-wave receivers. Characterizing SIS devices is a difficult task at present, since commercially available network analyzers use test-signal power levels high enough to saturate or destroy SIS junctions.

This Phase I study showed that construction of a microwave network analyzer operating at frequencies up to a few gigahertz with a test signal power in the 100 pW range is feasible using the firm's sampled-line technique. This instrument could characterize SIS devices at their intermediate frequencies. A general purpose network analyzer can be converted to a low-power analyzer by changing one circuit module. This allows construction of a "convertible network analyzer," a general purpose analyzer which can be easily reconfigured to perform low-power SIS measurements.

Potential Commercial Application: Wide applications are expected in industrial and government microwave engineering laboratories.

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135
87-1-08.18-6642
High-Temperature Superconductors in Monolithic Microwave and Millimeter-Wave Integrated Circuits
Microwave Monolithics Inc.
465 East Easy Street, Unit F
Simi Valley, CA 93065
Daniel P. Siu (805-584-6642)
JPL -- NAS7-1011

Due to finite resistive circuit losses, many potentially useful microwave integrated circuit (MIC) and monolithic microwave integrated circuit (MMIC) system components have not been successfully implemented or even seriously considered. Recent discovery of high-temperature superconductivity (HTSC) in a number of ceramic materials with critical temperatures above the boiling point of nitrogen (77 K) promises to eliminate this restriction.

The six-month Phase I project evaluated the current and projected strengths and weaknesses of this rapidly emerging HTSC technology from a circuit-applications viewpoint. It identified a parallel development path whereby applications research need not be delayed while waiting for maturation of the extensive underlying materials research efforts around the world. This interim "laminated substrate" approach to HTSC integrated circuits is fully compatible with yet-to-be-developed, thin-film HTSC techniques which can be inserted at low risk as they become available.

Potential Commercial Application: Use of high-temperature superconductors in monolithic microwave and millimeter-wave integrated circuits will create a new era in high performance and versatility for important NASA systems and other applications.

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*** 136**
87-1-08.19-8775
Self-Referencing, Full-Aperture Metrology for Large Aspheric Mirrors
Bauer Associates, Inc.
177 Worchester Road, #101
Wellesley, MA 02181
Paul Glenn (617-235-8775)
GSFC -- NAS5-30268

The Phase I effort addressed the problem of measuring figure errors on large aspheric mirrors. The two primary drawbacks of conventional approaches are that they require a special reference, an interferometric null corrector, to be created for each test piece and a large test facility with metrology towers, special foundations, vacuum chambers, etc. Some optical devices, e.g., optical flats and convex shapes, are almost unable to be tested in large sizes.

The purpose of the research was to investigate a new non-contacting, self-referencing technique which offers interferometric accuracy for low-frequency errors and Angstrom-level accuracy for mid-frequency errors. It is compact, has high immunity to vibration and drifts, and accommodates a very wide range of curvatures, asphericities, and meter class diameters. It can measure optical devices in a coarse-ground state without reconfiguration, can be adapted to measuring cylindrical optical components, and could apply to an integrated, robust, computer-controlled fabrication machine for measuring and polishing a test piece. A complete systems analysis was performed, and a base-line system defined. The results are a conceptual layout, sophisticated analysis algorithms, and detailed performance predictions which demonstrate the feasibility of the instrument and its subsystems.

Potential Commercial Application: Potential applications include metrology of various high quality spherical and aspherical optical components, both large and small, and other diverse applications such as definition of ultra-straight linear ways and the metrology of very large granite surface plates.

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137
87-1-08.19-9450
Photoelectrochemical Fabrication of Spectroscopic Diffraction Gratings in Silicon Carbide
EIC Laboratories Inc.
111 Downey Street
Norwood, MA 02062
Michael M. Carrabba (617-769-9450)
GSFC -- NAS5-30277

Gratings and optical components that operate in the vacuum ultraviolet and the X-ray region are important components of spectroscopic instrumentation for many of NASA's space missions (e.g., LYMAN).

Silicon carbide (SiC) possesses the requirements of high reflectivity, low scattering, high stiffness, and low thermal stress for an optical material suitable for the region of the spectrum of interest. Photoelectrochemical (PEC) etching has been demonstrated as a promising method for the fabrication of diffraction gratings directly in the semiconducting material, silicon carbide. The SiC, used as an electrode in an electrochemical cell, is held at a positive voltage and illuminated. Etching occurs in only the illuminated regions to a depth proportional to the illumination intensity and exposure time.

In Phase I, it was determined that chemical-vapor-deposited and epitaxial forms of SiC exhibit PEC etching capabilities. In addition, grating structures and projected images were etched into the surface of SiC by the PEC method. The general conclusion from the Phase I research is that photoelectrochemical etching is a promising method for the fabrication of diffraction gratings directly in SiC. Although technical feasibility of PEC for the fabrication of grating structures has been demonstrated, further work is necessary on the PEC process itself to generate practical structures.

Potential Commercial Application: Major applications are in spectroscopic instrumentation operating in the vacuum ultraviolet and the X-ray region. Other possible uses are in blue-emitting, distributed-feedback, solid-state lasers. The etching process for SiC could be applied to high-temperature electronic devices.

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138
87-1-08.20-2870
High-Temperature and High-Response Skin Friction Sensor
Exotech, Inc.
3935 Beacon Avenue, Suite D
Fremont, CA 94538
Ian N. Moyle (415-790-2983)
LaRC -- NAS1-18611

An innovative approach to the development of flush-mounted, high-response, skin-friction gauges that can be used in high-temperature environments has been studied in this project. The objective was to increase the useful temperature range of Reynolds analogy sensors used for data acquisition in flow research and high-speed flight vehicles. High-response, skin-friction sensors must be small, reliable, and capable of operating in extremely high-stagnation-temperature flows.

The anemometer concept examined in Phase I involved the development of a ceramic substrate, a microstrate. The purpose of the microstrate was to enhance the frequency response and signal output of a conventional, surface-film and buried-wire configuration. Success was achieved with several types of high-temperature microstrates which were evaluated for further work on sensor integration. Some highly uniform, thin-film tantalum anemometer filaments were also satisfactorily sputtered onto alumina substrates. The process involved a repetitive photo-mask and etch process. The elements were then further evaluated or tested. Elements coated with a thin, oxidation-protective, alumina film were fired to 1300K in air and inspected.

Potential Commercial Application: The sensors could apply to flow research, design-data acquisition, and diagnostic testing on high-speed flight vehicles and jet engines.

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*** 139**
87-1-08.20-5630
An Optical Angle of Attack Sensor
Complere, Inc.
PO Box 1697
Palo Alto, CA 94302
F. K. Owen (415-321-5630)
ARC -- NAS2-12854

A major source of data uncertainty in transonic and supersonic wind tunnel testing is due to angle-of-attack measurement errors caused by unknown sting and balance deflections under load. Since dynamic loads in the Unitary Plan Facilities generally exceed those in conventional, low-speed, atmospheric wind tunnels, the need to account for these distortions during model testing is acute. To meet this challenge, a novel, laser-based instrument for the in-situ measurement of wind tunnel model angle of attack was proposed that will enable continuous, time-dependent measurements to be made without signal dropout.

In Phase I, successful proof-of-concept experiments were conducted to determine the reliable range, sensitivity, and long-term stability of the instrument. This work clearly shows that the optical angle-of-attack instrument could provide improved, time-averaged and time-dependent angle-of-attack information during Unitary Plan Facility testing. Detectors capable of 0.01 degrees resolution over a ±9 degree range and 0.03 degrees resolution over a ±22 degree range with time-dependent outputs of 60 Hz have been developed. This capability will be sufficient to provide accurate, real-time, angle-of-attack information for correlation with model balance measurements during transport and fighter model testing.

Potential Commercial Application: The innovative new technology generated to develop this instrument will be directly applicable to wind tunnel facilities in the public and private sectors.

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*** 140**
87-1-08.20-7377
Fiber Optic Pressure Sensor for Wind Tunnel Applications
Opcoa, Inc.
12281 Knott Street, Suite 109
Garden Grove, CA 92641
William H. Quick (714-558-7377)
LaRC -- NAS1-18626

A broad-range, pressure sensor immune to harsh environments and extreme temperatures is required for research in wind-tunnels. The proposed sensor--an integral terminus of a single, multi-mode, fiber-optic cable--is essentially all glass and, hence, immune to high temperatures and electromagnetic interference. The results of the Phase I study indicate that the pressure sensor is indeed feasible. Critical theoretical and experimental aspects of the system design--sensor element and optical de-modulator--were considered during Phase I as were proposed fabrication procedures for a prototype model. Also, the design of the de-modulator and microprocessor interface was generated. Accuracy analyses, both experimental and theoretical, show great potential for the pressure sensor system; however, evaluation needs to proceed further using a complete prototype system.

Potential Commercial Application: Multi-purpose pressure sensors which are immune to electrical noise and extreme temperature environments could find broad applications in process and automotive industries as well as in the military.

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141
87-1-08.20-9030
Remote Characterization of Wind-Tunnel Turbulence
Physical Sciences, Inc.
Research Park
PO Box 3100
Andover, MA 01810
Lawrence G. Piper (617-475-9030)
LaRC -- NAS1-18617

An innovative monitor for density fluctuations in the boundary layer of turbulent flows around test objects in wind tunnels is the subject of this project. It is based upon the laser-induced fluorescence from molecular oxygen which is excited when 193 nm light from an argon-fluoride excimer laser propagates through the air. Partial pre-dissociation gives the excited molecular oxygen a very short lifetime and, therefore, renders it immune to electronic quenching. In consequence, the intensity of the observed laser-induced fluorescence is directly proportional to the local number density of the volume being probed. Detecting this fluorescence with a two-dimensional diode array as the laser beam scans above the surface of the test object maps out the turbulence in two dimensions. Three-dimensional mapping results from repeating the laser scans at a number of distances above the surface of the test object.

The Phase I program used an available, lower power laser to investigate the properties of room-temperature oxygen fluorescence. Laser-excitation scans of several absorption bands were detected in fluorescence, and the results used to demonstrate a potential extension of the technique to simultaneous temperature measurements. A preliminary imaging experiment was conducted in order to validate a computer model of the fluorescence yield.

Potential Commercial Application: Applications would be in government research laboratories, aerospace industries, automotive industries, universities, and other organizations conducting gas-dynamic experiments.

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09 SPACECRAFT SYSTEMS AND SUBSYSTEMS

*** 142**
87-1-09.01-0540A
Superconducting Magnetic Bearings in an Advanced Momentum-Exchange Effector
SatCon Technology Corporation
71 Rogers Street
Cambridge, MA 02142
James R. Downer (617-661-8942)
LaRC -- NAS1-18682

An advanced, large-angle, magnetic suspension (LAMS) for use in an actuator for slewing large payloads is the innovation addressed in this project. The advantages of angular-momentum-exchange effectors over thrusters include reduced maintenance (no fluids to be periodically replaced) and improved compatibility with optical components (no effluent). Slewing of large payloads at high rates, however, requires torques and angular momentum storage capacities that exceed the capabilities of available angular-momentum-exchange hardware. High torque creates an extremely difficult design requirement for instrument-grade mechanical bearings. For conventional magnetic bearings, the magnetic structure would be excessively massive.

The problem of providing the torque and angular momentum storage capacity may be solved by an advanced control moment gyro (CMG) supported and gimballed by a superconducting LAMS. The baseline LAMS concept analyzed in Phase I combines the functions of gimbals, torque motors, and rotor bearings in a CMG. This innovative design approach employs several advanced magnet design technologies: a superconducting source coil and high-purity, cryo-resistive aluminum hyperconductors as control coils. It produces a factor of 36 improvement in the specific output torque, output torque per unit of mass. In addition to a study of the baseline design, a technology demonstration was identified and sized.

Potential Commercial Application: Low-noise torque sources could be used to control and point large future missions such as Space Station, co-orbiting platforms, the Hubble Space Telescope, and the large weapons payloads and sensor platforms of the Strategic Defense Initiative.

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*** 143**
87-1-09.03-0762
Full-Color, AC-Plasma, Flat-Panel Display for Space Station Applications

Photonics Technology, Inc.
6967 Wales Road
Northwood, OH 43619
Peter S. Friedman (419-666-0762)
JSC -- NAS9-17948

Full-color, large-area, dot-matrix flat-panel displays are not currently available. Plasma displays, which represent the leading edge of large-area, flat-panel color technology, were the focus of this project.

In Phase I, both the operating window voltage and panel brightness were improved by 600 percent, resulting in the world's brightest, dot-matrix, flat-panel, color emissive display. This display, which has a diagonal of 8.5 inches, an area luminance of 64 fL, and a contrast ratio of over 25:1, was delivered to NASA-JSC with drive electronics and demonstration software. The photometric characteristics of the Phase I panel delivered to NASA surpass the performance reported for all other types of flat-panel emissive display technology. In addition, Phase I involved the fabrication of 23 experimental color panels with four sets of specially designed, color-drive electronics. Results of experiments on these panels suggest that almost a two-order of magnitude improvement in panel brightness is feasible.

Potential Commercial Application: Applications include high-resolution color graphic smart terminals, avionics, medical imaging, engineering work stations, CAD/CAM, scientific instruments, military command and control, navigation and communication systems, portable computers, operating room displays, air traffic control, radar and sonar systems, video displays, personnel training and simulators, interactive educational systems, and sensor monitors.

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* **144**
87-1-09.04-3200
Non-Azeotropic Heat Pump for Crew Hygiene Water Heating
Foster-Miller, Inc.
350 Second Avenue
Waltham, MA 02254
David H. Walker (617-890-3200)
MSFC -- NAS8-37624

One of the power consuming systems required by the Space Station is the heating of water for crew hygiene, which may be accomplished through the use of an electric resistance heater or a heat pump. Of the two, the heat pump offers the most efficient operation by utilizing available waste heat sources. Performance of the heat pump can be improved through the use of a non-azeotropic refrigerant mixture as the working fluid.

For the Phase I effort, a heat pump operating with a working-fluid mixture of 70 percent R-11 and 30 percent R-22 was investigated through the construction and successful testing of a bench-scale unit. Experimental results showed a significant increase in coefficient of performance when compared to a heat pump using R-12 as the refrigerant. The benefits that can be achieved by the use of this heat pump were estimated to be a reduction in power demand from 46 kW to 450 W and an annual electrical energy savings of 2,044 kWhr. The value of these savings was calculated to be $429,240 per year.

Potential Commercial Application: Non-azeotropic refrigerant mixtures could be applied successfully to commercially available heat pumps now used in many heating, ventilating, air conditioning, and water heating applications.

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145
87-1-09.04-3200A
Hybrid Measurement of Two-Phase Flows
Foster-Miller, Inc.
350 Second Avenue
Waltham, MA 02254
Wayne S. Hill (617-890-3200)
JSC -- NAS9-17941

Monitoring and control of spacecraft thermal management systems involving two-phase flows requires the determination of the mass flow and quality at various places in the system. Short of separating the fluid phases, the only means of determining both the mass flow rate and flow quality in a two-phase flow is to make simultaneous, complementary measurements and to process the readings using an appropriate analysis. This technique, called hybrid flow measurement, has been of limited applicability in the past because of the limited turndown achievable with most volume flow meters. The bearingless flowmeter is a volumetric flowmeter that appears to offer the desired turndown performance.

In Phase I, a bearingless flowmeter was examined as a two-phase flowmeter in a preliminary test program. This work demonstrated the feasibility of the program concept: employing simultaneous, complementary measurements to determine the mass flow and quality. However, the pulse output data for the bearingless flowmeter displayed a bifurcation that indicated the presence of unstable rotor motions resulting in a low pulse output. This instability was not found in the liquid flow data or in some of the two-phase flow data, but occurred consistently in the gas flow data. Through an analysis of the design, this instability was traced to the fact that the bearingless flowmeter is a poor gas bearing. An alternative design approach was identified that should provide stable rotor motion in liquid, two-phase, and gas flows with an acceptable overall pressure drop.

Potential Commercial Application: A two-phase flowmeter could see widespread application in the nuclear, medical, and chemical process industries.

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* **146**
87-1-09.04-3800
Compact, High-Performance Heat Exchangers for Space Station Thermal Control
Creare Incorporated

PO Box 71
Etna Road
Hanover, NH 03755
Javier A. Valenzuela (603-643-3800)
JSC -- NAS9-17936

This project addresses the development of a novel single-phase, heat exchanger which can easily achieve heat fluxes comparable to evaporating and condensing heat exchangers while maintaining high effectiveness and low pressure-drop. This heat exchanger is ideally suited for the thermal control systems of Space Station crew and laboratory modules, which are constrained to use single-phase water as the heat transport fluid. They typically suffer from high pumping power requirements due to pressure losses in the heat exchangers and large size and weight due to single-phase heat transfer limitations.

Scoping analyses and proof-of-concept experiments performed during Phase I demonstrated the feasibility of this heat-exchanger concept. A water-cooled heat exchanger achieved a heat flux of 56 watts per square centimeter with an effectiveness of 84 percent and only 116 Pa (0.017 psi) pressure drop. The same heat flux and effectiveness were achieved with air at a somewhat higher, but still very modest, pressure drop (10 kPa, 1.4 psi).

Potential Commercial Application: Applications range from cooling electronic components to cooling internal combustion engines and terrestrial power plant condensers. Civilian and military space applications, such as Brayton cycle heat exchangers and recuperators or integral heaters and coolers for Stirling engines, could also benefit from the new technology.

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147
87-1-09.05-2228
Novel Heat Pipe Systems
Membrane Technology and Research, Inc.
1360 Willow Road, Suite 103
Menlo Park, CA 94025
Richard W. Baker (415-328-2228)
GSFC -- NAS5-30281

The objective of this project was to demonstrate the feasibility of a new membrane-based heat pipe concept in which the evaporator and condenser sections are connected by vapor and liquid lines. In both the evaporator and condenser, the liquid and vapor phases are separated by membranes that selectively permit only the vapor to pass through them. Theoretical calculations show that this membrane heat pipe would have a number of significant advantages over conventional heat pipes.

The membranes used in this project were asymmetric, composite materials. Modules containing these membranes were installed into the evaporator and condenser sections of a heat pipe system. Because the modules used in the heat pipe require different properties than those employed in other membrane applications, their development for this project required more time than originally planned. Furthermore, the task of constructing airtight modules proved to be more tedious and time-consuming than had been expected.

The heat pipe system was equipped with pressure and temperature gauges and a flowmeter so that system parameters could be monitored and varied during testing. In the time allowed for Phase I, the experiments verified that the evaporator module operates in the desired manner; however, condensation occurs on the vapor side rather than on the liquid side of the condenser module membrane. This problem and possible solutions were evaluated in some detail.

Potential Commercial Application: If successfully developed, the system could find a wide application in aerospace thermal management applications and be extended for use in industrial energy conservation systems.

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* **148**
87-1-09.05-3800
Three-Phase Invertor for Ultra-High-Speed Motor Drive
Creare Incorporated
PO Box 71
Etna Road
Hanover, NH 03755
Javier A. Valenzuela (603-643-3800)
GSFC -- NAS5-30272

A novel, rotating-field invertor for converting dc power to high frequency, three-phase alternating current was investigated in this project. In addition to the commercial applications listed below, this invertor is ideally suited for driving the ultra-high-speed, miniature turbocompressors presently under development for use in cryocoolers needed for space-borne sensors.

Scoping analyses and proof-of-concept experiments performed during Phase I demonstrated the feasibility and potential of this invertor concept. A breadboard invertor was built and tested over a frequency range from 1 to 16 kHz. Throughout the entire frequency range the three-phase output was close to sinusoidal. The low harmonic content of the ac output will result in significantly higher motor efficiencies when compared to efficiencies obtained using existing rectangular wave invertors. Preliminary design of the invertor indicates that invertor efficiencies of 90 percent or higher can be achieved.

Potential Commercial Application: Variable-frequency motor drive systems conserve energy in applications such as process control, pumping, high speed grinding spindles, and high performance machine tool drives.

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149
87-1-09.06-7958
DC-to-400 Hz Invertor
NDT Technologies, Inc.

P.O. Box 637
South Windsor, CT 06074
Herbert R. Welschedel (203-644-5655)
JSC -- NAS9-17944

The company demonstrated the feasibility of a simple, lightweight, high-efficiency power conditioning module. The module is versatile and can be used as a building block for a wide variety of applications. Furthermore, in many cases, use of the module can eliminate heavy and expensive low-frequency transformers and other inductive system components. In particular, this new module appears well-suited as a dc-to-400 Hz invertor.

The Phase I effort involved experimental evaluations of several classes of high-frequency-switched dc-to-ac inverters. A resonant approach, using a high-frequency link, was identified as the most promising method for advanced high-power, high-switching-frequency applications. Because these resonant circuits operate without switching losses, very high switching frequencies (to the mega-Hertz range) without electromagnetic interference problems are possible. This, in turn, allows the design of very light and compact inverters and converters. The control of resonant invertor circuits is difficult and presents an unresolved problem. However, its advantages make the resonant approach a promising candidate for developing a dc-to-ac invertor.

Potential Commercial Application: Applications are expected in ac and dc drives, space power systems, uninterruptible power supplies, robots, space shuttle systems, surveillance equipment, autopilots, appliances, business equipment, environmental systems, flight test equipment, aircraft, vans and jeeps, security systems, telemetry, underwater systems, X-ray systems, lasers, laboratory equipment, radars, and hospitals.

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*** 150**
87-1-09.07-1262
Hierarchical 3-D and Doppler-Imaging CO_2 Ladar with Programmable Fovea and Peripheral Vision
Autonomous Technologies Corporation
520 North Semoran Boulevard, Suite 180
Orlando, FL 32807
Randy W. Frey (305-282-1262)
JSC -- NAS9-17934

To address specific NASA mission applications of spaceborne automation and robotics, this project applies specific innovations to the emerging technology area called coherent infrared laser radar (ladar). The innovations proposed result in an imaging ladar approach tailored to operate safely in a large-area dynamic environment while providing highly accurate data required to accomplish complex tasks.

Phase I project objectives were: to evaluate the hierarchical scan concept of programmable fovea with simultaneous peripheral vision, to fabricate a breadboard ladar, and to create range and Doppler images of simulated spaceborne targets in the laboratory. The project demonstrated the programmable fovea and peripheral vision scanning concept using a breadboard, CO_2 laser imaging ladar. The project also generated Doppler and intensity images and performed electronic tests of the range electronics.

Potential Commercial Application: Ladar vision for intelligent robotics offers significantly increased automation for broad-based industrial applications.

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*** 151**
87-1-09.07-8600
Laser Orientation Transceiver System
Applied Research, Inc.
5025 Bradford Boulevard
Box 11220
Huntsville, AL 35814
John Morris (205-837-8600)
JSC -- NAS9-17930

An innovative sensor concept termed the laser optical transceiver system (LOTS) has been investigated for remotely determining a cooperative vehicle's orientation in pitch, yaw, and roll. Such a system would be useful to support automation of spacecraft rendezvous, station-keeping, and docking. The Phase I effort successfully demonstrated the technical feasibility of this concept with a two-dimensional, laboratory breadboard demonstration.

Potential Commercial Application: Applications are in the remote sensing of a cooperative target's orientation with respect to the sensor's frame of reference.

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152
87-1-09.08-5050A
Damage Inspection and Verification of Tethers
ANCO Engineers, Inc.
9937 Jefferson Boulevard
Culver City, CA 90232
George E. Howard (213-204-5050)
MSFC -- NAS8-37618

Most scenarios for utilization of tethers in space have a common denominator--they are dependent on the reuse of such tethers for reasons of economy. Because of the lack of data on potential tether damage, a substantial margin of safety is applied in order to reduce risks in reusing a tether. The consequent increase in the weight of tether systems makes them less attractive options for mission applications. An optical system for automatic inspection and damage detection of tethers during deployment and retrieval would permit tether safety margins and weight to be reduced immediately. In addition, the operational data obtained as a consequence of in-flight monitoring could allow next-generation tethers to be made more lightweight.

Work conducted during Phase I successfully demonstrated the feasibility of an opto-electronic, non-contacting, damage inspection and verification system by which inspection of a tether can be performed quickly and automatically. Demonstration hardware

was designed, fabricated, and tested to verify its ability to detect damage similar to that caused by micrometeorite impact. Among other items, these experiments investigated the threshold for detection of damage, geometric sensitivity, and the ability to inspect at velocities above one meter/second.

Potential Commercial Application: The primary application is expected to be in space missions performed by NASA or commercial organizations. In addition, non-space applications are possible--e.g., the use of a modified system for inspection of cable systems (electrical and structural), tow lines, and similar extended structures.

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* **153**
87-1-09.09-1000
Standard Get-Away Special Satellite
Defense Systems Inc.
7903 Westpark Drive
McLean, VA 22102
Richard Fleeter (703-883-1497)
GSFC -- NAS5-30276

To expand low-cost access to space for a variety of scientific experiments, there is a need for the development of a low-cost, modular payload bus for scientific payloads that can provide weight, volume, electric power, optional stabilization, and extended life (by means of a propulsion system to raise orbit altitude). The approach for this project is based on the firm's pioneering role in the use of the Get-Away Special (GAS) payload concept of the shuttle to launch low-cost, free-flying payloads.

In Phase I, the design of the bus as well as an optional propulsion unit capable of raising the satellite 100 nautical miles above the nominal shuttle orbit was completed. In addition, the firm successfully demonstrated the command and telemetry link in a bench test that met NASA GSFC specifications and defined steps leading to a qualified satellite ready for payload integration as early as November 1989.

Potential Commercial Application: A flight-worthy, low-cost, free-flyer spacecraft bus has numerous commercial and scientific applications including materials technology, space-qualified component development, and scientific research. The company plans to make this modular spacecraft widely available.

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10 SPACE POWER

* **154**
87-1-10.01-2376
Improved Mirror Facet for Space Applications
Solar Kinetics, Inc.
10635 King William Drive
Dallas, TX 75220
David L. White (214-556-2376)
LeRC -- NAS3-25335

The advanced solar-dynamic, space power system utilizes a precision optical concentrator to focus the sun's energy for conversion to electricity. The first generation concentrator consists of highly accurate mirror facets. An innovative, all-metal, advanced honeycomb design for these facets was proposed as a means to meet or exceed the accuracy goal of one milli-radian slope error. The mirror facet is a "sandwich" construction of thin, preformed sheet titanium or stainless steel with a welded honeycomb core. The convex surface is coated with aluminum or silver and an appropriate protective material such as SolGel. The facet will be interchangeable with the graphite/epoxy-/aluminum panel currently under development and provides a conservative "back up" approach. Dimensional stability, thermal properties, and corrosion resistance are some of the potential advantages of the new design.

Results of Phase I successfully demonstrated highly accurate, contoured facet samples. The accuracy goal of one milli-radian was exceeded with facets weighing between 1.1 and 1.6 Kg/m^2.

Potential Commercial Application: The accurate surface of these lightweight metallic structures could have applications in space power, space communications, and other aerospace industries where precise compound curves are required.

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155
87-1-10.01-2520
Ultra-High-Temperature 20 kHz Induction Generator for VSCF Operating Mode
Power Silicon and Monolithic Technologies Corp.
750 Braddock Avenue
East Pittsburgh, PA 15112
Stephen Kuznetsov (301-656-2520)
LeRC -- NAS3-25350

A high-temperature, brushless, electrical generator for 20 kHz space power systems uses an azimuthal-cascaded, internally excited induction machine (IEIG) operating at 44,000 rpm maximum shaft speed. The upper operating temperature for the rotor is 400 C. The module provides a constant frequency output at variable turbine input speeds. A distinct advantage of the IEIG is the inherent reliability of the rotor construction and direct stator output. The IEIG rotor is a solid forging of Hiperco 27 magnetic steel with an Inconel 718 and copper containment shell; no permanent magnets or saliency effects are used. The rotor is continuously magnetized by the dc component of induced current established by the "exit-edge" effect. In Phase I, a 15 kVA IEIG unit was fabricated. Assembly and testing were incomplete as of this writing.

Potential Commercial Application: Applications are in high-specific-density electrical generators for mobile use and adaptation to commercial aircraft generators.

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* 156
87-1-10.01-4000
Advanced Stirling Engine Heater Head
Stirling Technology Co.
2952 George Washington Way
Richland, WA 99352
Peter Riggle (509-375-4000)
LeRC -- NAS3-25334

The goal of this project is to build and demonstrate a proprietary, pressure-stabilized, heater head (PSHH) for a Stirling engine which offers long life, high reliability, improved performance, and lower costs relative to existing technologies. The U.S. Patent Office has recently issued a patent allowance for this unique heater head concept. Evaluations of the PSHH by the firm's engineers show that it has the potential for eliminating virtually all the problems currently experienced by existing heater-head designs.

Phase I work, now successfully completed, expanded the analytical basis for the proposed design. The reference engine selected for the evaluation of the PSHH is a 25-kW solar engine conceptually designed under NASA contract. A key result of Phase I is the preliminary design and layout of a PSHH configuration upon which to base the test-bed design. A full-scale, three-dimensional model of the heat-pipe condenser portion of the PSHH was fabricated as part of Phase I to allow visualization of the hardware geometry. Phase I also defined the approach and objectives for future testing.

Potential Commercial Application: Commercial applications include space-reactor or solar-thermal power generation, terrestrial solar power generation, heat pumps, Stirling automotive engines, and portable or remote power generators.

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* 157
87-1-10.01-6000A
Indium-Phosphide Solar Cells on Silicon Substrates
Spire Corporation
Patriots Park
Bedford, MA 01730
Stanley M. Vernon (617-275-6000)
LeRC -- NAS3-25283

Growth of indium-phosphide photovoltaic cells on silicon substrates avoids the use of InP as a substrate and could drastically reduce the cost and weight of InP cells. The inherent radiation resistance of InP may result in a higher end-of-life efficiency than can be achieved with silicon as the active material. Although the eight percent difference in crystal lattice spacing is expected to result in some loss of efficiency due to the formation of dislocations, a number of techniques show some promise for reducing the dislocation density, based on recent work with gallium-arsenide.

Phase I demonstrated the feasibility of InP-on-Si solar cells, showing that the hetero-epitaxial growth procedures developed for GaAs-on-Si can be used there and that only minor changes from the previously developed InP-on-InP cell fabrication process are needed. The work also gave a measure of the defect densities which occur in the material and how strongly they affect the cell performance. The highest cell efficiencies achieved with a silicon substrate were 7.2 percent AMO. One unexpected problem was revealed in Phase I: diffusion from the silicon wafer into the p-type buffer makes contact to the back of the cell difficult.

Potential Commercial Application: The most likely application of this technology would be power systems for satellites and spacecraft operating in orbits with the highest radiation levels.

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* 158
87-1-10.01-9030
Arcing on Space Structures in Low Earth Orbit
Physical Sciences, Inc.
Research Park
PO Box 3100
Andover, MA 01810
Guy Weyl (617-475-9030)
LeRC -- NAS3-25402

Arcing of partially insulated space components has been observed when these components are biased negatively with respect to the space plasma. Arcing is detrimental to system performance and may cause material deterioration and eventual failure of the component. This project sought to identify the key design parameters that determine onset of arcing and to incorporate them into an arcing model. Exercise of this model will establish limitations of system performance due to arcing. Particular physical effects considered were: field emission, sputtering, outgassing of surfaces, electron impact ionization, and negative ion formation.

Phase I identified two distinct phases in the arcing process: ignition and discharge development. Two different field emission sources were postulated as the triggers: microscopic metallic protrusions ("whiskers") at a triple junction line and thin oxide layers. The Phase I study also indicated that the ignition process was strongly dependent on the ability of a biased surface to attract charged particles from the ambient plasma and that the ionization of de-absorbed gases from the surfaces was important in allowing the discharge to proceed.

Potential Commercial Application: This application of this project is in understanding the mechanisms of arcing on spacecraft solar cells in low earth orbit.

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159
87-1-10.02-1140
High-Cycle-Life, Rechargeable Aluminum Batteries
Covalent Associates, Inc.
52 Dragon Court
Woburn, MA 01801
Victor R. Koch (617-938-1140)
JPL -- NAS7-1023

NASA has current and future needs for advanced rechargeable batteries for spacecraft and planetary rover missions. These applications require batteries that can safely deliver in excess of 1,000 deep discharge cycles at a 10 mA/cm^2 rate while providing specific energy densities on the order of 100 Wh/kg. To date, rechargeable lithium batteries with intercalation cathode systems, such as lithium with titanium-sulfide ($Li\backslash TiS_2$) and with molybdenum-sulfide ($Li\backslash MoS_2$), have not met NASA's discharge rate, cycle life, and energy-density specifications.

An investigation was conducted of several highly oxidizing, organic and inorganic cathodes operating with a rechargeable aluminum anode in a room-temperature, $AlCl_3$-based molten salt. The aluminum anode in this electrolyte is known to deliver cycling efficiencies in excess of 99 percent at rates of up to 25 mA/cm^2 without degrading the electrolyte. The research carried out during Phase I involved the synthesis of new cathode materials, preparation of the cathode matrix, and cycling the cells against Al under a variety of conditions. Three promising cathode candidates were discovered, two of which appear to reversibly intercalate and de-intercalate Al^{+3} for over 900 cycles.

Potential Commercial Application: Safe, high rate, high cycle life rechargeable aluminum batteries will find uses in satellites, portable communications equipment and a host of consumer products such as cellular phones, camcorders, and lap-top computers which currently use nickel-cadmium batteries.

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11 SPACE PROPULSION

* **160**
87-1-11.01-3350
Thrust Vector Control
Sparta, Inc
3440 Carson Street, Suite 300
Torrance, CA 90503
Irving B. Osofsky (213-542-6090)
MSFC -- NAS8-37640

This innovation concerns obtaining thrust vector control in a solid-propellant, booster rocket motor by means of controlled insertion and withdrawal of probes into various locations of the supersonic flow portion of the rocket nozzle. The objectives of Phase I were to: determine analytically the degree of thrust vector deflection that can be caused by probe insertion, determine the flow-field environment on the probe, determine what existing materials are suitable for use inside a solid propellant booster rocket nozzle, make preliminary mechanical and structural designs of probes, and define an analytical and test program for future work.

Phase I determined that transpiration-cooled vanes made of porous, tungsten-molybdenum and probes with internal reservoirs could survive the full control duty cycle of the solid rocket booster with no apparent change in dimensions. Wedge-shaped vanes were found to be approximately twice as efficient as cylindrical probes. Vanes are capable of producing pure torque in a single nozzle. The production of porous transpiration-cooled vanes and probes is sufficiently advanced to assure availability of test specimens for proof of principle testing.

Potential Commercial Application: This innovation applies to thrust-vector control units for general use on spacecraft and rocket-propelled vehicles, both civilian and military.

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161
87-1-11.03-6576
Modeling of Turbulent Spray Combustion in Liquid Rocket Engine Components
CFD Research Corporation
3313 Bob Wallace Avenue #205
Huntsville, AL 35805
Ashok K. Singhal (205-536-6576)
MSFC -- NAS8-37619

Recent advances in computational fluid dynamics (CFD) provide a basic mechanism for detailed analyses of the complex combustion processes in liquid rocket engines. However, the application of CFD techniques to rocket engines requires adequate models for the physical processes involved: atomization and spray formation under sub- and super-critical conditions, droplet-droplet interaction, turbulence, mass transfer via evaporation and diffusion, and combustion of dilute and dense sprays.

In Phase I, an interim version of the code (named REFLEQS) was developed by the systematic modification and validation of an existing CFD code. Modifications included the implementation of advanced numerical methods and advanced turbulence models. The validation study included six benchmark problems selected to assess individually the code's capability in numerical analysis and turbulent processes. Results of the validation study indicated that: central differencing with artificial damping significantly reduced numerical diffusion; the modified SIMPLEC solution algorithm greatly enhanced the code's convergence rate and robustness, e.g. its capability of handling highly non-uniform (high cell aspect ratio) grids; and the extended k- turbulence model and the multi-scale turbulence model outperformed the standard k- turbulence model. In addition, the code's capabilities of simulating reactive flows and of using body-fitted coordinates were demonstrated separately.

Potential Commercial Application: These computer codes would be engineering analysis tools of interest to all organizations involved in rocket propulsion, aircraft engines, and other liquid fuel combustors.

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162
87-1-11.03-8887
Advanced Diagnostics for Rocket Engine Spray Characterizations
Aerometrics, Inc.
894 Ross Drive , Suite 150
Sunnyvale, CA 94089
William D. Bachalo (415-965-8887)
MSFC -- NAS8-37617

Understanding the injection of propellants into the turbulent combustion processes of liquid rocket engines requires detailed information on the propellant drop-size distributions, mass flux of oxidizer and fuel, drop dynamics, and continuous-phase turbulence parameters. The recently developed phase Doppler particle analyzer (PDPA) can, with further development, provide these data for spray environments produced by atomizers used in gas turbine combustors and similar environments.

This project investigated advanced signal processing methods which will lead to the reliable application of the PDPA technique in the high number-density environments associated with rocket fuel atomizers. A method incorporating high-speed, analog-to-digital converters and the fast-Fourier transform (FFT) was evaluated through experiments and computer simulations. The analytical simulations indicated that the FFT method could process signals with a signal-to-noise ratio (SNR) as low as 0 dB with an accuracy to two percent. A slow, breadboard FFT processor and software were developed during the Phase I program to evaluate the method while operating under dense spray measurement conditions. Comparisons of the measurements with high SNR to the results obtained with degraded signals show that the FFT method could produce reliable results at very low SNRs. A thorough study of the parameters affecting the accuracy of signal processing was conducted, and a conceptual design of a high-speed FFT processor allowing Doppler frequencies to 200 MHz and data rates to 150 kHz was developed.

Potential Commercial Application: The development of an advanced diagnostic instrument for spray characterization in harsh environments will benefit research in gas turbines and supersonic combustion, currently of great interest to NASA, the Department of Defense, and their contractors.

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* **163**
87-1-11.04-6576
A Computer Model for Liquid Jet Atomization in Rocket Thrust Chambers
CFD Research Corporation
3313 Bob Wallace Avenue #205
Huntsville, AL 35805
Andrzej J. Przekwas (205-536-6576)
MSFC -- NAS8-37620

Liquid propellant atomization plays a dominant role in stable and efficient operation of rocket thrust chambers. Despite the recent progress in computational fluid dynamics (CFD) and spray combustion modelling techniques, no satisfactory approach has yet been developed for propellant atomization modelling. The major innovative element of this project is the prediction of the droplet breakup rate and average droplet diameter after primary atomization. The approach is to predict the wave formation on the jet surface and its transport. These models will be coupled with the jet embedding technique of predicting the atomization process. These improvements will be incorporated into NASA's multi-dimensional, reactive flow code, REFLAN, and tested on the thrust chamber geometry of the space shuttle main engine.

Phase I established the feasibility of predicting primary atomization of liquid propellent coaxial injectors. The developed model used linear stability analysis of surface-wave dynamics in conjunction with the jet-embedding technique for liquid jets. Predictions of location, size and frequency of drop formation showed good agreement with available data for both low-velocity (Rayleigh regime) and high-velocity (atomization regime) jets.

Potential Commercial Application: The physical models and the computer code would be of significant value to all organizations concerned with the design and operation of liquid rocket engines as well as other industrial equipment using liquid injectors.

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164
87-1-11.04-8581
Improvement to Viscous Flow Field Calculations in Regeneratively Cooled Nozzles
Remtech, Inc.
3304 Westmill Drive
Huntsville, AL 35805
Swart C. Praharaj (205-536-8581)
MSFC -- NAS8-37637

Some of the engines being considered for space operations use regenerative cooling of nozzles for enhancing their performance. In this process, both enthalpy and entropy of the coolant gas rise while those for the nozzle gas fall. The objective of this work was to resolve the enthalpy-entropy consistency issues utilizing the algorithm of the boundary-layer, integral-matrix procedure in order to calculate accurately the performance of such engines.

The work performed in the Phase I effort checked and improved the existing JANNAF procedure to include the effects of "enthalpy pumping" on the performance calculation of a regeneratively cooled rocket engine. It was found from a limited study that when regenerative cooling was compared to an "adiabatic wall" situation, the inviscid specific impulse value was increased, the boundary-layer thrust deficit was increased only slightly, and the overall specific impulse was enhanced to a value close to the adiabatic wall value.

Potential Commercial Application: The procedure could be applied by the rocket engine community to

make performance calculations for rocket nozzles with a fairly general arrangement of the cooling system.

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12 HUMAN HABITABILITY AND BIOLOGY IN SPACE

* 165
87-1-12.01-0264
Zero-Gravity Phase Separation Via Ultrasonic Coalescence
S. R. Taylor & Associates
516 S.W. Kaw
Bartlesville, OK 74003
Scott R. Taylor (918-337-0264)
JSC -- NAS9-17950

Space-borne environmental and life support systems require innovations in many areas. This project addressed the need for a compact, reliable, low-power technique to separate gas (e.g., air) from a water transport loop in a zero or low gravity environment, for example, during suit backpack charging. The primary objective of the Phase I program was to demonstrate the feasibility of using an ultrasonic standing wave field to cause coalescence of gas bubbles prior to the use of inertial separation in devices such as "hydrociones" and centrifuges.

Phase I results met and, in fact, exceeded the objectives in that the method not only caused rapid and effective coalescence of the suspended bubbles but also provided sufficient force to promote actual separation as well. Therefore, it now appears that the action of the coalescence field alone will be sufficient to promote successful separation without the additional cost and complexity of a subsequent inertial separator. The method promises to be energy efficient as well.

Potential Commercial Application: The method will improve the efficiency of space flight operations by ensuring high-quality, liquid stream composition, which is critical for several potential, zero-gravity applications.

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166
87-1-12.01-1711
Water Quality Monitor
O.I. Corporation
PO Box 2980
College Station, TX 77841
Bernie B. Bernard (409-690-1711)
JSC -- NAS9-17945

A water quality monitor capable of measuring the conductivity, pH, organic content, and ammonia levels of reclaimed water in a regenerative life support system is required. The primary goal of this project was the definition of a system for accurately and precisely measuring total organic carbon (TOC) in the concentration range of 10 ppb to 1 ppm while minimizing the need for crew interaction and limiting the use of utilities such as gases, reagents, and power.

Phase I consisted of a literature study and experiments to evaluate the analytical and mechanical aspects of a space-borne laboratory TOC analyzer. The experiments investigated a wet oxidation process for completely reacting organic compounds to and detection of CO_2. The recommended method relies on temperature-promoted persulfate oxidation of organic compounds and a non-dispersive infrared detector (NDIR). Two innovations were applied to this approach: first, microwave energy was used to provide an instantaneous, as-needed heat source to promote oxidation and, second, a flow-through-trapping, reverse-flow-desorb scheme was applied in the NDIR. Other results were performance evaluations of prototype instrument hardware and a concept for a tiny optical bench IR detector that could replace the NDIR and give multiple results such as total hydrocarbon, total oxidizable nitrogen, and CO_2 concentrations for air and water.

Potential Commercial Application: An analyzer applying this technology could be applied in process monitoring in industries involved in manufacture of semiconductors, pharmaceuticals, and chemicals and in power generation and environmental control.

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167
87-1-12.01-2878
Space Suit Thermal Control Using Non-Toxic Microencapsulated Two-Phase PCM Fluid
Triangle Research and Development Corp.
PO Box 12696
Research Triangle Park, NC 27709
David P. Colvin (919-467-2878)
JSC -- NAS9-17952

An investigation was conducted of a novel latent cooling fluid containing microencapsulated phase change materials (PCMs) for spacesuit liquid cooling garments. The PCM slurry could provide enhanced thermal properties and crew comfort as well as thermal control simplicity. Emphasis was placed upon development of a PCM slurry coolant system with a passive control strategy.

The Phase I results indicated the technical feasibility for the approach and suggested specific criteria for its implementation. Both single-PCM slurries and multiple-PCM mixtures exhibited novel and enhanced thermal properties exceeding those for water. Fluid thermal capacitance exceeded by 50 times that of water while the heat transfer coefficient was enhanced by over 100 percent. Latent heat transport within the microencapsulated PCM slurry was also seen to provide practically isothermal thermal management across the circulating fluid system. A non-toxic and non-flammable coolant with microencapsulated PCMs should provide enhanced heat transport in a liquid-cooled garment and improve astronaut comfort. Current designs of liquid-cooled garments use water with a sophisticated active control system. A PCM coolant requires a simpler passive control strategy.

Potential Commercial Application: Liquid-cooled garments can be used by fire fighters, deep sea divers, Arctic workers, patients, and industrial and military personnel.

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* **168**
87-1-12.01-4995
Extravehicular Mobility Unit Helmet-Mounted Display
APA Optics, Inc.
2950 N.E. 84th Lane
Blaine, MN 55432
David E. Stoltzman (612-784-4995)
JSC -- NAS9-17929

Helmet-mounted-display (HMD) systems present many potential benefits in the use of space suits for extravehicular operations. Phase I investigated the preliminary optical and mechanical design of a new concept for incorporating an HMD system with the extravehicular mobility unit (EMU), taking into consideration day and night operations. The Phase I study was conceived initially as a conventional optics study. At NASA's request, however, a preliminary evaluation of a holographic optics approach was conducted.

Phase I has shown that the requirements for an HMD for the EMU can be satisfied by either a conventional or a holographic-based optical system using available cathode-ray-tube technology. The conventional optical system can be fabricated with high confidence and will meet or exceed requirements. The conventional optics design was completed and a mock-up constructed to demonstrate the concept. The alternate optics design concept using holographic elements has the potential for a smaller envelope and could provide an improved operational system. Thus, this approach has been chosen as the prime concept.

Potential Commercial Application: The helmet-mounted-display unit can be used to provide information in maintenance and repair operations in remote locations or restrictive spaces and in situations involving use of protective clothing. Specific examples are aircraft maintenance, all forms of nuclear operations, surgery, servicing during inclement weather, construction, and commercial space operations.

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169
87-1-12.01-8553
Oxygen Extraction from Mars for Advanced Life Support and Power
Aquanautics Corp.
980 Atlantic Avenue #101
Alameda, CA 94501
Bruce D. Zenner (415-652-8553)
JSC -- NAS9-17931

For all advanced missions, in addition to oxygen supplies carried from earth, NASA has a requirement for a system that either collects in-situ planetary oxygen or generates it from plant growth chambers. Conventional oxygen separation techniques are not capable of efficient extraction from a low concentration atmosphere such as Mars. A system based on circulating-carrier oxygen-separation (CCOS) technology to extract oxygen in such situations was explored. This technology is a spin-off from a five-year Department of Defense program to develop an artificial gill. During Phase I, feasibility was explored by performing a preliminary design of a base-case system to extract oxygen from the Martian atmosphere. Estimated specific power, mass, and volume compare favorably with other technologies. Feasibility was demonstrated by an experiment that used a small-scale CCOS system to extract oxygen from simulated Martian atmosphere.

This technology may apply to advanced missions that require capturing the free oxygen in-situ from the Martian atmosphere, recovering oxygen from the Martian or lunar soil, or concentrating oxygen from plant growth chambers in planetary bases. The technology may also be useful for recovering oxygen leaking from a cabin module.

Potential Commercial Application: The company has several commercial, joint-venture partners that are supporting the technology, including L'Air Liquide, the world's largest industrial gas manufacturer.

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* **170**
87-1-12.01-9450
A Variable Transmittance Electrochromic Space Suit Visor
EIC Laboratories, Inc.
111 Downey Street
Norwood, MA 02062
Stuart F. Cogan (617-769-9450)
JSC -- NAS9-17939

An astronaut in a space suit will experience sharp changes in direct and indirect solar flux which can result in visual impairment. Present helmet assemblies are equipped with a fixed transmittance sun-visor and opaque fiberglass eye shades that are manipulated manually by the astronaut. The proposed innovation is a variable transmittance sun-visor based on electrochromic optical switching. The sun-visor would have a laminated, thin-film structure that could be integrated into the protective visor of a spacesuit helmet assembly. The visor would have an optical transmittance variable between 10 and 70 percent controlled by the astronaut or an automatic sensor. Selective modulation of prescribed locations on the helmet is possible, allowing built-in peripheral eye shading.

The Phase I program demonstrated electro-chromic switching in polycarbonate laminates and near-neutral density optical modulation. Electro-chromic devices on glass substrates have been tested for 20,000 full switching cycles without degradation, with typical switching ranges between 15 and 65 percent transmittance (400-700 nm). Thus far the program has emphasized an electro-chromic system based on thin films of amorphous tungsten trioxide and amorphous

iridium oxide which color and bleach synchronously in a laminated structure.

Potential Commercial Application: Aerospace applications include sun-visors, space vehicle windows, optical scientific equipment, and thermal management-/glare control coatings in aircraft transparencies. Terrestrial commercial opportunities include eye-wear, automobile sunroofs, variable reflectance mirrors, optical equipment, and some building window applications.

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* 171
87-1-12.02-5202B
Removal of Contaminants from Experiment Waste Water Using Immobilized Enzymes
Umpqua Research Company
PO Box 791
Myrtle Creek, OR 97457
Gerald V. Colombo (503-863-5201)
MSFC -- NAS8-37642

Reverse osmosis and conventional adsorption methods do not remove some types of organic contaminants from waste streams. Examples of such contaminants are ethanol, methanol, and urea. Specific enzymes exist that catalyze reactions to convert these contaminants to compounds that are efficiently removed. These enzymes, when immobilized, can be used in a packed-bed configuration which can be integrated with water reclamation units of current environmental closed life support systems (ECLSS).

Immobilized enzymes were demonstrated during the Phase I effort as highly efficient biocatalysts to convert urea and alcohols to compounds that are efficiently removed by existing technologies. Immobilized urease beds were successfully tested for a continuous period of 80 days. When included in an adsorption system and challenged with waste shower water, all measurable urea and its decomposition products were removed.

Alcohol oxidase was shown to catalyze the oxidation of ethanol and methanol to the corresponding aldehydes and was identified as a catalyst for oxidation of twelve potential waste stream contaminants. One of the reaction products, hydrogen peroxide, was found to inhibit enzyme function. Methods to decompose the H_2O_2 to water and oxygen were identified but not developed under Phase I.

Potential Commercial Application: The immobilized urease developed in this project has applications in kidney dialysis and in treatment of wastewater containing urea, e.g., municipal wastewater and effluents from slaughterhouses and urea manufacturing plants. A stable alcohol oxidase preparation would be useful for elimination of alcohols and formaldehyde from dilute aqueous solution.

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* 172
87-1-12.03-1113
Red Blood Cell Measurements Using Resonance Ionization Spectroscopy
Atom Sciences, Inc.
355 Paint Branch Drive
College Park, MD 20742
Larry J. Moore (301-454-7751)
JSC -- NAS9-17932

Astronauts and animals flown in micro-gravity have experienced a loss of red blood cell mass, but mechanisms causing this phenomenon are not understood. Preparations for in-flight hematology studies include a desire to eliminate radioactive tracers and substitute safe, stable isotopes, while utilizing microliter volume blood samples for making red cell measurements. Phase I studies have demonstrated the basic feasibility of using stable isotopes of chromium and iron as tracers to measure red cell mass, survival, and production in ten microliter blood samples from rats. Picogram and femtogram sensitivities were demonstrated for the minor isotopes of iron and chromium, respectively, using laser resonance ionization spectroscopy.

Potential Commercial Application: Possible applications are in diagnostic tests for hematologic disorders, pediatric and neonatalogical monitoring, and general stable isotope monitoring of physiological functions.

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173
87-1-12.03-1304
Medical Microbiology Test Station for Microgravity
Austin Biological Laboratories, Inc.
6620-A Manor Road
Austin, TX 78723
Dennis Ray Schneider (512-928-1304)
JSC -- NAS9-17933

The purpose of this project was to develop a prototype comprehensive microbiological system suitable for use in microgravity. A unique, thin-film system was investigated which provides for the isolation and identification of bacterial, viral, and fungal pathogens and, where appropriate, allows for determination of antibiotic susceptibility. The film is stored in a desiccated state stable at room temperature for extended periods and is rehydrated immediately prior to use. Only small amounts of liquids are required, thus reducing the likelihood of infectious aerosol formation when in use. Film size is 1 mm x 7.5 cm x 2.5 cm.

During Phase I testing of this system, 100 percent sensitivity and specificity was obtained in the identification of various species of bacteria. The dry-film format also proved to be effective in determining bacterial susceptibility to antibiotics. Other research showed how this innovation could be applied in the detection of viruses. The prototype system developed in this project is readily usable in an automated reader or in visual analysis.

Potential Commercial Application: A need exists for a reduced-space, modular, microbiology work station in both the physician's office and third world hospital facilities.

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174
87-1-12.04-1987
Kinematic Data Gathering System for Determining Human Motion in Zero Gravity
Phoenix Engineering & Computing, Inc.
3102 Watford Way
Madison, WI 53713
Rimantas Buinevicius (608-274-1987)
JSC -- NAS9-17947

A need currently exists to develop a kinematic data gathering system small enough to allow free movement of subjects in both ground-based, zero-G simulation studies and space-based shuttle missions. The system studied in this project measures kinematic motion through the use of orthogonally mounted, linear accelerometers.

Initial results of the Phase I study of a five- segment model show that the use of five, three-dimensional accelerometer units gives inaccurate results. At least eight such units are needed for mounting points on the shoulder joints, the wrists, the hip joints, and the ankles. A nine-segment model requires at least eleven accelerometers. Here mounting would occur at the wrists, elbows, shoulder joints, waist, knees, and ankles. Since each joint would be equipped with units containing three orthogonally mounted accelerometers, motion of each limb segment would be measured by six accelerometers. Phase I studies confirmed the technical feasibility of fabricating small, unobtrusive measurement units which overcome the inhibiting effects of current kinematic measurement systems. Size constraints are within bounds, required accelerometer response is achievable, and software will allow real-time mapping of positional data.

Potential Commercial Application: The system described would have commercial applications in judging athletes' performance by graphical representation, in rehabilitation medicine, in the science of kinesiology for monitoring prosthetic motion in real-time, and in the science of epidemiology for monitoring habitual physical activity.

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175
87-1-12.05-0298B
High-Resolution Electronic Photography
CCE - Robotics
PO Box 9315
Berkeley, CA 94709
M. J. Malachowski (415-848-0298)
JSC -- NAS9-17935

A reusable, photosensitive panel was proposed to capture images which can be used to produce high-resolution electronic photographs. The technology involved parallels that of xerography in copiers. Once the image is stored on the dielectric panel, it can be "read" by stimulating a pixel region with laser light. Absorption or excitation by the light is a function of the image intensity of the pixel. This value will be measured by the monitoring photo luminescence charge. The photo current produced is converted to a digital value. The digital image can be stored, manipulated, and displayed using currently available computer imaging technology.

In Phase I, designs were prepared for two imaging plate configurations which have the potential of meeting the criteria required for high-resolution, panchromatic electronic photography. One would be assembled from commercially available components; the second requires the custom fabrication of thin films produced by chemical vapor deposition. Image resolution is proportional to size of the image plate.

Potential Commercial Application: The electronic still camera has numerous applications for space, scientific, industrial, commercial, and amateur photography. It is ideal for long-term missions where resupply is difficult, e.g., lunar and Martian trips and missions where microgravity makes wet processing difficult.

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176
87-1-12.05-5201
Space Laundry Cleansing Agent and Filter Development
Umpqua Research Company
PO Box 791
Myrtle Creek, OR 97457
Gerald V. Colombo (503-863-5201)
JSC -- NAS9-17953

NASA's Space Station laundry facility requires a suitable cleansing agent and a filter for treating laundry water before it is fed to a water reclamation system. The laundry cleansing agent must be compatible with the cleansing agents developed for the shower when the two waste streams are combined in the water reclamation system. The filter must eliminate the fouling observed in waste treatment systems involving shower and laundry water containing hair, lint, and epithelia. A disposable filter has been developed for the shower which efficiently removes all particles larger than 100 mesh and has been shown to dramatically increase the life of subsequent finer filters. A similar filter is needed for the treatment of laundry water immediately as it is generated to prevent fouling of pumps and separators and to provide compatibility with the reclamation subsystems.

During Phase I, a laundry filter concept was evaluated. In this concept, a roll of filter media unwinds from a spool, advances across a filter support, and is then rewound onto a second spool. Candidate filter materials were tested with real laundry water, and designs were projected for the Space Station application. In addition, five cleansing formulations were developed that meet requirements of the Space Station and were recommended for further evaluation.

Potential Commercial Application: The cleansing agent may prove to be superior to present available formulations. The automatic coarse filter should have a wide range of industrial applications.

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177
87-1-12.06-1262
Modular Environmental Control Life Support System for a Mid-Deck Animal Habitat
Down to Earth
2039 Shattuck Avenue, Suite 402
Berkeley, CA 94704
Richard C. Mains (415-548-1262)
ARC -- NAS2-12820

Existing holding facilities for animal specimens used in spaceflight life science studies are inadequate for supporting long-duration experiments for the Space Station and bioplatforms. New technologies are required to provide biological, gaseous, and radioisotope isolation, specimen interchangability, and independent life support for earth-to-orbit transport and on biosatellites. These new technologies will require extensive ground and space-based testing with specimens. The goal of this project was to assess the feasibility of developing a modular environmental control and life support system (ECLSS) for an animal specimen habitat compatible with installation in two shuttle mid-deck lockers. The system, the controlled environment animal habitat (CEAH), is designed to require only power from the shuttle and to operate in a closed mode for 14 days.

The work of Phase I indicates that the basic concept is feasible and accomplished the following: identified essential life-support parameters for mice, rats, and squirrel monkeys; specified which parameters are to be monitored and controlled; designed and fabricated the CEAH; developed software for system control; conducted short-term CEAH hardware tests and a seven-day system test with two rats; produced conceptual designs of CEAH contained within two mid-deck lockers; and assessed the capabilities of CEAH to accommodate mice and squirrel monkeys.

Potential Commercial Application: Applications will be in support of ground and in-flight bioengineering testing for the Space Station or bioplatforms developed by US and international commercial, space services companies.

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178
87-1-12.06-3053
Accelerating Seed Germination and Plant Growth through Manipulation of Atmospheric Pressure
Growth Systems, Inc.
PO Box 2214
Glenview, IL 60025
R. Louis Ware (312-446-3053)
KSC -- NAS10-11467

Research conducted a few years ago indicated that subjecting seeds and plants to frequent changes in atmospheric pressure may shorten germination time, improve the rate of growth of young plants, and cause more massive and rapid root growth. The pressure changes were within the range of atmospheric barometric variations; hence, an environmental chamber of relatively simple construction with air expelled and ingested by a vacuum turbine could create the required pressure differentials that may produce accelerated germination and growth. Coupled with control of other environmental parameters, this concept, if successful, could benefit applications such as the NASA Controlled Ecological Life Support System (CELSS).

In Phase I, test results showed some positive responses of accelerated and more uniform seed germination with pressure cycling. Although the effects were species-dependent, pressure cycling also produced positive effects on plant growth. The Phase I results were less than satisfactory because the experimental apparatus could not maintain desirable humidity levels of 90 percent rather than the 40 to 70 percent range experienced. This project has explored a phenomenon that effects plant growth in a variety of ways. Further research should be done in a laboratory with sufficient resources and enough time to understand better the growth responses and apply the findings to intensive cultivation.

Potential Commercial Application: Prospective applications include commercial greenhouses requiring more intensive cultivation and faster yields, in particular, for high value crops and seedling production, commercial pre-conditioning (pressure) of seeds for faster germination, and seed company use for germination tests.

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179
87-1-12.07-7670
Cell Culture in Microgravity: An Instrument to Monitor Growth and Cell Markers
Optra, Inc.
66 Cherry Hill Drive
Beverly, MA 01915
Bruce Crary (617-535-7670)
KSC -- NAS10-11457

Existing methods in cell culture for monitoring population growth and for localizing and quantifying cellular bio-molecules require harvesting of cells and extensive handling which usually results in cell death. These limitations must be overcome for microgravity environments if applications of cell culture are to be realized in the manned space station. An automated instrument proposed for monitoring cell cultures includes the capability to quantify such cellular probes as antibodies that have been labeled with heavy-metal colloids. The principles of laser-light scattering are the conceptual basis for this instrument.

A breadboard instrument for static light scattering was built and tested during the Phase I contract. It was well-suited to studies of the angular spectrum of light scattered by dead cells in a culture and morphological indices of common cell types, but the instrument was not able to quantify the presence of cellu-

lar probes because the cells could not be labeled with enough colloidal gold for such measurements. The firm developed new technologies which improved the sensitivity of light scattering measurements. This led to the creation of a second breadboard instrument with far greater potential than the original design. This dynamic light scattering instrument measures phase rather than the intensity of the interference patterns scattered from cells, particles, and macro-molecules in a suspension.

Potential Commercial Application: The expected applications are in scientific and industrial research conducted both in space and on earth.

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* **180**
87-1-12.07-8606
A Space-Rated Nutrient Delivery Root/Support System
PhytoResource Research, Inc.
707 Texas Avenue, Suite 101-E
College Station, TX 77840
H. W. Scheld (409-693-8606)
KSC -- NAS10-11461

There is a growing understanding that the interaction of the plant root with its environment is critical to plant productivity. In a microgravity environment, available evidence indicates that the activity in the root zone may become the major limiting factor. Understanding of the exchange of metabolic gases and nutrient uptake by roots is, thus, a critical issue in the development of plant support systems employed in space for life support or for basic research. To address this issue, this project was aimed specifically at providing data and technology for support of plant root systems in advanced space life support systems.

Several configurations of a root metabolic chamber were designed for studies of the effects of aeration and gas exchange upon plant functions. The read-out of plant function in this apparatus is a system for measurement of carbon-11 uptake and phloem transport generally known as the short-lived isotope kinetics system, which allows real time observations of effects of changing shoot or root environments upon the allocation of carbon in growing plants. A prototype of a shuttle locker-sized, plant growth flight experiment facility was developed consisting of computer-controlled valves and pumps to allow the regulation of aeration and watering in six or more small plant growth chambers within the plant growth facility.

Potential Commercial Application: The applications are in the development of more effective hydroponic systems for intensive greenhouse culture and for use in highly controlled, compact, plant-growth systems for space applications. This information is of significant value for terrestrial agriculture in environments that are waterlogged or otherwise subject to poor aeration.

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13 QUALITY ASSURANCE, SAFETY AND CHECK-OUT FOR GROUND AND SPACE OPERATIONS

181
87-1-13.01-0161
Fiber Sensors for High Temperatures and Pressures
LaserGenics Corporation
PO Box 611330
San Jose, CA 95161
Richard G. Schlecht (408-433-0161)
JSC -- NAS9-17943

Ground operations and flight instrumentation for rocket engines as well as many other NASA applications require sophisticated sensing devices for measuring temperature and pressure on a continuous basis in an extremely harsh environment. Present-day sensors do not operate reliably in this environment. Fiber-optic sensors offer a possible solution, but present fibers of glass or silica are not able to withstand the temperatures and pressures encountered in rocket engines. A novel approach using single crystal fibers of sapphire and yttrium-aluminum-garnet (YAG) has been investigated in Phase I. The results of the Phase I effort demonstrate that Nd:YAG has significant potential for sensing high temperatures and pressures in a single fiber.

Potential Commercial Application: This sensor system could find wide application in process control in the steel, chemical, and semiconductor industries, in fossil fuel and nuclear power generation plants, and in plasma, fusion, MHD, combustion, and chemical research.

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182
87-1-13.01-4770
Surface Organic Contamination Sensor
Spectral Sciences, Inc.
99 South Bedford Street, #7
Burlington, MA 01803
Steven M. Adler-Golden (617-273-4770)
KSC -- NAS10-11459

A non-contact instrument that can determine the quantity of organic contamination on metal surfaces is required for use in liquid oxygen systems. The instrument must monitor surfaces as small as 0.04 square inch, fit into 1/4-inch pipe, extend at least 5 feet, and be sensitive to 1 mg per square foot of organic contamination. The purpose of this project was to provide proof-of-principle for a surface organic contamination sensor (SOCS) employing a sensing scheme that uses excited gases generated in a electric arc at atmospheric pressure. These gases should react with the contaminants yielding products which emit ultraviolet and visible radiation providing, thereby, a measure of surface contamination. Both clean and contaminated test surfaces were tested. Excited nitrogen discriminated clean and contaminated surfaces. The presence of contamination was

indicated by an increase in the radiation characteristic of the CN radical. For the Phase I test set-up, the limit of detection for mechanical vacuum pump oil was about 2 mg per square foot.

Potential Commercial Application: The SOCS sensor could be used for detecting organic or other materials on surfaces in industrial as well as aerospace applications which utilize liquid oxygen or other potentially explosive oxidizers.

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183
87-1-13.01-6239
Continuous Detection of Toxic Vapors Using a Field Domain Ion Mobility Spectrometer
Femtometrics
1721 Whittier Avenue, Suite A
Costa Mesa, CA 92627
Raymond L. Chuan (714-722-6239)
KSC -- NAS10-11456

Ion mobility spectrometry (IMS), under development for about 18 years, identifies molecules by time-of-flight measurements. The technique is extremely sensitive, being capable of detecting compounds in the low parts-per-billion and high parts-per-trillion concentration range and doing so at atmospheric pressure. A new method was proposed whereby, instead of measuring time-of-flight, a retarding electric field is used to stop an ion from reaching the collector in a streaming gas mixture used to characterize the ion. The purpose of Phase I was to demonstrate that a field-domain, ion-mobility spectrometer (FDIMS) can be developed which will be smaller, simpler, faster, and less power-consuming than the conventional time-domain ion mobility spectrometer.

The FDIMS concept has been verified through an experimental study under a Phase I contract. The results, based on experiments with several test gases, demonstrate that it is feasible to develop a compact, low-voltage, highly selective and sensitive ion mobility spectrometer capable of the detection of toxic vapors in the parts-per-billion concentration range. By using a varying electric field to control the drift velocities of ions, rather than using drift times in a constant field (i.e., operating in the field domain rather than time domain), it has been possible to reduce both the length and voltage required to achieve mobility resolution.

Potential Commercial Application: A compact, portable, easy-to-operate, and low-cost toxic gas monitor with adequate sensitivity and specificity would be very valuable at launch sites and in the environmental and industrial sectors.

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* **184**
87-1-13.02-2423A
Wireless Headset
Apeiron
P.O. Box 1006, Midstation 220
McKinney, TX 75069
Kurt K. Christensen (214-952-4616)
KSC -- NAS10-11462

This project involves the development of a wireless headset system. The system is an application of digital, audio-encoding, packet switching, local area networking, and time-address multiplexing techniques to form a network of personal headsets. This innovation would allow many headsets on the same carrier frequency to operate from a single base-unit or repeater with software controllable cross-talk, audio mixing, and channel selection. Information on the network may be encrypted.

During Phase I, an architecture for a wireless headset network was investigated. This demonstrated the feasibility of supporting a number of wireless headsets linked to a network. Phase I results showed voice coding at both 15,625 bits per second and 31,250 bits per second, packetizing of this data, and communication of this data across a two million bit per second data link. Other digital data can be transmitted simultaneously with full duplex voice. As a result of Phase I, concept feasibility has been proven and supporting up to fifty fully digital headsets from a single base-station was shown to be possible.

Potential Commercial Application: Application of this innovation can be found in command, control, and communications, fire-fighters and rescue workers, security systems, sports helmets, and law enforcement.

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185
87-1-13.02-3226
Microwave Fiber Optic Link for Satellite Communications and Antenna Remoting
E-Tek Dynamics, Inc.
1885 Lundy Ave.
San Jose, CA 95131
J. J. Pan (408-532-6300)
KSC -- NAS10-11460

Microwave fiber optic links provide performance and cost advantages for antenna remoting, microwave communications, and satellite earth terminals. Phase I activities included a system level parameter investigation of a microwave fiberoptic link, analysis of the use of a coherent detection system to improve performance, a vendor survey, and the design, fabrication and test of a 12 GHz fiberoptic link. Both direct and external modulation were demonstrated. The conclusions of this effort are that microwave fiberoptic links for antenna remoting are viable and have many advantages.

Potential Commercial Application: Applications are expected in SATCOM systems, for interconnecting microwave towers and control rooms, for radar and communication terminals on shipboard and aircraft, and in replacing expensive waveguides.

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186
87-1-13.04-2060
Human Envelope Manipulator
SEES, Inc.
11020 Solway School Road
Knoxville, TN 37931
R. L. Andrews (615-483-2060)
KSC -- NAS10-11463

The tasks for robots in support of ground-based shuttle operations may involve such functions as opening and closing doors, turning wheels, pulling levers, pushing buttons, turning rotary switches, moving toggle switches, and handling equipment modules. Robots may be used on some of the existing hazardous and repetitive shuttle and payload processing activities such as loading and unloading hypergolic propellants, handling cryogenic fluids, and connection and disconnecting electrical power, fibre optic communication, and data transmission systems. Since all of these functions are currently being accomplished using humans, a robot device with similar reach abilities would allow it to perform these tasks with minimum hardware change. The focus of project is a human envelope manipulator (HEMan), a prototype, two-armed, end effector that can perform support of shuttle ground processing operations and that mimics human reach and movement. It will be attached to a heavy lift robot. Force, tactile, proximity, range, and vision information is provided in a sensor package to assist in actual applications.

In Phase I, sensors were identified. The vision sensor is the major sensor that can provide large amounts of data. A conceptual design was evolved during Phase I.

Potential Commercial Application: The resulting end effector will have superior manipulative and sensory ability for performing tasks in common applications for robots.

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187
87-1-13.06-1512
Laser Doppler Velocimeter for Flow Rate Measurement in Thermal Control Fluid Systems
Ophir Corporation
3190 S. Wadsworth Blvd., Suite 100
Lakewood, CO 80277
Gregory J. Fetzer (303-976-1512)
MSFC -- NAS8-37631

A non-intrusive flow measurement system is required for small-diameter, low-flow-rate, and low-pressure-differential fluid systems for thermal control functions. This innovation utilizes a continuous-wave, diode-based laser Doppler velocimeter (LDV) which captures scattered radiation from minute ($\leq 10.0\ \mu m$) inert particles suspended in the flow medium. The particulates may occur naturally as impurities in the coolant or may be mixed in the coolant at the time of a system fill. Theoretical calculations indicate that the system will provide flow measurement capabilities at flow rates as low as 10.0 lbs/hr for Freon-12 and deionized water cooling systems in pipe diameters of 1/8 to 1/2 inch with accuracies of 0.5 percent or better.

The prototype device tested in Phase I was an optical heterodyne system which measures a Doppler-induced frequency shift. Results of these tests indicate that the LDV concept is both feasible and practical for flow measurement in small diameter tubing. It is particularly well-suited to low-pressure-differential systems designed for laminar flow and applies as well for turbulent flows. The use of a diode laser allows for an inexpensive, compact, rugged device which exceeds the performance objectives of this project.

Potential Commercial Application: An accurate flow measurement system for small-volume, low-differential-pressure systems has applications in process control, fuel-flow control, bioengineering, and other areas.

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* 188
87-1-13.07-0463
Double-Pulsed, Phase-Sampled, Laser-Speckle Interferometric Metrology for Non-Destructive Testing
McMahan Electro-Optics, Inc.
2160 Park Avenue N.
Winter Park, FL 32789
Robert K. McMahan (305-645-0463)
LaRC -- NAS1-18643

A novel non-destructive testing and evaluation system based on double-pulsed, phase-sampled, laser-speckle metrology is the focus of this project. The potential of this technology is, in an industrial context, the determination of static and temporal deformation of both materials and assemblies without contact and with a resolution of spatial displacement of 0.25 m and resonance mode frequencies approaching 50,000 Hz. The method will be capable of resolving both the absolute and gradient in-plane and out-of-plane surface displacements and the dynamic and resonant behavior of objects under test.

In Phase I, theoretical models and engineering designs were prepared for the development of the proposed double-pulsed, phase-sampled, laser-speckle interferometry method for non-destructive testing and evaluation.

Potential Commercial Application: Areas of commercial application include the characterization of: composite delamination, vibration analysis, thin weld inspection, stress, strain, and finite-element analysis, hydraulic strain, and others.

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* 189
87-1-13.07-6498
Thermoelectric Assessment of Precipitation-Hardening Stainless Steels
QCI, Inc.
PO Box 1067
Oak Ridge, TN 37831

Roger W. Derby (615-483-6498)
LaRC -- NAS1-18641

Field experience and preliminary laboratory data have shown that the techniques of thermoelectric sorting could become a valuable tool in the assessment of precipitation-hardening stainless steels. The Phase I investigation involved heat-treating a variety of carefully controlled specimens and correlating their thermoelectric characteristics with heat-treating variables.

The thermoelectric characteristics of five different types of precipitation-hardening steels were found to be strongly correlated with both Rockwell hardness and with time and temperature of aging. A similar situation was discovered to exist for the nickel-based, heat-resistant alloy, Inconel 718. The results of these tests along with several instrument improvements, particularly for small specimens, suggest the feasibility of developing new thermoelectric instruments for the assessment and study of a wide variety of precipitation-hardening alloys. Of particular interest are their use for testing heat-affected zones around welds and studying damage or reduced service life in components subjected to high service temperatures. Further, a specialized instrument can be built for nondestructive examination of a wide variety of miniature specimens ranging from research materials to precious metals to samples used in forensic investigations.

Potential Commercial Application: Primary uses are in the assessment of the condition of both precipitation-hardening stainless steels and heat-resistant, nickel-based alloys commonly used in the aerospace industry. Other applications include precious metal control, materials research, and forensic investigation.

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* **190**
87-1-13.08-4122
Kennedy Space Center Atmospheric Boundary Layer Experiment
ENSCO, Inc.
445 Pineda Court
Melbourne, FL 32940
Gregory E. Taylor (305-254-4122)
KSC -- NAS10-11466

In order to reduce the interference of weather on critical launch operations, NASA has a great need for detailed meteorological data and analyses of the three-dimensional structure of the planetary boundary layer at Merritt Island/Cape Canaveral. A phased project, Kennedy Space Center Atmospheric Boundary Layer Experiment (KABLE), has been designed to provide NASA with a cost-effective, innovative method of obtaining a data set which will help improve its short-term weather forecasting for phenomena such as thunderstorms and low-level wind shear. The data collected during KABLE will also be used to evaluate the transport and diffusion algorithms in models (e.g., Emergency Dose Assessment System and the Rocket Exhaust Effluent Diffusion Model) used operationally at KSC and Cape Canaveral Air Force Station and will lead to the development of new and more accurate models for atmospheric circulation.

The major result of the Phase I effort was the development of a detailed, well-organized experimental plan employing several different data collection systems to study the planetary boundary layer in the Merritt Island and Cape Canaveral area. KABLE is unique because it will be the first consolidation of meteorological data in this area over an extended period. New data collection systems such as acoustic sounders and wind profilers have never been used over an extended time period in conjunction with other existing systems. The final data set acquired by KABLE will benefit future meteorological research at the Kennedy Space Center.

Potential Commercial Application: The data set collected will be useful to researchers who are working with meteorological problems at or near the Merritt Island and Cape Canaveral area. This data will be particularly helpful to industries that are involved with atmospheric transport and diffusion studies for power plants located near land-water interfaces.

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14 SATELLITE AND SPACE SYSTEMS COMMUNICATIONS

191
87-1-14.01-3900A
Programmable Rate Digital Modem Utilizing Digital Signal Processing Techniques
Multipoint Communications Corporation
1284 Geneva Drive
Sunnyvale, CA 94089
Robert Wallace (408-734-3900)
LeRC -- NAS3-25336

A programmable-rate, digital modem operating in the burst or continuous mode has several potential applications in future communication satellite systems. This project studied the design of a low-cost, robust modem capable of supporting burst and continuous transmission modes. The preferred implementation is an all-digital one which uses as much digital signal processing as possible.

The Phase I design study addressed nine significant aspects of the design of a variable rate modem. These were transmit data filtering, transmit clock generation, carrier synthesizer, receive automatic gain control, receive data filtering, radio-frequency oscillator phase noise, receiver carrier selectivity, carrier recovery, and timing recovery. The studies addressed and examined various techniques for achieving viable circuit designs and resulted in specific design recommendations.

Potential Commercial Application: Application would be for satellite earth stations to support point-to-point

or interactive, full-mesh networks for both digitized voice and data traffic.

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192
87-1-14.01-4995B
High Speed Optoelectronic Switch
APA Optics, Inc.
2950 N.E. 84th Lane
Blaine, MN 55432
Lynn D. Hutcheson (612-784-4995)
LeRC -- NAS3-25424

High-speed switches and switching systems are needed for efficient high- and low-data-rate FMD and TDM communications in a large network in which data from many processors and sensors must be transmitted and routed at tremendous rates for effective decision making. The large band-width of the data from certain sources (GHz rates) mandates the use of optical communication technology. To address these needs, an effort was focused on the critical component of high-speed, optoelectronic switches and switching networks using total internal reflection in a GaAs-AlGaAs material system. This concept promises very high speeds because the technique minimizes electrode area and capacitance. In addition, this switch can be made very small, will consume little power, can be scaled to large switching networks, and is compatible with monolithic integration.

The Phase I project was focussed on epilayer growth and processing for a $GaAs/Al_xGa_{1-x}As$ total-internal-reflection (TIR) switch including low-loss, well-confined, channel waveguides and p-type and n-type ohmic contacts. Waveguide structures were successfully fabricated for 0.83 and 1.3 μm operation, and their electrical and optical characteristics measured. Electro-optic coefficient for the switch structure was measured using a Bragg cell. Rudimentary TIR switches have been fabricated and currently are undergoing evaluation.

Potential Commercial Application: The company wants to offer the TIR switch as an off-the-shelf component to the fiber optics telecommunications industry. The device also has numerous applications for high-speed data transmission in advanced computer systems.

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* **193**
87-1-14.01-7111
30 GHz Reflection Mode FET Solid State Power Amplifier
LNR Communications, Inc.
180 Marcus Boulevard
Hauppauge, NY 11788
Eric Ng (516-273-7111)
LeRC -- NAS3-25339

This project investigated a low-cost, high-performance alternative to an IMPATT (impact avalanche transit time) solid-state amplifier for the 30 GHz uplink transmitter. This alternative is a Ka-band solid-state power amplifier (SSPA) employing a cascade of circulation-coupled, Ku-band or K-band field-effect transistor (FET) amplifier stages, each operating in the one-port negative resistance, reflection-amplification mode. Use of the reflection-mode FET in lieu of an IMPATT amplifier in the Ka-band uplink transmitter provides the advantages of greater input/output linearity and potentially lower large quantity costs.

In the completed Phase I study, the feasibility of implementing 30 GHz reflection-mode FET power amplifier "building block" stages providing 0.5 W (min) RF output power, 7 dB gain, 1 GHz band width, and 16 percent power added efficiency has been demonstrated by detailed analysis and limited experimentation. These results were used in the design of a 16-way, corporate-combinatorial, 8 W, 30 GHz SSPA with 16 percent efficiency and 1 GHz minimum band width.

Potential Commercial Application: The 30 GHz-reflection mode FET SSPA will provide a low-cost alternative to other candidate uplink transmitter amplifiers.

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194
87-1-14.02-4288A
Evaluation of CDMA System Capacity
Spread Spectrum Systems, Inc.(S^3I)
5225 Pooks Hill Road #1629N
Bethesda, MD 20814
Patrick O. Smith
JPL -- NAS7-1027

A specific, innovative, direct-sequence, pseudo-noise (DS/PN), code-division, multiple-access (CDMA) mobile satellite (MSAT) system was proposed. Proponents of CDMA claim that increased system capacity, reduced mobile terminal cost, increased flexibility in service offerings, interference suppression, and increased MSAT operator profitability are achievable. Detractors claim that the required mobile terminal sophistication is too costly, that the system capacity is not increased relative to frequency-division, multiple-access (FDMA) systems, and that the existing technology base is immature. This project evaluated the capacity of a baseline DS/PN CDMA MSAT system under some simplified assumptions.

The Phase I results show that an overall, equivalent spectral efficiency per fixed spot beam of near unity is achievable with a BER of 10^{-3} and received Eb/No of 10 dB. This spectral efficiency figure includes the resource sharing effect associated with an all-voice traffic scenario with voice-activated modem operation. Specific innovations that can further significantly increase the spectral and power efficiencies of candidate CDMA designs alternates were outlined for future developments.

(Note: Spread Spectrum Systems, Inc. has acquired the rights to Phase I data from Techno-Sciences, Inc., who submitted the original proposal.)

Potential Commercial Application: The firm intends to design and manufacture mobile, hub, and NMC equip-

ment for use in DS/CDMA mobile satellite systems for domestic and international markets.

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* 195
87-1-14.03-6642
High-Efficiency, Low-Cost GaAs Monolithic RF Module for SARSAT Distress Beacons
Microwave Monolithics Inc.
465 East Easy Street, Unit F
Simi Valley, CA 93065
Wendell C. Petersen (805-584-6642)
LeRC -- NAS3-25403

World-wide deployment and widespread use of the SARSAT rescue system depends critically on the development and commercialization of high-performance, low-cost beacons. In Phase I, the firm has identified that a bi-phase modulator and an ultra-high-efficiency power amplifier chain are key components of the emergency beacon which, when implemented on gallium-arsenide, monolithic microwave integrated circuits (MMICs), will provide substantial production cost and technical performance improvements.

Measurement of existing GaAs power amplifiers (FETs) during Phase I under not yet optimum conditions yielded performance clearly indicating the technical feasibility of these devices for the critical power amplifier application. Small signal measurements, computer simulations, and detailed cost analysis further demonstrated the feasibility of applying GaAs integrated circuit technology to the SARSAT beacon modulator and power amplifier. GaAs MMICs operating at frequencies well below their performance limits are expected to result in high-yield production due to relaxed geometric constraints, thus further insuring the cost effectiveness of the proposed approach.

Potential Commercial Application: Each performance improvement attained for the SARSAT beacon via advanced technology opens new segments of the government, commercial, and eventually even the private sector to world-wide rescue beacon coverage.

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196
87-1-14.04-8080
Switched Hemispherical Antenna
Technical Research Associates, Inc.
410 Chipeta Way, Suite 222
Salt Lake City, UT 84108
Stephen Peterson (801-582-8080)
JSC -- NAS9-17951

A switched hemispherical antenna was proposed for use on space transportation systems, space stations, and satellites. The antenna, operating in the Ku band, would be able to scan over 2 pi steradians, sample signal strength from a beacon, and route data to the appropriate sector. An on-board computer would serve as an interface to an inertial reference frame to allow a controller to compensate for satellite spin. Two such antennas would cover 4 pi steradians; the gain of an individual unit antenna would be approximately 16 dB; and the system would support circular polarization. Because the antenna would be under software control, diverse and flexible operation should be possible.

Phase I evaluated different, low-profile antennas for use in a switchable array; designed and evaluated two different, pin-switch configurations; designed and built a 5-unit directional coupler, and designed a microprocessor-driver for the prototype pin switch. Hardware was produced but was not completely effective. The general conclusions of this project are that it appears impossible to provide the necessary band-width with a dielectric-loaded, patch-type antenna. The firm believes that two antenna types, the cavity mounted helix and the flat, cavity-backed spiral, would meet (or come close to) the specifications for a 16-unit antenna array and that either of these two antennas might work in an 8-unit array if mated with a diverging dielectric lens.

Potential Commercial Application: The applications would be in switched microwave antennas for aircraft, ships, and vehicles, especially for automobile-to-satellite communications links.

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197
87-1-14.05-6070
Microstrip Multiple Function Antenna Feed
Scientific Technology, Inc.
2 Research Place
Rockville, MD 20850
Ting-I Wang (301-948-6070)
JPL -- NAS7-1017

This project involves development of a multi-layer, micro-strip, circularly polarized, multiple-function, focal-point feed for MMII deep-space-probe, high-gain antennas. The feed will illuminate a 1.47-meter diameter reflector for generating a high-gain beam and also serve as a low-gain antenna. The low-gain beam is directed along the axis of the high-gain beam and has a wide spread pattern. The feed is capable of being switched to transmit and receive simultaneously in either the high-gain or low-gain mode of operation or transmit in high gain while receiving in low gain.

Phase I feasibility studies including theoretical analysis and laboratory experiments indicated that the proposed feed assembly using multi-layer, micro-strip techniques meets the requirements of the low-gain antenna as well as the focal point feed of a MMII deep-space-probe, high-gain antenna. This assembly is able to cover a dual-band (7.1 and 8.4 GHz) in circular polarization. Its low profile, light weight, and well-behaved radiation pattern is ideal for deep-space communications.

Potential Commercial Application: This antenna feed technique may apply to many communication systems in spacecraft, earth stations, and terrestrial links.

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15 MATERIALS PROCESSING, MICROGRAVITY, AND COMMERCIAL APPLICATIONS IN SPACE

198
87-1-15.01-0156
Effect of Gravity on Foam Decay
H & N Instruments, Inc.
PO Box 955
104 E. Shields Street
Newark, OH 43055
Gary M. Nishioka (614-927-0156)
MSFC -- NAS8-37625

Foams are used in many industries, yet the mechanisms that control foam stability are not well understood. The decay of foam is controlled largely by Ostwald ripening of large foam cells at the expense of small foam cells. The decay mechanism is complicated by gravitational effects. A novel method to measure foam stability was proposed. By measuring head-space pressure over a foam in a closed, thermostatically controlled chamber, the area decay of the foam can be computed. The measurement of foam decay in low gravity, the ultimate objective of the proposed work, will result in novel information that will aid theoretical understanding of foam decay and Ostwald ripening mechanisms.

The Phase I research demonstrated the feasibility and usefulness of a space flight experiment to measure foam stability. The required temperature control, space, and power for the experimental apparatus are easily attainable in a flight experiment. A foam generation procedure and some model systems were found that give reproducible foam decay.

Potential Commercial Application: An instrument and a low-gravity facility for measuring foam decay may find use by industries interested in foam.

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*** 199**
87-1-15.01-0156A
A New Method for the Measurement of Surface Tension
H & N Instruments, Inc.
PO Box 955
104 E. Shields Street
Newark, OH 43055
Gary M. Nishioka (614-927-0156)
MSFC -- NAS8-37626

Surface tension is a fundamental property of all liquids. The surface tension of liquids during processing affects the properties of a variety of high performance materials, i.e.: alloys, ceramics, composites, and polycrystalline materials. Surface tension is not routinely measured for most experimental new materials because no simple, accurate, yet versatile commercial instrument exists. Measurement of surface tension for viscous liquids or liquids at high temperatures or pressures is particularly difficult. This project studied the bubble-period method to determine surface tension. The technique measures the average period of bubbles formed under well-defined conditions and has the potential to be simple, accurate, and versatile.

The Phase I research demonstrated the feasibility of the bubble counting method to measure surface tension. Accurate values of surface tension were obtained for a wide variety of liquids once corrections for viscous and detachment errors were applied. The bubble counting method appears to be reasonably accurate (±10 percent) for measuring surface tension. Its chief advantage is that it may work under conditions where more accurate methods do not. There are two concerns with this technique. First, viscous effects can interfere with the measurement, and, second, wetting effects were found to affect the measurement critically.

Potential Commercial Application: A versatile and simple instrument for measuring surface tension would find wide a wide range of applications and may lead to a commercial facility for the measurement of surface and interfacial tension and wetting characteristics of materials.

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*** 200**
87-1-15.01-0540
Active Magnetic Micro-G Isolator for Space Station
SatCon Technology Corporation
71 Rogers Street
Cambridge, MA 02142
Bruce G. Johnson (617-661-8942)
MSFC -- NAS8-37639

Systems will be required to isolate the experimental payloads from inherent Space Station vibrations. The vibration requirements can best be met by active isolation systems that have the capability to adjust to differing vibration environments, changes in payloads, and changes in desired isolator dynamics. Magnetic suspensions are an extremely promising approach to implementing these active isolation systems. Their desirable characteristics include high band-width, linearity, stability, high efficiency, multi-axis capability, and ease of integration with electronic control systems.

Phase I of this research program developed typical vibration isolation requirements for Space Station. A magnetic suspension system capable of meeting these requirements was then designed. This design features six-degree-of-freedom actuation in a single compact unit.

Potential Commercial Application: Vibration isolation systems may be used in commercial applications as well as in Space Station, e.g., precision pointing and tracking systems, inertial instrument test tables, crystal growth, and optical benches.

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201
87-1-15.01-0760
Miniaturized Fiber-Pulling Apparatus for Producing Single-Crystal-Core Glass Fibers in Microgravity
Crystal Research
1441 Sunnyside Terrace
San Pedro, CA 90732
Paul J. Shlichta (213-831-0760)
LeRC -- NAS3-25400

Production of crystalline-core fibers will satisfy unmet needs in low-loss infrared fibers, superconductor filaments, and infrared image converters. Gravity adversely affects the pulling of glass fibers because sagging severely restricts feasible glass viscosities during pulling. This effect is especially troublesome for the pulling of single-crystal-core glass fibers, where the requirement of matching the thermal expansion of the glass and crystal versus the core melting point dictates pulling at glass viscosities that are too low to be feasible at one g. In this project, the goal of producing crystal-core glass fibers in microgravity for various applications was explored. As a means toward this goal, a miniaturized prototype fiber-drawing apparatus was designed during Phase I. This apparatus embodies several novel design features for compactness, easy fiber removal and storage, and automation.

Potential Commercial Application: The proposed apparatus could facilitate the drawing of new kinds of glass fibers during spaceflight missions and thereby open a new area for space commercialization.

***

202
87-1-15.01-3855
Temperature Measurement by Noncontact Method for Czochralski-Type Crystal Growth
Electro Design Manufacturing, Inc.
PO Box 2569
Highway 31 South
Decatur, AL 35602
Robert D. Young (205-353-3855)
MSFC -- NAS8-37622

In the growth of crystals from melting materials using the Czochralski method, a good technique of accurately controlling the process does not exist. Thermocouples are largely used at present, but they do not provide adequate information such as the thermal gradient across a single large crystal. The use of charge-coupled devices to measure and control crystal growth using the Czochralski method is the innovation being studied in this project. Arrays of charge-coupled devices and photovoltaic detectors detect temperature variations of a surface area. These detectors can be adapted to monitor the temperature measurements within the crystal growth ovens and provide feed-back control to regulate the oven.

During Phase I, the work concentrated on testing sensor types and researching the various components of a control system. It was concluded that charge-coupled devices were sufficiently uniform to be used as a thermal sensor above 200 C.

Potential Commercial Application: This product could be applied in control of steel production and heat treating, evaluation of electronic circuit boards for out-of-specification temperature conditions, and in the medical field for examining inflamed areas of the human body.

***

* 203
87-1-15.01-8371
Digital, Active Materials Processing Platform Effort
Applied Technology Associates, Inc.
1900 Randolph S.E.
Albuquerque, NM 87106
John Gniady (505-247-8371)
LeRC -- NAS3-25362

This project explored active isolation for the creation of ultra-stable platforms specifically designed for materials processing in space. Phase I work was successfully completed. A preliminary assessment of isolation requirements was performed, and a concept for a unique, fully inertial approach to active, platform isolation was devised.

Potential Commercial Application: The resulting materials-processing platform could be applied to exploit fully the micro-g environment for development and manufacture of alloys, crystals, polymers, microelectronic components, and optical processes.

***

204
87-1-15.03-2620
Computational Methodologies for Convection-Diffusion Phase Change Problems
CHAM of North America, Inc.
1525-A Sparkman Drive
Huntsville, AL 35816
C. Prakash (205-830-2620)
LeRC -- NAS3-25331

The objective of this project was to develop numerical methodologies for analyzing solid-liquid phase change problems involving multi-component materials such as binary mixtures and alloys. The potential NASA interest for this work stems from materials science applications in space, e.g. crystal growth.

The aim of Phase I was to define a framework for development of a general purpose computer program by examining both single- and two-phase models. The single-phase model equations are relatively easy to solve but require a prescription of the solid phase-velocity and other assumptions for computing the local mass fractions of the phases. The two-phase model does not have these shortcomings but needs data on interfacial exchange coefficients which require further research. The problem of freezing in a square

was studied to illustrate the use of the single- and two-phase models. The conclusion drawn from this work is that a general purpose code for binary solid-liquid phase change problems must include both single-and two-phase options.

Potential Commercial Application: Solutions to problems of convection-diffusion, multi-component, phase change would reduce the need for experiments and would supplement space materials processing research.

***

Appendix A

DESCRIPTION OF THE SBIR PROGRAM

The Small Business Innovation Research program was instituted in 1982 by Public Law 97-219 and reauthorized through Fiscal Year 1993 by the enactment of Public Law 99-443 in 1986. Implementation of the program follows policy directives issued by the Small Business Administration (SBA). Eligibility is limited to US-owned companies operating in the US having fewer than 500 employees at the time a contract is awarded.

Purposes of the Program: The purposes of the Small Business Innovation Research program include stimulating US technological innovation in the private sector, strengthening the role of small businesses in meeting Federal research and development needs, increasing the commercial application of Federally supported research results, and fostering and encouraging participation by minority and disadvantaged persons in technological innovation. Achievement of these purposes is accomplished through actions taken by the agency to meet its own particular R&D needs within the program framework established by the laws and the SBA policy directive guidelines.

SBIR Program Phases: As specified by the enabling legislation, SBIR is a three-phase R&D program. For Phase I, the objectives are to establish the feasibility and merit of an innovative scientific or technical concept proposed by a small business responding to a need or opportunity delineated by the agency in an annual program solicitation. Contracts for Phase I are awarded through a competitive selection process based upon the evaluation of Phase I proposals submitted in response to an annual program solicitation.

Phase II of SBIR is the principal research and development effort, having as its purpose the further development of the proposed ideas to meet the particular program needs. Only Phase I contractors can submit proposals to continue into Phase II. The selection of Phase II awards considers the scientific and technical merit and feasibility evidenced by the first phase, the expected value of the research to the agency, and the competence of the firm to conduct Phase II. In addition, for Phase II proposals considered to have essentially equivalent scientific merit and feasibility, special consideration is given to those for which valid non-federal funding commitments have been obtained for Phase III activities.

In Phase III, the small business can pursue commercial applications of the results of the SBIR-funded research and research and development (R/R&D). Phase III for commercial purposes is strongly encouraged by NASA as a major SBIR objective. Phase III may also take the form of follow-on R/R&D or production contracts with NASA or other federal agencies for products and processes intended for use by the United States Government; however, such Phase III activities cannot be supported by the SBIR program funding set-aside.

Phase I and II Funding Levels: NASA funding for SBIR projects is in keeping with guidelines for the SBIR program issued by the Small Business Administration. Phase I contracts are generally limited to six months in duration and $50,000, while contracts for Phase II, the major R&D effort, are normally limited to two years' duration and funding of not more than $500,000. NASA may make justifiable exceptions.

Proposal Evaluation and Award Selection: Evaluations of both Phase I and II proposals follow SBA Policy guidelines include technical merit and innovativeness, NASA R&D needs and priorities, program balance, and company capabilities. There are no quotas for specific technical areas. For Phase I, proposed cost within the stated cost guideline is not an evaluation or selection criterion and appropriate for the proposed activity. For Phase II, the Phase I results are a major factor and cost is an important consideration. And as noted above, for Phase II proposals of essentially equivalent merit, special consideration is given to those which include valid non-federal capital commitments for Phase III activities, particularly for pursuing commercial applications. Evaluators include NASA technical staff members at the field centers responsible for the Subtopics and the NASA Headquarters program officials. NASA at its discretion may also use outside evaluators.

Program History: The NASA SBIR program began in 1983 with the issuance of the first of its annual program solicitations. Support for this program is shown in Table A-1, which displays the annual R&D funding set-aside (which progressively increased to the present 1.25 percent level) for the NASA SBIR program. Table A-2 shows the number of Phase I proposals received each program year and the number of resulting awards and funding for Phase I contracts. This table also presents the number of Phase II proposals that were submitted from each group of Phase I projects and the numbers selected for award and the total value of the Phase II contracts for each program year. (A program year includes all Phase I and Phase II projects resulting from an annual Program Solicitation.) During the first five complete Program Years (1983 through 1987) and Phase I of the 1988 and 1989 programs, $244 million

was obligated or committed for 1231 Phase I and 398 Phase II awards. On the average, approximately 16 percent of NASA's SBIR funds have been used for Phase I projects and 84 percent for Phase II in each program year.

Small businesses have responded vigorously to the opportunities presented by the SBIR program. The number of Phase I proposals grew from 977 in 1983 to 2,141 in 1989. The number of Phase I awards selected has been limited each year not by the number of acceptable proposals, but by the funds available and the desire that at least half of the Phase I projects proceed into Phase II. Awards have been made to 650 firms in 42 states, the District of Columbia and Puerto Rico. The numbers of Phase I and Phase II awards made within each state are shown on Exhibit A-1. Approximately 18 percent of the firms submitting proposals have received Phase I awards, and about 48 percent of those firms have received Phase II continuations.

TABLE A-1

NASA SBIR FISCAL YEAR FUNDING

	FISCAL YEAR 1983	FISCAL YEAR 1984	FISCAL YEAR 1985	FISCAL YEAR 1986	FISCAL YEAR 1987	FISCAL YEAR 1988	FISCAL YEAR 1989
NASA R&D BUDGET - $M	2473	2205	2425	2619	3128	3270	4166
% R&D BUDGET FOR SBIR	0.2	0.6	1.0	1.25	1.25	1.25	1.25
NASA SBIR BUDGET - $M	4.94	13.23	24.25	32.74	38.92	40.87	52.97
CUMULATIVE TOTALS - $M	4.94	18.17	42.42	75.16	114.08	154.95	207.92

TABLE A-2

NASA SBIR PROGRAM AWARD STATISTICS

PROGRAM SOLICITATION YEAR	PHASE I			PHASE II			PHASE I & II
	PROPOSALS	AWARDS	TOTAL FUNDING $M	PROPOSALS	AWARDS	TOTAL FUNDING $M	TOTAL PROGRAM FUNDING $M
1983	977	102	5.0	92	58	24.0	29.0
1984	919	127	6.3	113	71	32.5	38.8
1985	1164	150	7.4	129	84	39.4	46.8
1986	1628	172	8.5	154	85	39.6	48.0
1987	1826	204	10.0	179	100	47.9	57.9
1988	2379	228	11.2	NA	NA	NA	NA
1989	2142	248	12.3	NA	NA	NA	NA
TOTALS TO DATE	11035	1231	60.6	667	398	183.4	220.6 (1) 244.0 (2)

NOTE: (1) TOTAL PROGRAM FUNDING SHOWN IS FOR FIRST FIVE PROGRAM SOLICITATION YEARS

(2) TOTAL PROGRAM FUNDING SHOWN IS FOR FIRST FIVE PROGRAM SOLICITATION YEARS, PLUS 1988 PHASE I AND 1989 PHASE I

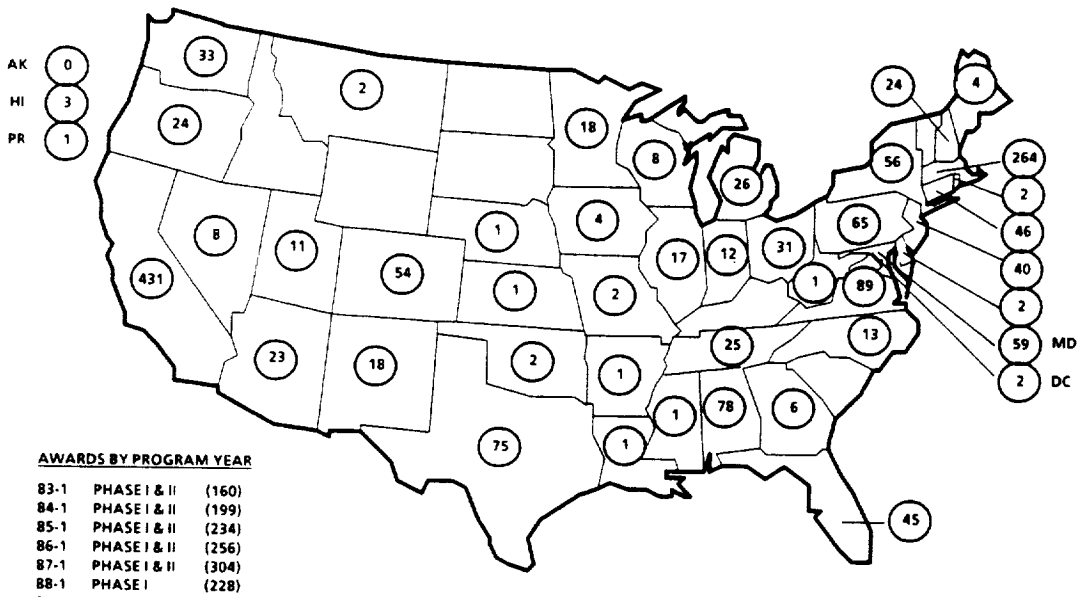
TABLE A-3

NASA SBIR AWARDS
DISTRIBUTION BY NASA FIELD CENTER

FIELD CENTER	1983 PROGRAM		1984 PROGRAM		1985 PROGRAM		1986 PROGRAM		1987 PROGRAM		1988 PROGRAM		1989 PROGRAM	
	PHASE I	PHASE II	PHASE I	PHASE II	PHASE I	PHASE II	PHASE I	PHASE II	PHASE I	PHASE II	PHASE I	PHASE II	PHASE I	PHASE II
AMES RESEARCH CENTER	17	12	18	7	18	10	20	11	24	12	26	NA	26	NA
GODDARD SPACE FLIGHT CENTER	12	10	15	10	19	12	23	11	28	13	33		37	
JET PROPULSION LABORATORY	8	4	12	7	19	10	20	10	23	11	24		25	
JOHNSON SPACE CENTER	12	4	18	10	22	13	23	12	28	13	32		37	
KENNEDY SPACE CENTER	2	1	6	2	8	5	8	4	13	6	10		11	
LANGLEY RESEARCH CENTER	18	9	22	12	23	12	26	14	31	15	32		34	
LEWIS RESEARCH CENTER	19	8	19	12	22	11	26	10	30	16	34		37	
MARSHALL SPACE FLIGHT CENTER	14	10	17	11	19	11	23	12	27	14	33		36	
STENNIS SPACE CENTER	--	--	--	--	--	--	3	1	--	--	4		5	
TOTALS	102	58	127	71	150	84	172	85	204	100	228	--	248	--

EXHIBIT A-1

NASA SBIR AWARD
DISTRIBUTION BY STATES



AWARDS BY PROGRAM YEAR

83-1	PHASE I & II	(160)
84-1	PHASE I & II	(199)
85-1	PHASE I & II	(234)
86-1	PHASE I & II	(256)
87-1	PHASE I & II	(304)
88-1	PHASE I	(228)
89-1	PHASE I	(248)
	TOTAL	1629

Appendix B

1987 TOPICS AND SUBTOPICS

01 Aeronautical Propulsion and Power
- 01.01 Internal Fluid Mechanics for Aerospace Propulsion Systems
- 01.02 Components for Aeropropulsion Systems
- 01.03 Instrumentation Sensors and Controls for Aeropropulsion Systems
- 01.04 Hypersonic Propulsion
- 01.05 Novel Propulsion Concepts

02 Aerodynamics and Acoustics
- 02.01 Computational Fluid Dynamics
- 02.02 Experimental Fluid Dynamics
- 02.03 Viscous Flows
- 02.04 Theoretical Aerodynamics
- 02.05 Turbulence Simulation and Modeling
- 02.06 Hypersonic Aerothermodynamics
- 02.07 Rarefied Gas Dynamics
- 02.08 Vacuum Plume Effects
- 02.09 Configurational Aerodynamics Including Vortices
- 02.10 Rotorcraft Aerodynamics and Dynamics
- 02.11 Prediction Methods for Powered-Lift Vehicle Aerodynamics
- 02.12 Aircraft Noise

03 Aircraft Systems, Subsystems, and Operations
- 03.01 Icing and Ice Protection Systems
- 03.02 Aircraft Flight Environment
- 03.03 Aeronautical Flight Management and Human Factors
- 03.04 Expert Systems for Aerospace Applications
- 03.05 Control Concepts for Aircraft
- 03.06 Automatic Guidance for Rotorcraft Nap-of-the-Earth Flight
- 03.07 Aircraft Flight Testing Techniques and Instrumentation
- 03.08 Hypersonic Flight Systems Technology

04 Materials and Structures
- 04.01 Composite Materials/Structures for Aerospace Propulsion
- 04.02 Composite Materials for Non-Propulsion Structural Applications
- 04.03 Structural Metallics for Aerospace Applications
- 04.04 Intelligent Automated Structural Design Optimization
- 04.05 Space Structures Concepts and Materials
- 04.06 Specialized Materials For Space Flight Applications
- 04.07 Specialized Materials for Launch Site Facilities
- 04.08 Welding Technology
- 04.09 Thermal Protection Materials
- 04.10 Structural Designs for Future NASA Space Missions
- 04.11 Reduced Weight Gondolas For Stratospheric Balloons
- 04.12 Lunar Materials Utilization

05 Teleoperators and Robotics
- 05.01 Telerobotic Technology
- 05.02 Artificial Intelligence for Space Station Applications
- 05.03 Servo-Drive Mechanisms for Robotic Manipulators
- 05.04 Telescience
- 05.05 Martian Surface Sample Acquisition Processing and Earth Return

06 Computer Sciences and Applications
- 06.01 Engineering Computer Science
- 06.02 Automated Software Development and Maintenance
- 06.03 Knowledge Understanding Representation and Implementation
- 06.04 Knowledge-Base Technology for Software Components
- 06.05 Software Systems for Mission Planning and Flight Control
- 06.06 Integrated CAD/CAE and Knowledge-Based Systems
- 06.07 Computer Sciences Advances In Suppport of Computational Physics

07 Information Systems and Data Handling
- 07.01 Focal-Plane Image Processing
- 07.02 Spacecraft Operations and Data Management
- 07.03 Signal and Information Processing
- 07.04 Management Information Communications
- 07.05 Ground-Based Data Management Systems
- 07.06 Heterogeneous Distributed Data Base Management
- 07.07 Software/Work Station Development for Remotely Sensed Data
- 07.08 Image Analysis Techniques
- 07.09 Search for Extraterrestrial Intelligence (SET)

08 Instrumentation and Sensors
- 08.01 Planetary Earth Sensing and Astrophysics Instrumentation
- 08.02 Earth Sensing from Space
- 08.03 High Resolution Remote Sensing for Earth Observations

08.04 Global Biology Sensors
08.05 Oceanographic Instruments and Software
08.06 Instruments for Geological Research
08.07 Spectroradiometric Standards for Ultraviolet Remote Sensing
08.08 Tunable Solid State Lasers Detectors and Lidar Subsystems
08.09 Sensors for Atmospheric Aerosols
08.10 Atmospheric Measurements and Analyses in Manned Space Missions
08.11 Behavior and Effects of Contamination in Space
08.12 Infrared Technology for Astronomical Applications
08.13 Exobiological Analysis of Cosmic Dust
08.14 Spacecraft Instruments
08.15 Instrument Power Distribution and Control
08.16 Detectors and Detector Arrays
08.17 Focal Plane Array Processing for Position Determinations
08.18 Submillimeter Radiometer and Antennas
08.19 Optical Components and Systems
08.20 Wind Tunnel Instrumentation
08.21 Aeroheating Flight Instrumentation

09 Spacecraft Systems and Subsystems
09.01 Control of Large Space Structures
09.02 Space Construction and Maintenance Tools and Techniques
09.0 Space Station Crew Workstation Displays and Controls
09.04 Manned Spacecraft and Planetary Base Thermal Management Systems
09.05 Thermal Control for Unmanned Space Applications
09.06 STS Power Control and Distribution Subsystems
09.07 STS Tracking Systems
09.08 Tether Applications in Space
09.09 GAS ELV and Spartan Systems

10 Space Power
10.01 Large Scale Space Power Systems
10.02 Spacecraft and Planetary Rover Power/Energy Systems

11 Space Propulsion
11.01 Solid Rocket Motor Technology
11.02 High Performance Long Life Small Chemical Rockets
11.03 Rocket Engine Combustion Processes
11.04 Liquid Engine Internal Flow Dynamics
11.05 Experimental Fluid Dynamics of Rocket Engines

12 Human Habitability and Biology in Space
12.01 Environmental Control and Life Support Systems
12.02 Waste Water Reclamation and Monitoring for Space Station
12.03 Medical Sciences for Manned Space Programs
12.04 Human Factors for Space Crews
12.05 Intravehicular Systems for Space Crews
12.06 Animal and Plant Life Support and Protective Systems
12.07 Biological Sciences Operations

13 Quality Assurance, Safety, and Check-out for Ground and Space Operations
13.01 Ground Operations Instrumentation
13.02 Ground Checkout Communications
13.03 Launch Processing Quality Assurance Technology
13.04 Robotic Ground Processing of Space Systems and Components
13.05 Production and Handling of Aerospace Fuels and Propellants
13.06 Flow Measurement Device for Ground Test and Checkout
13.07 Non-destructive Evaluation
13.08 Launch and Landing Site Weather

14 Satellite and Space Systems Communications
14.01 Advanced Communications Satellite Systems
14.02 Satellite-Based Mobile Voice and Data Communication Services
14.03 Monolithic Distress Beacon
14.04 Communications for Manned Space Systems
14.05 Multiple Function Antenna Feed
14.06 Optical Communications for Deep Space

15 Materials Processing, Microgravity, and Commercial Applications in Space
15.01 Materials Processing in Space
15.02 Solidification Processing Concepts
15.03 Microgravity Science Technology and Engineering Experiments
15.04 Chemical Vapor Deposition Analysis and Modeling Tools
15.05 Reduced Gravity Process Chemistry
15.06 Life Science Commercial Research and Applications in Space

Appendix C

NASA 1986 AND AIR FORCE PHASE I PROJECTS SELECTED FOR PHASE II

While the body of this report focusses on the results of NASA's Phase I SBIR projects for the 1987 program year, two additional Phase I projects were added to those in competition for Phase II follow-on contracts on the basis of recommendations of NASA technical personnel. One project is a NASA Phase I from the 1986 program year whose circumstances in 1988 prevented its completion and competition with the 86-1 group. The other is an Air Force Phase I which was recommended by the Air Force and which NASA found to be of great value to the NASA R&D program. Both of these highly regarded efforts were selected for Phase II awards.

* 205
86-1-01.02-0664
Catalytic Ignition Rotary Combustion Engine
Precision Combustion Inc.
25 Science Park
New Haven, CT 06511
William C. Pfefferle (203-786-5216)
LeRC -- NAS3-25129

Catalytic ignition technology, involving an active catalytic surface propagating heat and free radicals to ignite gas-phase combustion, offers the potential to improve combustion effectiveness, emissions, and ignition system durability in the rotary combustion engine. As a proof-of-concept that catalytic ignition could be achieved in a rotary engine and provide useful results, an investigation was performed to determine whether glow-plug operating temperature in a Deere diesel-fueled, direct injection, stratified-charge SCORE rotary engine could be reduced through the use of a sufficiently active catalytic surface. Four catalytic ignition designs were evaluated for Phase I work, two designs were selected for prototype construction, and one was successfully constructed. Tests were performed in the Deere two-rotor rotary engine. Phase I results showed that a prototype catalytic glow plug in a Deere SCORE engine could operate the engine at plug surface temperatures well below those required by identical best-technology, non-catalytic plugs.

Potential Commercial Application: Catalytic glow plugs and catalytic ignition could find useful applications in gas turbines, reciprocating engines, and high speed combustors as well as in rotary engines.

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* 206
87-1-03.06-8228
A Gravity-Induced Loss of Consciousness Detection and Recovery System
Eidetics International, Inc.
3415 Lomita Blvd.
Torrance, CA 90505
Robert W. Parker (213-326-8228)
LaRC -- USAF Phase I

Incidents of gravity-induced, loss-of-consciousness (G-LOC) with accompanying loss of aircraft and lives have occurred with increasing frequency in today's high-performance tactical fighters. In addition, the number of G-LOC-related mishaps now occurring in peace-time may be considerably less than that which might be expected in combat or with more advanced fighters now being developed. The ability of the human body to withstand high G and high G-onset rates that fighters are now capable of achieving will continue to be a challenge. Previous crew member support system developments have concentrated on preventative measures and should be continued. Phase I demonstrated that is possible to exploit the on-board computers, data buses, and programmable digital flight controls of today's fighters to provide a G-LOC detection, warning, and recovery system in the event that prevention fails. For the recovery system, special effort is required to develop an appropriate combat recovery profile due to the inherent vulnerability of the pilot during the LOC period

Potential Commercial Application: A successful G-LOC system could lead to full-scale development of production systems for retrofit and incorporation into future fighter aircraft

Appendix D

INDEX OF PROJECTS BY STATE

* Project selected for Phase II

Appendix E

INDEX OF PARTICIPATING COMPANIES

* Project selected for Phase II

Cambridge Research and Instrumentation, Inc.,
Cambridge, MA 02139
* 117 Stabilized Lasers as Spectro-Radiometric Standards for Ultraviolet Electro-Optic Detectors

CCE - Robotics,
Berkeley, CA 94709
175 High-Resolution Electronic Photography

Center for NeuroDiagnostic Study, Inc.,
San Jose, CA 95119
* 034 Electroencephalographic Monitoring of Complex Mental Tasks

CFD Research Corporation,
Huntsville, AL 35805
161 Modeling of Turbulent Spray Combustion in Liquid Rocket Engine Components
* 163 A Computer Model for Liquid Jet Atomization in Rocket Thrust Chambers

CHAM of North America, Inc.,
Huntsville, AL 35816
204 Computational Methodologies for Convection-Diffusion Phase Change Problems

Charles Evans & Associates,
Redwood City, CA 94063
* 126 Microanalytical Characterization of Biogenic Components of Interplanetary Dust

Charles River Analytics Inc.,
Cambridge, MA 02138
* 041 Expert Systems for Real-Time Monitoring and Fault Diagnosis

Chronos Research Laboratories, Inc.,
San Diego, CA 92121
057 Polymer with Biaxial Strength for Pyroelectric Applications

Coherent Research, Inc.,
Syracuse, NY 13210
* 092 A Knowledge-Based Expert System to Coordinate CAD/CAE with Integration and Test

Colorado Research Development Corporation,
Denver, CO 80293
085 Asynchronous, Multi-level, Adaptive Methods for Partial Differential Equation on Navier-Stokes Computer

Complere, Inc.,
Palo Alto, CA 94302
018 A Laser Based Transition Detector
* 139 An Optical Angle of Attack Sensor

Consultant's Choice, Inc.,
Atlanta, GA 30350
105 Symbolic Imagery Management System

Continuum Dynamics, Inc.,
Princeton, NJ 08543
* 027 Performance Optimization for Rotors in Hover and Axial Flight
030 Analysis of Main-Rotor-Wake/Tail-Rotor Interaction Noise

Covalent Associates, Inc.,
Woburn, MA 01801
159 High Cycle Life, Rechargeable Aluminum Batteries

Creare Incorporated,
Hanover, NH 03755
* 001 Multigrid Solution of Internal Flows Using Generalized Solution Adaptive Meshes
* 146 Compact, High-Performance Heat Exchangers for Space Station Thermal Control
* 148 Three-Phase Inverter for Ultra High Speed Motor Drive

Crystal Research,
San Pedro, CA 90732
201 Miniaturized Fiber-Pulling Apparatus for Producing Single-Crystal-Core Glass Fibers

Crystallume,
Menlo Park, CA 94025
128 PE-CVD Diamond Thin Film for UV Detectors

Daedalus Enterprises Inc.,
Ann Arbor, MI 48106
075 3-D Laser Imager
* 116 Portable Multispectral Thermal Infrared Camera

Datawise, Inc.,
Orlando, FL 32803
087 An Automated Database Design Methodology

David Hall Consulting,
Sunnyvale, CA 94080
035 Integrated Design System for High-Altitude Long-Endurance Aircraft for Micro-Computers

Deacon Research,
Palo Alto, CA 94304
006 Simultaneous Temperature, Density, and Flow Diagnostics for Aeropropulsion Systems
017 Stimulated Brillouin Diagnostics of Hypersonic Flows

Decision Science Consortium, Inc.,
Reston, VA 22091
* 033 Aeronautical Human Factors Research

Defense Systems Inc.,
McLean, VA 22102
* 153 Standard GAS Satellite

Digital Signal Corporation,
Springfield, VA 22151
* 072 Improvement of Range of Coherent Laser Radar 3-D Imaging System
073 Integrated Fiber Optic Coupled Proximity Sensor for Robotic End Effectors and Tools

Down to Earth,
Berkeley, CA 94704
177 Modular Environmental Control Life Support System for a Mid-Deck Animal Habitat

DWA Composite Specialties, Inc.,
Chatsworth, CA 91311
* 054 Low CTE, Particulate-Reinforced Metal Matrix Composite Material

Dynamic Analysis & Testing Associates,
Carlsbad, CA 92008
005 Propeller-Wake-Induced Structure-Borne Interior Noise

E-Tek Dynamics, Inc.,
Melbourne, FL 32904
185 Microwave Fiber Optic Link for Satellite Communications and Antenna Remoting

Earth Space Research, Inc.,
San Diego, CA 92109
114 Software Package to Compute the Incoming & Net Solar Irradiance at the Surface from GOES-VISSR Data

EIC Laboratories, Inc.,
Norwood, MA 02062
137 Photoelectrochemical Fabrication of Spectroscopic Diffraction Grating in Silicon Carbide
* 170 A Variable Transmittance Electrochromic Space Suit Visor

Eidetics International, Inc.,
Torrance, CA 90505
026 Wing-Rock Dynamics and Control

Electro Design Manufacturing, Inc.,
Decatur, AL 35602
202 Temperature Measurement by Noncontact Method for Czochralski Type Crystal Growth

Engineering Development Laboratory,
Newport News, VA 23606
039 Smart Angle-of-Attack and Angle-of-Sideslip Sensor

Engineering Mechanics Associates, Inc.,
Torrance, CA 90503
* 061 Methods for Evaluating the Predictive Accuracy of Structural Dynamic Models

ENSCO, Inc.,
Springfield, VA 22151
* 190 Kennedy Space Center Atmospheric Boundary Layer Experiment

Epitaxx, Inc.,
Princeton, NJ 08540
* 130 High Performance In-Ga-As Detector Arrays for the 1.0-to-1.7 Micron Spectrum

Ergo-Tech Systems Inc.,
Tujunga CA 91042
022 Direct Simulation Monte Carlo of Vacuum Plumes

Exotech, Inc.,
Fremont, CA 94538
138 High-Temperature and High-Response Skin Friction Sensor

Femtometrics,
Costa Mesa, CA 92627
183 Continuous Detection of Toxic Vapors Using a Field Domain Ion Mobility Spectrometer

Fibre Optics Development Systems, Inc.,
Santa Barbara, CA 93101
131 Scintillating Optical Fiber Trajectory Detectors

Flow Research, Inc.,
Kent, WA 98032
009 Shock Waves for Enhanced Mixing in Scramjet Combustors

Foster-Miller, Inc.,
Waltham, MA 02254
* 048 Controlled CTE High-Performance Films for Space Structures
055 Ultra-High Stiffness Net-Shape Tubular Space Structures
062 Reduced Weight Gondolas for Stratospheric Balloons
* 144 Non-Azeotropic Heat Pump for Crew Hygiene Water Heating
145 Hybrid Measurement of Two-Phase Flows

G.M.A.F., Inc.,
Freeport, NY 11520
015 Three-Dimensional Euler Solver

Geo-Centers, Inc.,
Newton Centre, MA 02159
* 045 Embedded Fiber Optic Sensors for Polymer Matrix Composite Process Monitoring

Global Information Systems Technology,
Savoy, IL 61874
* 090 Intelligent Evaluation System for Simulator Training

Growth Systems, Inc.,
Glenview, IL 60025
178 Accelerating Seed Germination & Plant Growth thru Manipulation of Atmospheric Pressure

GT-Devices, Inc.,
Alexandria, VA 22312
023 Numerical Modeling of Fully Viscous Rocket Plume Flows

H & N Instruments, Inc.,
Newark, OH 43055
198 Effect of Gravity on Foam Decay
* 199 A New Method for the Measurement of Surface Tension

Incubator Technologies, Inc.,
Rolla, MO 65401
046 Micro-Mechanical Model for Prediction of Failure Modes in Ceramic-Matrix Composites

International Technical Associates (InTA),
Santa Clara, CA 95054
* 060 Adaptive Weld Control Through Expert System Interpretation

Irvine Sensors Corporation,
Costa Mesa, CA 92626
* 108 HYMOSS™ Signal Processing for Push-broom Spectral Imaging
* 122 On-Focal-Plane Processing for Atmospheric Measurements

ISX Corporation,
Thousand Oaks, CA 91360
* 089 Fault-Tolerant Distributed Knowledge Bases

JAI Associates, Inc.,
Mountain View, CA 94086
012 Computational Fluid Dynamics of Store Separation

KMS Fusion, Inc.,
Ann Arbor, MI 48106
* 077 High-Performance, View-Generated Database for World Model Definition and Update

* Project selected for Phase II

Kuck and Associates, Inc.,
Champaign, IL 61820
011 Software Package for Solving Large Systems of Nonlinear Equations

L.N.K. Corp.,
Riverdale, MD 20737
102 Intelligent Data Abstraction and Analysis

LaserGenics Corporation,
San Jose, CA 95161
181 Fiber Sensors for High Temperatures and Pressures

LNR Communications, Inc.,
Hauppauge, NY 11788
* 193 30 GHZ Reflection Mode FET Solid State Power Amplifier

M. L. Energia, Inc.,
Princeton, NJ 08542
* 019 Photochemical Ignition and Enhancement of Supersonic Combustion

Mathematical Research, Inc.,
Houston, TX 77058
094 System to Create Models of Fluid Flow Phenomena

McMahan Electro-Optics, Inc.,
Winter Park, FL 32789
* 188 Double-Pulsed, Phase-Sampled, Laser-Speckle Interferometric Metrology for Non-Destructive Testing

Membrane Technology and Research, Inc.,
Menlo Park, CA 94025
147 Novel Heat Pipe Systems

Meridian Corporation,
Alexandria, VA 22302
* 071 Force Reflecting Joysticks for Manipulator Control

MetriWave, Inc.,
Pasadena, CA 91101
* 134 Microwave Network Analyzer for Superconductor-Insulator-Superconductor Mixer Research

Microtronics Associates, Inc.,
Pittsburgh, PA 15213
* 096 Hardware for Parallel Asynchronous Focal Plane Image Processing
129 Infrared Detector Systems for High Dynamic Range Radiometry and Imaging

Microwave Monolithics Incorporated,
Simi Valley, CA 93065
135 High-Temperature Superconductors in Monolithic Microwave and Millimeter-Wave Integrated Circuits
* 195 High-Efficiency, Low-Cost GaAs Monolithic RF Module for SARSAT Distress Beacons

Mid-South Engineering, Inc.,
Nashville, TN 37207
059 Robotic Weld Path Programming

Mosaic Industries, Inc.,
Mountain View, CA 94043
123 Automated Atmospheric Analysis for Manned Space Missions

MSNW, Inc.,
San Marcos, CA 92069
052 Chemical Vapor Deposition of Ti-Al Foils

Multipoint Communications Corporation,
Sunnyvale, CA 94089
191 Programmable Rate Digital Modem Utilizing Digital Signal Processing Techniques

NDT Technologies, Inc.,
South Windsor, CT 06074
149 DC-to-400 HZ Inverter

Neurogen Inc.,
Brookline, MA 02146
068 Neural Network Controller for Adaptive Movement in Robots

Niagara Scientific, Inc.,
Syracuse, NY 13206
038 Miniature Airborne Dew Point Sensor

Nielsen Engineering & Research, Inc.,
Mountain View, CA 94043
* 008 Supersonic Turbulent Reacting Flow Modeling and Calculation

North American Aerospace Corp.,
Austin, TX 78716
* 040 Aircraft Flight Testing Techniques and Instrumentation

Novatech, Inc.,
Logan, UT 84321
115 Imaging Altimeter Using Imaging Doppler Interferometry

O.I. Corporation,
College Station, TX 77841
166 Water Quality Monitor

Odetics, Inc.,
Anaheim, CA 92802
* 065 Control Algorithm for Redundant Degree-of-Freedom Manipulators
066 Telepresence Sensor and Control Helmut

Omitron, Inc.,
Greenbelt, MD 20770
* 098 Concept-Oriented Distributed Expert System for Spacecraft Control

Ontologic Inc.,
Billerica, MA 01821
091 CLIPS--Vbase Feasibility Study

Opcoa, Inc.,
Garden Grove, CA 92641
* 140 Fiber Optic Pressure Sensor for Wind Tunnel Applications

Ophir Corporation,
Lakewood, CO 80235
110 Low-Cost Doppler Micro-Radar Rain Gauge
187 Laser Doppler Velocimeter for Flow Rate Measurement in Thermal Control Fluid Systems

Optra, Inc.,
Beverly, MA 01915
179 Cell Culture in Microgravity: An Instrument to Monitor Growth and Cell Markers

PDA Engineering,
Costa Mesa, CA 92626
056 Filament Winding Process for Thermoplastic Matrix Composites
063 Lightweight Advanced Composite Gondola for Stratospheric Balloons

Phoenix Engineering & Computing, Inc.,
Madison, WI 53713
174 Kinematic Data Gathering System for Determining Human Motion in Zero Gravity

Photometrics Limited,
Tucson, AZ 85745
133 A High-Resolution Multi-CCD, Time-Delayed-Integration Camera System

Photonics Technology, Inc.,
Northwood, OH 43619
* 143 Full-Color, AC-Plasma, Flat-Panel Display for Space Station Applications

Physical Sciences Inc.,
Andover, MA 01810
007 High Temperature LDV Seed Particle Development
* 013 Propulsion Simulation for Magnetically Suspended Wind Tunnel Models
* 020 Aerothermodynamic Radiation Studies
141 Remote Characterization of Wind-Tunnel Turbulence
* 158 Arcing on Space Structures in Low Earth Orbit

PhytoResource Research, Inc.,
College Station, TX 77840
* 180 A Space-Rated Nutrient Delivery Root-Support System

Power Silicon & Monolithic Technologies Corp.,
East Pittsburgh, PA 15112
155 Ultra High Temperature 20 KHZ Induction Generator for VSCF Operating Mode

Prospective Computer Analysts, Inc.,
Roslyn, NY 11576
* 093 CAD\CAE Knowledge-Base Development Tool

Proteon, Inc.,
Westborough, MA 01581
* 101 High Speed Packet Switching

QCI, Inc.,
Oak Ridge, TN 37831
* 189 Thermoelectric Assessment of Precipitation-Hardening Stainless Steels

Radiation Monitoring Devices,Inc.,
Watertown, MA 02172
084 High-Resolution, Avalanche Diode X-Ray Spectrometer for Planetary Exploration

Remtech, Inc.,
Huntsville, AL 35805
* 021 Rarefied Gas Aerodynamic Bridging Procedures
* 024 Vacuum Plume Impingement Evaluator
164 Improvement to Viscous Flow Field Calculations in Regeneratively Cooled Nozzles

Robotics Research Corporation,
Milford, OH 45150
078 Telerobot Collision and Obstacle Avoidance Based on Real-Time Proximity Sensors

Rose Engineering & Research, Inc.,
Incline Village, NV 89450
* 002 Boundary Layer Control Methods in High Speed Inlet Systems

Ross-Hime Designs, Inc.,
Minneapolis, MN 55414
* 076 Development of Telerobot Hand Joint

S. R. Taylor & Associates,
Bartlesville, OK 74003
* 165 Zero Gravity Phase Separation Via Ultrasonic Coalescence

San Diego Semiconductors, Inc.,
San Diego, CA 92121
132 Position Sensitive CdTe Detector Using Improved Crystal Growth Method

SatCon Technology Corporation,
Cambridge, MA 02142
* 142 Superconducting Magnetic Bearings in an Advanced Momentum-Exchange Effector
* 200 Active Magnetic Micro-G Isolator for Space Station

Science and Technology Corporation,
Hampton, VA 23666
* 120 Automatic Scanning Lidar System to Map Upper Tropospheric Aerosols and Cloud

Scientific Materials Corporation,
Bozeman, MT 59716
* 118 A Method to Provide Lower Cost Crystal Properties Study Samples

Scientific Research Associates, Inc.,
Glastonbury, CT 06033
* 067 Spatial Planning for Mobile Articulated Vehicles and Dendritic Robotic Systems

Scientific Technology, Inc.,
Rockville, MD 20850
197 Microstrip Multiple Function Antenna Feed

SEES, Inc.,
Knoxville, TN 37931
186 Human Envelope Manipulator

Silicon Engines, Inc.,
Mountain View, CA 94304
106 Continuous-Wave Signal Detector for SETI

SKW Corp.,
Arlington, VA 22209
* 124 Free-Space Particulate Contamination Sizing and Counting System for Space Applications

Solar Kinetics, Inc.,
Dallas, TX 75220
* 154 Improved Mirror Facet for Space Applications

Solidlite Corporation,
Redmond, WA 98052
119 New Four Level All-Solid-State Laser Source Within the 1.5 to 4 Micron Range

Space Computer Corporation,
Santa Monica, CA 90404
* 037 Passive Electro-Optical Sensor Processing for Helicopter Obstacle Avoidance

Sparta, Inc,
Torrance, CA 90503
* 160 Thrust Vector Control

Spectral Sciences, Inc.,
Burlington, MA 01803
182 Surface Organic Contamination Sensor

* Project selected for Phase II

Spectrex, Inc.,
Gloucester, VA 23061
014 Modelling of Massively Separated Flows: Renormalization Group Formulation

Spire Corporation,
Bedford, MA 01730
044 Oxidation Resistant Ti/6Al/4V-SIC Composite Materials by Ion Implantation
* 157 Indium-Phosphide Solar Cells on Silicon Substrates

Spread Spectrum Systems, Inc.(^{3}I),
Bethesda, MD 20814
194 Evaluation of CDMA System Capacity

Springborn Materials Science, Inc.,
Enfield, CT 06082
* 058 Development of Specialized Floor Coverings for Launch Site Facilities

Stirling Technology Co.,
Richland, WA 99352
* 156 Advanced Stirling Engine Heater Head

Structural Analysis Technology, Inc.,
Cupertino, CA 95014
* 053 An Expert System for Integrated Structural Analysis & Design Optimization

Symbiotics, Inc.,
Cambridge, MA 02139
* 088 Distributed Artificial Intelligence Representation Language Language

Systems & Processes Engineering Corp.,
Austin, TX 78721
* 099 Discrete Fourier Transform (DFT) Algorithms for Bit Serial GaAs Processor Architectures

Systems Technology, Inc.,
Hawthorne, CA 90250
036 Practical Application of Multivariable Robustness Methods to Advanced Flight Control
042 Real-Time Mondification of Structural Modes

Technical Research Associates, Inc.,
Salt Lake City, UT 84108
196 Switched Hemispherical Antenna

TeleRobotics International, Inc.,
Knoxville, TN 37931
* 097 Optimizing the Camera and Positioning System for Telerobotic Work Station Viewing

Textile Technologies, Inc.,
Harboro, PA 19040
049 Development of Composite Structures with Enhanced Damage Tolerance

The Computational Mechanics Company, Inc.,
Austin, TX 78705
* 010 Adaptive Schemes for Complex Subsonic 3D-Flow Problems in Arbitrary Domains

The Navtrol Company, Inc.,
Dallas, TX 75243
* 070 Telerobotic Digital Controller System

The Radiometrics Corporation,
Altadena, CA 91001
109 High Sensitivity Active Cavity Radiometer

TiNi Alloy Company,
Oakland, CA 94608
* 095 Digital Storage Device Using Thin-Film Shape-Memory Alloy

Transmission Research, Inc.(Div. of NASTEC, Inc.),
Cleveland, OH 44106
* 083 Roller-Gear Drive for Robotic Manipulators

Triangle Research and Development Corp.,
Research Triangle Park, NC 27709
* 069 Telerobotic Rendezvous and Docking Vision System Architecture
167 Space Suit Thermal Control Using Non-Toxic Microencapsulated Two-Phase PCM Fluid

TS Infosystems, Inc.,
Lanham, MD 20706
112 High Resolution Remote Sensing for Earth Observation

Turbulence Prediction Systems,
Boulder, CO 80301
* 032 Airborne Advance Warning of Air Turbulence

UFA, Inc.,
Newton, MA 02159
* 081 Toward Intelligent Control of Robotics for Space Station Maintenance

Ultramet,
Pacoima, CA 91331
003 Advanced Thermal Protection Materials
043 High Performance, High Temperature Heat Pipes
* 050 High Temperature Turbine Blades

Umpqua Research Company,
Myrtle Creek, OR 97457
* 171 Removal of Contaminants from Experiment Waste Water Using Immobilized Enzymes
176 Space Laundry Cleansing Agent and Filter Development

Universal Energy Systems, Inc.,
Dayton, OH 45432
051 Response of Rapidly-Solidified Ti Alloys to Thermochemical Treatment

Vexcel Corporation,
Boulder, CO 80301
* 104 EOS Workstation

Vigyan Research Associates, Inc.,
Hampton, VA 23666
* 025 Low-Speed Visualization Studies of Vortex Systems on Chine-Forebody/Delta Wing Configurations

Viking Instruments Corporation,
Sterling, VA 22170
* 121 Miniaturized Tandem Mass Spectrometer for Manned Space Missions

Appendix F

INDEX OF PRINCIPAL INVESTIGATORS

* Project selected for Phase II

* *Project selected for Phase II*

Appendix G

INDEX OF PROJECTS MANAGED BY EACH NASA CENTER

AMES RESEARCH CENTER

GODDARD SPACE FLIGHT CENTER

JET PROPULSION LABORATORY

JOHNSON SPACE CENTER

KENNEDY SPACE CENTER

LANGLEY RESEARCH CENTER

* Project selected for Phase II

LEWIS RESEARCH CENTER

001*	01.01-3800
002*	01.01-5094
003	01.02-0236
004	01.02-7300
005	01.02-9511
006	01.03-1520
007	01.03-9030
008*	01.04-9457
009	01.05-8500
023	02.08-8150
031*	03.01-8887
044	04.01-6000
045*	04.01-7070
046	04.01-7747
047	04.01-9785
050*	04.03-0236A
053*	04.04-1319
083*	05.03-1391A
154*	10.01-2376
155	10.01-2520
156*	10.01-4000
157*	10.01-6000A
158*	10.01-9030
191	14.01-3900A
192	14.01-4995B
193*	14.01-7111
195*	14.03-6642
201	15.01-0760
203*	15.01-8371
204	15.03-2620

MARSHALL SPACE FLIGHT CENTER

010*	02.01-0618
011	02.01-3600
021*	02.07-8581
022	02.08-1759
024*	02.08-8581A
056	04.05-8900
059	04.08-0960
060*	04.08-9955
076*	05.01-5860
081*	05.02-5172A
082	05.02-5272
121*	08.10-2214A
122*	08.10-8211
123	08.10-9054
144*	09.04-3200
152	09.08-5050A
160*	11.01-3350
161	11.03-6576
162	11.03-8887
163*	11.04-6576
164	11.04-8581
171*	12.02-5202B
187	13.06-1512
198	15.01-0156
199*	15.01-0156A
200*	15.01-0540
202	15.01-3855

** Project selected for Phase II*

Appendix H

INDEX OF PROJECTS BY NASA CONTRACT NUMBER

1: LANGLEY RESEARCH CENTER

NAS1-18606	085	06.01-4131
NAS1-18607	030	02.12-9282
NAS1-18610	014	02.03-9778
NAS1-18611	138	08.20-2870
NAS1-18615	052	04.03-7648
NAS1-18616	013*	02.02-9030
NAS1-18617	141	08.20-9030
NAS1-18618	015	02.04-8450
NAS1-18619	119	08.08-7528
NAS1-18620	051	04.03-6900B
NAS1-18621	087	06.02-7701
NAS1-18622	029*	02.12-7070
NAS1-18623	038	03.07-0821
NAS1-18625	034*	03.03-2975
NAS1-18626	140*	08.20-7377
NAS1-18627	097*	07.01-5600
NAS1-18628	049	04.02-5325
NAS1-18629	078	05.01-9570
NAS1-18631	120*	08.09-1894
NAS1-18634	036	03.05-2281
NAS1-18636	048*	04.02-3200
NAS1-18637	032*	03.02-2150
NAS1-18639	068	05.01-2215
NAS1-18639	118*	08.08-0438A
NAS1-18640	072*	05.01-4910
NAS1-18641	189*	13.07-6498
NAS1-18643	188*	13.07-0463
NAS1-18644	043	03.08-0236
NAS1-18645	096*	07.01-0888
NAS1-18662	039	03.07-0905
NAS1-18682	142*	09.01-0540A

2: AMES RESEARCH CENTER

NAS2-12643	125*	08.12-3708A
NAS2-12725	041*	03.07-3474
NAS2-12726	042	03.07-4674
NAS2-12741	040*	03.07-0979
NAS2-12773	035	03.04-9024
NAS2-12774	037*	03.06-8740
NAS2-12776	113	08.04-9500
NAS2-12777	089*	06.03-8265
NAS2-12778	016	02.05-1427
NAS2-12779	012	02.01-3922
NAS2-12780	025*	02.09-0794A
NAS2-12781	018	02.06-5630
NAS2-12782	019*	02.06-7970
NAS2-12787	026	02.09-9316
NAS2-12789	027*	02.10-9282
NAS2-12795	033*	03.03-0660
NAS2-12796	094	06.07-2555
NAS2-12797	095*	06.07-4109
NAS2-12801	028	02.11-8060
NAS2-12808	106	07.09-2140
NAS2-12815	112	08.03-4080
NAS2-12818	126*	08.13-4567
NAS2-12820	177	12.06-1262
NAS2-12854	139*	08.20-5630

3: LEWIS RESEARCH CENTER

NAS3-25282	083*	05.03-1391A
NAS3-25283	157*	10.01-6000A
NAS3-25284	007	01.03-9030
NAS3-25285	008*	01.04-9457
NAS3-25326	044	04.01-6000
NAS3-25327	053*	04.04-1319
NAS3-25331	204	15.03-2620
NAS3-25332	009	01.05-8500
NAS3-25333	046	04.01-7747
NAS3-25334	156*	10.01-4000
NAS3-25335	154*	10.01-2376
NAS3-25336	191	14.01-3900A
NAS3-25337	045*	04.01-7070
NAS3-25338	005	01.02-9511
NAS3-25339	193*	14.01-7111
NAS3-25348	031*	03.01-8887
NAS3-25349	050*	04.03-0236A
NAS3-25350	155	10.01-2520
NAS3-25362	203*	15.01-8371
NAS3-25400	201	15.01-0760
NAS3-25401	006	01.03-1520
NAS3-25402	158*	10.01-9030
NAS3-25403	195*	14.03-6642
NAS3-25404	004	01.02-7300
NAS3-25405	001*	01.01-3800
NAS3-25406	047	04.01-9785
NAS3-25407	023	02.08-8150
NAS3-25408	002*	01.01-5094
NAS3-25411	003	01.02-0236
NAS3-25424	192	14.01-4995B

5: GODDARD SPACE FLIGHT CENTER

NAS5-30265	103*	07.06-3759
NAS5-30266	111*	08.02-9388
NAS5-30267	100	07.03-8442
NAS5-30268	136*	08.19-8775
NAS5-30269	117*	08.07-2627
NAS5-30270	057	04.06-8200B
NAS5-30271	105	07.08-8430
NAS5-30272	148*	09.05-3800
NAS5-30273	128	08.16-0660
NAS5-30274	127	08.15-2960
NAS5-30275	075	05.01-5649
NAS5-30276	153*	09.09-1000
NAS5-30277	137	08.19-9450
NAS5-30278	130*	08.16-1188
NAS5-30279	131	08.16-2589
NAS5-30280	102	07.05-3223
NAS5-30281	147	09.05-2228
NAS5-30282	129	08.16-0888
NAS5-30283	070*	05.01-3319
NAS5-30284	098*	07.02-1700
NAS5-30285	110	08.02-1512
NAS5-30286	063	04.11-8900
NAS5-30287	101*	07.04-2800
NAS5-30288	109	08.02-0071
NAS5-30289	132	08.16-4645

* Project selected for Phase II

NAS5-30290	124*	08.11-3888A
NAS5-30291	099*	07.03-0081
NAS5-30292	069*	05.01-2878

7: JET PROPULSION LABORATORY

NAS7-1004	073	05.01-4910A
NAS7-1005	114	08.05-5049
NAS7-1006	065*	05.01-0300A
NAS7-1007	062	04.11-3200
NAS7-1008	108*	08.01-8211
NAS7-1009	077*	05.01-8500
NAS7-1010	116*	08.06-5649
NAS7-1011	135	08.18-6642
NAS7-1012	067*	05.01-0333
NAS7-1014	092*	06.06-0929
NAS7-1015	074	05.01-5042B
NAS7-1016	115	08.06-2035
NAS7-1017	197	14.05-6070
NAS7-1018	084	05.05-1167
NAS7-1019	066	05.01-0300C
NAS7-1020	061*	04.10-2551
NAS7-1021	107*	08.01-7513
NAS7-1022	133	08.17-8961
NAS7-1023	159	10.02-1140
NAS7-1024	071*	05.01-3600
NAS7-1025	134*	08.18-0669
NAS7-1026	104*	07.07-0094
NAS7-1027	194	14.02-4288A

8: MARSHALL SPACE FLIGHT CENTER

NAS8-37616	082	05.02-5272
NAS8-3776617	162	11.03-8887
NAS8-37618	152	09.08-5050A
NAS8-37619	161	11.03-6576
NAS8-37623	022	02.08-1759
NAS8-37620	163*	11.04-6576
NAS8-37621	010*	02.01-0618
NAS8-37622	202	15.01-3855
NAS8-37624	144*	09.04-3200
NAS8-37625	198	15.01-0156
NAS8-37626	199*	15.01-0156A
NAS8-37627	060*	04.08-9955
NAS8-37628	122*	08.10-8211
NAS8-37629	059	04.08-0960
NAS8-37630	123	08.10-9054
NAS8-37631	187	13.06-1512
NAS8-37632	056	04.05-8900
NAS8-37633	011	02.01-3600
NAS8-37635	021*	02.07-8581
NAS8-37636	024*	02.08-8581A
NAS8-37637	164	11.04-8581
NAS8-37638	076*	05.01-5860
NAS8-37639	200*	15.01-0540
NAS8-37640	160*	11.01-3350
NAS8-37641	081*	05.02-5172A
NAS8-37642	171*	12.02-5202B
NAS8-37643	121*	08.10-2214A

9: JOHNSON SPACE FLIGHT CENTER

NAS9-17926	079	05.02-3912
NAS9-17927	080*	05.02-3912A
NAS9-17928	064*	04.12-8112
NAS9-17929	168*	12.01-4995
NAS9-17930	151*	09.07-8600
NAS9-17931	169	12.01-8553
NAS9-17932	172*	12.03-1113
NAS9-17933	173	12.03-1304
NAS9-17934	150*	09.07-1262
NAS9-17935	175	12.05-0298B
NAS9-17936	146*	09.04-3800
NAS9-17937	017	02.06-1520
NAS9-17938	054*	04.05-1504
NAS9-17939	170*	12.01-9450
NAS9-17940	055	04.05-3200A
NAS9-17941	145	09.04-3200A
NAS9-17942	090*	06.05-1165
NAS9-17943	181	13.01-0161
NAS9-17944	149	09.06-7958
NAS9-17945	166	12.01-1711
NAS9-17946	091	06.05-2383
NAS9-17947	174	12.04-1987
NAS9-17948	143*	09.03-0762
NAS9-17949	020*	02.06-9030
NAS9-17950	165*	12.01-0264
NAS9-17951	196	14.04-8080
NAS9-17952	167	12.01-2878
NAS9-17953	176	12.05-5201

10: KENNEDY SPACE FLIGHT CENTER

NAS10-11455	058*	04.07-8371
NAS10-11456	183	13.01-6239
NAS10-11457	179	12.07-7670
NAS10-11458	093*	06.06-4610
NAS10-11459	182	13.01-4770
NAS10-11460	185	13.02-3226
NAS10-11461	180*	12.07-8606
NAS10-11462	184*	13.02-2423A
NAS10-11463	186	13.04-2060
NAS10-11464	088*	06.03-3635
NAS10-11465	086	06.02-3900
NAS10-11466	190*	13.08-4122
NAS10-11467	178	12.06-3053

** Project selected for Phase II*

* U.S. GOVERNMENT PRINTING OFFICE:1990-261-446:00067

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