SMALL BUSINESS INNOVATION RESEARCH

ABSTRACTS OF PHASE I AWARDS

1999

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PREFACE

This booklet presents technical abstracts of Phase I awards made in Fiscal Year (FY) 1999 under the DOE Small Business Innovation Research (SBIR) program. SBIR research explores innovative concepts in important technological and scientific areas that can lead to valuable new technology and products. The work described in the abstracts is novel, high-risk research, but the benefits will also be potentially high if the objectives are met. Brief comments on the potential applications, as described by the awardee, are given after each abstract. Individuals and organizations, including venture capital and larger industrial firms, with an interest in the research described in any of the abstracts are encouraged to contact the appropriate small business directly.

The Federal SBIR Program

This program, which has completed its 17th year, was established in compliance with the Small Business Innovation Development Act of 1982, Public Law (PL) 97-219. The program was extended in October 1992 until the year 2000 by the Small Business Research and Development Enhancement Act of 1992, PL 102-564. Ten Federal agencies have SBIR programs - those with extramural research and development (R&D) budgets of over \$100 million. The agencies were required to set aside 2.5% of those budgets in Fiscal Year (FY) 1999 to fund SBIR projects. (This amounted to about \$75 million in FY 1999 for the Department of Energy.) Each agency solicits grant applications from small science- and technology-based U.S. firms (with 500 employees or less) and makes awards competitively. SBIR research explores innovative concepts in important technological and scientific areas that can lead to valuable new technology and products. It supports innovative R&D and encourages conversion of that R&D into commercial applications of economic benefit to the Nation.

As prescribed in the legislation, the program is designed for implementation in three phases, with Phase I determining, insofar as possible, the scientific or technical merit and feasibility of ideas proposed for investigation. The period of performance in this initial phase is about six months, and the awards were limited to \$100,000. Phase II is the principal research or R&D effort, and only the previous year's Phase I awardees may compete for the following year for Phase II awards of up to \$750,000. Phase II work is performed for a period of up to two years. In Phase III, commercial applications of the research or R&D are pursued using non-Federal funding or, alternatively, Phase III may involve follow-on non-SBIR Federal contracts for products or services desired by the Government.

The DOE SBIR Program

DOE's FY 1999 annual solicitation contained 40 technical topics in the areas of basic energy sciences, biological and environmental research, high energy and nuclear physics, fusion energy, energy efficiency and renewable energy, fossil energy, nuclear energy, environmental management, nonproliferation and national security, and computational and technology research.

The 202 Phase I projects described here were selected in a highly competitive process from a total of 1,135 grant applications received in response to the 1999 DOE annual SBIR solicitation. The selections for awards were based on scientific and technical quality, as well as on the perceived impact of the research, as judged against specific criteria listed in the solicitation. Conclusions were reached on the basis of reviews performed by personnel in DOE laboratories, universities, private industry, and government. It is expected that between one-third and one-half of the Phase I projects will be continued into Phase II.

TABLE OF CONTENTS

Award Number

Page Number

BIOMASS POWER

1. Power from Farm Animals System Technology
Altex Technologies Corporation, Santa Clara, CA.....1
2. Cost-Effective, Clean and Modular Biomass Power System for the Utilization of
Farm Animal Waste
Manufacturing and Technology Conversion International, Inc., Baltimore, MD....1
3. Processing and Drying of Biomass Residue for Feedstock to a Dedicated
Cogeneration Facility
Reaction Engineering International, Salt Lake City, UT2
4. The Development of a Modular System to Burn Farm Animal Waste to Generate
Heat and Power
Spinheat Limited, Fairfield, CT2

HIGH-TEMPERATURE ELECTRONICS FOR GEOTHERMAL DRILLING

5. High-Temperature Oscillator and Digital Clock
Linear Measurements, Inc., San Diego, CA2
6. A Novel Potentiometric Pressure Sensor with a Temperature-Independent Signal
for Geothermal Drilling
Materials and Systems Research, Inc., Salt Lake City, UT3
7. Capacitors for Extreme Temperature Applications
Sigma Technologies International, Inc., Tucson, AZ3
8. A High Temperature Microelectromechanical Inclination Sensor for Geothermal
Drilling
Silicon Designs, Inc., Issaquah, WA.....4

ADVANCED MEASUREMENT AND CONTROL TECHNOLOGIES FOR INDUSTRIAL MANUFACTURING APPLICATIONS

9. New Optical Coupling of Infrared Analyzers to Industrial Processes
Advanced Fuel Research, Inc., East Hartford, CT5
10. Fiber Optic Sensor for Industrial Process Measurement and Control
MetroLaser, Inc., Irvine, CA.....5

11. High Temperature Micromachined Sensor for Industrial Gas Streams
Nanomaterials Research Corporation, Longmont, CO6
12. Real-Time Gas Composition Analyzers for On-Line Process Control
Nanomaterials Research Corporation, Longmont, CO6
13. Portable Parallel Beam X-Ray Diffraction System for In-Line Process Control in
the Steel Industry
X-Ray Optical Systems, Inc., Albany, NY7

HYBRID ELECTRIC VEHICLE TECHNOLOGY

14. N Type Quantum Well Films and Devices
Hi-Z Technology, Inc., San Diego, CA7
15. Thermoelectric Quantum Well Device
Hi-Z Technology, Inc., San Diego, CA8
16. High-Temperature Tolerant Automotive Switched-Reluctance Motor
SatCon Technology Corporation, Cambridge, MA8
17. Improved Rotor Cooling for Permanent Magnet Machines
Unique Mobility, Inc., Golden, CO9
18. Meeting Motor Cost and Performance Goals Through Integration and Thermal
Management
Visual Computing Systems Corporation, Greenville, IN9

SYSTEMS AND PRODUCTS FOR PASSIVE SOLAR LOW ENERGY BUILDINGS

19. Passive Desiccant Air Conditioners
AIL Research, Inc., Princeton, NJ10
20. Intercalated Phosphonate-Clay Composites as Latent Heat Storage Materials for
Masonry
Cape Cod Research, Inc., East Falmouth, MA10
21. Fiber-Reinforced Polymer-Composite Building Panels Capable of Energy Storage
Through High Enthalpy Solid-State Phase Transition
DPD, Inc., Lansing, MI10
22. SunGuard: A Roofing Tile for Natural Cooling
PowerLight Corporation, Berkeley, CA11

23. Evaluation of Integrated Wall Systems Incorporating Electrochromic Windows
SAGE Electrochromics, Inc., Faribault, MN11

COAL/GAS POWER SYSTEMS

24. Cost-Saving Alternative for Stack Reformer Packaging in Tubular Solid Oxide
Fuel Cells
Blasch Precision Ceramics, Inc., Albany, NY12
25. Novel Backup Filter Device for Candle Filters
CeraMem Corporation, Waltham, MA12
26. Abatement of Filter Corrosion and Plugging in Integrated Gasification Combined
Cycle Systems
Microbeam Technologies, Inc., Grand Forks, ND13
27. Ion-Conducting Oxide Ceramic Materials for Solid-Oxide Fuel Cells Using Novel
Low Cost Combustion Chemical Vapor Deposition
MicroCoating Technologies, Inc., Chamblee, GA13
28. Cathode-Suported Thin-Film Solid Oxide Cells with Low Operating
Temperatures
NexTech Materials, Ltd., Worthington, OH14
29. Advanced Catalytic Pilot for Advanced Gas Turbine Systems
Precision Combustion, Inc., New Haven, CT14
30. Thermally Stable Catalysts for Methane Combustion
TDA Research, Inc., Wheat Ridge, CO15
31. Heat Pipe Preheater for Low Nitrogen Oxide (NO_x) Catalytic Combustor
Thermacore, Inc., Lancaster, PA15

RECOVERY AND UTILIZATION OF FOSSIL FUELS

32. Improved Carbon Molecular Sieve Membranes for Oxygen-Nitrogen Separation
Advanced Fuel Research, Inc., East Hartford, CT16
33. Integrated Natural Fracture Characterization Technology in Tight Gas
Formations: Application in Clinton Gas Storage Reservoirs
Advanced Resources International, Inc., Arlington, VA16

<u>Award Number</u>		<u>Page Number</u>
34.	Improved Precursors for Oxygen-Selective Membranes in Practical Devices for Methane Conversion CeraMem Corporation, Waltham, MA	17
35.	Supported Flat Plate Thin Films for Oxygen Separation Eltron Research, Inc., Boulder, CO	17
36.	Biocatalyzed Chemical Gels for Permeability Modification in Injection and Production Wells Geo-Microbial Technologies, Inc., Ochelata, OK	18
37.	Mixed-Conducting Oxide Ceramic Membranes for Oxygen Separation Using Novel Low-Cost Combustion Chemical Vapor Deposition MicroCoating Technologies, Inc., Chamblee, GA.....	18
38.	Nine-Component Cross-Well Seismic Imaging of Fractured Gas Reservoirs Paulsson Geophysical Services, Inc., La Habra, CA	19
FUSION PLASMA SCIENCE RESEARCH		
39.	A Diagnostic Tool for Identification and Visualization of Resistive-Wall-Modes in Tokamak Plasmas FARTECH, Inc., San Diego, CA.....	19
40.	Filtered Coherent Thomson Scattering for Plasma Diagnostics M.L. Energia, Inc., Princeton, NJ	20
41.	Development of a High Resolution X-Ray Imaging-Spectrometer Radiation Science, Inc., Belmont, MA	20
42.	Novel Method for Plasma Density Measurements Southwest Sciences, Inc., Santa Fe, NM	21
ENABLING TECHNOLOGIES FOR FUSION PLASMA EXPERIMENTS		
43.	Power Supply for Plasma Heating Diversified Technologies, Inc., Bedford, MA	21
44.	A New Radiation Resistant Epoxy Resin System for Liquid Impregnation Fabrication of Composite Insulation Eltron Research, Inc., Boulder, CO	22

45.	Advanced Heat Sink Materials for Fusion Energy Devices Plasma Processes, Inc., Huntsville, AL	22
46.	Economical Fabrication of Large Micro-Impingement Cooling Panels Saddleback Aerospace, Los Alamitos, CA	23
47.	Helium Cooled Refractory Metal Divertor Panel Thermacore, Inc., Lancaster, PA.....	23
48.	Enabling Materials for Magnetic Fusion Energy Ultramet, Pacoima, CA	24
49.	Fast Repetitive Arc Free Current Limiting Circuit Breaker UTRON, Inc., Manassas, VA	24

ADVANCED TECHNOLOGIES AND MATERIALS FOR FUTURE FUSION SYSTEMS

50.	Robust Ceramic Coatings for Vanadium Alloys to Use in Lithium Cooled Fusion Systems Composite Technology Development, Inc., Lafayette, CO	25
51.	Hybrid Three-Dimensional SiC/C High Thermal Conductivity Composites MER Corporation, Tucson, AZ	25
52.	Low Cost Dispersion Strengthened Ferritic Steels Powdermet, Inc., Sun Valley, CA.....	26

ADVANCED CONCEPTS AND TECHNOLOGY FOR HIGH ENERGY ACCELERATORS

53.	Inexpensive, High Performance, Electron Gun Advanced Energy Systems, Inc., Medford, NY.....	26
54.	A Drive Beam Micro-Pulse Injector FM Technologies, Inc., Fairfax, VA.....	27
55.	Virtual Accelerator Simulation System for Operations, Research and Training G. H. Gillespie Associates, Inc., Del Mar, CA	27
56.	Nitride-Based Cold Cathodes for Miniature and Rugged Electron Sources Ionwerks, Houston, TX.....	28
57.	Computer Software for Magnicon Design, Including Beam Space Charge Effects Omega-P, Inc., New Haven, CT	28

58.	Laser-Driven Cyclotron Autoresonance Accelerator Omega-P, Inc., New Haven, CT	29
59.	Multi-Terawatt, 50 Femtosecond Laser for Laser Accelerator Positive Light, Inc., Los Gatos, CA	29
60.	An Automatic Beam-Based System for Analyzing Accelerator Misalignment Problems Sandia View Software, Inc., Albuquerque, NM	30
61.	High-Performance Three-Dimensional Simulation Code for Laser Plasma Accelerators and Plasma Processing of Integrated Circuits, with a Graphical User Interface Tech-X Corporation, Boulder, CO	30
62.	A Non-Interceptive Transverse Size Monitor for Charged-Particle Beams Y.Y. Labs, Inc., Fremont, CA	31

RADIO FREQUENCY ACCELERATOR TECHNOLOGY FOR HIGH ENERGY ACCELERATORS AND COLLIDERS

63.	Radio Frequency Pulse Compression Using a Diamond Switch Alameda Applied Sciences Corporation, San Leandro, CA	31
64.	Design of a 10 MW, 91 GHz Gyroklystron for Linear Accelerators Calabazas Creek Research, Saratoga, CA	31
65.	Low Field Solenoid Periodic Focusing of Accelerator Klystrons California Tube Laboratory, Inc., Watsonville, CA	32
66.	New Concepts for Pulsed Power Modulators Diversified Technologies, Inc., Bedford, MA	32
67.	10-MW, W-Band Radio Frequency Source for a High Gradient Linear Accelerator Omega-P, Inc., New Haven, CT	33

HIGH-FIELD SUPERCONDUCTOR AND SUPERCONDUCTING MAGNET TECHNOLOGIES FOR HIGH ENERGY PARTICLES COLLIDERS

68.	Bent Solenoids with Superimposed Dipole Fields Advanced Magnet Laboratory, Inc., Palm Bay, FL	34
69.	A Novel Process for the Fabrication of Advanced High Temperature Superconductors American Superconductor Corporation, Westborough, MA	34

70.	Co-Processed Ceramic Insulation for High Field Accelerator Magnets Composite Technology Development, Inc., Lafayette, CO.....	35
71.	Hg-Ba-Ca-Cu-O HTS Current Leads for High Energy Physics Applications at High Magnetic Field and Temperature EURUS Technologies, Inc., Tallahassee, FL.....	35
72.	Low-Cost, Long-Length Manufacturing of Continuously Melt-Quenched Processed, Fully Stabilized, Multifilamentary High-Field Niobium Aluminum (Nb ₃ Al)Superconductor Plastronic, Inc. Subsidiary of Eurus Technologies, Inc., Tallahassee, FL.....	36
73.	Development of a High Current Density Niobium-Tin Conductor with Ga and Mg Dopants for High Field Application Supercon, Inc., Shrewsbury, MA.....	36
74.	Improvement of High Field Performance and Reliability of Nb ₃ Sn Conductor by Power-In-Tube Method Supercon, Inc., Shrewsbury, MA.....	36
75.	High Performance Nb ₃ Sn (Ta) Wires by Tin Enrichment and Increased Filament Content Superconducting Systems, Inc., Waltham, MA.....	37
76.	A High Current Very Low Cost Niobium-Tin Titanium-Doped Conductor Utilizing a Novel Internal Tin Process, with Separate Stabilizing Elements Scalable to Modern Niobium Titanium Production Economics Supergenics, Sarasota, FL.....	37

TECHNOLOGIES FOR THE NEXT-GENERATION ELECTRON-POSITRON LINEAR COLLIDER

77.	Automated Diamond Turning Lathe for the Production of Copper Accelerator Cells DAC Vision, Inc., Carpinteria, CA.....	38
78.	High Power Switch Diversified Technologies, Inc., Bedford, MA	38
79.	Hybrid Next-Generation Linear Collider Modulator Diversified Technologies, Inc., Bedford, MA	39
80.	Next Linear Collider Switching Power Supply Diversified Technologies, Inc., Bedford, MA	39

81. Innovative, New and Advanced High Voltage Power Supply for Capacitor
Charging at Linear Collider
International Power Group, Inc., Kent, WA40
82. Adiabatic Forming of Copper Accelerator Cells for the Next Generation
Linear Collider
LMC, Inc., De Kalb, IL.....40
83. Pulse Capacitors for Next Generation Linear Colliders
Nanomaterials Research Corporation, Longmont, CO40
84. Ultra Low Loss Radio Frequency Window Materials
TPL, Inc., Albuquerque, NM.....41

HIGH ENERGY PHYSICS DATA ACQUISITION AND PROCESSING

85. Double Fused 1.55 Micrometer Vertical Cavity Lasers for 80K Operation
Conductus, Inc., Sunnyvale, CA.....41

HIGH ENERGY PHYSICS DETECTORS

86. Carbon-Carbon Composite Closeout Frames for Space Qualified, Stable
High Thermal Conductivity Detector Support Structures
HYTEC, Inc., Los Alamos, NM42
87. Low Cost Support Structures, with New Advanced Composite Materials
Tailored for Ultra-Stable Particle Tracking Detectors
HYTEC, Inc., Los Alamos, NM42
88. Superpressure Neutrino Detector
L'Garde, Inc., Tustin, CA.....43

NUCLEAR PHYSICS INSTRUMENTATION AND TECHNIQUES

89. New Fullerene-Based Resistor Technology for Use in Low Noise Instrumentation
Cremat, Watertown, MA.....43
90. SQUID Susceptometers for Read Out of Magnetic Microcalorimeters
HYPRES, Inc., Elmsford, NY44
91. Low Cost Waveform Digitizer for Physics Using Advanced Computer Graphics
Technology
Jorway Corporation, Westbury, NY44

92.	Application of the Combinatorial Synthesis and Laser-Heated Pedestal Growth Techniques to the Development of New Scintillator Materials Lasergenics Corporation, San Jose, CA.....	45
93.	Large Volume Detectors from New Cadmium Zinc Telluride Growth Process Radiation Monitoring Devices, Inc., Watertown, MA.....	45
94.	Nuclear Data Evaluation Tools Scientific Digital Visions, Inc., San Jose, CA	46
95.	Technologies for Data Evaluation and Electronic Scientific Articles Scientific Digital Visions, Inc., San Jose, CA	46
96.	Technologies to Produce Evaluated Nuclear Structure Data File-Traceable Libraries for Gamma-Ray Spectroscopy Scientific Digital Visions, Inc., San Jose, CA	47

NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

97.	Development of High Power Radio Frequency Windows for Next-Generation Superconducting and Normal Conducting Accelerators Advanced Energy Systems, Inc., Medford, NY.....	47
98.	Electromagnetically Forming a Seamless Niobium Radio Frequency Superconducting Cavity Advanced Energy Systems, Inc., Medford, NY.....	48
99.	Fabrication of Seamless Niobium Superconducting Accelerating Cavities Using Directed Light Fabrication Advanced Energy Systems, Inc., Medford, NY.....	48
100.	Superconducting Radio Frequency Photocathode Electron Gun Advanced Energy Systems, Inc., Medford, NY.....	49
101.	A 200 Kilowatt Average Power Microwave Window for L-Band Applications AMAC International, Inc., Newport News, VA	49
102.	A High Efficiency Electron Cyclotron Resonance Ion Source System for the Production of Radioactive Ion Beams Berkeley Ion Equipment, Inc., Santa Clara, CA	50
103.	Microwave Absorbing Materials for Accelerators in Cryogenic Environments Ceradyne, Inc., Costa Mesa, CA.....	50

104. A High Force Actuator for Superconducting Radio Frequency Cavity Tuning
Energen, Inc., Billerica, MA51
105. A Digital SQUID Instrument for High-Precision Particle Beam Current
Measurement
HYPRES, Inc., Elmsford, NY51

WASTE CHARACTERIZATION

106. Development and Evaluation of Modified Fujiwara Chemistry for Use with a
Cone Penetrometer
Intelligent Optical Systems, Inc., Torrance, CA52
107. Next-Generation, Portable X-Ray Fluorescence System
Photon Imaging, Inc., Northridge, CA52
108. A Multifunctional Fiber Optic Sensor for Cone Penetrometer Applications
Physical Optics Corporation, Torrance, CA53
109. An Advanced Avalanche-Photodiode Based Spectroscopic Radiation Imager
Radiation Monitoring Devices, Inc., Watertown, MA53

WASTE TREATMENT AND STABILIZATION

110. Improved Method for Fixating Sludges and Soils Contaminated with Mercury and
Other Heavy Metals
ADA Technologies, Inc., Englewood, CO54
111. Separation of Metal Ions from Liquid Waste Streams
Applied Sciences, Inc., Cedarville, OH54
112. Selective Separation of Multiple Radioactive Contaminants from Liquid Waste
Streams
Bader Engineering & Research, Inc., The Woodlands, TX55
113. Novel Fouling Resistant Ultrafiltration Membranes for Use in Separation of
Contaminants from Aqueous Waste Streams
Compact Membrane Systems, Inc., Wilmington, DE55
114. *In Situ* Remediation of Heavy Metals Using Surfactant Foams
Envirogen, Inc., Lawrenceville, NJ56
115. Enhanced Selective Leaching of Chromium from Radioactive Sludges
Lynntech, Inc., College Station, TX56

116. Resonant Shock Compaction of Low Level Waste and Low Level Mixed Waste
Resonant Shock Compaction, LLC, Denver, CO57
117. *In Situ* Removal of Cadmium and Chromium from Groundwater Using
ZeoTech Reactive Barriers
Prudent Technologies (formerly ZeoTech Corporation), Drexel Hill, PA57

TECHNOLOGY FOR TREATMENT, MANAGEMENT, AND DISPOSITION OF URANIUM HEXAFLUORIDE

118. Extraction of Fluorine from Uranium Hexafluoride for the Production of Titanium
Metal
Starmet Corporation, Concord, MA.....58
119. Production of High Value Fluorine Gases for the Semiconductor Industry
Starmet Corporation, Concord, MA.....58

ADVANCED ENVIRONMENTAL MONITORING TECHNOLOGY

120. Fiber Optic Grating-Based Moisture Sensor
Blue Road Research, Fairview, OR59
121. Development of a Fiber-Optic Sensor for Nitrate Detection
CC Technology, Inc., Sentennial, WY59
122. Novel Solid State Electrochemical Sensor
H.V. Setty Enterprises, Inc., Burnsville, MN59

ATMOSPHERIC MEASUREMENT AND SAMPLING TECHNOLOGY

123. Automated Balloon Sonde Launcher for Remote Locations
ADA Technologies, Inc., Englewood, CO.....60
124. Development of III-Nitride Ultraviolet Detectors
Avyd Devices, Inc., Costa Mesa, CA60
125. Mercury Cadmium Telluride Detectors for Near Infrared Applications
Avyd Devices, Inc., Costa Mesa, CA61
126. Optical Fiber Fluorescent Based Water Vapor Sensor
M.L. Energia, Inc., Princeton, NJ61
127. Low Temperature, High Altitude Humidity Sensor
Nanomaterials Research Corporation, Longmont, CO62

128. A Multi-Holographic Filter with a Liquid Crystal Scanner for Surface Optical Reflectance
Physical Optics Corporation, Torrance, CA62
129. Self-Calibrating Multi-Mode Filter Spectroradiometer with Measurement Applications for Column Amounts of Ozone, Nitrogen Dioxide, Sulfur Dioxide, and Aerosol Optical Depths
Research Support Instruments, Inc., Boulder, CO63
130. Low Cost Optical Moisture Sensor for Weather Balloons
Southwest Sciences, Inc., Santa Fe, NM63
131. A Cost-Effective Automatic Balloon Launcher
Visidyne, Inc., Burlington, MA63
132. A Low Cost Automated Radiosonde Launch System
Yankee Environmental Systems, Inc., Turners Falls, MA.....64

CARBON CYCLE MEASUREMENTS OF THE ATMOSPHERE AND THE BIOSPHERE

133. A Diode Laser Sensor for High Precision Measurement of Terrestrial CO₂ Sources and Sinks
Physical Sciences, Inc., Andover, MA.....64

MEDICAL APPLICATIONS

134. Rapid Processing of Positioning Information for Hand-Held Gamma Camera
PEM Technologies, Inc., Bethesda, MD.....65
135. Small Animal SPECT Camera for Quantitative Molecular Medicine
Photon Imaging, Inc., Northridge, CA.....66
136. Compact Gamma-Ray Imager for In-Vivo Gene Imaging
Spire Corporation, Bedford, MA66
137. Low-Cost, High Resolution and High Sensitivity PET Detector Modules
Tomotronics, Inc., Wayland, MA66

GENOME, STRUCTURAL BIOLOGY, AND RELATED BIOTECHNOLOGIES

138. DNA Diagnostics Using Electrical Detection
Atom Sciences, Inc., Oak Ridge, TN.....67

139.	Microarrays of Affinity Probes for the Analysis of Gene Products CombiMatrix Corporation, Burlingame, CA.....	67
140.	A Visual Data-Flow Editor Capable of Integrating Data Analysis and Database Querying CyberConnect Corporation, Storrs, CT	68
141.	Commercialization of the GRAIL EXP Gene Discovery System Genome Informatics Corporation, Oak Ridge, TN.....	68
142.	Versatile Liquid Crystal Tunable Interference Filter for Chromosome Analysis Physical Optics Corporation, Torrance, CA	69
143.	Fluorescent-Based High Throughput Protein Kinase and Phosphatase Assays SymBiotech, Inc., Wallingford, CT	69

METAL FORMING

144.	A Generic Approach to Improved Semi-Solid Forming of Metals Chesapeake Composites Corporation, New Castle, DE	70
145.	High-Strain-Rate Superplastic Forging of Aluminum Alloys Materials Modification, Inc., Fairfax, VA	70
146.	Desktop Prototyping of Metals and Alloys Nanomaterials Research Corporation, Longmont, CO	71
147.	Semi-Solid Metal Freeform Fabrication Semi-Solid Technologies, Cambridge, MA.....	71

PROCESSING FOR SURFACE HARDNESS

148.	Ultra-Hard Diamond-Like Nanocomposite Coatings for Wear Applications Advanced Refractory Technologies, Inc., Buffalo, NY.....	72
149.	Ultra-Hard Nanolayered Coatings for Wear-Resistant Applications Applied Thin Films, Inc., Evanston, IL	72
150.	Functionally Graded, Nanocrystalline, Multiphase, Boron-and-Carbon-Based Superhard Coatings Spire Corporation, Bedford, MA	73

151. Large Area Filtered Arc Deposition of Carbon and Boron Based Hard Coatings
UES, Inc., Dayton, OH73
152. Ultra-Hard Nano-Structured Diamond Thin Films Using Inductively Coupled
Plasma
UHV Technologies, Inc., Mount Laurel, NJ.....74

MATERIALS JOINING

153. Friction Stir Welding of High-Melting-Temperature Materials with the Aid of
Auxiliary Heating Sources
Engineering Mechanics Corporation of Columbus, Hilliard, OH74
154. Hermetic Reaction Bonded Silicon Carbide Tube Joints with Microwave Heating
FM Technologies, Inc., Fairfax, VA.....75
155. A Novel Solid State Joining Technique for High Thermal Conductivity
Aluminum Nitride Components
Sienna Technologies, Inc., Woodinville, WA75
156. Innovative Vanadium Alloy Joining for Fusion Reactor Applications
Surmet Corporation, Burlington, MA.....76

SUPERCONDUCTIVITY MATERIALS FOR ELECTRIC POWER

157. High Current Density in Bismuth-2223 Tape and Low AC Loss Wire
American Superconductor Corporation, Westborough, MA76
158. Low Cost Bismuth-2223 Conductors for High Temperature Superconducting
Transformers
American Superconductor Corporation, Westborough, MA77
159. Meter Length YBCO Coated Conductor Development
American Superconductor Corporation, Westborough, MA77
160. Non-Vacuum, Reel-to-Reel Processing of High-Temperature Superconducting
Coated Conductors
MicroCoating Technologies, Inc., Chamblee, GA.....78

NEUTRON INSTRUMENTATION

161. An Advanced Cold Moderator Using Solid Methane Pellets
Cryogenic Applications F, Inc., Clinton, TN.....78

162.	Supersmooth Neutron Optical Surfaces by Gas Cluster Ion Beam Processing Epion Corporation, Bellerica, MA.....	79
163.	Three-Dimensional Silicon Imaging Array for Cold Neutrons Intraspec, Inc., Oak Ridge, TN	79
164.	Solid-State Neutron Detection Materials Radiation Monitoring Devices, Inc., Watertown, MA.....	80
165.	A High-Pressure ³ He Neutron Spin Filter Science Research Laboratory, Inc., Somerville, MA.....	80

ALTERNATIVE SYNTHETIC PATHWAYS FOR ENERGY EFFICIENT AND ECONOMIC INDUSTRIAL CHEMICAL MANUFACTURE

166.	Novel Catalyst for Methane and Carbon Monoxide Conversion CeraMem Corporation, Waltham, MA	81
167.	Hydrophobic Ionic Liquid Biphasic Catalysis Covalent Associates, Inc., Woburn, MA	81
168.	Pyrolytic-Catalytic Conversion of Methane to Fullerene F. S. Lab, Belmont, MA.....	82
169.	Oxidative Coupling of Methane in a Catalytic Micro-Channel Membrane Reactor InnovaTek, Richland, WA	82

REACTIVE SEPARATIONS

170.	SiC-Based Hydrogen Selective Membranes for Catalytic Membrane Reactor Applications Media and Process Technology, Inc., Pittsburgh, PA.....	82
171.	Membrane Reactor Designs for the Production of Butadiene Membrane Technology and Research, Inc., Menlo Park, CA	83
172.	Sonic Assisted Membrane Processing for Separation of Metals from Difficult Chemical Environments Montec Associates, Inc., Butte, MT	83
173.	Partial Oxidation Reactor Based on Low-Cost Thin-Film Ceramic Membrane NexTech Materials, Ltd., Worthington, OH	84

174. Simplified, Energy Efficient, Catalytic, Reactive Distillation of
Conventional Ethylbenzene Containing Mixed Xylenes to Produce High
Purity Para-Xylene Product
Ozok Systems Incorporated, Aurora, IL84
175. Economic and Self-Sustaining Production of Saleable Products from
Waste Anions Using Phase-Transfer Catalysis
PTC Value Recovery, Mt. Laurel, NJ85

**INNOVATIVE R&D FOR ADVANCED, LOW-EMISSION, ELECTRIC AND HYBRID
VEHICLE TECHNOLOGIES**

176. Novel Non-Flammable Electrolytes for Lithium Batteries
Cape Cod Research, Inc., East Falmouth, MA86
177. Flame Retardant Electrolytes for Lithium-Ion Batteries
EIC Laboratories, Inc., Norwood, MA86
178. Diesel Emission Reduction by On-Board Fuel Reformation
Hydrogen Microplasmatron Technologies, LLC, Cambridge, MA86
179. Nonflammable Lithium-Ion Battery Electrolytes
TechDrive, Inc., Oak Brook, IL87

COMPUTATIONAL GEOSCIENCES

180. High-Resolution Seismic Imaging of Geothermal Reservoirs with
Tomo-Datuming and Migration
3DGeo Development, Inc., Mountain View, CA87
181. Imaging the Distribution of Reservoir Properties with Time
Correlations Company, Socorro, NM88
182. Irregular Grid Generation and Rapid Three-Dimensional Color Display
Algorithm
StrataMagnetic Software, LLC, Houston, TX88
183. A Geometry-Based Interactive Pre- and Post-Processor for Reservoir
Simulation and Visualization
Thunderhead Engineering Consultants, Inc. (Joint Venture), Manhattan, KS89

HIGH PERFORMANCE NETWORKS AND APPLICATIONS

184. A Differentiated Services Allocation System for the Energy Sciences
Network
Aldea Communication, Inc., Carlsbad, CA89
185. Massively Parallel, Optical Fiber to Chip Interconnect and Low Loss
Splitter for High Speed DWDM Networking, Communication and
Computing
Ionic Systems, Inc., San Jose, CA90
186. Cyberwarfare on the Electricity Infrastructure
Logobots, LLC, Chicago, IL90
187. Holographic Memory Module with Ultra-High Capacity and Throughput
MetroLaser, Inc., Irvine, CA91
188. Plug-and-Play Phase Conjugate Quantum Cryptography for Secure Private
and Public Key Distribution
Physical Optics Corporation, Torrance, CA91
189. Low Cost 10 Gigabits Per Second Optical Links for Gigabit Networks
Princeton Electronic Systems, Inc., Princeton, NJ92
190. CoWorker: An Application Server for Collaborative Work
Tech-X Corporation, Boulder, CO92
191. Real Time 30 Gigabits per Second Pattern Analyzer
Conductus, Inc., Sunnyvale, CA92

**ADVANCED SENSORS AND DATA ANALYSIS TECHNIQUES FOR NATIONAL
SECURITY APPLICATIONS**

192. Fluorescence Chemical Sensor for Chemical Warfare
ALTAIR Center, LLC., Marlborough, MA93
193. Chemosensor Array for Detecting the Proliferation of Weapons of Mass
Destruction
Intelligent Optical Systems, Inc., Torrance, CA94
194. Autofocusing Catadioptric Telescope for Lidar Applications
Logicom International, Mundelein, IL94

195.	A Hand Held Instrument Using an Array-Based Sensor for the Detection of Signatures of Weapons of Mass Destruction Lynntech, Inc., College Station, TX	95
196.	A New Detection System for Determination of Bacterial Pathogens on Contaminated Objects and People Lynntech, Inc., College Station, TX	95
197.	Compact Reflector Telescope Optra, Inc., Topsfield, MA.....	96
198.	Effluent Plume Chemical Analysis Algorithms Using Hyperspectral and Ultraspectral Data ORINCON Hawaii, Inc., Kailua, HI	96
199.	Fast Analysis of Ultraspectral Measurements of Chemical Plumes Spectral Sciences, Inc., Burlington, MA.....	97

**ADVANCED RESEARCH IN SUPPORT OF
THE COMPREHENSIVE NUCLEAR-TEST BAN TREATY**

200.	Seismic Monitoring System Calibration Using Ground Truth Database Multimax, Inc., Largo, MD.....	97
201.	Use of Multidimensional Databases and On-Line Analysis Processing for Pattern Recognition in Nuclear Explosion Monitoring Multimax, Inc., Largo, MD	98

**ADVANCED RESEARCH AND DEVELOPMENT INTO DETECTION AND
CLEARANCE TECHNOLOGIES FOR UNEXPLODED ORDNANCE**

202.	Automated Hand-Held Unexploded Ordnance Detection, Classification and Discrimination Sensor AETC, Inc., San Diego, CA.....	98
Appendix A: Alphabetical List of Awards		101
Appendix B: State List of Awards.....		111
Appendix C: Grant Application Submission and Awards Listed by States, Territories, and Possessions.....		112
Appendix D: Subject Index.....		113

BIOMASS POWER

1

Power from Farm Animals System Technology--Altex Technologies Corporation, 650 Nuttman Street, Suite 114, Santa Clara, CA 95054-2620; 408-982-2303
Dr. John T. Kelly, Principal Investigator
Dr. Mehdi Namazian, Business Official
DOE Grant No. DE-FG03-99ER82738
Amount: \$99,998

Animal wastes are an environmental problem, particularly in feed lot areas where animals are concentrated. If the wastes could be upgraded to a fuel and burned in efficient small-scale engines, high value electric power could be produced, while mitigating environmental problems. This project will develop a small-scale power generation method to pretreat and combust the animal waste, so that reliable and low cost electric power can be generated using existing engines. Preliminary economic analyses have shown that the concept will be competitive in geographical areas of interest. In Phase I, animal waste power generation opportunities will be identified and concept designs will be prepared to address those opportunities. Available test equipment will be utilized to fill in key data gaps. Test results will then be used to update the concept design and, with the support of manufacturers, an economic analysis will be performed to show feasibility. In Phase II, pilot-scale tests will be combined with economic analyses to prove viability.

Commercial Applications and Other Benefits as described by the awardee: The concept should allow for the generation of electric power from animal wastes, primarily in remote rural areas in the U.S. and abroad. Over 100 million of tons of animal wastes will be beneficially used, thereby reducing ground and water environmental problems. Also, burning of the renewable waste will reduce CO₂ greenhouse gas emissions by over 100 million tons. These substantial benefits should be accomplished at a competitive cost.

2

Cost-Effective, Clean and Modular Biomass Power System for the Utilization of Farm Animal Waste--Manufacturing and Technology Conversion International, Inc., 6001 Chemical Road, Baltimore, MD 21226; 410-354-0420
Dr. Ravi R. Chandran, Principal Investigator
Dr. Momtaz N. Mansour, Business Official
DOE Grant No. DE-FG02-99ER82822
Amount: \$99,997

The intensive production of poultry and livestock (e.g., billions of chickens and millions of cattle and pigs annually in the United States) has increased manure generation, causing concern for human health and safety, endangering aquatic plant and animal populations, and affecting soil fertility. Concurrently, the demand for cost-effective, modular, small scale (10 KW_e to 5 MW_e) biomass power systems is rising worldwide. This project will configure, develop, and test an integrated pulse-enhanced steam reformer/fuel cell system to recover nutrients and energy from farm animal waste in a cost effective and environmentally benign manner. Phase I will generate fundamental test data that will help establish the technical and engineering feasibility of the integrated biomass power system for cost effective, clean, and modular power generation from farm animal waste.

Commercial Applications and Other Benefits as described by the awardee: The commercial application of this technology will help solve the animal waste disposal problem, generate green power, improve public health, protect the environment, recycle nutrients, create jobs in the U.S., generate additional tax revenue, and enhance export of American technology.

Processing and Drying of Biomass Residue for Feedstock to a Dedicated Cogeneration Facility--Reaction Engineering International, 77 West 200 South, Suite 210, Salt Lake City, UT 84101-1609; 801-364-6925

Dr. N. Stanley Harding, Principal Investigator
Dr. Michael P. Heap, Business Official
DOE Grant No. DE-FG03-99ER82871
Amount: \$100,000

Biomass residue streams from biomass-to-ethanol processes have very high moisture contents and must be dried to efficiently utilize their energy. In this project, the heat from the catalyst regeneration and steam production is used to partially dry these residues, rendering them useful in a dedicated cogeneration fluidized bed boiler. The reduced-moisture streams would then be suitable as a boiler feedstock for a dedicated biomass residue-fired boiler, producing steam that would supply the process and/or be used to generate electricity. In Phase I, biomass residues, will be prepared, analyzed and dried. Combustion tests in a laboratory-scale fluidized-bed combustion unit will be carried out on the dried samples. A complete engineering analysis of the process will be performed to determine overall process feasibility.

Commercial Applications and Other Benefits as described by the awardee: Economic drying of biomass residues is critical to the success of many biomass processes including biomass-to-ethanol. This technology should provide an economic method of utilizing biomass residue streams to generate process steam and electricity.

The Development of a Modular System to Burn Farm Animal Waste to Generate Heat and Power--Spinheat Limited, 1222 Bronson Road, Fairfield, CT 06430-2824; 203-259-6101
Mr. Michael J. Virr, Principal Investigator
Mr. Michael J. Virr, Business Official
DOE Grant No. DE-FG02-99ER82890
Amount: \$99,940

This project will develop a range of modular systems to economically convert farm animal wastes to heat and electric power using a new packaged fluid bed boiler and micro-turbine. The Internally Circulating Fluid Bed (ICFB) boiler minimizes emissions and ensures maximum efficiency, thus eliminating the dumping of animal wastes on the ground with the attendant chance of contaminating ground water. The complete system will utilize distributive control for unattended operation. Phase I will focus on the design of an integrated system. Preliminary fuel tests will be conducted to establish material and energy balances. A preliminary market and resource assessment will be performed, along with initial estimates of costs and environmental emissions/benefits. Ultimately, animal wastes, such as poultry litter, will be burned in a packaged ICFB coupled to a new packaged back-pressure micro-turbine.

Commercial Applications and Other Benefits as described by the awardee: Packaged ICFB boilers and micro-turbines should be sold to farmers, poultry producers, and similar industry waste generators, to save heat and power costs.

HIGH-TEMPERATURE ELECTRONICS FOR GEOTHERMAL DRILLING

High-Temperature Oscillator and Digital Clock--Linear Measurements, Inc., 4174 Sorento Valley Boulevard, San Diego, CA 92121-1483; 619-535-2172

Mr. Harper J. Whitehouse, Principal Investigator
Mr. Robert Hatch, Business Official
DOE Grant No. DE-FG03-99ER82812
Amount: \$97,762

The Department of Energy and the renewable energy industry need electronic devices and sensors to control and optimize the drilling of geothermal wells. This project will develop a high-temperature oscillator and digital clock to provide the precision timing required to control other components and subsystems in such high temperature systems as measurement-while-drilling (MWD), logging-while-drilling (LWD), and data telemetry. The frequency of these instruments will be accurate to ± 500 ppm between 1-12 MHz at temperatures from 20°C to greater than 300°C. The high-temperature oscillator and digital clock will utilize a surface acoustic wave (SAW) device in which a pair of metal transducers operates on a piezoelectric crystal substrate. An electronic amplifier connected to one transducer generates an acoustic surface wave that propagates along the surface to the second transducer where the acoustic wave is converted into an electrical signal and fed back to first transducer. The analog electrical signal from the surface acoustic wave oscillator will be electronically converted to a digital clock signal. In Phase I, different crystals will be analyzed to determine their suitability for use as high-temperature SAW substrates. Experimental SAW crystal oscillators and digital clock circuits will be constructed and tested to determine how well they meet the accuracy requirements for temperature and frequency.

Commercial Applications and Other Benefits as described by the awardee: In addition to geothermal well drilling and logging, the high-temperature digital clock should have applications in the petroleum, automotive, nuclear power plant, and aerospace industries. Applications include aircraft piston, jet engine, and automobile engine control, as well as nuclear power plant safety.

6

A Novel Potentiometric Pressure Sensor with a Temperature-Independent Signal for Geothermal Drilling--Materials and Systems Research, Inc., 1473 South Pioneer Road,

Suite B, Salt Lake City, UT 84104-4135;
801-973-1199

Dr. Jan-Fong Jue, Principal Investigator
Dr. Anil V. Virkar, Business Official
DOE Grant No. DE-FG03-99ER82824
Amount: \$99,958

State-of-the art pressure sensors for geothermal drilling suffer from the following shortcomings: a power source is required; the signal is temperature-dependent, and the temperature range is narrow. This project will develop an electrochemical, potentiometric pressure sensor that does not require a power source, has a temperature-independent signal, and can be used at temperatures over 400°C, possibly even higher. When pressure is applied to the sensor, a millivolt signal is created, but because the sensor is not piezoelectric, the signal can be amplified using techniques from the microelectronics industry. In addition, the sensor can be miniaturized. In Phase I, the active element of the sensor will be fabricated and the sensor's functionality will be demonstrated from room temperature to over 400°C, over a wide pressure range. This will demonstrate that the signal is both temperature-independent and linear. Two approaches will be used to amplify the signal up to 100 times: mechanical amplification, and electrical amplification. In Phase II, photomicrolithographic techniques will be used to amplify the signal a thousand times. Miniaturized yet rugged sensors will be demonstrated in geothermal drilling operations.

Commercial Applications and Other Benefits as described by the awardee: Commercial applications for these low-cost pressure sensors include: geothermal drilling, oil drilling, monitoring pressure in chemical reactors, aviation, the automotive industry, and the measurement and monitoring of pressure in any high temperature (up to 700°C) application.

7

Capacitors for Extreme Temperature Applications--Sigma Technologies International, Inc., 10960 N. Stallard Place, Tucson, AZ 85737; 520-575-8013

Dr. Angelo Yializis, Principal Investigator
Dr. Angelo Yializis, Business Official
DOE Grant No. DE-FG03-99ER82884
Amount: \$100,000

There is a need to develop high temperature electronic components that can withstand the harsh environment of geothermal well drilling. The development of state-of-the-art polymer/metal capacitors would introduce major improvements to high temperature scalable, on-the-spot, information systems associated with well drilling, data telemetry, and process control. This project will use high-rate vacuum based polymer/metal multilayer (PML) technology to fabricate solvent free, low cost, light weight, high temperature capacitors. Phase I will establish proof-of-concept for the manufacture of PML capacitors composed of thousands of high temperature polymer dielectric layers separated with self-healing metal electrodes. Polymer material screening will first be performed with single layer capacitors, and then candidate polymers will be used to produce multilayer capacitors with ratings of 25 - 100 VDC, 10-100 micro Farads, and 250-300°C.

Commercial Applications and Other Benefits as described by the awardee: The PML capacitors should find uses in the high temperature capacitor and sensor market sectors, including deep geothermal wells, power electronic applications for aircraft, automotive, and specialty instrumentation.

8

A High Temperature Microelectromechanical Inclination Sensor for Geothermal Drilling--
Silicon Designs, Inc., 1445 NW Mall Street,
Issaquah, WA 98027; 425-391-8329

Mr. John C. Cole, Principal Investigator
Mr. John C. Cole, Business Official
DOE Grant No. DE-FG03-99ER82885
Amount: \$100,000

Directional drilling, commonly used in oil and gas production, uses magnetometers and inclination sensors to measure the azimuth and inclination of the drill bit. However, for geothermal wells, the drilling equipment must be capable of operating at much higher temperatures than for oil and gas, i.e., up to 300°C. No miniature inclination sensor is now available to accurately measure the direction of earth gravity at such temperatures. This project will develop a family of high temperature accelerometers for measuring inclination and vibration at operating temperatures up to 300°C. With these accelerometers and other digital components, temperature-compensated inclination sensor units will be built for geothermal drilling. Phase I consists of designing a sensor-interface integrated circuit in a high temperature Complementary Metal-Oxide Semiconductor process, evaluating and improving the stability of miniature sense elements when exposed to high temperatures, identifying suitable packaging methods, and designing a high temperature calibration system.

Commercial Applications and Other Benefits as described by the awardee: The high temperature accelerometers and inclination sensors would be available to producers of directional drilling equipment for geothermal and oil and gas drilling. They also should be useful in other high temperature industrial applications, as well as in space and military applications where high radiation dose rates are present.

ADVANCED MEASUREMENT AND CONTROL TECHNOLOGIES FOR INDUSTRIAL MANUFACTURING APPLICATIONS

9

New Optical Coupling of Infrared Analyzers to Industrial Processes--Advanced Fuel Research, Inc., 87 Church Street, P.O. Box 380379, East Hartford, CT 06108-3742; 860-528-9806

Mr. James R. Markham, Principal Investigator
Dr. Michael A. Serio, Business Official
DOE Grant No. DE-FG02-99ER82729
Amount: \$99,966

Energy-intensive and waste-intensive industries in the U.S. could become more efficient with improved measurement and control technology. However, the harsh environments in these industries have made it difficult to take advantage of advanced optical sensors for in-process use. In addition, it is well known that although monitoring the infrared electromagnetic spectrum can provide important information on process streams, much of this information can not be relayed to the new sensors by standard fiber optics. This project will develop advanced optical coupling technology that does relay the important information while still being rugged, flexible, and easy to install. In Phase I, the advanced optical coupling technology will be tested in laboratory experiments that simulate harsh industrial processes. Discussions will be conducted with industry representatives to identify target field-test locations for in-process measurements in Phase II.

Commercial Applications and Other Benefits as described by the awardee: The improved in-process sensors should be particularly applicable to the large combustion market. The industrial boiler market itself exceeds 50,000 installed units in the U.S., and the process heating market has an additional 25,000 installed units.

10

Fiber Optic Sensor for Industrial Process Measurement and Control--MetroLaser, Inc., 18010 Skypark Circle, Suite 100, Irvine, CA 92614-6428; 949-553-0688

Dr. Jeffrey Segall, Principal Investigator
Dr. Cecil F. Hess, Business Official
DOE Grant No. DE-FG03-99ER82828
Amount: \$99,991

An increasingly competitive global marketplace requires energy- and waste-intensive industries to improve efficiency while also generating fewer pollutants and other wastes. Achieving the necessary improvements requires improved in-process chemical sensor technology that will provide faster and more accurate measurements of key parameters. Existing monitoring instrumentation is either difficult to use, expensive, or has insufficient time response. This project will develop advanced diode laser-based fiber optic sensors for direct, rapid, and quantitative measurement of gaseous species and temperature in industrial processes. In Phase I, computational simulations of conditions in industrial processes will be performed to determine appropriate measurement conditions. A breadboard diode laser-based chemical sensor system will be developed and demonstrated in laboratory conditions designed to replicate the industrial process environment.

Commercial Applications and Other Benefits as described by the awardee: These fiber optic chemical sensors should be attractive in industrial applications where conventional monitoring systems are either large, expensive, slow, or not versatile enough. The sensors should significantly improve process and energy efficiency and reduce emissions of unwanted pollutants and greenhouse gases. Particular applications include the forest products, glass, aluminum, and chemical industries.

High Temperature Micromachined Sensor for Industrial Gas Streams--Nanomaterials Research Corporation, 2620 Trade Center Avenue, Longmont, CO 80503-7551; 303-702-1672

Dr. Dmitri Routkevich, Principal Investigator
Ms. Molly M. W. Kostecky, Business Official
DOE Grant No. DE-FG03-99ER82842
Amount: \$100,000

The energy industry, along with such waste-intensive industries as pulp and paper, primary metals, chemicals, and glass have been targeted by the Department of Energy for improvements in resource efficiency and competitiveness, as well as for minimizing the generation of waste and pollutants. Advanced sensor technologies addressing such generic needs as reliability and robustness in harsh environments, miniaturization, sensitivity, and selectivity are significant components of this mission. This project will develop new high-temperature microsensors for the real-time monitoring of industrial gas streams in harsh conditions. The approach is based on a micromachined nanoporous ceramic with high thermal, mechanical, and chemical stability. The sensitive material will be deposited inside a self-organized network of nanoscale pores, and will offer the potential for higher precision, better accuracy, and longer lifetime. The process would allow for economic production in bulk quantities. Phase I will establish the proof-of-concept that high temperature gas microsensors from chemically modified nanoporous ceramic have increased reliability, sensitivity, selectivity, and stability in the harsh environments of industrial gas streams. The concept will be evaluated by using a prototype resistive oxygen microsensor.

Commercial Applications and Other Benefits as described by the awardee: Any application requiring low cost, low power, reliable, durable, sensitive, and selective microsensor for real-time gas monitoring should benefit including the chemical, steel, and glass industries. The sensors could also be used for boiler furnaces,

internal combustion engines, systems for reducing cold start pollution, and in emission testing stations.

Real-Time Gas Composition Analyzers for On-Line Process Control--Nanomaterials Research Corporation, 2620 Trade Center Avenue, Longmont, CO 80503-7551; 303-702-1672

Dr. Chuanjing Xu, Principal Investigator
Ms. Molly M. W. Kostecky, Business Official
DOE Grant No. DE-FG03-99ER82843
Amount: \$100,000

Instruments are needed to increase the energy efficiency and optimum operation of processes in the steel, aluminum, metal casting, glass, and chemical industries. Real-time, on-line, gas composition analyzers would be a candidate technology, but state-of-the-art gas analyzers are very expensive, poor in reliability, and not suitable for demanding environments. This project will develop gas composition analyzers that cost almost 100-fold less and offer reliable, stable, and rapid response in demanding environments. The approach is to develop miniature gas composition sensors from proprietary materials that can withstand demanding environments. Phase I will produce prototype sensors, characterize them, and test them to establish the proof-of-concept.

Commercial Applications and Other Benefits as described by the awardee: Reliable, real-time gas composition analyzers should save over \$250 million per year in energy costs in the steel, aluminum, metal casting, glass, and chemical industries. They can also increase product yield and prevent pollution. As an illustration, it is estimated that in the U.S. glass industry alone, product yields can be increased by over \$100 million per year with real-time analyzers.

Portable Parallel Beam X-Ray Diffraction System for In-Line Process Control in the Steel Industry--X-Ray Optical Systems, Inc., 30 Corporate Circle, Albany, NY 12203; 518-464-3334

Dr. Michael Haller, Principal Investigator
Mr. David Usher, Business Official
DOE Grant No. DE-FG02-99ER82918
Amount: \$99,861

In-line process control is a vital method for improving and assuring product quality, maximizing process efficiency, and minimizing waste generation in many manufacturing industries, including the steel industry. X-ray diffraction, one of the most versatile analytical tools available, could provide valuable contributions. However, its use has essentially been confined to the laboratory environment because current techniques require prepared samples and the equipment is not suitable for use in a harsh manufacturing environment. This project will develop a parallel beam, x-ray diffractometer for in-line monitoring of phase,

grain size, grain orientation, and residual stress. No sample preparation will be required, and the data quality will not be affected by sample vibration or roughness. Polycapillary x-ray optics will collect x-rays over a large solid angle from a low-power x-ray source and form an intense parallel beam. During Phase I, an existing compact, low-power, bread-board, x-ray diffraction unit will be modified to evaluate a specific microstructure condition, which is important in slab steel rolling and finishing. Actual steel samples will then be evaluated in the laboratory. The quality of the data and the ability of the system to operate reliably in the relevant manufacturing environment will also be evaluated.

Commercial Applications and Other Benefits as described by the awardee: Currently x-ray diffraction is used off-line to provide critical feedback to manufacturing. Continuous, in-line monitoring of material properties using x-ray diffraction should improve yield, decrease power requirements, and improve quality for a wide range of industries including steel, aluminum, cement, and pharmaceuticals.

HYBRID ELECTRIC VEHICLE TECHNOLOGY

N Type Quantum Well Films and Devices--Hi-Z Technology, Inc., 7606 Miramar Road, Suite 7400, San Diego, CA 92126-4202; 619-695-6660

Dr. Saeid Ghamaty, Principal Investigator
Mr. Norbert Elsner, Business Official
DOE Grant No. DE-FG03-99ER82798
Amount: \$100,000

Quantum well films may more than double the efficiency of present thermoelectric modules used in remote power supplies and for converting waste heat into electricity. Two-dimensional quantum wells have been synthesized by alternating layers of B_4C and B_9C . Such nanostructures are being investigated as candidate thermoelectric materials with high

figures of merit (Z). In this project, new compounds will be investigated to develop N-type quantum well films to mate with the P-type B_4C/B_9C films. This combination will dramatically increase the device efficiency of the thermoelectric at temperatures of $300^\circ C$ or more. The Phase I project will identify a number of potential compounds (quantum wells with barrier materials) that can be used with B_4C/B_9C alloys. The B_4C/B_9C films will be modeled for their thermoelectric transport properties to help find a N-type equivalent material. Based on known data, Si/SiC and $NdSe_{1.45}/NdSe_{1.50}$ are candidate quantum well materials that should exhibit favorable properties. Phase II will develop the films into the N-leg of a uniconouple to mate with the P-type B_4C/B_9C quantum wells and a power module.

Commercial Applications and Other Benefits as described by the awardee: The anticipated large increase in thermoelectric performance should lower the cost/watt by half and open up many more commercial opportunities for recovering waste heat from vehicles, furnaces, incinerators, fuel cells, etc.

15

Thermoelectric Quantum Well Device--Hi-Z Technology, Inc., 7606 Miramar Road, Suite 7400, San Diego, CA 92126-4202; 619-695-6660

Dr. Saeid Ghamaty, Principal Investigator
Mr. Norbert Elsner, Business Official
DOE Grant No. DE-FG03-99ER82797
Amount: \$100,000

Quantum well devices have the potential to more than double the efficiency of present thermoelectric devices used in remote power supplies and for converting waste heat into electricity. Over the past five years, it has been shown that very large improvements in the figure-of-merit (Z) of thermoelectric (TE) materials appear feasible with multi-layer quantum well (QW) films, but no device has been fabricated with QW materials. QW TE films are very thin multi-layers of B_4C/B_5C or $Si/SiGe$ ceramics; each layer is approximately 100Å thick, on a substrate (typically Si). To create a QW TE device, the films have to be fabricated with many layers. Although the substrate is a thermal short, it is needed for mechanical support. Therefore, the challenge is to maximize the ratio of film-to-substrate thickness. The Phase I project will fabricate very thick ($>10\mu$) P type B_4C/B_5C , or N and P type $Si/SiGe$, on a very thin Si substrate ($\sim 5\mu$), and then connect them in series to make multi-couple power or cooling devices.

Commercial Applications and Other Benefits as described by the awardee: The anticipated large increase in thermoelectric performance should lower the cost per watt by half and open up many more commercial opportunities for recovering waste heat from vehicles, furnaces, incinerators, fuel cells, etc.

16

High-Temperature Tolerant Automotive Switched-Reluctance Motor--SatCon Technology Corporation, 161 First Street, Cambridge, MA 02142-1228; 617-661-0540
Dr. Mouhoub Mekhiche, Principal Investigator
Dr. James L. Kirtley, Jr., Business Official
DOE Grant No. DE-FG02-99ER82877
Amount: \$99,934

Substantial motor power density improvements are needed to meet Partnership for a New Generation of Vehicles (PNGV) goals, which is ultimately an economically viable eighty-mile-per-gallon hybrid electric vehicle for the automotive industry. Switch reluctance motors (SRM) offer reasonably high efficiency over a variable power and speed range at low cost. This project will develop a SRM with an innovative high temperature coil that would increase power density and reduce cost per kilowatt. By increasing the maximum allowable motor temperature, the power output can be increased while the amount of required magnetic material decreases. Thus the overall weight and the associated material cost are reduced, for a given power output. Phase I will design and develop a high temperature 50 kW switch reluctance traction motor using a high temperature coil that was previously developed for high temperature (1200°F) magnetic bearings. The major technical challenges are motor integration, manufacturing for cost, and rotor cooling. Prototype construction and testing is planned for Phase II.

Commercial Applications and Other Benefits as described by the awardee: A high temperature SRM should result in higher power density, lower cost traction motors, thereby contributing to PNGV goals and the production of a commercially viable electric and/or hybrid-electric vehicle. Other applications include high-power industrial drives, turbo-alternators, and other power-dense machines. Further, the technology is applicable to other power-dense equipment such as power electronics.

Improved Rotor Cooling for Permanent Magnet Machines--Unique Mobility, Inc., 425 Corporate Circle, Golden, CO 80401-5635; 303-278-2002

Mr. Jon F. Lutz, Principal Investigator
Mr. Donald A. French, Business Official
DOE Grant No. DE-FG03-99ER82914
Amount: \$99,711

Electric drive motors for hybrid electric vehicles require improvements in cost reduction and power density. In particular, the brushless permanent magnet (PM) motor, which has thus far demonstrated superior performance, requires improvements in both cost-effectiveness and packaging. This project will improve the rotor cooling of a brushless PM motor by utilizing an innovative self-cooling concept. This cooling method not only will reduce the cost of the permanent magnets, but also will reduce the size of the motor for a given power rating. During Phase I, several designs for the cooling concept will be analyzed using computational fluid dynamics and thermal finite-element analysis models. The most effective designs will be determined and an existing permanent magnet will be modified accordingly and tested.

Commercial Application and Other Benefits as described by the awardee: As the power source for hybrid electric vehicles improves, the drive motors are being asked to handle more power without overheating or becoming larger in size. This technology should improve the power rating of electric motors without increasing size and reduce the cost of the motor due to lower cost permanent magnets.

Meeting Motor Cost and Performance Goals Through Integration and Thermal Management--Visual Computing Systems Corporation, 9540 Highway 150, P.O. Box 250, Greenville, IN 47124-0250; 812-923-7474

Mr. Roy L. Kessinger, Principal Investigator
Mr. Robert J. Westerkamp, Business Official
DOE Grant No. DE-FG02-99ER82917
Amount: \$100,000

Advances in electric motors are needed to meet joint program goals for electric and hybrid electric vehicle power trains. However, conventional methods for increasing motor power density lead to difficult cooling requirements and increased cost. In addition, conventional cost-reduction methods lead to reduced motor performance. This project will develop highly integrated, motor and electronic modules that will allow for the optimization of electromagnetic, thermal, structural and control design parameters. This systems approach will provide required motor performance while minimizing cost through high-volume production processes. Phase I will begin with experiments and research for reducing the size, weight, and cost of motor/electronic modules. Existing computer models for vehicles, motors, and electronics will be expanded to predict system performance as various sub-systems become integrated. Emphasis will be placed on the evaluation of advanced thermal management techniques within the integrated motor modules.

Commercial Applications and Other Benefits as described by the awardee: Affordable, high performance electric motor modules should be provided for vehicles and for industrial and military applications.

SYSTEMS AND PRODUCTS FOR PASSIVE SOLAR LOW ENERGY BUILDINGS

19

Passive Desiccant Air Conditioners--AIL Research, Inc., P.O. Box 3662, 50 Washington Road, Princeton, NJ 08543; 609-452-2950
Mr. Jeffrey A. Miller, Principal Investigator
Dr. Andrew Lowenstein, Business Official
DOE Grant No. DE-FG02-99ER82735
Amount: \$99,662

Passive cooling systems, which have the potential to greatly reduce the energy needed to maintain comfortable conditions in buildings, have very limited applications. One limiting factor is their inability to serve latent loads. This project will apply new technology, recently developed for liquid-desiccant air conditioners, to passive cooling systems. In Phase I, computer modeling will be used to identify practical configurations of the novel cooling system. Modules that calculate the performance of a liquid-desiccant system will be developed for a building simulation code that is now in common use. A passive desiccant air conditioner will then be designed and its benefits determined by simulating its performance on several buildings in different geographical locations. Commercial feasibility will be assessed. In Phase II, an actual system will be built and tested.

Commercial Applications and Other Benefits as described by the awardee: The passive desiccant cooling system should save energy when applied to both residences and commercial buildings. It can be used on both low-energy and conventional buildings.

20

Intercalated Phosphonate-Clay Composites as Latent Heat Storage Materials for Masonry--Cape Cod Research, Inc., 19 Research Road, East Falmouth, MA 02536-4440; 508-540-4400

Dr. Brian G. Dixon, Principal Investigator
Ms. Katherine D. Finnegan, Business Official
DOE Grant No. DE-FG02-99ER82757
Amount: \$100,000

Effective utilization of thermal storage in a passive solar low-energy building can significantly improve the building's energy performance and comfort. Traditional building materials are economical, functional, and insulative; however, they do not possess the capability of reversibly storing heat. This project will develop low cost masonry materials with enhanced heat storage capabilities. Practical clay-alkylphosphonate compositions, which undergo energetic and reversible solid-solid state energy storage transitions, will be examined. The desirable properties of high latent heat storage capacity will result in materials that can be readily used as state-of-the-art masonry materials, such as wallboard. Phase I will involve the synthesis of alkyl phosphonates, followed by intercalation within clays. Heat storage evaluations will also be conducted.

Commercial Applications and Other Benefits as described by the awardee: The technology should allow present masonry materials to be replaced with improved products.

21

Fiber-Reinforced, Polymer-Composite Building Panels Capable of Energy Storage Through High Enthalpy Solid-State Phase Transition--DPD, Inc., 2000 Turner Street, Lansing, MI 48906-4053; 517-349-5653
Dr. Habibur Chowdhury, Principal Investigator
Ms. Farangis Jamzadeh, Business Official
DOE Grant No. DE-FG02-99ER82780
Amount: \$100,000

Heat storage is an important factor in passive use of solar energy. However, the common practice of sensible heat storage in thermal mass

is inefficient, and the corresponding temperature variations damage comfort. There are also structural limitations on use of massive building elements. Latent heat storage in phase-change materials would be an alternative technology, but it is limited because of its reliance on the solid-to-liquid phase transition, which requires containment of the liquid phase and the addition of new building elements. This project will identify polymers that provide solid-to-liquid phase transition and process them into fiber-reinforced composite panels. These lightweight panels will act as both sheathing and heat storage elements. Phase I will select polymers with high-enthalpy, solid-state phase transition, develop fiber-reinforced composites with the selected polymers for use in building panels with high heat storage capacity, determine the impact of the new sheathing panels on energy performance and cost, and assess the commercial prospects of the technology.

Commercial Applications and Other Benefits as described by the awardee: The new lightweight sheathing panels should be compatible with mainstream construction and retrofit practices, and allow for substantial heat storage at constant temperature. They should significantly improve the energy performance of buildings without sacrificing comfort or adding extra elements to the building.

22

SunGuard: A Roofing Tile for Natural Cooling--PowerLight Corporation, 2954 San Pablo Avenue, Berkeley, CA 94710; 510-540-0550

Mr. Thomas L. Dinwoodie, Principal Investigator

Mr. Thomas L. Dinwoodie, Business Official

DOE Grant No. DE-FG03-99ER82862

Amount: \$100,000

Maintaining a cool roof deck can significantly reduce air conditioning costs in cooling-dominated climates while reducing humidity build-up and other moisture problems within the home. A preferred method of cooling roof decks is by natural convection, which should have

wide market acceptance for residential applications. This project will develop novel residential roofing technology that accomplishes significant roof deck temperature reduction through strictly passive means. The technology integrates cooling load avoidance and humidity removal to reduce building cooling loads. Phase I will optimize product construction and validate product performance under full-scale system testing. A system prototype will be constructed for *in situ* testing at the Florida Solar Energy Center's Flexible Roof Facility.

Commercial Applications and Other Benefits as described by the awardee: The passive cooling technology targets residential roofing for roof slopes of 2:12 and higher, representing 77 percent of the residential roofing market. Assuming 5 percent market penetration, the U.S. would save over 35 million barrels of oil per year, with annual environmental reductions of 18.6 million tons of CO₂, 80 kilotons of NO_x and 178 kilotons of SO_x.

23

Evaluation of Integrated Wall Systems Incorporating Electrochromic Windows--

SAGE Electrochromics, Inc., 2150 Airport Drive, Faribault, MN 55021; 507-333-0078

Dr. Neil Sbar, Principal Investigator

Mr. Kenneth Ney, Business Official

DOE Grant No. DE-FG02-99ER82875

Amount: \$100,000

In the U.S., billions of dollars are spent annually on energy lost through the use of inefficient windows. Even wall systems with high performance static glazings and moveable shading devices are not optimal because they can't effectively respond to changing solar and environmental conditions. In this project, electrochromic (EC) glazings and other advanced technologies will be incorporated into building wall systems for improved energy efficiency, daylighting, and environmental benefits. In Phase I, the energy saving performance of fully dynamic wall systems containing EC windows will be compared with that of conventional systems. The unique

optical and thermal properties of the EC window will be measured (using a statistical sample), and the data will be input into a computer model. Total costs for the different integrated building scenarios will be calculated over the expected lifetime of the window/wall systems. In Phase II, the best system options will be installed and tested in a demonstration site.

Commercial Applications and Other Benefits as described by the awardee: Advanced wall

systems containing EC windows could be incorporated into a wide range of residential and commercial window products. The estimated annual reduction in energy use could exceed \$6 billion if EC captures just 10 percent of the market. There should also be significant reductions in peak demand, AC capacity, building operating costs, and pollutants from the burning of fossil fuels.

COAL/GAS POWER SYSTEMS

24

Cost-Saving Alternative for Stack Reformer Packaging in Tubular Solid Oxide Fuel Cells-- Blasch Precision Ceramics, Inc., 580 Broadway, Albany, NY 12204-2802; 518-436-1263
Mr. David A. Larsen, Principal Investigator
Mr. David W. Bobrek, Business Official
DOE Grant No. DE-FG02-99ER82752
Amount: \$99,983

Solid oxide fuel cells are a very efficient and clean method of power generation, but to be commercially viable, significant cost reduction is necessary to reduce the cost of power generated. The stack reformer packaging in tubular solid oxide fuel cells is expensive because it is comprised of machined high alumina ceramic fiber board, costing over \$88,000 for a 100 kilowatt unit. This project will replace the current machined fiber board with a much more economical ceramic particulate material, and utilize unique ceramic technology to form the new ceramic into the appropriate shapes. Phase I will develop a fine-grained ceramic particulate-based material that is then formed with a unique process into an economical prototype outer-stack-reformer board shape for tubular solid oxide fuel cells. This ceramic material will be designed to meet required chemical purity (no crystalline silica), strength, and thermal properties.

Commercial Applications and Other Benefits as described by the awardee: The commercial application is in tubular solid oxide fuel cells. The major benefit is cost savings, since the cost of currently used, machined ceramic fiber boards is >\$88,000 per 100 kilowatt fuel cell unit. Savings of at least \$55,000 (65 percent) should be attained with ceramic particulate-based shapes, resulting in reduction of the cost of power generated.

25

Novel Backup Filter Device for Candle Filters--CeraMem Corporation, 12 Clematis Avenue, Waltham, MA 02154-7011; 781-899-4495
Dr. Bruce A. Bishop, Principal Investigator
Mr. Robert L. Goldsmith, Business Official
DOE Grant No. DE-FG02-99ER82760
Amount: \$100,000

Hot gas particulate removal is required for advanced coal conversion process systems to protect downstream equipment such as turbines, catalyst beds and fuel cells. The currently preferred means of particulate removal is filtration with candle filters. However, candle filters have not shown the reliability necessary to be commercially viable. This project will develop a simple backup filter for candle filters which will protect downstream equipment in case of candle failure. In Phase I, a prototype

device will be developed and tested. Initial tests will be made under ambient conditions; subsequently, tests will be performed at elevated temperature and pressure.

Commercial Applications and Other Benefits as described by the awardee: Successful development of the backup filter device should resolve a problem which limits commercialization of the two most advanced coal conversion processes.

26

Abatement of Filter Corrosion and Plugging in Integrated Gasification Combined-Cycle Systems--Microbeam Technologies, Inc., 1521 24th Avenue, South, Suite B-2, P.O. Box 14758, Grand Forks, ND 58201-6736; 701-772-4482
Dr. Steven A. Benson, Principal Investigator
Ms. Roxanne Benson, Business Official
DOE Grant No. DE-FG03-99ER82829
Amount: \$99,956

Pluggage of gas filters is a major problem in the Integrated Gasification Combined-Cycle system, a process that produces synthesis gas from coal. The pluggage is caused by deposition of trace elements and other inorganic residues originating from the fuel used to operate the system. This decreases reliability and increases operation and maintenance costs. This project will test sorbents that have the potential to capture vaporized chemical species in a form that can be removed from the Integrated Gasification Combined-Cycle system. The captured materials would thus be prevented from depositing in the gas filters. The Phase I project will test several sorbents for their ability to capture vaporized trace inorganic species in a simulated gasification atmosphere. The form and stability of the sorbed product will be assessed to ascertain the most effective means of removal from gasifier.

Commercial Applications and Other Benefits as described by the awardee: This trace-element sorbent technology should apply to advanced coal gasification cleanup systems to increase

overall system reliability and decrease operation and maintenance costs.

27

Ion-Conducting Oxide Ceramic Materials for Solid-Oxide Fuel Cells Using Novel Low Cost Combustion Chemical Vapor Deposition--MicroCoating Technologies, Inc., 3901 Green Industrial Way, Chamblee, GA 30341; 770-457-8400

Dr. Girish N. Deshpande, Principal Investigator
Mr. Jerome J. Schmitt, Business Official
DOE Grant No. DE-FG02-99ER82830
Amount: \$100,000

In comparison to conventional methods of energy production, the solid oxide fuel cell (SOFC) offers higher energy conversion efficiency, compact design, and lower production of pollutants. However, for the existing thin-film SOFC processes, the expense of the required chemical precursors and equipment is high. Widespread commercialization will require a fabrication process to deposit low-cost, high-quality SOFC thin films without complex post-deposition treatment/sintering. This project will develop a Combustion Chemical Vapor Deposition (CCVD) process to fabricate the solid-oxide fuel cell by depositing high quality, dense, thin layers of ionic-conducting oxide ceramic membrane electrolyte onto porous substrates. The resulting thin film will be pinhole-free and gas-tight, and will have high oxygen transport rates. Fuel cells with power density greater than 2 W/cm² will be demonstrated. Phase I will develop a prototype CCVD system for producing the thin, supported SOFC membrane electrolyte. Coupon-sized ionic conducting membrane electrolyte samples will be prepared and tested for ionic conductivity using complex impedance analysis. A small high-temperature test fuel cell will be to measure specimen performance.

Commercial Applications and Other Benefits as described by the awardee: The new fuel cell electrolyte materials should improve fabrication,

efficiencies, transport rates, and lifetimes while lowering overall costs to dramatically enhance the widespread use of fuel cells in the commercial sector. Successful development should result in vehicles that achieve three times better fuel economy and emit practically no pollution.

28

Cathode-Supported Thin-Film Solid Oxide Cells with Low Operating Temperatures--

NexTech Materials, Ltd., 720-I Lakeview Plaza
Boulevard, Worthington, OH 43085-4733;
614-842-6608

Dr. Scott L. Swartz, Principal Investigator

Mr. William J. Dawson, Business Official

DOE Grant No. DE-FG02-99ER82844

Amount: \$100,000

Solid oxide fuel cell systems with very high power generation efficiencies (>80 percent) are possible by combining fuel cell stacks that operate at low temperatures with existing high-temperature fuel cell stacks. However, in order to achieve low operating temperatures, solid oxide fuel cells with very thin electrolyte membranes are required. This project will develop low-cost manufacturing methods for solid oxide fuel cells comprising thin zirconia electrolyte films supported on porous lanthanum manganite cathode substrates. High power densities at low operating temperatures (700°C) will be demonstrated, technology for incorporating the planar thin-film fuel cell elements into stacks will be developed, and planar stacks of cathode-supported thin-film fuel cells will be produced. In Phase I, novel powder processing and fabrication methods will be used to improve the mechanical properties and to control the porosity of a ceramic lanthanum manganite (LSM) cathode material. Yttrium-stabilized zirconia (YSZ) films will be deposited onto LSM substrates from aqueous suspensions of nanoscale YSZ crystallites, and the LSM/YSZ bi-layer structure will be sintered to densify the YSZ electrolyte film. The electrochemical performance of the LSM-supported YSZ films will be evaluated.

Commercial Applications and Other Benefits as described by the awardee: Low-cost fabrication technology for producing supported thin-film electrolyte membranes in solid oxide fuel cells should contribute to clean and efficient power generation from abundant and/or renewable fuels, including natural gas, hydrogen, gasified coal, and biomass-derived fuels. Other applications include membrane reactors for the production of chemicals and fuels, and gas separation membranes for large-scale oxygen production.

29

Advanced Catalytic Pilot for Advanced Gas Turbine Systems--Precision Combustion, Inc.,

25 Science Park, Box 24, New Haven, CT
06511-1968; 203-787-8614

Dr. Shah Etemad, Principal Investigator

Mr. Paul Donahe, Business Official

DOE Grant No. DE-FG02-99ER82863

Amount: \$100,000

Current natural gas turbine engine systems operate with reduced efficiencies because aftertreatments are required to reduce NO_x emissions. By enhancing Dry Low NO_x (DLN) gas turbines with catalytic pilot technology, NO_x emissions could be reduced below 9 PPM, lower than is feasible with current DLN systems using standard non-catalytic pilots. This project will develop a catalytically stabilized lean premixed fuel/air pilot burner to replace the standard diffusion flame pilot burner. All pilot burner functions will be performed while achieving low NO_x emissions (through lean premixed operation) and lean stability (through the catalytic reaction of a portion of the fuel mixture). In Phase I, computational fluid dynamics and stress analysis calculations will be performed and a prototype of an optimum reactor will be fabricated. An atmospheric pressure combustor test will then determine whether the pilot can successfully increase turndown capability and bring down emissions to meet the goals of NO_x < 10 ppm and CO < 10 ppm.

Commercial Applications and Other Benefits as described by the awardee: This technology

should enable the lowering of NO_x emissions from DLN (dry low NO_x) combustion systems for natural gas fueled ground power ATS (Advanced Turbine Systems) gas turbine engines. A substantial retrofit market could also emerge for replacing conventional high NO_x pilots with ultra-low NO_x catalytic pilots.

30

Thermally Stable Catalysts for Methane Combustion--TDA Research, Inc., 12345 West 52nd Avenue, Wheat Ridge, CO 80033-1917; 303-940-2301

Dr. David T. Wickham, Principal Investigator
Mr. Michael E. Karpuk, Business Official
DOE Grant No. DE-FG03-99ER82902
Amount: \$100,000

Catalytic combustion is a very promising technology for reducing NO_x emissions from gas turbine power generators. Its primary difficulty is that the catalysts must be able to withstand extremely high temperatures, up to 1500°C. Hexaaluminates are compounds that have potential to be suitable catalysts, but their activities are still too low and they are difficult to synthesize. A fundamentally different route has been developed for the production of high surface area hexaaluminate catalysts. This method would allow for the preparation of many compounds with well-controlled stoichiometries for testing. In Phase I, many combinations of bimetallic hexaaluminates will be synthesized and tested for methane oxidation activity. The testing will utilize a previously developed, high throughput catalysts testing apparatus, which has the capability to test up to 12 samples per run. Experimental results will be used to guide subsequent catalyst compositions. The most active catalysts will be tested to measure their thermal stability.

Commercial Applications and Other Benefits as described by the awardee: The use of a combustion catalyst to control NO_x would allow power generators to meet NO_x emission standards without installing costly post combustion treatment. This should result in significant capital and operational cost savings.

31

Heat Pipe Preheater for Low Nitrogen Oxide (NO_x) Catalytic Combustor--Thermacore, Inc., 780 Eden Road, Lancaster, PA 17601-4275; 717-569-6551

Mr. James E. Lindemuth, Principal Investigator
Mr. Donald M. Ernst, Business Official
DOE Grant No. DE-FG02-99ER82907
Amount: \$100,000

In advanced gas turbine systems, sophisticated and expensive control schemes are required to coordinate between preheating burners and catalytic combustors, especially during startups and fast transients. This is one of the main obstacles to the commercialization of Low NO_x Catalytic Combustion Technology. The Heat Pipe Preheater, a passive heat transfer device that is integrated into a catalytic combustor to extract heat from combustion exhausts and dissipate it to the compressed air for preheating, is capable of quickly responding to changing combustor conditions and self-adjusting according to combustion and preheating zone temperatures. The Heat Pipe Preheater's passive and fast responses eliminate the need for expensive active control schemes and consequently improve the marketability of Low NO_x Catalytic Combustion Technology. Phase I will design, fabricate and test a proportionally scaled, proof-of-concept Heat Pipe Preheater segment to verify the feasibility of the technology. The Heat Pipe Preheater segment will be 1/11th of full scale and capable of transporting 20kW of heat and sustaining a maximum temperature of 1,430°C. Also, theoretical models will be developed to simulate Heat Pipe Preheater Based Catalytic Combustor performance under various steady state and transient conditions.

Commercial Applications and Other Benefits as described by the awardee: Heat Pipe Preheaters should eliminate the need for expensive active control schemes/equipment and improve marketability of Low NO_x Catalytic Combustion Technology. The technology also offers more NO_x reduction by replacing NO_x producing preheating burners with NO_x free Heat Pipe Preheaters. Commercial applications include gas

turbine generators, aircraft turbine engines, and industrial burners in such energy intensive industries as chemical, forest products, steel,

petroleum refining, aluminum, glass, metal casting, utility, and general aviation.

RECOVERY AND UTILIZATION OF FOSSIL FUELS

32

Improved Carbon Molecular Sieve Membranes for Oxygen-Nitrogen Separation- Advanced Fuel Research, Inc., 87 Church Street, P.O. Box 380379, East Hartford, CT 06108-3742; 860-528-9806

Dr. Marek A. Wojtowicz, Principal Investigator
Dr. Michael A. Serio, Business Official
DOE Grant No. DE-FG02-99ER82728
Amount: \$99,993

Widespread commercial production of fuels or chemicals from synthesis gas has been hindered by the high cost of producing oxygen, which is required for either the gasification of coal or the reforming of natural gas. Currently, oxygen is produced in cryogenic air separation plants, which require high capital investment and high energy penalties. This project will develop carbon molecular sieve (CMS) membranes having high permeability and improved selectivity towards oxygen-nitrogen separation. This will be accomplished through the use of carefully selected polymer-based precursors and a special char-activation technique developed previously. Good control over pore-size distribution of CMS material is expected to lead to substantial improvements in membrane selectivity. Phase I will demonstrate the feasibility of obtaining good control over membrane selectivity by varying the CMS activation conditions. Specifically, CMS membranes with different pore-size distributions will be prepared, characterized, and tested with respect to their O₂/N₂ separation.

Commercial Applications and Other Benefits as described by the awardee: Commercial applications for the technology include oxygen generation for the production and processing of synthesis gas, biological wastewater treatment,

steel making, non-ferrous metal smelting, paper and pulp industry, medical applications, and various partial-oxidation processes.

33

Integrated Natural Fracture Characterization Technology in Tight Gas Formations: Application in Clinton Gas Storage Reservoirs--Advanced Resources International, Inc., 1110 North Glebe Road, Suite 600, Arlington, VA 22201-4795; 703-528-8420
Dr. David J. Campagna, Principal Investigator
Mr. Jonathan R. Kelafant, Business Official
DOE Grant No. DE-FG02-99ER82732
Amount: \$99,886

Tight (low permeability) gas formations contain an increasingly important component of the Nation's natural gas resources and gas storage reservoirs. In recent years, operators have come to realize that well-developed natural fractures are the dominant controlling production mechanism in these types of reservoirs and are, by far, the most critical element allowing economical production. This project will develop techniques for natural fracture characterization, including the orientation, spacing, and extent, as well as areas of optimum permeability due to natural fracture systems. A multi-faceted, integrated technological approach will emphasize the use of geomechanical modeling. Phase I will implement an integrated approach for characterizing natural fractures using geomechanical modeling, based on input parameters defined by remote sensing, aeromagnetic data, well logs, seismic interpretation, and other subsurface data. The study will delineate natural fractures for the Stark-Summit and Chippewa gas storage reservoirs of eastern Ohio.

Commercial Applications and Other Benefits as described by the awardee: The natural fracture characterization technology should greatly increase the efficiency of exploring for, developing, and managing natural gas resources in difficult-to-access low-permeability reservoirs. The potential base to which the technology could be applied is more than double current U.S. reserves.

34

Improved Precursors for Oxygen-Selective Membranes in Practical Devices for Methane Conversion--CeraMem Corporation, 12 Clematis Avenue, Waltham, MA 02154-7011; 781-899-4495

Dr. Richard Higgins, Principal Investigator
Dr. Robert L. Goldsmith, Business Official
DOE Grant No. DE-FG02-99ER82761
Amount: \$100,000

Liquid transportation fuels derived from natural gas have great potential to supplement or replace fuels derived from imported petroleum. Conversion of natural gas to these fuels is not currently cost-effective, but recent laboratory developments involving use of oxygen-permeating ceramic membrane reactors clearly show the possibility of making natural gas conversion economic. However, improved materials and device fabrication methods are required to scale up such reactors. This project will demonstrate a cost-effective method of synthesizing improved precursors for the oxygen-permeating materials used in state-of-the-art ceramic membrane reactors for natural gas conversion. In Phase I, synthesis of the improved precursor materials on a bench scale will be performed. These materials will be processed to form small membrane samples and selected critical performance characteristics of these membranes will be demonstrated.

Commercial Applications and Other Benefits as described by the awardee: The availability of these materials would facilitate the fabrication and scale-up of ceramic membrane reactors for natural gas conversion. Other applications include the partial oxidation of low-value

hydrocarbons to high-value products, oxidative gas clean-up processes, and high-temperature oxygen separation.

35

Supported Flat Plate Thin Films for Oxygen Separation--Eltron Research, Inc., 5660 Airport Boulevard, Boulder, CO 80301-2340; 303-440-8008

Dr. Richard Mackay, Principal Investigator
Ms. Eileen E. Sammells, Business Official
DOE Grant No. DE-FG03-99ER82783
Amount: \$99,998

Wide spread commercial production of fuels or chemicals from synthesis gas has been hindered by the high cost of producing oxygen, which is required for either the gasification of coal or the reforming of natural gas. Membrane processes for oxygen separation have shown potential, but polymeric membranes suffer from low selectivity, while ceramic membranes require high temperature to increase flux rate. In previous work, ceramic mixed ionic and electronic conductors were developed that exhibit high oxygen flux when placed in catalytic membrane reactors. These flux rates could be further increased by decreasing membrane thickness. Therefore, this project will develop an economical process for fabricating the ceramic membranes as thin films. Phase I will develop a procedure for fabricating dense, crack-free thin film ceramic membranes in a flat plate geometry. Films will be formed from a mixed polymer/particle precursor layered onto a porous substrate.

Commercial Applications and Other Benefits as described by the awardee: A quick, reliable, and inexpensive method of making ceramic thin films capable of separating oxygen from air will find use in applications requiring a source of pure oxygen. In combustion processes, for example, the use of pure oxygen would increase heating efficiency by removal of N₂ diluent, with simultaneous reduction in NO_x emissions.

Biocatalyzed Chemical Gels for Permeability Modification in Injection and Production Wells--Geo-Microbial Technologies, Inc., East Main Street, P.O. Box 132, Ochelata, OK 74051-0132; 918-535-2281

Dr. Scott Bailey, Principal Investigator
Mr. Daniel C. Hitzman, Business Official
DOE Grant No. DE-FG03-99ER82795
Amount: \$99,974

The combination of low oil production and excessive water production causes many domestic oil wells to reach their economic limit when they still contain one-half to two-thirds of their original oil. Gelled polymer systems, traditionally used to treat these marginal wells in order to increase their production, are highly toxic and technically difficult to use. Nontoxic gels are needed to treat marginal wells so that domestic producers can economically recover additional oil in an environmentally sound way. In this project, biocatalysts will be used to gel non-petroleum based chemical gelants. This will eliminate toxic compounds from the gel systems and simplify the gelation mechanism. The result will be an environmentally friendly gel system applicable to a greater number of domestic oil wells. Phase I will focus on formulating the gelant and optimizing the biocatalyst to drive the gelation reaction. Performance of the biocatalyzed gel for permeability modification will then be tested in coreflood experiments.

Commercial Applications and Other Benefits as described by the awardee: Biocatalyzed gels promise to be an environmentally sound technology for increasing oil production from previously bypassed zones and currently producing wells, and could revive oil fields which are nearing their economic limit. The technology also should help domestic oil producers compete better with imports.

Mixed-Conducting Oxide Ceramic Membranes for Oxygen Separation Using

Novel Low Cost Combustion-Chemical Vapor Deposition--MicroCoating Technologies, Inc., 3901 Green Industrial Way, Chamblee, GA 30341; 770-457-8400

Dr. Girish Deshpande, Principal Investigator
Mr. Jerome J. Schmitt, Business Official
DOE Grant No. DE-FG02-99ER82835
Amount: \$100,000

The efficient separation and purification of oxygen gas from air is very important to industry due to its increased utilization in various processes ranging from natural gas conversion to transportation fuel, refinery processing, chemical processing, and fuel cells. The development of new membrane materials could improve separation efficiencies, transport rates, and membrane lifetimes and lower overall costs. This could dramatically increase the utility of oxygen recovery. This project will develop and demonstrate a family of hybrid, multilayer membranes, based on the Combustion Chemical Vapor Deposition (CCVD) process, that have improved efficiencies and lifetimes at reduced cost. These membranes will combine the strengths of the individual component layers, while eliminating their inherent weaknesses, thus decreasing the cost of oxygen recovery from air tremendously. In Phase I, a prototype system for the production of composite membranes will be developed, specific solutions and deposition conditions for the CCVD process will be prepared, and coupon-sized mixed-ionic conducting membrane samples will be fabricated. The membranes will be tested for ionic conductivity using complex impedance analysis, and a high-temperature gas permeation cell will be constructed to test membrane performance.

Commercial Applications and Other Benefits as described by the awardee: The composite membrane uses air to generate pure oxygen and thus eliminates the need for a cost-intensive cryogenic plant. These ceramic membranes could be used in a stack or shaped into a hollow-tube reactor for *in situ* oxidation of methane (natural gas) to useful transportation fuels.

Nine-Component, Cross-Well Seismic Imaging of Fractured Gas Reservoirs--
Paulsson Geophysical Services, Inc., 1300
Beach Boulevard, La Habra, CA 90631-6374;
562-694-7161

Dr. Bjorn N. P. Paulsson, Principal Investigator
Dr. Bjorn N. P. Paulsson, Business Official
DOE Grant No. DE-FG03-99ER82851
Amount: \$100,000

In a fractured rock, natural gas reservoir, the fractures, not the matrix, provide the largest contribution to the bulk permeability. The ability to effectively map fracture properties is the key to identifying economically productive gas reservoirs. This project will develop a nine-component, cross-well seismic data acquisition technology for mapping the

fracture properties of gas reservoirs. Phase I will first collect data at a fractured reservoir with two deep wells. P and S wave data will be collected at 80 source points using an existing downhole axial vibrator, an orbital vibrator, and an 80 level, three-component clamped receiver array. The data will be used to generate both cross-well tomographic images and reflection images, and a visco-elastic code will be used to model the observed behavior.

Commercial Applications and Other Benefits as described by the awardee: A commercially available, nine-component, cross-well seismic system should provide gas producers with a tool to effectively map the fracture properties in fractured gas reservoirs. This should lower the risk of development of many reservoirs and make it possible to economically produce some reservoirs that otherwise would be abandoned.

FUSION PLASMA SCIENCE RESEARCH

A Diagnostic Tool for Identification and Visualization of Resistive-Wall-Modes in Tokamak Plasmas--FARTECH, Inc., 3146
Bunche Avenue, San Diego, CA 92122-2247;
619-455-6655

Dr. Jin-Soo Kim, Principal Investigator
Dr. Jin-Soo Kim, Business Official
DOE Grant No. DE-FG03-99ER82791
Amount: \$100,000

The resistive-wall-mode is an instability that limits the optimum operation of tokamak plasmas used in fusion energy research. The identification of such dangerous modes at the on-set of instability is one of the key issues for higher performance operation. This project will develop computational technology to identify the rotation, phase, and structure of resistive-wall-modes in real time; if the onset of the instability can be identified, the technology can be used in plasma feedback control. In Phase I, a computational tool will be developed for resistive-wall-mode identification of mode-

rotation, phase, and structure at the probe location. The identification algorithm will be optimized for real-time analysis, which will take place in Phase II along with a demonstration of its capability to control tokamak plasma instabilities.

Commercial Applications and Other Benefits as described by the awardee: The computational tool that identifies the resistive-wall-mode in real time should be an essential component of any system for controlling these instabilities. Such a tool would play a large role in the success of the tokamak as a future fusion energy source. The completed package with visualization also could be used as an education tool and has application to other visualization software development.

Filtered Coherent Thomson Scattering for Plasma Diagnostics--M.L. Energia, Inc., P.O. Box 470, Princeton, NJ 08542-0470; 609-799-7970

Dr. Moshe Lavid, Principal Investigator
Ms. Nira Lavid, Business Official
DOE Grant No. DE-FG02-99ER82820
Amount: \$100,000

Improved diagnostics of magnetic fusion plasmas are needed for economically and environmentally viable fusion energy. Current measurements suffer from interference of large stray light and plasma luminosity. This project will develop a filtered coherent Thomson scattering system that is capable of suppressing large stray light and plasma luminosity. The approach relies on a dispersive resonance filter which exploits the narrow absorption profile of an optically thick atomic vapor. The system will have high light throughput and will be capable of spectrally dispersing the narrow ion and electron features characteristic of coherent Thomson scattering. In Phase I, a rubidium vapor dispersive filter will be constructed and used in concert with a narrow bandwidth Ti:Sapphire laser to provide attenuation and dispersion of the incident laser used in coherent Thomson scattering. Measurements of spectral profiles will be conducted, and filter performance will be evaluated for a range of scattering angles, extinction and dispersion. Finally, a prototype system will be constructed and tested.

Commercial Applications and Other Benefits as described by the awardee: This diagnostic should find wide application in magnetic fusion devices for monitoring plasma properties such as electron temperature and density. It should also benefit smaller plasma systems used in materials processing, remediation of hazardous and toxic wastes, and analytical instrumentation.

Development of a High Resolution X-Ray Imaging-Spectrometer--Radiation Science, Inc., P.O. Box 293, Belmont, MA 02178-0002; 617-621-7076

Dr. Allen S. Krieger, Principal Investigator
Dr. Allen S. Krieger, Business Official
DOE Grant No. DE-FG02-99ER82868
Amount: \$100,000

Measurements of ion temperature and density as a function of position are required to study particle and power balance in the National Spherical Torus Experiment for Fusion Energy Sciences program. Spatially resolved, high resolution measurements of x-ray spectra can provide this information. This project will design and develop a high resolution imaging spectrometer that provides information on plasma conditions simultaneously over a large number of chords through the plasma. The spectrometer design relies on the unique collimation properties of spherically bent crystals at Bragg angles close to 45°. Phase I will develop a technique to produce highly precise, spherically bent crystals. The x-ray imaging properties of crystals bent in this manner will be measured, and a preliminary design for a high resolution imaging spectrometer using such crystals will be generated.

Commercial Applications and Other Benefits as described by the awardee: High resolution imaging spectrometers should be useful in general plasma research. A compact, economical collimating system should also have applicability to the x-ray lithography of specialized integrated circuits.

Novel Method for Plasma Density Measurements--Southwest Sciences, Inc., 1570 Pacheco Street, Suite E-11, Santa Fe, NM 87505-3937; 505-984-1322

Dr. Daniel J. Kane, Principal Investigator

Dr. Alan C. Stanton, Business Official

DOE Grant No. DE-FG03-99ER82886

Amount: \$100,000

As requirements for more detailed fusion plasma diagnostics increase, the need for more efficient and less complicated alternatives becomes more prevalent. This issue will be addressed through the application of ultra-fast lasers, which allow for better measurements of neutrals and electrons in plasmas. While interferometry using ultra-fast lasers has been used successfully to measure *absolute* phase changes, this project will use spectral interferometry to measure *relative* phase changes between a continuum of

wavelengths. Measuring the relative phase, using ultra-fast lasers pulses to measure plasma densities, rather than absolute phase changes in a laser beam relaxes constraints on the interferometer making it more stable and robust against noise and vibration. Consequently, the interferometer will be easier to use than existing interferometers, have a higher dynamic range, and be more resistant to vibration. Phase I will focus on demonstrating the accuracy and stability of interferometers based on ultra-fast lasers. Plasma densities using these interferometers will also be measured in laboratory experiments.

Commercial Applications and Other Benefits as described by the awardee: This research should facilitate the development of improved instrumentation for the measurement of plasma densities. It should also improve existing ultra-fast laser techniques and diagnostics for researchers.

ENABLING TECHNOLOGIES FOR FUSION PLASMA EXPERIMENTS

Power Supply for Plasma Heating--Diversified Technologies, Inc., 35 Wiggins Avenue, Bedford, MA 01730-2314; 781-275-9444

Dr. Marcel P. J. Gaudreau, Principal Investigator

Mr. Michael Kempkes, Business Official

DOE Grant No. DE-FG02-99ER82777

Amount: \$99,476

Future high power physics experiments will require an order of magnitude increase in power delivery over present systems. The cost and inefficiency of conventional power supplies is a significant issue in both the deployment and operation of future systems in the 10 MW - 200 MW average power range. Improved power supply designs which are cost effective and efficient are critical to the technical and economic feasibility of fusion research. This project will leverage high voltage, solid state switching technology to design and build

prototype high frequency (5 - 20 kHz), high voltage, multi-megawatt DC power supplies with significant improvements in life cycle cost over conventional 60 Hz power supplies. Phase I will design a 4 MW buck regulator power supply, and assess its reliability, efficiency, and cost of manufacture. A 4 MW CW switching power supply will be built and installed on a selected facility for test, assessment and initial operation in Phase II.

Commercial Applications and Other Benefits as described by the awardee: In a 200 MW system, each percentage increase in power supply efficiency saves approximately \$1M/year in electricity costs alone. This savings, and expected manufacturing cost reduction, should significantly reduce the cost of future high-energy fusion systems and programs. Commercial applications of this technology include large ion implantation systems and pulsed electric field food sterilization.

A New Radiation Resistant Epoxy Resin System for Liquid Impregnation Fabrication of Composite Insulation--Eltron Research, Inc.,
5660 Airport Boulevard, Boulder, CO
80301-2340; 303-440-8008

Dr. James B. Schutz, Principal Investigator
Ms. Eileen E. Sammells, Business Official
DOE Grant No. DE-FG03-99ER82782
Amount: \$99,997

Superconducting magnet coils are a major component of fusion plasma experiment devices. The electrical insulation in these magnet coils is an epoxy matrix composite, which must exhibit good mechanical strength and radiation resistance at cryogenic temperatures. The liquid epoxy must also have good processing characteristics for impregnating the magnet coils. Current epoxy systems do not combine good processing characteristics with mechanical strength and radiation resistance. Another major problem is the release of gases by the epoxy material during irradiation. This project will develop an epoxy/hardener system which exhibits good processing characteristics and reduced radiation outgassing. The formulation will be systematically optimized to further enhance processing properties and cryogenic mechanical strength. In Phase I, the effects of several modifiers on radiation outgassing and processing characteristics of the basic epoxy/hardener system will be evaluated. Promising modifiers will be selected for inclusion in a systematic optimization to further enhance mechanical properties and processing characteristics. The optimized formulation will be subjected to further characterization, including radiation outgassing measurements.

Commercial Applications and Other Benefits as described by the awardee: The epoxy resin formulation should find use as electrical insulation for cryogenic superconducting magnet systems, particularly those which will be subjected to irradiation. The formulation also should be of interest for cryogenic composite structural applications, as well as for commercial, industrial, and aerospace

composites fabricated by liquid impregnation methods such as Resin Transfer Molding.

Advanced Heat Sink Materials for Fusion Energy Devices--Plasma Processes, Inc.,
4914-D Moores Mill Road, Huntsville, AL
35811-1558; 256-851-7653

Mr. Timothy McKechnie, Principal Investigator
Mr. Timothy McKechnie, Business Official
DOE Grant No. DE-FG02-99ER82859
Amount: \$100,000

Cheaper and higher efficiency heat sinks are needed for future fusion energy devices. Existing heat sink materials cannot achieve higher heat flux operation without costly efficiency enhancements for heat transfer in water and gas cooled components. This project will fabricate advanced heat sink materials, such as CuCrNb, tungsten, molybdenum, and niobium alloys, to near net shape for high flux testing. Also, heat transfer enhancements will be built into the internal cooling passages during heat sink formation. Phase I will demonstrate the forming of plasma facing components with enhanced heat transfer and advanced materials. Divertor mockups will be produced for high heat flux testing. The advanced heat sinks will be cheaper and have higher heat flux operational capabilities than currently produced components.

Commercial Applications and Other Benefits as described by the awardee: Applications for these heat sinks include heat pipes, rocket engines, combustors, chemical processing equipment, nose cones, counterweights, power generation systems, furnace components, x-ray, sputter and beam targets.

Economical Fabrication of Large Micro-Impingement Cooling Panels--
 Saddleback Aerospace, 10523 Humbolt Street,
 Los Alamitos, CA 90720; 562-598-3700
 Dr. Geoffrey O. Campbell, Principal Investigator
 Ms. Elizabeth A. Campbell, Business Official
 DOE Grant No. DE-FG03-99ER82874
 Amount: \$99,806

Plasma-facing components in fusion reactors are exposed to high temperature/high heat flux environments. The development of cooling structures, capable of operating reliably for extended periods in these harsh environments, is a major technical challenge to fusion reactor development. Microchannel cooling systems offer excellent thermal performance in high strength structures, but have traditionally been restricted to small geometries. This project will demonstrate a practical means of incorporating micro-impingement cooling channels in large structures. The approach will also allow the armor and heatsink to be integrated, eliminating the vulnerable joint between them. Phase I will develop two heatsink models with micro-impingement cooling designs. The first is a small thermal bench test model; the second is a large panel to demonstrate the scale-up potential. Tungsten processing studies will also be conducted to facilitate future fabrication of monolithic tungsten armor/heatsink designs.

Commercial Applications and Other Benefits as described by the awardee: The cooled panel concept is an enabling technology for commercial fusion reactor development. The same technology also should be well suited to a variety of aerospace and electronic cooling applications, including cooling of hypersonic vehicles and high speed aircraft, and cooling of radar components.

Helium Cooled Refractory Metal Divertor Panel--Thermacore, Inc., 780 Eden Road,
 Lancaster, PA 17601-4275; 717-569-6551
 Dr. Mark T. North, Principal Investigator
 Mr. Donald M. Ernst, Business Official
 DOE Grant No. DE-FG02-99ER82906
 Amount: \$99,990

The cooling of high heat flux components provides a significant challenge to designers of plasma facing components. In a tokamak fusion reactor, divertor plates are used to remove waste heat and particles. If distributed non-uniformly over the plasma-facing surface of the divertor panel, the peak heat flux could exceed 30MW/m^2 . At 30MW/m^2 , the heat removal is limited by the critical heat flux of the coolant, the maximum permissible temperature of the coolant channel, and the maximum temperature of the plasma facing material. This project will develop a helium-cooled, refractory-metal, porous metal heat exchanger (PMHX). A helium-cooled, refractory-metal divertor panel will be able to reach temperatures of up to 2800°C at the surface of the armor and the helium exit temperatures can approach 700°C . Phase I will develop and demonstrate the technology to use PMHXs to remove the heat absorbed by a divertor panel in a fusion reactor environment.

Commercial Applications and Other Benefits as described by the awardee: Porous metal cooling should surpass all competing technologies for cooling applications in high power optics, aircraft avionics, and laser diode devices. At the high temperatures permitted, the heated outlet gas can be used to drive an industrial gas turbine with a high thermal efficiency.

Enabling Materials for Magnetic Fusion Energy--Ultramet, 12173 Montague Street, Pacoima, CA 91331-2210; 818-899-0236
 Mr. Brian E. Williams, Principal Investigator
 Mr. Craig N. Ward, Business Official
 DOE Grant No. DE-FG03-99ER82913
 Amount: \$99,996

The potential economic, environmental, and strategic benefits associated with the development of magnetic fusion energy are numerous. However, practical application will not be realized until advanced materials are developed that allow operation under the high heat flux conditions necessary for cost-competitive electric energy generation. In this project, innovative materials and material systems will be developed and demonstrated to allow extended fusion energy system operation at heat flux levels greater than 10 MW/m^2 . This will be accomplished by using chemical vapor deposition/infiltration to produce refractory materials and structures that cannot be fabricated by conventional processing techniques. In Phase I, a heat exchanger, composed of thin tungsten facesheets integrally bonded to an open-cell tungsten foam core, will be fabricated. The tungsten foam core will provide both the primary mechanical structure as well as extremely efficient coolant channels for thermal control. A modeling effort will be used to evaluate thermo-mechanical durability and heat transfer characteristics.

Commercial Applications and Other Benefits as described by the awardee: Fusion energy is ideal for large-scale energy generation and offers replacement for increasingly scarce fossil fuel energy sources. Practical application is absolutely dependent on the development of advanced materials.

Fast Repetitive Arc Free Current Limiting Circuit Breaker--UTRON, Inc., 8506 Wellington Road, Suite 200, Manassas, VA 20109-3915; 703-369-5552
 Dr. F. Douglas Witherspoon, Principal Investigator
 Dr. F. Douglas Witherspoon, Business Official
 DOE Grant No. DE-FG02-99ER82915
 Amount: \$99,893

The Department of Energy seeks fault protection devices which will effectively limit the current damage to radio frequency (RF) tubes during fault conditions associated with fusion plasma heating. This project will develop a new innovative circuit breaker capable of fast, arc-free current interruption. In a fault situation, the circuit breaker will limit the energy to RF tubes to less than a few joules at heating power levels of 10-50 MW. This will be demonstrated experimentally on a small scale in a single shot mode in Phase I, by interrupting 10 kA in 2 ms without arc formation. In Phase II, repetitive operation will be demonstrated. A current limiting circuit breaker device will be fabricated utilizing a pulsed high pressure discharge to separate the contacts.

Commercial Applications and Other Benefits as described by the awardee: Successful development of this device should result in faster arc-free opening switches/circuit breakers for both the commercial power industry and pulsed power applications, with longer component lifetimes, smaller physical size, and lower cost than currently available.

ADVANCED TECHNOLOGIES AND MATERIALS FOR FUTURE FUSION SYSTEMS

50

Robust Ceramic Coatings for Vanadium Alloys to Use in Lithium Cooled Fusion Systems--Composite Technology Development, Inc., 1505 Coal Creek Drive, Lafayette, CO 80026-2782; 303-664-0394

Mr. Craig Hazelton, Principal Investigator
Dr. Naseem A. Munshi, Business Official
DOE Grant No. DE-FG03-99ER82767
Amount: \$100,000

Future Tokamak-based fusion research devices and power plants will use a breeder blanket incorporating vanadium alloy heat exchanger materials, and a circulating liquid metal, such as liquid lithium, for heat removal and tritium breeding. However, heat removal rates will remain unacceptable unless a robust electrically insulating layer between the lithium coolant and vanadium piping is developed. This project will develop a solution-derived ceramic coating for the vanadium alloy piping. This approach will allow for *in situ* coating application, system compatibility, and reduced thermal stresses. Composite coating materials will be developed that match the expansion behavior of the vanadium alloy, eliminating thermally induced spallation and cracking that lead to a breakdown in electrical resistance. The Phase I project will evaluate and optimize several candidate coating materials and measure their electrical and thermal performance. Candidate materials include fusion compatible, electrically insulating, radiation resistant, ceramic composite coating. Material evaluation will include testing for tolerance of thermal cycling and electrical performance and estimation of liquid lithium compatibility.

Commercial Applications and Other Benefits as described by the awardee: Protective coatings for metals are essential to industry for electrical insulation, thermal barriers, corrosion resistance, and abrasion resistance. This technology should be useful for thermal barrier coatings for the

conventional power generation industry, and for coating applications in the transportation, aerospace, paper processing, and other industries.

51

Hybrid Three-Dimensional SiC/C High Thermal Conductivity Composites--MER Corporation, 7960 South Kolb Road, Tucson, AZ 85706; 520-574-1980

Dr. Witold Kowbel, Principal Investigator
Mr. R. O. Loutfy, Business Official
DOE Grant No. DE-FG03-99ER82823
Amount: \$100,000

To provide improved strength and toughness, continuous fiber reinforced silicon carbide (SiC) composites (SiC-SiC), being developed primarily for advanced aerospace applications, are being examined for fusion reactor applications. Unfortunately, while the thermomechanical properties of SiC-SiC can be improved over that of monolithic SiC, the thermal conductivity is significantly reduced. This project will develop a hybrid three-dimensional SiC/C composite in which a high thermal conductivity carbon fiber (Z direction) is used to improve the thermal conductivity. This system appears to have potential for improving through-the-thickness thermal conductivity, while maintaining composite properties upon irradiation. In Phase I, an SiC fabric, produced by chemical vapor reaction, will be used for X-Y reinforcement while K-1100 fibers will be used as Z-reinforcement. A high conductivity SiC-matrix, fabricated with a hybrid process that combines chemical vapor infiltration with polymer infiltration and pyrolysis, will also be used. Each composite will be characterized with respect to microstructure as well as thermal and mechanical properties.

Commercial Applications and Other Benefits as described by the awardee: The key benefit is for the fusion program. Commercial applications also exist in such energy related fields as heat exchangers.

52

Low Cost Dispersion Strengthened Ferritic Steels--Powdermet, Inc., 9960 Glenoaks Boulevard, Unit A, Sun Valley, CA 91352-1047; 818-768-6420

Mr. Asit Biswas, Principal Investigator
Mr. Andrew J. Sherman, Business Official
DOE Grant No. DE-FG03-99ER82861
Amount: \$99,969

Relaxation of current temperature and pressure limits for structural materials used in the ITER fusion reactor will enable increased thermal efficiency and safety for future fusion power reactors. Oxide dispersion strengthened (ODS) ferritic steels offer the potential for relaxing these limits over 316 alloy steels, the current baseline material for the ITER reactor structures. This project will demonstrate an innovative,

potentially low cost process for producing more uniformly distributed, higher levels of dispersants in modified Cr-Mo-V steels for use in fusion reactor structures. Current attrition milling production techniques will be replaced with newly available nanoengineered powder production techniques. In Phase I, *in situ* ODS steel powders will be produced using a modified carbonyl iron powder manufacturing process, samples will be consolidated through sinter/extrusion powder metallurgy techniques, and the resultant material microstructures and properties will be characterized. The process will result in improved control over dispersant size, composition, distribution, and uniformity and will lead to lower cost alloys capable of higher temperature operation and improved performance.

Commercial Applications and Other Benefits as described by the awardee: The proposed ODS powder manufacturing techniques should lead to lower cost, higher performance metal alloys for use in steel alloys, aluminum alloys, and refractory alloys, enabling safer, more reliable, energy efficient systems.

ADVANCED CONCEPTS AND TECHNOLOGY FOR HIGH ENERGY ACCELERATORS

53

Inexpensive, High-Performance, Electron Gun--Advanced Energy Systems, Inc., 27 Industrial Boulevard, Suite E, Medford, NY 11763; 516-345-6264

Dr. Hans Bluem, Principal Investigator
Dr. Alan Todd, Business Official
DOE Grant No. DE-FG02-99ER82723
Amount: \$99,477

High-performance, high-brightness, radio-frequency photocathode electron guns are in operation at many facilities worldwide. However, the development of reliable, low-cost photocathode sources has proven difficult. This need is driven by both the high cost of the drive

laser for photocathode systems and by the poor durability of high-quantum-efficiency photocathode materials that require an ultra-high-vacuum environment. This project will develop a robust photocathode with a quantum efficiency greater than one percent that does not require an ultra-high-vacuum environment. It would permit a major reduction in the photocathode gun system cost by significantly reducing the drive laser power. In Phase I, a cathode will be fabricated and tested under various conditions to demonstrate robustness under transportation, handling, storage, and use. A preliminary design of an S-Band radio-frequency gun based upon utilizing this cathode concept will be completed. Ultimately, the photocathode will be used in an existing electron

source to demonstrate its robustness and high quantum efficiency.

Commercial Applications and Other Benefits as described by the awardee: High-performance, affordable, photocathode radio-frequency guns should find application in research and development accelerator applications. A specific commercial application would be as a source for a near-field infrared microscope system used for quality assurance. Sources based upon this cathode might also find use in electron beam lithography tools.

54

A Drive Beam Micro-Pulse Injector--FM Technologies, Inc., 10529-B Braddock Road, Fairfax, VA 22032-2236; 703-425-5111
Dr. Frederick M. Mako, Principal Investigator
Dr. Frederick M. Mako, Business Official
DOE Grant No. DE-FG02-99ER82792
Amount: \$100,000

Many applications in high-energy physics and elsewhere require a source which can produce several thousand high-charge and short-duration electron bunches. Photocathodes, which are typically used, can provide only up to 100 bunches containing tens of nano-coulombs per bunch. Also, they require expensive high-power lasers and complicated timing circuitry. This project will develop a new device, called the Drive Beam Micro-Pulse Injector, based on an existing design that produces electron bunches having 6 nano-coulombs of charge in a pulse train of up to 13 micro-coulombs, a micro-pulse duration of 15-20 ps, a normalized transverse emittance of about 23 mm-milliradians, and a particle energy of 2-3 MeV. Phase I will develop a detailed analysis to further refine the injector concept and determine the key requirements. Preliminary work suggests that the device should be capable of producing high-current densities (much larger than a kA/cm^2), and short pulses (1-100 ps) at nominally 2-5 percent of the radio-frequency period.

Commercial Applications and Other Benefits as described by the awardee: The electron gun

should provide a high-charge, low-emittance, picosecond-long electron source suitable for many applications including high-charge, high-energy picosecond electron injectors for accelerators, future linear colliders, medical and industrial radio-frequency linacs, and accelerator test facilities.

55

Virtual Accelerator Simulation System for Operations, Research and Training--G.H. Gillespie Associates, Inc., P.O. Box 2961, Del Mar, CA 92014-5961; 619-677-0076
Dr. George H. Gillespie, Principal Investigator
Dr. George H. Gillespie, Business Official
DOE Grant No. DE-FG03-99ER82793
Amount: \$100,000

Future high-energy accelerators will have unprecedented beam power, brightness, and luminosity. Accordingly, these advances will impose additional requirements on the operational needs of these machines. This project will develop a Virtual Accelerator Simulation System as a computer assisted training tool to meet the operational challenges of the next generation of machines. Using a unique object-oriented framework, the system will include a graphic user interface, a dynamic interactive tutorial system, expert system capabilities, and a suite of particle optics and accelerator simulation codes. Users can interact with it directly or through their control system via an application programming interface. A demonstration package of the Virtual Accelerator Simulation System concept will be developed in Phase I. The demonstration software will address defined accelerator control problems and include state-of-the-art particle optics codes, prototype operations tutorials, and interfaces to representative control system environments. The utility of the concept to support accelerator operations, research, and training will be established.

Commercial Applications and Other Benefits as described by the awardee: The Virtual Accelerator Simulation System should provide operations personnel and researchers, involved

in the control or study of accelerators, with innovative new modeling and training tools. Research laboratories, industrial facilities, and medical centers that utilize accelerators would benefit.

56

Nitride-Based Cold Cathodes for Minature and Rugged Electron Sources--Ionwerks, 2472 Bolsover, Suite 255, Houston, TX 77005-2537; 713-522-9880

Dr. Abdelhakim Bensaoula, Principal Investigator

Dr. J. Albert Schultz, Business Official

DOE Grant No. DE-FG03-99ER82808

Amount: \$99,877

Diamond is one of the most popular materials for various field emission applications, including high energy electron and ion sources used in high energy physics, and has demonstrated superior characteristics in threshold electric field and current density. However, many practical applications of cold cathode emission, which is likely to replace hot filament emission in the near future, requires more oxidation-resistant materials. This requirement would be especially critical if an electron emitter were intended to work as an ionization source in low vacuum, such as with growth/process reactors or during environmental sampling operations. This project will fabricate boron nitride (BN) and carbon boron nitride (CBN) based cold cathodes to facilitate the development of rugged miniature ion sources with low power requirements and operation at pressures up to 0.1 Torr. In Phase I, BN and CBN structures will be grown, optimized, characterized, and evaluated for their field emission capabilities. Also, doping methods and materials stability will be investigated.

Commercial Applications and Other Benefits as described by the awardee: Emitter structures that are impervious to operation in oxygen and hydrocarbon environments should lead to the straightforward commercialization of mass spectrometers, ion sources, and electron sources.

57

Computer Software for Magnicon Design, Including Beam Space Charge Effects--Omega-P, Inc., 345 Whitney Avenue, Suite 100, New Haven, CT 06511; 203-789-1164

Dr. Viacheslav P. Yakovlev, Principal Investigator

Mr. George Trahan, Business Official

DOE Grant No. DE-FG02-99ER82845

Amount: \$100,000

Continued progress in high energy physics demands a new generation of linear collider, which in turn requires new high-power, high-efficiency radio frequency (rf) sources. One of the most attractive candidates for this role is the magnicon are needed microwave amplifier with circular deflection of an electron beam. In order to realize optimum performance, detailed numerical design simulations of the magnicon are needed that take into account beam space charge. This project will develop sophisticated computer software to simulate the 3-D electron beam dynamics in magnicons, including realistic rf field distributions, static magnetic field profiles, and beam space charge. The result is expected to be a powerful tool for evaluating the performance of candidate magnicon amplifier designs, in both time-dependent and steady-state operation. The software will also be useful for design of gyroklystrons and gyroharmonic converters. During Phase I, a 3-D Poisson solver will be developed, based on a second-order finite element method, together with a generator of a 3-D curvilinear mesh. A particle pusher routine and an economic space charge model also will be developed. Preliminary physical simulations to show the influence of beam space charge on the performance of a high-power magnicon will be demonstrated.

Commercial Applications and Other Benefits as described by the awardee: In a future linear collider, several thousand high-power, high-efficiency microwave amplifiers will be required. If the magnicon were adopted for such an application, it would represent a business opportunity with a potential in the range of \$200 million. Additional markets for magnicon amplifiers could include rf sources for the

accelerator in a fourth-generation synchrotron radiation light source, as well as numerous related commercial uses.

58

Laser-Driven Cyclotron Autoresonance Accelerator--Omega-P, Inc., 345 Whitney Avenue, Suite 100, New Haven, CT 06511; 203-789-1164

Dr. Jay L. Hirshfield, Principal Investigator
Mr. George P. Trahan, Business Official
DOE Grant No. DE-FG02-99ER82846
Amount: \$100,000

High-energy electron acceleration using intense laser acceleration, with a gradient of the order of 100 MeV/m, for meter-length distance, and in a manner that facilitates staging, has not yet been demonstrated. This project will use laser-driven cyclotron autoresonance acceleration (LACARA) to exploit gyroresonance to achieve all of the above parameters. LACARA is an outgrowth of its microwave counterpart, but enjoys the benefit of long interaction length in weakly-focused laser radiation with no stalling limit. Preliminary computations show that acceleration from 50 to 178 MeV can occur over 150 cm in the focus of a 4 TW, 10.4 micron Gaussian laser beam with a minimum waist diameter of 0.20 cm. Phase I will perform a thorough computational study of LACARA to assess the effects of finite initial emittance for the beam, errors in the magnetic field profile, beam loading, finite bunch-length and slippage, and orbit gyrations. Then, an experimental layout suitable for the Brookhaven National Laboratory Accelerator Test Facility, including optimization of a cryomagnet, will be designed, and tests will be conducted during Phase II.

Commercial Applications and Other Benefits as described by the awardee: A laser-based electron accelerator that can accelerate all particles in a short bunch equally, with a continuous acceleration gradient of the order of 100 MeV/m over meter-long paths, and in a manner that facilitates staging, should be attractive to commercial users of energetic electron beams. Applications include in

experimental and industrial light sources, and medical therapy.

59

Multi-Terawatt, 50 Femtosecond Laser for Laser Accelerator--Positive Light, 101 Cooper Court, Los Gatos, CA 95030; 408-399-7744
Mr. Rimas Viselga, Principal Investigator
Mr. Jeremy Weston, Business Official
DOE Grant No. DE-FG03-99ER82860
Amount: \$99,892

The Department of Energy has identified a need for terawatt-class laser systems for advanced laser-driven particle acceleration applications. Specifically, multi-terawatt systems are sought that are capable of providing 1 J, 50 femtosecond (fs) single wavelength pulses or, alternately, 60 J, 4 ps pulses in dual frequency operation. This project will develop a compact terawatt chirped pulse amplifier laser system using Ti:sapphire as the gain medium to achieve short pulse widths. By combining a sub-50 fs regenerative amplifier with novel, image-relayed multi-pass amplifiers, this system will offer the potential for generating 1 J, 50 fs pulses. Adaptation of a novel spectral filtering technique currently being developed will also offer the potential for simultaneous dual frequency amplification. The Phase I project will define the design of a 1 J/pulse, 50 fs amplifier system. This system will integrate a high energy, flash-lamp-pumped Nd:glass laser system as the pumping source for two novel, image-relayed, multi-pass Ti:sapphire amplifier stages. Modeling and experimental characterization of the gain and gain narrowing in a 9.5 mm diameter multi-pass amplifier will be used to demonstrate the feasibility of scaling to 1 J, 50 fs system to be built in Phase II.

Commercial Applications and Other Benefits as described by the awardee: The availability of compact, relatively affordable laser-driven particle accelerators should open the door to a variety of new medical, scientific and industrial applications based on synchrotron optical sources and free-electron lasers.

An Automatic Beam-Based System for Analyzing Accelerator Misalignment Problems--Sandia View Software, Inc., 613 Sandia View Road NW, Albuquerque, NM 87107; 505-345-4147

Dr. Carl R. Stern, Principal Investigator
Dr. Carl R. Stern, Business Official
DOE Grant No. DE-FG03-99ER82876
Amount: \$99,979

Misalignment is one of the last remaining processes in accelerator commissioning that remains to be automated. Misalignment is especially critical in the commissioning and operation of large complex accelerators such as the Next Linear Collider (NLC) because of its time consuming nature and its impact on accelerator performance. This project will develop a system to automate the analysis of misalignment problems and the establishment of an accurate central trajectory. An optics model will be used to identify those regions of an accelerator that are well aligned. These regions will define local reference trajectories that will anchor the analysis of misalignments in surrounding regions. Phase I will develop prototypes and test several beam-based misalignment analysis algorithms. These will include a quad scanning algorithm as well as an algorithm based on local reference trajectories. A system that automates misalignment analysis by integrating several misalignment analysis algorithms will be designed and its feasibility demonstrated.

Commercial Applications and Other Benefits as described by the awardee: A tool for the automated analysis of alignment errors in the NLC during commissioning and operations should provide large savings in time and expense and could also yield improvements in operational performance. A commercial version of this system should provide the same benefits to accelerator facilities worldwide.

High-Performance Three-Dimensional Simulation Code for Laser Plasma Accelerators and Plasma Processing of Integrated Circuits, with a Graphical User Interface--Tech-X Corporation, 1280 28th Street, Suite 2, Boulder, CO 80303-1758; 303-448-0727

Dr. David L. Bruhwiler, Principal Investigator
Dr. John R. Cary, Business Official
DOE Grant No. DE-FG03-99ER82903
Amount: \$99,953

Laser plasma accelerators have demonstrated accelerating gradients many orders of magnitude higher than conventional metal structures, opening possibilities for much higher energy electron linacs. However, there are many non-linear, three-dimensional (3-D) processes that can disrupt or limit particle acceleration; therefore, new 3-D parallel simulation tools are needed to fully understand these processes. This project will develop a flexible 3-D simulation code for modeling laser-plasma interactions using fluid, particle-in-cell (PIC) or hybrid fluid-PIC models. The code will have a graphical user interface and will run on PC's, Unix workstations, distributed clusters, and massively parallel supercomputers. In Phase I, a prototype, 2-D hybrid simulation of a short laser pulse in a long ionized channel will be implemented by integrating a fluid model with the existing PIC algorithms of the parallel XOOPIC code, with attention to the accuracy and stability of the hybrid algorithm. A prototype, 3-D, moving-window simulation of the same problem will be implemented using the parallel C++ POOMA framework.

Commercial Applications and Other Benefits as described by the awardee: The software should bring fluid, PIC, and hybrid modeling capabilities to designers of laser plasma accelerators. It should also be applicable to the 3-D simulation of plasma etching processes, critical to the computer chip industry.

A Non-Interceptive Transverse Size Monitor for Charged-Particle Beams--Y.Y. Labs, Inc.,
P.O. Box 597, Fremont, CA 94537-0597;
510-739-6049

Dr. Yan Yin, Principal Investigator

Dr. Yan Yin, Business Official

DOE Grant No. DE-FG03-99ER82919

Amount: \$100,000

An important problem in high energy physics is the non-interceptive reconstruction of the transverse size and shape of charge-particle beams, using electrostatic electrodes. Although it has been attempted in the past, previous efforts have not met with success. This project addresses the problem through a novel non-intercepting method for measuring complete sets of transverse geometric higher-order moments,

which gives information on the transverse shape, size, and centroid position of the beams. A new type of monitor that utilizes this method will be developed for the analysis of charged-particle beams, particularly intense beams with radii down to the micron level. Phase I will consist of computer simulations to prove the principle, to design a monitor, and to carry out preliminary bench tests.

Commercial Applications and Other Benefits as described by the awardee: The proposed new non-intercepting beam transverse size diagnostic instrumentation should be especially applicable to intense small-sized beams from spallation neutron sources, intense heavy-ion or fusion accelerators, linear colliders, and the accelerator production of tritium. For these applications, there are no instruments available on the market.

RADIO FREQUENCY ACCELERATOR TECHNOLOGY FOR HIGH ENERGY ACCELERATORS AND COLLIDERS

Radio Frequency Pulse Compression Using a Diamond Switch--Alameda Applied Sciences Corp., 2235 Polvorosa Avenue, Suite 230, San Leandro, CA 94577-2249; 510-483-4156

Dr. Rahul R. Prasad, Principal Investigator

Dr. Mahadevan Krishnan, Business Official

DOE Grant No. DE-FG03-99ER82736

Amount: \$99,938

This project will develop a new type of radio frequency (RF) pulse compressor based on a diamond membrane that can be turned from its normal insulating state (thus transmitting RF) to a conducting state (thus reflecting RF) when irradiated by a fast pulse (~1ns) of ultraviolet (UV) radiation. This pulse compressor would enable the generation of high power (>50 MW) X-band and higher frequency RF systems required for the Next Linear Collider. Phase I will use a low power RF source to demonstrate that a diamond window transparent to RF radiation will reflect the same RF radiation when

UV radiation is absorbed by the window. The reflection of microwave power from the window will be measured to determine the UV power required for practical devices. Then, a diamond pulse compression RF switch will be designed for a higher power RF source to be validated in Phase II.

Commercial Applications and Other Benefits as described by the awardee: The technology should be applicable to next generation particle accelerators, semiconductor fabrication processes, medical applications, high range resolution (clutter rejection) radar systems, and directed energy weapons.

Design of a 10 MW, 91 GHz Gyrokystron for Linear Accelerators--Calabazas Creek Research, 20937 Comer Drive, Saratoga, CA 95070-3753; 408-741-8680

Dr. Jeffrey Neilson, Principal Investigator

Dr. R. Lawrence Ives, Business Official
DOE Grant No. DE-FG03-99ER82754
Amount: \$100,000

In recent design scenarios for advanced linear colliders with center-of-mass energies above 1 TeV, the expected radio frequency (RF) drive frequency is typically above X-Band. Unfortunately, the capability of current RF source technology in terms of peak power is several orders of magnitude below anticipated requirements. It has been well demonstrated in the past that gyrotrons significantly outperform conventional tubes in the millimeter regime. This project will utilize gyroklystron technology with state-of-the-art X-Band klystrons to develop a gyroklystron tube at 91.392 GHz that has a peak power capability about 3 orders of magnitude above the state-of-the-art for linear tubes. Phase I will design and characterize the anticipated performance of a 10 MW W-Band gyroklystron amplifier for advanced linear collider applications. Critical components will be investigated, including the electron gun, the magnetic field coils, the microwave circuit, the input system, the output waveguide and conditioning system, and an energy recovery system. Ultimately, a source will be produced that is capable of testing W-Band accelerator components and (with pulse compression) capable of driving a W-Band accelerator structure.

Commercial Applications and Other Benefits as described by the awardee: High power W-Band sources should have applicability at research centers to test the viability of W-Band accelerator components in terms of breakdown fields, peak and average power capabilities, etc. The tube could also power an accelerator structure to look at issues such as dark current. Other potential applications include land- and ship-based radars, medical accelerators, and materials processing.

65

Low Field Solenoid Periodic Focusing of Accelerator Klystrons--California Tube

Laboratory, Inc., 125 Aviation Way,
Watsonville, CA 95076; 831-761-1199
Mr. David E. Blank, Principal Investigator
Mr. Peter S. Campbell, Business Official
DOE Grant No. DE-FG03-99ER82755
Amount: \$98,505

As currently configured by the Stanford Linear Accelerator Center (SLAC), the Next Linear Collider (NLC) is slated to use 6,000 periodic permanent magnet (PPM)-focused 75 MW klystrons. However, the PPM approach is not necessarily the lowest cost solution. This project will investigate a hybrid, periodic-solenoid approach. In this approach, the peak or average power of accelerator klystrons is increased by using low power, solenoid driven periodic beam focusing. The savings to NLC could be as much as \$100M. Phase I will design a SPM (solenoid periodic magnet) beamstick that is compatible with the SLAC XL4 klystron geometry, conduct a computer evaluation of beam focusing, and fabricate a beamstick for evaluation by SLAC.

Commercial Applications and Other Benefits as described by the awardee: SPM focusing could be used in any application requiring large numbers of high-power klystrons (e.g. the NLC). The use of SPM technology could also be used to facilitate the laborious process of designing PPM klystrons.

66

New Concepts for Pulsed Power Modulators--
Diversified Technologies, Inc., 35 Wiggins
Avenue, Bedford, MA 01730-2314;
781-275-9444
Dr. Jeffrey Casey, Principal Investigator
Mr. Michael A. Kempkes, Business Official
DOE Grant No. DE-FG02-99ER82775
Amount: \$99,832

Future particle accelerators and colliders will require orders of magnitude improvement in pulsed power generation and control. These systems are projected to require millions of volts and thousands of amperes for very short pulses. Current pulsed power technology utilizes large

gas discharge tubes, pulse forming networks, and pulse transformers. However, these technologies are incapable of scaling to the peak power requirements of the next generation of high power physics systems. In this project, previously developed solid state pulse power systems, up to 140 kV and 2000 A, will be scaled-up by nearly an order of magnitude in voltage. A prototype modulator with very high voltage and very high power will be built to demonstrate and assess the scalability of this technology. Phase I will develop new design and technological approaches to scaling solid state switching systems to MV levels. These designs will be assessed for cost, efficiency, and reliability, and an optimal systems approach will be selected. The prototype modulator will be constructed in Phase II.

Commercial Applications and Other Benefits as described by the awardee: In addition to accelerators, these pulsed power systems should be applicable to new materials modification and treatment processes, such as plasma source ion implantation. Other applications include semiconductor fabrication and food sterilization. Very high voltage systems, may enable the development of new manufacturing and materials processing techniques across a wide range of industrial and medical applications.

suitable for testing advanced W-Band high-gradient accelerating structures. The development of the W-Band source is based on the principle of harmonic multiplication, using a 1-MeV, 60 A gyrating electron beam prepared in a cyclotron autoresonance accelerator cavity. The TE-111 mode cavity will be driven with 40 MW pulses from a 55 MW X-Band magnicon. Eighth-harmonic power will be generated in a TE-81 mode output waveguide, and coupled out using a quasi-optical system. Preliminary simulations, using an ideal beam, predict 91.4 GHz output power at a level of 131 MW. Phase I will design the 10-MW W-Band source. This will involve detailed theory and simulation studies of the electron gun, the rf circuit, the quasi-optical output structure, and the beam collector

Commercial Applications and Other Benefits as described by the awardee: Applications for a multi-megawatt W-Band source already exist for use in evaluating candidate structures for advanced high-gradient electron accelerators. Success with such evaluations should create demand for numbers of such W-Band sources to drive a W-Band test accelerator, and, ultimately, for thousands of such sources should a full-scale multi-TeV, W-Band electron-positron collider be built.

67

10-MW, W-Band Radio Frequency Source for a High Gradient Linear Accelerator--
Omega-P, Inc., 345 Whitney Avenue, Suite 100,
New Haven, CT 06511; 203-789-1164
Dr. Jay L. Hirshfield, Principal Investigator
Mr. George P. Trahan, Business Official
DOE Grant No. DE-FG02-99ER82847
Amount: \$100,000

Efforts are underway within the accelerator community to develop high-gradient accelerating structures operating at 91 GHz (W-Band). However, no high-power radio frequency (rf) sources are currently available to test such structures. This project will develop a 10-MW, W-Band, pulsed source, with a pulse width of one microsecond, that would be

HIGH-FIELD SUPERCONDUCTOR AND SUPERCONDUCTING MAGNET TECHNOLOGIES FOR HIGH ENERGY PARTICLE COLLIDERS

68

Bent Solenoids with Superimposed Dipole Fields--Advanced Magnet Laboratory, Inc.,
2730 Kirby Avenue, NE, Building 5, Palm
Bay, FL 32905-3402; 407-728-7543
Dr. Rainer B. Meinke, Principal Investigator
Mr. Mark W. Senti, Business Official
DOE Grant No. DE-FG02-99ER82730
Amount: \$99,725

Superconducting, bent solenoid magnets with superimposed dipole fields are needed for the planned U.S. Muon Collider that will be used for high energy physics research. This will require the development of a conductor pattern that generates the required field configuration, related coil manufacturing technology, and appropriate coil support structure and cryostat. In addition, the magnet also has to be able to operate in a strong radiation environment. This project will develop a bent solenoid with superimposed dipole field by tilting the turns of the solenoid winding with respect to the magnet axis. A round, Kapton-insulated mini-cable would be wound over a fiber-reinforced composite tube to form the coil. The technique will make use of radiation resistant adhesive systems and materials developed for fusion applications. During Phase I, a preliminary design of the bent solenoid with superimposed dipole field will be performed, which includes field calculations, operating conditions of the superconducting magnet, and a Finite Element Analysis of the coil support structure. A conceptual design of the required winding machine will also be developed. The concept of the winding machine will be demonstrated by building a simple tabletop winding fixture.

Commercial Applications and Other Benefits as described by the awardee: The bent solenoids with superimposed dipole fields should allow for attaining the field strength required by the proposed Muon Collider. Placement of mini cables on large cylindrical structures should also

benefit next generation gradient coils for MRI magnets.

69

A Novel Process for the Fabrication of Advanced High Temperature Superconductors--American Superconductor Corporation, Two Technology Drive, Westborough, MA 01545; 508-836-4200
Dr. Gilbert N. Riley, Jr., Principal Investigator
Mr. Tom Rosa, Business Official
DOE Grant No. DE-FG02-99ER82742
Amount: \$100,000

Improved high-field superconductor technology is needed in High Energy Physics (HEP) to enable next generation machines with field performance in the range of 15-20 T. Short lengths of high temperature superconductors based on Bi-2223 and fabricated using demonstrated scalable processes have already achieved very promising superconductor critical current densities in this field range, approaching 1500 A/mm² in a 12 T field at 4.2 K. However, BiSrCaCuO composites have not yet been made available with price-performance metrics appropriate for HEP; performance improvements are still required and costs must be significantly reduced. This project will investigate a novel process for producing very high performance BiSrCaCuO composite suited for HEP applications. Phase I will evaluate and develop a new long-length fabrication process that allows for new wire and cable designs. Ultimately, very high performance BiSrCaCuO material for HEP applications will be developed, with cross section current densities far greater than the minimum target of 250 A/mm² in fields of 12 T at 4.2 K.

Commercial Applications and Other Benefits as described by the awardee: Advanced BiSrCaCuO materials should advance the state-of-the-art of High Energy Physics machines and

also should enable or facilitate other government and commercial HTS applications that are dependent on performance and price.

70

Co-Processed Ceramic Insulation for High Field Accelerator Magnets--Composite Technology Development, Inc., 1505 Coal Creek Drive, Lafayette, CO 80026-2782; 303-664-0394

Mr. John A. Rice, Principal Investigator
Dr. Naseem A. Munshi, Business Official
DOE Grant No. DE-FG03-99ER82766
Amount: \$100,000

Some high performance superconducting magnets, such as wind-before-react systems, cannot be manufactured because of the temperature limits of current organic based insulation materials. This limitation forces the designer to accept either lower performance or higher costs. A ceramic-based insulation that is stable at the processing temperatures would eliminate this problem. This project will develop a ceramic composite insulator that offers the ease of application and processing of conventional organic insulation but is able to withstand the same heat treatment as the superconducting wire itself. This wrappable ceramic insulation will be compatible with high temperature reactions in the 750-900°C range and will be capable of supporting higher mechanical loads at cryogenic temperatures. Phase I will develop a co-processed ceramic insulation that can withstand the high temperature processing of the superconducting wire. Mechanical and chemical compatibility will be measured. Phase II will optimize the material and process to minimize costs. A magnet material property model will be generated to facilitate implementation in accelerator magnet designs.

Commercial Applications and Other Benefits as described by the awardee: The high temperature stability of the ceramic insulation would eliminate complex coil fabrication steps, lowering production costs. Applications such as high field magnets, fusion magnets, and medical

MRI instruments would become more viable with improved magnet processing, higher strength, and improved reliability.

71

Hg-Ba-Ca-Cu-O HTS Current Leads for High Energy Physics Applications at High Magnetic Field and Temperature--EURUS Technologies, Inc., 2031 East Paul Dirac Drive, Tallahassee, FL 32310-3711; 850-574-1800

Dr. Richard Hodges, Principal Investigator
Mr. John A. Romans, Business Official
DOE Grant No. DE-FG02-99ER82788
Amount: \$99,922

Present technology for current leads is insufficient for the demands of High Energy Physics (HEP) applications. Materials and technology are needed for current leads that will operate at temperatures above 77K in the presence of high magnetic field. This project will develop high Jc Hg-Ba-Ca-Cu-O based High Temperature Superconducting (HTS) material suited to high volume production. This material will then be incorporated in current leads for operation at temperatures above 77K and magnetic fields greater than 1 tesla. Phase I will merge two established technologies which independently produce material with properties unsurpassed in their respective fields. A large scale manufacturing process will be selected and its principles will be applied to a laboratory scale process in order to assess the feasibility of producing HTS components with superior properties in high volumes.

Commercial Applications and Other Benefits as described by the awardee: HTS current leads that demonstrate high current carrying capacities at temperatures above 77K in high magnetic fields should dramatically reduce operating costs for existing HEP Low Temperature Superconducting magnet systems. Market entry for advanced electric power systems should accelerate, with smaller footprints, reduced costs, and improved performance.

Low-Cost, Long-Length Manufacturing of Continuously Melt-Quenched Processed, Fully Stabilized, Multifilamentary High-Field Niobium-Aluminum (Nb_3Al) Superconductor—Plastronic, Inc., Subsidiary of Eurys Technologies, Inc., 2031 East Paul Dirac Drive, Tallahassee, FL 32310; 850-574-2998

Mr. Michael Tomsic, Principal Investigator

Mr. Michael Tomsic, Business Official

DOE Grant No. DE-FG02-99ER82789

Amount: \$100,000

The economical manufacture of fully stabilized multifilamentary Nb_3Al wire is needed to produce very high magnetic coils for nuclear magnetic resonance, accelerators, and research magnets. Such a wire is required for future high-energy accelerator magnets because Nb_3Al maintains a high critical current density in fields in the 10-25 tesla range. This project will develop a low cost manufacturing process for a near-net shape- Nb_3Al wire. A rapid quench process will be used to manufacture precursor wire in 1 km lengths. Phase I will focus on producing near-net-shape powder metallurgy precursor wires, designing high speed wire diameter reduction machines, and developing methods for putting a copper stabilizer on the Nb_3Al wire after the rapid quench process.

Commercial Applications and Other Benefits as described by the awardee: A low cost, high magnetic field wire that enables magnets in the 10-25 tesla range should find applications in nuclear magnetic resonance for medical and biological purposes. It should also enable the next generation of accelerators for the high energy physics community.

Development of a High Current Density Niobium-Tin Conductor with Ga and Mg Dopants for High Field Application—Supercon, Inc., 830 Boston Turnpike, Shrewsbury, MA 01545-3301; 508-842-0174
Mr. Mark Rudziak, Principal Investigator
Mrs. Elaine Tarkiainen, Business Official

DOE Grant No. DE-FG02-99ER82897

Amount: \$100,000

There is a clear demand from the high-energy physics community for conductors suitable for the fabrication of magnets operating at fields of 12T and above. Such magnets are needed for the next generation of particle accelerators, such as the Very Large Hadron Collider. Currently, Nb_3Sn -based conductors are the only commercially available conductors capable of satisfying these high performance needs. This project will advance the performance limits of Nb_3Sn conductors through the simultaneous addition of gallium and magnesium dopants. The gallium addition will enhance upper critical field and critical temperature, while the magnesium addition will provide gain refinement, enhancing critical current density. In Phase I, two gallium-and magnesium-doped monofilaments and an un-doped control monofilament will be assembled and processed to multifilamentary wire through a series of restacking steps. The gallium addition will be achieved by a novel process, whereby copper-gallium bronze rods are incorporated into a niobium filament core. The magnesium addition will be achieved by conventional alloying with a Nb-Sn bronze. The critical properties of the doped wires will be compared with the un-doped wire.

Commercial Applications and Other Benefits as described by the awardee: The enhanced Nb_3Sn -based conductors should be capable of satisfying the high performance needs for future particle accelerators.

Improvement of High Field Performance and Reliability of Niobium-Tin Conductor by Powder-In-Tube Method—Supercon, Inc., 830 Boston Turnpike, Shrewsbury, MA 01545-3301; 508-842-0174
Mr. Terrence Wong, Principal Investigator
Mrs. Elaine Tarkiainen, Business Official
DOE Grant No. DE-FG02-99ER82896
Amount: \$100,000

In order for the next generation high energy physics particle accelerators to reach higher collision energy levels, there is a need for higher field dipole magnets. This in turn demands superconductors that have higher critical current densities at higher fields than can typically be reached with NbTi. Thus Nb₃Sn conductors are the conductor of choice for the next generation dipole magnets (≥ 15 Tesla). This project will develop a high critical current density Nb₃Sn conductor produced by the powder-in-tube method with Ta and Ti elemental additions to the A15 phase. These additions have been shown to improve the upper critical field and high field critical current density. In Phase I, a Nb₃Sn conductor will be fabricated by the powder-in-tube (PIT) method with Ta and Ti added as dopants to improve high field performance. A multifilamentary assembly will be drawn to sample size, heat treated, and then tested for superconducting properties. Comparison of the Ta and Ti additions with a control sample will allow the PIT method to be evaluated as a means of improving Nb₃Sn conductor performance.

Commercial Applications and Other Benefits as described by the applicant: The principal application of a higher performing Nb₃Sn conductor would be in high field dipole magnets for high energy physics. However, other uses would be found in magnetic confinement systems for fusion reactors and nuclear magnetic resonance systems for chemical analysis.

75

High Performance Nb₃Sn (Ta) Wires by Tin Enrichment and Increased Filament Content-Superconducting Systems, Inc., 90 Rumford Avenue, Waltham, MA 02453; 781-642-6702
Dr. Shahin Pourrahimi, Principal Investigator
Ms. Minou Mossavat, Business Official
DOE Grant No. DE-FG02-99ER82898
Amount: \$99,933

The construction of next generation particle accelerators for high energy physics require that Nb₃Sn superconductors exhibit unprecedented performance and a substantial cost reduction. In

order to meet these needs, this project will develop an innovative route to fabricate a high-tin (Sn) content, bronze matrix wire with niobium (Nb) (7.5 wt percent Ta (tantalum)) filaments. The high Sn content will allow the filament content to increase and lead to achievement of Sn rich Nb₃Sn (Ta) phases with high performance. During Phase I, prototype high performance Nb₃Sn (Ta) wires, produced by tin enrichment and increased filament content, will be fabricated. In addition, superconducting and material properties will be characterized. Lastly, the economical advantages of the proposed wire fabrication approach will be demonstrated.

Commercial Applications and Other Benefits as described by the awardee: The Nb₃Sn (Ta) superconductors should find application in the next generation particle accelerator, energy storage, fusion reactor, and nuclear magnetic resonance magnets.

76

A High Current Very Low-Cost Niobium Tin Titanium-Doped Conductor Utilizing A Novel Internal Tin Process, with Separate Stabilizing Elements Scalable to Modern Niobium Titanium Production Economics-- Supergenics, 1233 Tree Bay Lane, Sarasota, FL 34242; 941-349-0930
Mr. Bruce A. Zeitlin, Principal Investigator
Mr. Bruce A. Zeitlin, Business Official
DOE Grant No. DE-FG02-99ER82899
Amount: \$99,500

Magnets for the next generation accelerators require a higher performance level in the superconductor to enable magnetic fields of 15 Tesla or more. The superconductor must also be cost effective in order for the magnets of these fields to be economically viable. This project will develop a superconductor of Nb₃Sn, using an internal tin process approach. The approach will utilize micron-size filaments doped with titanium to achieve high current in a process that allows large-scale production techniques, such as utilized in NbTi. The whole package would include a cable of low-cost copper, a

strengthening element if required, and the superconductor itself, resulting in a flexible overall conductor. Phase I will demonstrate the feasibility of the concept by processing several sub-scale billets to wire, followed by heat treatment and critical current testing. Various candidate materials will be evaluated to control the bonding of the superconductor stabilizer. Finally, cost models will be developed and cost reduction opportunities will be identified.

Commercial Applications and Other Benefits as described by the awardee: Lower cost superconductors should reduce the cost of MRI machines and expand the range of applications for MRI, a billion dollar industry. In addition, the next generation accelerators will require a significantly higher performance superconductor at an economical price. The conductor currently under development should meet these goals, and be readily and quickly scaleable to production.

TECHNOLOGIES FOR THE NEXT-GENERATION ELECTRON-POSITRON LINEAR COLLIDER

77

Automated Diamond Turning Lathe for the Production of Copper Accelerator Cells--
DAC Vision, Inc., 6390 Rose Lane, Carpinteria, CA 93013; 805-684-8307

Mr. James W. Drain, Principal Investigator

Mr. James W. Drain, Business Official

DOE Grant No. DE-FG03-99ER82774

Amount: \$100,000

Copper accelerator cells, as well as sub-micron tolerance metal parts, are now manually produced on research quality, single-point, diamond-turning lathes, largely of foreign manufacture. The process is costly and finished part quality is inconsistent due to human intervention. A production floor, diamond-turning lathe for single-point, diamond-turning metal parts based upon an existing product line will be built. It will feature automated part loading and unloading, and be optimized for the manufacture of copper accelerator cells. Phase I will investigate rotary cutting of parts, potential problems with automation and contamination, and the practicality of cutting both sides of a part on one machine. In addition, specifications for an automated lathe will be developed.

Commercial Applications and Other Benefits as described by the awardee: By improving part quality and consistency, the automated turning lathe should find application in the manufacture of sub-micron tolerance metal production parts.

This tool should also be valuable to industries that produce metal parts for precision motion control, such as the disk and tape drive industries, and metal optics industries.

78

High Power Switch--Diversified Technologies, Inc., 35 Wiggins Avenue, Bedford, MA 01730-2314; 781-275-9444

Dr. Jeffrey Casey, Principal Investigator

Mr. Micheal A. Kempkes, Business Official

DOE Grant No. DE-FG02-99ER82778

Amount: \$99,515

Existing solutions for high power switching in high energy physics applications are built upon vacuum and gas tube technologies, such as thyratrons and ignitrons. However, the Next Generation Linear Collider will require the use of new solid-state switch technology that has the potential to satisfy aggressive performance goals with lower cost and improved reliability. This project will utilize proven Insulated Gate Bipolar Transistor switching technology to replace the tubes in Pulse Forming Network pulsing and crowbar protection systems with fast, solid state, series switches. Phase I will design high power switches capable of replacing thyratrons in accelerator applications. The switches will be scalable to the needs of other colliders and high power applications. Also, the control systems required to provide

fast response to arc conditions will be prototyped.

Commercial Applications and Other Benefits as described by the awardee: Many of the drawbacks of existing thyatron and ignitron circuits – cost, lack of reliability, and use of hazardous materials – can be eliminated with the use of solid state switches. The high power, solid state switches should save millions of dollars in capital and operating costs in future accelerators and commercial operations, such as plasma-based materials modification and semiconductor fabrication.

79

Hybrid Next Generation Linear Collider Modulator--Diversified Technologies, Inc., 35 Wiggins Avenue, Bedford, MA 01730-2314; 781-275-9444

Dr. Jeffrey Casey, Principal Investigator
Mr. Michael A. Kempkes, Business Official
DOE Grant No. DE-FG02-99ER82776
Amount: \$99,927

The Next Generation Linear Collider (NLC) program will require 1600 klystron modulators capable of providing 500 kV, 500 A pulses at 120 Hz, representing one of the largest NLC cost factors. Modulators with the lowest possible life cycle cost are needed for this program to proceed in a cost-effective, realizable manner. This project will utilize solid state technology to design and build hybrid modulators (solid state switch/pulse transformer) that offer significant improvements in efficiency, reliability, and life cycle cost over conventional modulators. Phase I will design the hybrid NLC modulator and demonstrate the key technological capabilities to build it. The cost, reliability, and efficiency of the design will be assessed and compared to other NLC modulator architectures. Phase II will build one or more prototypes, which will be provided to the Stanford Linear Accelerator Center for assessment.

Commercial Applications and Other Benefits as described by the awardee: Reliable, low cost pulsed power is applicable to many commercial

processes, including semiconductor fabrication, metal treatments, and food sterilization.

80

Next Linear Collider Switching Power Supply--Diversified Technologies, Inc., 35 Wiggins Avenue, Bedford, MA 01730-2314; 781-275-9444

Dr. Timothy J. Hawkey, Principal Investigator
Mr. Michael A. Kempkes, Business Official
DOE Grant No. DE-FG02-99ER82779
Amount: \$99,893

Several high energy physics programs include technologies to build a TeV-scale, electron-positron, linear collider that would use normal conducting X-band (11.4 GHz) microwave power. However, the Next Generation Linear Collider (NLC) will be ten times the size of present-generation linear accelerators. Therefore, low cost, highly reliable, high voltage, high power supplies, with very high regulation and stability, will be required. This project will develop the high voltage designs needed to build a switching power supply that meets these specifications, and is capable of providing approximately 80 kW at 80kV (with efficiency over 95 percent and predicted reliability of over 100,000 hours). Another major objective will be to reduce the manufacturing cost of these supplies by a factor of five or more in volume production. During Phase I, a prototype power supply will be developed and evaluated for performance. This prototype will provide the basis for development of affordable, cost effective switching power supplies in Phase II and the subsequent production of the thousands of units needed for NLC.

Commercial Applications and Other Benefits as described by the awardee: The high voltage, switching power supply market is growing 24 percent annually worldwide. This power supply design should also directly translate into government and commercial pulsed-power applications such as, radar transmitters, broadcast power supplies, ion implantation, thin film deposition, and flat panel display

manufacturing.

81

Innovative, New and Advanced High Voltage Power Supply for Capacitor Charging at Linear Collider--International Power Group, Inc., 18250 68th Avenue, South, Kent, WA 98032; 206-949-5964

Mr. Wesley G. Clanin, Principal Investigator

Mr. David S. White, Business Official

DOE Grant No. DE-FG03-99ER82806

Amount: \$98,406

The Department of Energy requires a power supply for capacitor charging for a new linear accelerator. The supply must be over 90 percent efficient, reliable, and cost effective to manufacture and maintain. In addition, the market now demands decreased size while maintaining or increasing power output. This project will design and build a new high voltage power supply which is compact, cellular, easy to manufacture, over 95 percent efficient, and more reliable than a conventional power supply design. In Phase I, the feasibility of the new cellular power supply concept will be proven by using computer modeling and simulation along with the development and testing of a scaled down prototype. Based on the models, simulations, and prototype testing, the design for the high voltage power supply will be completed in order to meet the specification requirement for the linear collider.

Commercial Applications and Other Benefits as described by the awardee: Given its low stored energy and precise output, the new cellular high voltage power supply should improve design and performance of radar, x-rays, lasers, power vacuum tubes, and high voltage capacitor charging.

82

Adiabatic Forming of Copper Accelerator Cells for the Next Generation Linear

Collider--LMC, Inc., 333 Dietz Avenue, De Kalb, IL 60115; 815-758-3514

Mr. Lennart J. Lindell, Principal Investigator

Mr. Lennart J. Lindell, Business Official

DOE Grant No. DE-FG02-99ER82813

Amount: \$100,000

The linac for the next generation electron-positron linear collider (NLC) will be comprised of nine thousand accelerator structures each requiring 207 ultra-high precision copper cells. The cost of building these nearly two million copper cells is expected to be as much as ten percent of the total cost of building the entire machine. In order to reduce the cost of manufacturing these copper accelerator cells, this project will apply adiabatic forming methods to replace the rough machining of accelerator cells. The adiabatic process can form exotic lightweight metals into shapes not possible with conventional presses. It requires little or no lubricants or cutting fluids and therefore, can eliminate or reduce cleaning and water disposal. Phase I will develop models and perform calculations required for adiabatically forming the cells. The calculations will be verified by developing prototype tooling and producing scale size cells.

Commercial Applications and Other Benefits as described by the awardee: The adiabatic forming process should be the technology of choice for producing the accelerator cells for the NLC. It is extremely fast (milliseconds) and uses 80 percent less energy than conventional methods.

83

Pulse Capacitors for Next Generation Linear Colliders--Nanomaterials Research Corporation, 2620 Trade Center Avenue, Longmont, CO 80503-7551; 303-702-1672

Dr. Yuval Avniel, Principal Investigator

Ms. Molly M. W. Kostecky, Business Official

DOE Grant No. DE-FG03-99ER82840

Amount: \$100,000

Research and development programs in high energy physics require pulse capacitors with low series inductance and high capacitance at high

voltages. In addition, it is also desirable that the capacitor network be compact and able to survive partial voltage reversal during non-standard conditions. This project will develop nanostructured capacitors based on proprietary formulations that exhibit these unique properties. It is expected that the network of these capacitors will be able to meet the requirements of Next Generation Linear Colliders. Phase I will develop nanostructured formulations, and produce and test one hundred proof-of-concept nanostructured capacitors.

Commercial Applications and Other Benefits as described by the awardee: Future linear colliders, medical imaging, and high-voltage, pulse-power components should all benefit from this technology. Also, the technology could provide significant reductions in operating costs of high energy linear colliders and electric vehicles. Lighting products are another large commercial market.

84

Ultra Low Loss Radio Frequency Window Materials--TPL, Inc., 3921 Academy Parkway North, NE, Albuquerque, NM 87109-4416; 505-342-4414

Dr. Stuart T. Schwab, Principal Investigator
Dr. William F. Hartman, Business Official
DOE Grant No. DE-FG03-99ER82910
Amount: \$99,999

Silicon nitride is an excellent candidate for RF windows in accelerator applications. Unfortunately, additives used to process dense silicon nitride raise its loss factor to levels unacceptable for long term use in klystrons. Methods that do not use additives are prohibitively costly. This project will develop novel materials and chemical processing routes for producing dense silicon nitride without the use of additives. This approach will yield high purity, dense silicon nitride windows at low cost. In Phase I, new preceramic additives will be used in two different low-cost processing methods for manufacturing silicon nitride bodies. The effect of the additives will be determined through measuring mechanical and electromagnetic properties of the silicon nitride components.

Commercial Applications and Other Benefits as described by the awardee: Silicon nitride has been identified as a leading candidate for hot-zone applications in automotive engines. Current manufacturing methods are prohibitively expensive for these automobile applications.

HIGH ENERGY PHYSICS DATA ACQUISITION AND PROCESSING

85

Double Fused 1.55 Micrometer Vertical Cavity Lasers for 80K Operation--Conductus, Inc., 969 West Maude Avenue, Sunnyvale, CA 94086-2802; 408-523-9458
Dr. Yongming Zhang, Principal Investigator
Mr. Ron Wilderink, Business Official
DOE Grant No. DE-FG03-99ER82768
Amount: \$99,470

Ultra-wide bandwidth and low power dissipation make superconducting and cryogenic semiconductor electronics very attractive for routing and processing the vast amount of data acquired

in high energy physics experiments. However, cryogenic circuits cannot be used to build an ultra-high-speed fiber optic link because typical commercial laser diodes have threshold currents that exceed 10 mA. A wide band, low threshold laser could enable cryogenic circuits to modulate lasers directly and make it possible to build a cryogenic fiber optic link for wideband data transmission. This project will develop a low-threshold, long-wavelength vertical cavity laser (VCL) operating around 80K. Recent advances make it possible to develop the VCL with submilliamp threshold current, 10 GHz modulation bandwidth, and optimized for low temperatures. Device fabrication will

incorporate recent improvements in the design of GaAlAs/GaAs mirrors and the InGaAsP/InP multi-quantum well active region. In Phase I, the recently improved double-fused 1.55 μm vertical cavity lasers designed for room temperature operation will be investigated in detail at cryogenic temperatures. Devices for high-speed operation at 80K will also be designed, fabricated, and characterized.

Commercial Applications and Other Benefits as described by the awardee: This technology should impact future applications of superconducting electronics in fiber-optic communications, high energy physics instrumentation, cryogenic satellite communications, and the long-haul fiber-optical data transmission systems. Low cost, high performance vertical cavity lasers could also be used in fiber optic transport subsystems that could be implemented in future broadband wireless systems.

HIGH ENERGY PHYSICS DETECTORS

86

Carbon-Carbon Composite Closeout Frames for Space Qualified, Stable High Thermal Conductivity Detector Support Structures-- HYTEC, Inc., 110 Eastgate Drive, Suite 100, Los Alamos, NM 87544-3304; 505-661-0080
Dr. Eric Ponslet, Principal Investigator
Mr. William O. Miller, Business Official
DOE Grant No. DE-FG03-99ER82802
Amount: \$99,469

Large, high energy, particle-tracking detectors are now being planned for space-based instruments like the Gamma-Ray Large Area Telescope (GLAST). These detectors require ultra-stable, passively-cooled, low-radiation-length, low-mass support structures. Although carbon-carbon composites have these uniquely desirable properties, they have not yet been used or qualified as primary structural elements for space applications. This project will develop novel manufacturing techniques to allow production of ultra-light, space-qualified thermal/structural elements made of carbon-carbon composites. Phase I will identify various fabrication concepts for carbon-carbon thermo-structures with the required thermal conductivity and strength. The concepts will be rated on manufacturability, expected thermal performance, and mechanical ability to survive launch. Key features of the most promising will be prototyped to demonstrate manufacturability with desired characteristics. Finally, a

preliminary closeout frame will be designed, and its thermal and structural behavior will be predicted using numerical simulations.

Commercial Applications and Other Benefits as described by the awardee: The space qualified carbon-carbon closeout technology should be directly applicable to the tracker subsystems of the GLAST instrument, which could become the first, direct commercial application of this new technology. It should also greatly reduce multiple scattering problems and improve thermal management for that detector. The technology could then be generalized for applications in various space-based, ultra stable thermo-structures, such as optical benches.

87

Low Cost Support Structures, with New Advanced Composite Materials Tailored For Ultra-Stable Particle Tracking Detectors-- HYTEC, Inc., 110 Eastgate Drive, Suite 100, Los Alamos, NM 87544-3304; 505-662-0080
Mr. William O. Miller, Principal Investigator
Mr. William O. Miller, Business Official
DOE Grant No. DE-FG03-99ER82801
Amount: \$99,985

Precision charged-particle detectors for high energy physics research rely upon ultra-high-modulus composite materials. Designs which address the need for low mass, low percent

radiation length, and exacting stability, frequently make use of expensive fiber systems and equally expensive graphite-fiber honeycomb core materials. As detector sizes increase, the high costs of the materials themselves and the material processing labor can force cost/benefit tradeoffs that sacrifice detector performance. This project will develop new material processing techniques for producing high stiffness sandwich panels from inexpensive composite materials. A novel heat-treating process for carbon-carbon laminates produce sandwich facings with 60 percent greater stiffness at half the cost of resin-based composites. Also, a new very low-density, high modulus syntactic carbon foam material will be developed. Phase I will evaluate material properties of carbon-carbon laminates processed from low-cost, meso-pitch precursor material; validate material processing steps for producing ultra-high modulus carbon-carbon laminates; develop high-modulus syntactic carbon foam at .05 g/cc; construct sample sandwich panels; and establish bending properties. Ultimately, complete detector structures will be constructed, including carbon structures free of adhesives for maximum radiation resistance.

Commercial Applications and Other Benefits as described by the awardee: The new material processing techniques should have applicability to stable structures for next generation physics detectors, passive cooling of high heat flux electronics, and lightweight space-based optical structures requiring passive cooling. Cost savings of 50 percent should be achievable, along with performance increases of 60 percent.

88

Superpressure Neutrino Detector--L'Garde, Inc., 15181 Woodlawn Avenue, Tustin, CA 92780-6419; 714-259-0771

Dr. Koorosh Guidanean, Principal Investigator
Mr. Roger Garrett, Business Official
DOE Grant No. DE-FG03-99ER82810
Amount: \$99,913

For neutrino detection, used in high energy physics research, a sphere of scintillating liquid must be held precisely, without significant distortion, inside a sphere of oil. In this system, a pressurized balloon holds the scintillating oil submerged within the sphere of oil. Superpressure balloon technology allows the balloon to have a controlled shape without cable or strap reinforcements. The Phase I project will analyze critical and pertinent properties of balloon materials, including ultimate strength, modulus, permeability, and transmissivity for candidate thin films. After major candidates are selected, accelerated aging tests will determine their stability. Strong bonding techniques will be developed to produce the films and analytical modeling will be used to predict shape control.

Commercial Applications and Other Benefits as described by the awardee: This technology should provide an elegant and inexpensive method of neutrino detection, facilitating the next step in exploring the nature of the universe through observations of the type and possible mass of the elusive neutrino. Similar techniques should be generally applicable to water or fuel storage facilities, and directly applicable to atmospheric superpressure balloons for Earth or planetary exploration.

NUCLEAR PHYSICS INSTRUMENTATION AND TECHNIQUES

89

New Fullerene-Based Resistor Technology for Use in Low Noise Instrumentation--Cremat, 45 Union Street, Watertown, MA 02172-2523; 617-926-0661

Mr. Fred Olschner, Principal Investigator

Mr. Fred Olschner, Business Official
DOE Grant No. DE-FG02-99ER82771
Amount: \$100,000

Feedback resistors are critical components of the low noise preamplifiers used in almost every nuclear physics experiment. Unfortunately, no

commercial resistor manufacturer has addressed the stringent low noise requirements of these feedback resistors. As a result, producers of low noise instrumentation for nuclear physics must utilize resistors that are unnecessarily noisy. This project will develop resistor technology based on newly developed fullerene films, which may offer improved noise performance over currently available resistive materials. In addition, these resistors will be produced using packaging materials and in sizes that will further assist in minimizing electronic noise. Phase I will seek to demonstrate the low noise properties of the proposed fullerene-based resistors by fabricating sample resistors and testing their low noise properties. The noise contribution will be assessed as a function of film resistivity, dimensions, and substrate material to determine their relative importance in producing resistors possessing a minimum of electronic noise.

Commercial Applications and Other Benefits as described by the awardee: The proposed low noise resistors should find use in all charge sensitive preamplifiers which use discrete components. Charge sensitive preamplifiers are extensively utilized in instrumentation used in Nuclear Physics, High Energy Physics, Nuclear Verification, Medical Physics, and other fields where nuclear detectors are used. In addition, this resistor technology also should find use in other types of low noise circuitry, such as in photodiode preamplifiers used in the detection of weak optical signals.

90

SQUID Susceptometers for Read Out of Magnetic Microcalorimeters--HYPRES, Inc., 175 Clearbrook Road, Elmsford, NY 10523-1109; 914-592-1190
Dr. Masoud Radparvar, Principal Investigator
Dr. Elie Track, Business Official
DOE Grant No. DE-FG02-99ER82800
Amount: \$100,000

A magnetic calorimeter is an attractive candidate for an x-ray detector for nuclear physics research. This project will build an array of magnetic microcalorimeters with the best energy

dispersion for use as the spatial imaging array at the focal plane of an x-ray telescope. The calorimeters will use magnetic sensors to measure very small temperature changes resulting from the absorption of x-rays. The magnetization of localized paramagnetic ions in a metallic matrix will be determined by using a dc SQUID, which is extremely sensitive and ideally adapted to the measurement of flux changes. Furthermore, the sensitivity is only weakly dependent upon heat capacity, and, for a low temperature device, the magnetic sensor with the metallic host offers very fast response. In Phase I, the SQUID susceptometers will be developed, evaluated, and optimized. In Phase II, an array of magnetic microcalorimeters will be constructed, integrated with SQUID susceptometers, and demonstrated.

Commercial Applications and Other Benefits as described by the awardee: The availability of a magnetic microcalorimeter integrated with a low-cost SQUID susceptometer should have many nuclear and high energy physics research applications. In addition, the SQUID readout can be used for biomagnetometry for the mapping of brain functions, and the detection of corrosion and cracks in aircraft.

91

Low Cost Waveform Digitizer for Physics Using Advanced Computer Graphics Technology--Jorway Corporation, 27 Bond Street, Westbury, NY 11590-5042; 516-997-8120
Mr. Timothy D. Radway, Principal Investigator
Mr. Timothy D. Radway, Business Official
DOE Grant No. DE-FG02-99ER82809
Amount: \$99,750

Traditionally, separate analog-to-digital convertors and time-to-digital convertors have been used in many physics experiments to measure both the energy and timing of detected particles but these devices provide only charge and leading edge timing. A well known technique, Wave Form Digitizing at each detector is a better method, but it has been too expensive. It provides the evolutionary history

of the pulse, including pulse shape, which assists in particle identification. This project will investigate new developments in the personal computer marketplace, which offer the possibility of an order-of-magnitude reduction in the cost of high speed waveform digitizers. Phase I will determine the feasibility of employing these techniques in the design of high speed waveform digitizers for multi-channel physics applications. A successful conclusion will provide the basis for development of commercial products in FASTCAMAC, VME, VME-P and direct chamber mounted boards.

Commercial Applications and Other Benefits as described by the awardee: The ability to design high speed, low cost, and low power Wave Form Digitizers should provide the opportunity for the improvement of small experiments with multiple particles and high rate environments at a modest cost. The technique of evolution of particle shape should be valuable to nuclear, atomic and high energy physics as well as other related fields.

92

Application of the Combinatorial Synthesis and Laser-Heated Pedestal Growth Techniques to the Development of New Scintillator Materials--Lasergenics Corporation, 6830 Via Del Oro, Suite 103, San Jose, CA 95119-1353; 408-363-9791

Dr. Sandor Erdei, Principal Investigator
Dr. Richard Schlecht, Business Official
DOE Grant No. DE-FG03-99ER82811
Amount: \$99,915

Future nuclear and high energy physics experiments will use scintillators that must have greater time and energy resolution, higher radiation hardness, and larger crystal sizes than exist today. Currently, the materials that are closest to meeting the needs of the Department of Energy (DOE) and other users are silicates doped with cerium. This project will apply techniques of combinatorial synthesis and laser-heated pedestal growth (LHPG) to a wide variety of silicates to search for and develop new scintillator materials with improved performance

and greater crystal size. These techniques allow thousands of sample compositions to be surveyed in a short time. In Phase I, a combinatorial synthesis system will be used to synthesize over 1000 integrated materials chips that will be screened to determine which compositions are the most attractive for DOE nuclear experiments. These compositions will be grown in fiber form using the LHPG method to determine if crystals of large size can be grown, and if they will meet the needs of the users.

Commercial Applications and Other Benefits as described by the awardee: New scintillator materials having faster response times, higher energy resolution, greater radiation hardness, and greater physical size should find application in nuclear and high energy physics, medical diagnostics (e.g. XCT and PET equipment), industrial measurement, security inspections, and in the search for natural resources such as oil, gas and uranium.

93

Large Volume Detectors from New Cadmium Zinc Telluride Growth Process--Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02172-4624; 617-926-1167

Dr. Michael R. Squillante, Principal Investigator
Dr. Gerald Entine, Business Official
DOE Grant No. DE-FG02-99ER82865
Amount: \$100,000

During the past decade, revolutionary new x- and γ -ray detector designs have been proposed based upon the semiconductor cadmium zinc telluride (CdZnTe). While their demonstrated promise has been very good, their real future requires a consistent and cost effective supply of high quality, large volume substrates needed for detector fabrication. Current CdZnTe fabrication suffers from significant material defects, electrical nonuniformities, and prices exceeding \$1000/cm³. Detector grade CdZnTe has previously been grown by largely one method. This project will develop an alternative crystal growth technique that has been used with great success in the fabrication of IR detector

substrates. While known to yield exceptional physical properties, this technique must be extended to achieve the stringent electrical properties needed for γ -ray detection. In Phase I, the crystal growth will be tested under varying inert and Cd vapor pressures, and with addition of an additive dopant. Several electrical criteria will be evaluated to determine whether the growth technique can achieve the necessary detector properties.

Commercial Applications and Other Benefits as described by the awardee: More available, lower cost CdZnTe substrates should allow new detector designs to become feasible. In nuclear physics, high densities of less cumbersome detectors would lead to faster and more complete data. Other applications include nuclear medicine imaging, nonproliferation monitoring capabilities, and industrial non-destructive evaluation.

94

Nuclear Data Evaluation Tools--Scientific
Digital Visions, Inc., 2 North Second Street,
Suite 1215, San Jose, CA 95113-1310;
408-289-8492

Ms. Tracy Langlands, Principal Investigator
Ms. Tracy Langlands, Business Official
DOE Grant No. DE-FG03-99ER82880
Amount: \$99,979

The U.S. and international nuclear data networks have identified a critical need for new technologies for nuclear data evaluators. Out-of-date methods are currently used with the networks, which has been identified as a possible barrier to attracting young scientists. Tools are needed to determine the consistency of data, to aid in the processing of information, and to graphically display the information in the format of interactive level schemes. This project will address the broader issue of the electronic publication of nuclear data. Tools will be developed that support both the researcher who publishes articles containing nuclear data and the evaluator who can electronically extract the nuclear data for further processing. Phase I will examine the process of data entry that an author

or evaluator will use to define level schemes. Software will be designed to support textual and interactive methods for defining level schemes.

Commercial Applications and Other Benefits as described by the awardee: There is a significant need for publication tools that take the electronic document beyond a simple hypertext model. These technologies should have use throughout physics and can be extended to chemistry and other sciences.

95

Technologies for Data Evaluation and Electronic Scientific Articles--Scientific
Digital Visions, Inc., 2 North Second Street,
Suite 1215, San Jose, CA 95113-1310;
408-289-8492

Ms. Tracy Langlands, Principal Investigator
Ms. Tracy Langlands, Business Official
DOE Grant No. DE-FG03-99ER82879
Amount: \$99,690

Modern tools are needed to manage the complex nuclear properties data sets, to assist in the scanning of electronic journal articles, and to simplify the process of data evaluation. This project will develop tools that allow authors to prepare interactive tables, scientific equations editors, and reference tools to produce highly-functional electronic articles. Methods will be defined that allow the evaluator to easily extract and process the complex data. Phase I will define a model for electronic nuclear data publication tools. Software will be developed to test the interactive tables, the equation editor, and other tools identified in the research. Nuclear data evaluation software will be designed to display and process nuclear structure data sets. Results of the studies will be refined using comments from members of the U.S. Nuclear Data Network.

Commercial Applications and Other Benefits as described by the awardee: The proposed technology has a direct impact on the U.S. and international nuclear data networks. There is a significant need for publication tools that take

the electronic document beyond a simple hypertext model. The technologies proposed here can be used throughout science and beyond. This technology should assist in the collection and management of published nuclear data. The proposed software has direct applications to nuclear physics research.

96

Technologies to Produce Evaluated Nuclear Structure Data File-Traceable Libraries for Gamma-Ray Spectroscopy--Scientific Digital Visions, Inc., 2 North Second Street, Suite 1215, San Jose, CA 95113-1310; 408-289-8492
Mr. James Herro, Principal Investigator
Ms. Tracy Langlands, Business Official
DOE Grant No. DE-FG03-99ER82881
Amount: \$99,946

Gamma-ray spectroscopy relies on spectral libraries to help identify radiations detected in nuclear physics experiments. These libraries are not tailored to prior knowledge about a sample, and they are not directly traceable to the standard databases of the National Nuclear Data Center. Current practices are prone to

misidentification of nuclides and require significant interaction to the scientist. This project will develop technologies to manage custom gamma-ray spectral libraries. Data will be transferred from databases at the National Nuclear Data Center to a local computer where it will be converted into a library usable to commercial spectroscopy software. Graphic nuclide identification software will provide more sophisticated methods of identifying gamma rays in a spectrum. Phase I will define a model for the custom spectral libraries, evaluate the quality of the existing nuclear data, and develop software prototypes to test the concepts. A nuclide identification program will be designed and prototyped to establish a model that can be implemented in Phase II.

Commercial Applications and Other Benefits as described by the awardee: The technology should have application to Federal agencies, national laboratories, university research groups, and nuclear analytical laboratories. It could be applied in nuclear physics, nuclear chemistry, nuclear engineering, health physics, and environmental monitoring.

NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

97

Development of High Power Radio Frequency Windows for Next-Generation Superconducting and Normal Conducting Accelerators--Advanced Energy Systems, Inc., 27 Industrial Boulevard, Suite E, Medford, NY 11763; 516-575-9345
Mr. Michael Cole, Principal Investigator
Mr. Anthony Favale, Business Official
DOE Grant No. DE-FG02-99ER82725
Amount: \$99,981

High current, high duty factor accelerators have historically been plagued by the problem of transferring the necessary radio frequency (RF) power through the vacuum boundary between

the RF transmission system and the high vacuum environment of the accelerator. This problem has limited the practical levels of current and accelerating field because the amount of power delivered through a single window has been limited to approximately 200 - 300 kW at 100 percent duty factor. A higher power window assembly will deliver more power per meter of accelerator thereby reducing cost and complexity while improving reliability. This project will integrate electromagnetic, thermal, and structural analysis with novel mechanical design, material utilization, and manufacturing techniques to arrive at a window assembly that combines high thermal conductivity, effective ceramic cooling, optimized ceramic shape, and optimized

waveguide details. The goal is a window that is not limited by thermal effects. Phase I will concentrate on analytical iterations of the RF geometry and the thermal/structural performance. Suitable candidates will be carried to the detailed design stage to develop attachment details, process plans, and fabrication cost estimates. Two designs will be produced: one for the Jefferson Laboratory Free Electron Laser upgrade, and one for lower frequency applications such as the Cornell Electron Storage Ring.

Commercial Applications and Other Benefits as described by the awardee: A window assembly not limited by thermal effects would revolutionize the accelerator world by allowing much higher power input per unit length than currently possible. In superconducting systems particularly, significantly higher gradients with higher current could be produced, thereby improving overall cost, efficiency, and reliability of accelerator systems.

98

Electromagnetically Forming a Seamless Niobium Radio Frequency Superconducting Cavity--Advanced Energy Systems, Inc., 27 Industrial Boulevard, Suite E, Medford, NY 11763; 516-575-9345

Mr. Elvin Burger, Principal Investigator
Mr. Anthony Favale, Business Official
DOE Grant No. DE-FG02-99ER82727
Amount: \$88,968

This project will further develop the process of electromagnetically forming a niobium radio frequency (RF) superconducting cavity for nuclear physics accelerators. This process eliminates costly machining and electron beam welding and improves performance characteristics. Phase I will determine the power required in the magnetic coils, as well as the arrangement of the coils to the work piece and mandrel, using finite element analysis. An axisymmetric transient magnetic model will determine eddy currents, power loss due to the eddy currents, and induced magnetic forces in the niobium work piece, all as a function of

time. This data will be utilized in a detailed design of the tooling required to electromagnetically form a complete RF superconducting cavity. The Phase II project will manufacture and test a single cell niobium RF superconducting cavity.

Commercial Applications and Other Benefits as described by the awardee: Niobium exhibits superconductivity, that is, the lack of electrical resistance at very low temperatures. As a result, superconducting niobium forming should be useful in electron beam accelerators, power generation, propulsion, and other electronic devices.

99

Fabrication of Seamless Niobium Superconducting Accelerating Cavities Using Directed Light Fabrication--Advanced Energy Systems, Inc., 27 Industrial Boulevard, Suite E, Medford, NY 11763;

Dr. Stephan Melnychuk, Principal Investigator
Mr. Anthony Favale, Business Official
DOE Grant No. DE-FG02-99ER82726
Amount: \$100,000

Superconducting niobium radio frequency structures are increasingly being used for high brightness and high gradient accelerators. However, the primary methods used for fabricating niobium superconducting cavities, deep drawing and spinning, are labor intensive and introduce contaminants that degrade performance. This project will investigate the fabrication of RRR seamless niobium superconducting RF accelerating cavities using a directed light fabrication (DLF) technique. (RRR, the high residual resistivity ratio, is the customary gauge of niobium purity.) In Phase I, numerous test coupons will be fabricated from commercially procured Nb powder, and the physical and mechanical properties that most significantly influence the behavior of superconducting cavities will be measured. The DLF process parameters for producing fully dense niobium structures will be optimized. In Phase II, several 1.499 GHz single cell seamless cavities will be fabricated and tested at Thomas

Jefferson National Accelerator Laboratory.

Commercial Applications and Other Benefits as described by the awardee: By eliminating labor intensive manufacturing tasks, a significant cost reduction should be realized in the production of superconducting niobium cavities for RF accelerators. Increases in the RRR value should improve cavity performance, and the DLF process parameter optimization should improve the ability to control grain microstructure. In addition to particle accelerators, the DLF technique should also be applicable to many other advanced manufacturing tasks.

100

Superconducting Radio Frequency Photocathode Electron Gun--Advanced Energy Systems, Inc., 27 Industrial Boulevard, Suite E, Medford, NY 11763; 516-575-9345

Mr. Micheal Cole, Principal Investigator

Mr. Anthony J. Favale, Business Official

DOE Grant No. DE-FG02-99ER82724

Amount: \$98,808

High-brightness, superconducting continuous wave accelerators presently use an electron source that is separated from the initial accelerating modules. Significant gains in compactness, beam brightness, efficiency, and reliability could be realized by developing a superconducting gun where the photocathode is an integral part of the initial accelerating cavity. This project will develop a system that eliminates the need for a separate electron gun by utilizing the cavity endwall itself as the integral photocathode. Using existing cryogenic, laser, radio frequency, and diagnostic equipment, the achievement of superior brightness and beam quality from the gun will be demonstrated. In Phase I, the beam dynamics and thermal/mechanical design of a multi-cell, superconducting radio frequency cavity with an integral photocathode will be completed. The design will yield a high-brightness, high quality electron beam at the output of the injector system.

Commercial Applications and Other Benefits as described by the awardee: A superconducting photocathode gun would be an ideal source for superconducting electron accelerators and free electron lasers. Additional applications would ensue if the gun can be further developed towards the higher power required for commercial material processing and military free-electron laser applications, because of the improved cost, performance, and efficiency.

101

A 200 Kilowatt Average Power Microwave Window for L-Band Applications--AMAC International, Inc., Applied Research Center, 12050 Jefferson Avenue, Suite 717, Newport News, VA 23606; 757-269-5641

Dr. Quan-Sheng Shu, Principal Investigator

Dr. Quan-Sheng Shu, Business Official

DOE Grant No. DE-FG02-99ER82739

Amount: \$98,000

A reliable design for a 200 kW power window, for frequencies above 1 GHz, is needed for radio frequency (rf) cavities in the High-Power Free-Electron Laser upgrade at the Thomas Jefferson National Accelerator Facility. Most window designs use thin windows that are sensitive to charge build-up and arcing failures, or are designed so that they generate high tensile stresses, leading to eventual cracking and loss of vacuum. This project will develop a robust, manufacturable, ceramic window design for L-band applications. Advanced computer codes for microwave analysis and thermal stress analysis will be used to evaluate various design options rapidly and effectively. Phase I will evaluate several round and rectangular window designs at 1.5 GHz. These include a self-matched design in rectangular waveguide, a standard pillbox design, a traveling wave pillbox design, and a tapered rectangular-to-round waveguide window assembly. The compression ring used to pre-stress the ceramic and allow for greater thermal gradients across the window will also be designed. A low power microwave test will verify that the impedance matching and ghost modes match the computer analysis, and a

brazing test will verify the manufacturability of the compression ring design.

Commercial Applications and Other Benefits as described by the awardee: A reliable 200kW window for radio frequency cavities in the Free-Electron Laser upgrade should result. The same design can also be used to improve the reliability of the existing microwave system currently in use or to benefit other L-band Colliders. The design and unique manufacturing approach should also prove useful as a model for other frequency bands to help solve the high-average-power window problem.

102

A High Efficiency Electron Cyclotron Resonance Ion Source System for the Production of Radioactive Ion Beams--
Berkeley Ion Equipment, Inc., 3400 De La Cruz Boulevard V, Santa Clara, CA 95054; 408-727-9071

Dr. Zu Q. Xie, Principal Investigator
Mr. M. Wei, Business Official
DOE Grant No. DE-FG03-99ER82750
Amount: \$92,980

This project will evaluate and develop a high efficiency, high charge state electron-cyclotron-resonance ion source system for the production of radioactive ion beams used in nuclear physics accelerators. Specifically, a high performance electron-cyclotron-resonance ion source with a hot liner will be developed to increase the ionization efficiency. A thermal transfer line between the production target and the ion source will be used to reduce high radiation damage to the ion source. Isobar contamination will be minimized by controlling the thermal gradient of the transfer line for selective transport. Phase I will determine the optimum parameters for the thermal transfer line, the hot liner, and the high charge state electron-cyclotron-resonance ion source. Cost estimates and engineering drawings of the proposed ion source system will be produced.

Commercial Applications and Other Benefits as described by the awardee: In addition to the

applications in nuclear and atomic physics and applied science, the electron-cyclotron-resonance ion source should find application in industry for high energy ion implantation, ion milling, and surface modification.

103

Microwave Absorbing Materials for Accelerators in Cryogenic Environments--
Ceradyne, Inc., 3169 Red Hill Avenue, Costa Mesa, CA 92626; 714-549-0421
Dr. Biljana Mikijelj, Principal Investigator
Mr. Howard George, Business Official
DOE Grant No. DE-FG03-99ER82759
Amount: \$100,000

Current, commercially available microwave absorbing materials (terminations) do not provide adequate microwave absorption at the extremely low temperatures (2-50 K) that are required to operate many super-cooled, superconductor-based particle accelerators. Artificial, dielectric, lossy ceramics, with temperature-independent dielectric properties in the microwave frequency range, are being developed. These types of materials would satisfy all of the required properties for accelerator environment applications. The materials are being developed using the concepts of artificial dielectrics, and by identifying the type of conductive phase required in the system to yield temperature-independent, microwave absorption properties. Ceramic, aluminum nitride (AlN) based systems will be created and evaluated with emphasis on the selection of the conductive phase, which will provide low temperature loss and the capability of functioning in the accelerator environment. Due to temperature-independent properties, materials developed using this approach will be universally applicable in microwave absorbing applications such as use in Travelling Wave Tubes, Klystrons, Coupled Cavity Tubes etc., serving commercial and military communication applications. In Phase I, at least one artificial dielectric material family (based on AlN) will be designed and (to be determined) conductive phase, and its dielectric properties in the microwave frequency range will be characterized. The fact that it can meet material requirements for use in accelerator

environments will also be verified. Additionally, it is planned to further characterize the AlN-C (glassy) dielectric system. Hot pressing will be used as the manufacturing method.

Commercial Applications and Other Benefits as described by the awardee: These materials should, in addition to cryogenic environments, operate both at room and elevated temperatures, with more predictable properties than other currently available termination materials. Therefore, companies that commercially manufacture microwave amplification devices for communication, both commercial and military, should be able to use the material in their devices. Superconducting accelerators operating at extremely low temperatures should also have a reliable source of microwave absorbing materials to ensure optimal performance by reducing higher-order-modes during cavity rebuilds and for the design of new accelerators.

104

A High Force Actuator for Superconducting Radio Frequency Cavity Tuning--Energen, Inc., 17 D Sterling Road, Billerica, MA 01862-2518; 978-671-5400

Dr. Chad H. Joshi, Principal Investigator

Dr. Chad H. Joshi, Business Official

DOE Grant No. DE-FG02-99ER82784

Amount: \$100,000

Superconducting Radio Frequency (SRF) cavities used in high- and medium-energy physics research, are tuned by mechanically squeezing them along their axis. The tuner actuator must produce a force of several thousand pounds and have submicron positioning resolution. This project will develop an SRF tuner based on cryogenic magnetostrictive materials. The tuner is based on a linear stepper motor that use a pair of friction clamps to move a shaft along its axis. The stepper motor has a high force capability and will maintain its position when powered off. Thus, cavity tuning does not require active control and tuning is maintained in the event of a power failure. The Phase I project will design, fabricate and test a prototype SRF tuner. The

tuner will be installed and tested on a SRF cavity at Jefferson Laboratory.

Commercial Applications and Other Benefits as described by the awardee: Magnetostrictive actuators should have a wide range of applications including motion control, robotics, active vibration control and adaptive optics.

105

A Digital SQUID Instrument for High-Precision Particle Beam Current Measurement--Hypres, Inc., 175 Clearbrook Road, Elmsford, NY 10523-1109; 914-592-1190

Dr. Deepnarayan Gupta, Principal Investigator

Dr. Elie K. Track, Business Official

DOE Grant No. DE-FG02-99ER82799

Amount: \$100,000

Particle accelerators require a non-intercepting measurement of beam current with high precision and large dynamic range. By accurately measuring the average beam current, beam loss mechanisms can be diagnosed. This project will build a high-precision current measurement instrument using digital Superconducting Quantum Interference Device (SQUID) technology. The digital SQUID solution has many attractive features, such as extremely large dynamic range and simple, low-cost room-temperature electronics. The measurement instrument will be modular, versatile and programmable for use in a wide variety of beam diagnostic applications. In Phase I, the existing digital SQUID design will be improved in order to implement and characterize SQUIDs with different current resolutions. A subranging ammeter, employing two such digital SQUIDs for coarse and fine measurements, respectively, will be developed to alleviate slew-rate limitations to the measurement of rapidly changing current pulses. System requirements, pickup coil design, room-temperature hardware, and software will also be planned before constructing the prototype instrument in Phase II.

Commercial Applications and Other Benefits as described by the awardee: The digital SQUID instrument should provide unprecedented dynamic range, while producing digital outputs that can be processed with simpler, inexpensive electronics. It should not only satisfy beam current monitoring requirements but also enable

other demanding future measurements, such as direct measurement of polarization. The instrument could also be used to measure magnetic field and could replace present SQUID magnetometers used for biomagnetic measurements by offering superior performance at a lower cost.

WASTE CHARACTERIZATION

106

Development and Evaluation of Modified Fujiwara Chemistry for Use with a Cone Penetrometer--Intelligent Optical Systems, Inc., 2520 West 237th Street, Torrance, CA 90505-5217; 310-530-7130

Dr. Kisholoy Goswami, Principal Investigator

Dr. Robert Lieberman, Business Official

DOE Grant No. DE-FG03-99ER82804

Amount: \$99,996

The Department of Energy needs sensors for detecting halogenated hydrocarbons (such as trichloroethylene, TCE), one of the most toxic classes of toxic compounds present in subsurface waste plumes. Also, the sensors must be deployable by cone penetrometers. Fujiwara chemistry, which uses a liquid pyridine-based indicator for TCE and other related compounds, is a candidate approach. However, liquid pyridine is a toxic, offensive-smelling material whose accidental release may put the personnel using it at risk. In addition, environmental analysis using this technique is very expensive (\$1000/sample). This project will modify Fujiwara chemistry to produce a fully-engineered, all solid state, regulator-approved, halohydrocarbon sensor that can perform sample analysis at a cost of about \$50/sample. Phase I will develop such a compact sensor system for detecting halogenated hydrocarbons that employs multiple pyridine indicators simultaneously, uses a fiber-optic-based readout system, and utilizes proprietary neural network software for data processing.

Commercial Applications and Other Benefits as described by the awardee: The system should

offer a practical, efficient, and cost effective means for detecting halohydrocarbons in hazardous waste sites and industrial environments. It should also be rugged enough for deployment with cone penetrometers.

107

Next-Generation, Portable X-Ray Fluorescence System--Photon Imaging, Inc., 19355 Business Center Drive, Suite 8, Northridge, CA 91324-3503; 818-709-2468

Dr. Jan S. Iwanczyk, Principal Investigator

Dr. Bradley E. Patt, Business Official

DOE Grant No. DE-FG03-99ER82853

Amount: \$100,000

A truly portable x-ray fluorescence (XRF) analyzer would significantly help reduce the cost of treatment and disposal of hazardous metal contaminants by providing an improved characterization technology. This project will develop an XRF analyzer with unprecedented accuracy. By using an increased sampling frequency, statistical errors will be reduced. Not only will there be significant reductions in cost and time, environmental and personnel risks will be reduced by eliminating manual sample taking, transportation, and laboratory analysis of contaminated material. In Phase I, a miniature generic hermetic metal package will be developed that incorporates the new silicon drift detector structure. The feasibility of this approach for achieving improved performance in terms of energy resolution (compared to cryogenically cooled systems) and high count rate will be demonstrated.

Commercial Applications and Other Benefits as described by the awardee: New x-ray detectors and XRF instruments with high energy resolution, large active area, high count rate throughput, and near room temperature operation should open up numerous important market opportunities in environmental contamination monitoring, process control and materials identification, and electron column instruments.

108

A Multifunctional Fiber Optic Sensor for Cone Penetrometer Applications--Physical Optics Corporation, 20600 Gramercy Place, Building 100, Torrance, CA 90501-1821; 310-320-3088

Dr. Wei Qiu, Principal Investigator
Mr. Gordon Drew, Business Official
DOE Grant No. DE-FG03-99ER82857
Amount: \$99,997

As part of its Environmental Management program, the Department of Energy (DOE) is soliciting technologies to evaluate and distinguish environmental contaminants remaining from the production of nuclear weapons during the Cold War. Cone penetrometers, truck-mounted devices that hydraulically drive conically tipped rods into the ground, are used to provide access to the subsurface. To support cone penetrometer applications for waste characterization, as well as other applications requiring compact sensors with high sensitivity, high resolution, and high speed, this project will develop a sensor system to efficiently detect concentrations down to 10^{-12} g/ml at high speed. The sensor system will also be flexible, user friendly, and portable for real-time field-testing. Phase I will perform theoretical analysis and design of a multifunctional fiber optic sensor system for penetrometer waste characterization applications. The feasibility of the proposed sensing system concept will be demonstrated experimentally. Further improvement and commercial potential will be investigated.

Commercial Applications and Other Benefits as described by the awardee: This multifunctional sensing system should be widely applied throughout government and industry to inexpensively detect volatile organic compounds and heavy metals. It could also be used to monitor soil, industrial waste, and water resources, and could be employed for chemical and biochemical analysis and process control.

109

An Advanced Avalanche Photodiode Based Spectroscopic Radiation Imager--Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02172-4624; 617-926-1167
Dr. Mitchell Woodring, Principal Investigator
Dr. Gerald Entine, Business Official
DOE Grant No. DE-FG02-99ER82866
Amount: \$100,000

For many of its sites, the Department of Energy has a need to locate and identify radiation contamination. This project will develop a spectroscopic radiation imaging instrument that can conduct radiation surveys in near-real time; it will be compact, have high sensitivity, good energy resolution, good position resolution, and be relatively inexpensive. The key will be the development of a new avalanche photodiode array that is capable of x-y addressing and will form the basis of the spectroscopic radiation imager; x-y addressing will eliminate the dependence on prohibitively complex electronics. Phase I will produce an avalanche photodiode array capable of x-y addressing coupled to a thin sodium-doped cesium iodide scintillator. In addition, a pixel multiplexing scheme will be developed that allows for a large reduction in the amount of circuitry required for pulse processing. This phase will demonstrate the utility of the approach as a basis for a larger, high resolution array for use in a high-sensitivity, position-sensitive spectroscopic radiation imager.

Commercial Applications and Other Benefits as described by the awardee: This project will develop a pixellated position-sensitive radiation detector for radiation imaging that could find

extensive use from medicine to
decontamination and decommissioning
activities.

WASTE TREATMENT AND STABILIZATION

110

Improved Method for Fixating Sludges and Soils Contaminated with Mercury and Other Heavy Metals--ADA Technologies, Inc., 304 Inverness Way South, Suite 365, Englewood, CO 80112-5828; 303-792-5615

Ms. Andrea M. Faucette, Principal Investigator
Dr. Martin J. Mastroianni, Business Official
DOE Grant No. DE-FG03-99ER82722
Amount: \$99,986

Mercury is one of the most pervasive and difficult contaminants to stabilize in mixed waste. Direct stabilization of highly contaminated mercury wastes is preferred over the current treatment method, thermal retort followed by stabilization of the recovered mercury, because of its simplicity and low cost, and because it does not produce secondary wastes. This project will develop and demonstrate a direct approach to stabilizing high concentrations of mercury and other heavy metals in solid wastes and soils. The approach involves the conversion of mercury and other heavy metals to their stable sulfide forms. The process is inexpensive and uses commercially available mixing equipment. Phase I will establish the effective range of application for the technology, and includes testing beyond the expected range of operation to clearly define acceptable conditions for the process.

Commercial Applications and Other Benefits as described by the awardee: A simple, cost-effective method for stabilizing wastes and soils that are highly contaminated with mercury or other heavy metals should be useful for the clean up of Department of Energy sites. The method also should be applicable to a wide range of industries needing improved technologies for

waste stabilization, including mining, metal plating, and chlor-alkali production.

111

Separation of Metal Ions from Liquid Waste Streams--Applied Sciences, Inc., 141 West Xenia Avenue, P.O. Box 579, Cedarville, OH 45314-0579; 937-766-2020

Dr. D. Gerald Glasgow, Principal Investigator
Mr. Max L. Lake, Business Official
DOE Grant No. DE-FG02-99ER82744
Amount: \$99,674

Metal ions, such as uranium, strontium, cadmium, and transuranics, pose a threat to the environment because of their toxicity and radioactivity. This project will develop a new electrosorption technique based on carbon nanofiber electrodes, for removing metal ions from waste streams. Competing methods are not useful because, typically, the electrolyte dissociates before substantial electrosorption of metals such as uranium can occur. In Phase I, specially treated carbon nanofibers will be prepared and electrodes will be fabricated. The effectiveness of the electrodes in recovering adsorbed uranium, strontium, cadmium and other metals will be determined by reverse polarizing the electrodes and flowing a KNO_3 solution through the cell.

Commercial Applications and Other Benefits as described by the awardee: Commercial applications should include cleanup of liquid wastes, particularly at nuclear sites.

Selective Separation of Multiple Radioactive Contaminants from Liquid Waste Streams--
Bader Engineering & Research, Inc., P.O. Box
130228, The Woodlands, TX 77393;
409-760-2333

Dr. Manny S. Bader, Principal Investigator
Dr. Manny S. Bader, Business Official
DOE Grant No. DE-FG03-99ER82749
Amount: \$99,803

The selective removal of calcium/strontium from dilute aqueous streams, and cesium/strontium and/or sulfate ion from concentrated aqueous streams, is of vital interest to the Department of Energy (DOE) economic waste minimization strategy. Such removal would significantly reduce the radioactive contents of aqueous streams, contributing to a safe environment and providing for economic radioactive waste disposal. This project will apply a patented process for the selective separation of multiple radioactive contaminants from aqueous streams. The process will provide (1) excellent separation of cesium, calcium, strontium, barium, and sulfate; (2) applicability where no alternative processes are currently available; and (3) simplicity, flexibility, and potential economic viability. Phase I will (1) test the patented process with three simulated aqueous streams for the removal of cesium, calcium, strontium, barium, and sulfate; (2) evaluate the acquired data with a thermodynamic model; and (3) evaluate factors that influence the overall economics of the process for potential full-scale application.

Commercial Applications and Other Benefits as described by the awardee: The process should not only be applicable for the treatment of the DOE radioactive aqueous streams, but also for the treatment of naturally occurring radioactive materials in waters associated with oil and gas production. Other potential commercial applications include the removal of sulfate salts from seawater in offshore oil and gas production, from cooling tower blowdown, and from streams in membrane processes.

Novel Fouling Resistant Ultrafiltration Membranes for Use in Separation of Contaminants from Aqueous Waste Streams--
Compact Membrane Systems, Inc., 814 First
State Boulevard, Wilmington, DE 19804;
302-999-7996

Dr. Purushottam Shanbhag, Principal
Investigator
Dr. Stuart M. Nemser, Business Official
DOE Grant No. DE-FG02-99ER82765
Amount: \$100,000

The removal of contaminants from dilute aqueous streams, particularly heavy metal ions and radioactive constituents, is required at many Department of Energy (DOE) sites. Polymer enhanced ultrafiltration (PEF) processes are an attractive solution; however, the process is hampered by fouling of the ultrafiltration membrane. In this project, anti-fouling coatings will be applied to the ultrafiltration membranes to potentially double the flux capacity, and thereby make PEF processes extremely cost effective. Phase I will demonstrate the feasibility of conferring high fouling resistance on small pore ultrafiltration membranes that are suitable for metals removal. The possibility of much higher flux capacities in the treatment of contaminated wastewaters by polymer enhanced ultrafiltration will also be demonstrated.

Commercial Applications and Other Benefits as described by the awardee: The technology should be applicable to the selective removal and potential recovery of metal ions from a wide variety of aqueous streams such as metal plating wastes and radioactive contaminated waters. Other ultrafiltration membrane processes, where fouling unfavorably impacts flux capacity and cost effectiveness, may also benefit.

In Situ Remediation of Heavy Metals Using Surfactant Foams--Envirogen, Inc., 4100 Quakerbridge Road, Lawrenceville, NJ 08648-4702; 609-936-9300

Dr. Paul B. Hatzinger, Principal Investigator

Dr. Ronald Unterman, Business Official

DOE Grant No. DE-FG02-99ER82786

Amount: \$100,000

Heavy metals are exceedingly prevalent and persistent contaminants in groundwater aquifers at Department of Energy sites and throughout the United States. Current technologies for metals remediation in groundwater are limited primarily to expensive, long-term, *ex situ*, pump-and-treat systems. *In situ* remediation technologies for metals treatment are likely to have distinct economic and risk advantages, but few are currently available. This project will develop a new *in situ* technology to immobilize heavy metals and radionuclides in subsurface systems. The approach will make use of a surfactant foam as a delivery vehicle for bacteria and/or chemicals capable of precipitating heavy metals. In Phase I, the potential for surfactant foams to effectively distribute metal-reducing bacteria and sulfide reagents within contaminated aquifer sediments will be examined. The ability of various foams to enhance the transport of Cr(VI)-reducing bacteria and to improve the biological reduction of Cr(VI) to Cr(III) will be tested in a model aquifer system. In addition, the potential for surfactant foams to carry liquid and gaseous chemical reagents useful for immobilizing heavy metals will be assessed. Surfactant foams containing various sulfide reagents will be formulated, and the ability of these reagents to immobilize Cr(VI) as Cr-sulfide precipitates will be evaluated.

Commercial Applications and Other Benefits as described by the awardee: The *in situ* foam technology should be applicable for *in situ* immobilization of heavy metals in aquifers at numerous industrial and government sites. The advantages over conventional pump-and-treat systems are: (1) the treatment requires only a short-term injection rather than continuous pumping; and (2) the metals remain in-place in a nonmobile, nontoxic form rather than

continuously being brought to the surface for collection and disposal.

Enhanced Selective Leaching of Chromium from Radioactive Sludges--Lynntech, Inc., 7610 Eastmark Drive, College Station, TX 77840-4023; (409) 693-0017

Dr. Jinseong Kim, Principal Investigator

Dr. G. Duncan Hitchens, Business Official

DOE Grant No. DE-FG03-99ER82817

Amount: \$100,000

Techniques are needed for the safe and cost-effective remediation of radioactive wastes stored in more than 300 underground storage tanks at Department of Energy sites. The presence of chromium materials in the waste sludge is a major problem because it has a relatively large impact on the volume of high level waste when vitrified. Both cost and treatment time could be substantially reduced by using a selective oxidant combined with an enhanced selective oxidation process. This project will demonstrate the synergic effect of this combination to solve some problems in the pretreatment of sludge. The demonstration will use sludge simulants and address such issues as secondary waste generation and the ability to integrate the process into the existing pretreatment flowsheet. Phase I will use simulant waste to test the effectiveness of the process in separating reduced chrome species from sludge. The feasibility of the process will be demonstrated, and parameters for optimizing the process in the pretreatment flowsheet will be determined.

Commercial Applications and Other Benefits as described by the awardee: Besides its application to the remediation of nuclear waste, this process could be applied to the treatment of wastewater, such as from the dye, electroplating, and pharmaceutical industries, and municipal sewage.

Resonant Shock Compaction of Low Level Waste and Low Level Mixed Waste--Resonant Shock Compaction, LLC, 2075 S. University Blvd, Box 310, Denver, CO 80210; 303-316-4080

Mr. Robert E. Pressey, Principal Investigator
 Mr. Robert E. Pressey, Business Official
 DOE Grant No. DE-FG03-99ER82873
 Amount: \$99,700

A simple, flexible, robust process is needed to both stabilize and compact salts, ash, soil, sludge, and debris contaminated with low level waste and mixed low level waste at Department of Energy sites. Although many stabilization or binder systems have been developed to immobilize Resource Conservation Recovery Act metals and radioactive nuclides, they are limited by the percent of waste loading that can be achieved. For example, cement grouting limits the waste loading to about 40 percent; polymer and other binders may achieve 50 percent waste loading. This project will develop resonant shock compaction (RSC) technology which offers the possibility of 80-90 percent waste loading when processing salt, ash, soil or debris. RSC, which could be combined with previously developed binders, can process 100 tons/shift/day. In Phase I, surrogate waste will be treated with chemically bonded phosphate ceramics, cement, clay, and other binders. The treated surrogate will be resonant shock compacted, and the resultant compaction effectiveness will be measured. The binder/RSC effectiveness with radioactive nuclides will be tested, the compressive strength and durability of the specimens will be determined, and several sites will be identified for demonstration.

Commercial Applications and Other Benefits as described by the awardee: RSC should provide a cost effective, robust, flexible, high capacity (100 tons/shift/day) process that achieves 50 percent volume reduction.

In Situ Removal of Cadmium and Chromium from Groundwater Using ZeoTech Reactive Barriers--Prudent Technologies, (formerly Zeotech Corporation), 544 Shadeland Avenue, Drexel Hill, PA 19026; 215-895-2350

Dr. H. Rostami, Principal Investigator
 Mr. Thomas Silverstrim, Business Official
 DOE Grant No. DE-FG02-99ER82921
 Amount: \$100,000

Heavy metal pollution of groundwater is an extremely serious environmental problem. Of the sites to be remediated by the Department of Energy (DOE), 72 percent involve contaminated groundwater and 55 percent of the sites involve heavy metal contamination. Cleanup of contaminated groundwater is often difficult and can be prohibitively expensive or technically infeasible. One solution, currently under investigation, uses permeable reactive barriers that intercept the dissolved contaminants while allowing the groundwater to flow through. This project will demonstrate the technical feasibility and economical viability of an innovative permeable barrier material made of fly ash and activating chemicals to remove cadmium and chromium from contaminated groundwater. The Phase I project will construct the barrier material with controlled permeability, test its ability to remove cadmium and chromium from contaminated groundwater, construct a bench scale contamination barrier, and investigate the mechanisms for cadmium and chromium removal. In Phase II, a pilot scale contamination barrier will be constructed from the new barrier material and tested for longevity.

Commercial Applications and Other Benefits as described by the awardee: The technology should be useful in removing heavy metals such as chromium and cadmium from contaminated water at a cost that should be much less than current technologies. Eventual applications should include municipal, industrial, and agricultural wastewater treatment, and economical ammonia removal. Also, since 70 percent of the fly ash generated in the United States is landfilled, these contamination barriers would utilize a large quantity of fly ash that otherwise would have been landfilled.

TECHNOLOGY FOR TREATMENT, MANAGEMENT, AND DISPOSITION OF URANIUM HEXAFLUORIDE

118

Extraction of Fluorine from Uranium Hexafluoride for the Production of Titanium Metal--Starmet Corporation, 2229 Main Street, Concord, MA 01742; 978-369-5410

Dr. Matthew Stephens, Principal Investigator
Mr. Donald T. King, Business Official
DOE Grant No. DE-FG02-99ER82893
Amount: \$98,512

The Department of Energy (DOE) is responsible for managing nearly 1.5 billion pounds of uranium hexafluoride stored in carbon steel cylinders in Ohio, Kentucky, and Tennessee. The cylinders are corroding and beginning to become an environmental concern in the affected states. The cost of converting these cylinders to a more stable form such as an oxide is estimated at about \$2 billion. If valuable chemicals can be produced from the fluorine portion, the overall management cost to DOE and the taxpayers would be reduced. This project will develop and demonstrate technology for extracting the fluorine in the uranium hexafluoride and producing titanium tetrafluoride (TiF_4) a material that can subsequently be converted to titanium metal and a fluoride product. During Phase I, the basic chemistry of the conversion process for producing titanium tetrafluoride will be established, kinetic conversion rates will be determined at laboratory scale, and the TiF_4 purity level will be established. Process design data will be obtained to allow a pilot plant to be designed for demonstration during Phase II.

Commercial Applications and Other Benefits as described by the awardee: Successful implementation of this project will produce titanium metal, which can be sold as a powder or ingot, and a fluoride product (cryolite or HF). The titanium metal is a high-value metal product that can be used by industry in very large quantities. Also, the potential fluoride products

would be used in very large quantities by industry.

119

Production of High Value Fluorine Gases for the Semiconductor Industry--Starmet Corporation, 2229 Main Street, Concord, MA 01742; 978-369-5410

Dr. John Bulko, Principal Investigator
Mr. Donald T. King, Business Official
DOE Grant No. DE-FG02-99ER82894
Amount: \$99,587

The Department of Energy (DOE) is responsible for managing nearly 1.5 billion pounds of uranium hexafluoride stored in carbon steel cylinders in Ohio, Kentucky, and Tennessee. The cylinders are corroding and beginning to become an environmental concern in the affected states. The cost of converting these cylinders to a more stable form such as an oxide is estimated at about \$2 billion. If valuable chemicals can be produced from the fluorine portion, the overall management cost to DOE and the taxpayers will be reduced. This project will develop technology for extracting the fluorine in the uranium hexafluoride and producing high value, high purity gases for use in the semiconductor industry. These gases--tungsten hexafluoride and germanium hexafluoride--are used for chemical vapor deposition in semiconductor manufacturing. During Phase I, the basic chemistry of the conversion process will be established, kinetic conversion rates will be determined at laboratory scale, and gas purity levels will be established. Process design data will be obtained to allow the design of a pilot plant for subsequent demonstration in Phase II.

Commercial Application and Other Benefits as described by the awardee: Gases should be produced that can be sold to semiconductor chip

makers. These gases are but two of several similar gases that will be produced from the

uranium hexafluorine as it is converted to the more stable oxide.

ADVANCED ENVIRONMENTAL MONITORING TECHNOLOGY

120

Fiber Optic Grating-Based Moisture Sensor--
Blue Road Research, 2555 N.E. 205th Avenue,
Fairview, OR 97024; 503-667-7772

Mr. Whitten Schulz, Principal Investigator

Mr. Eric Udd, Business Official

DOE Grant No. DE-FG03-99ER82753

Amount: \$99,949

Water moving through a waste containment site often carries the contaminant beyond the site, thereby contaminating groundwater, etc. This project addresses this problem by monitoring the moisture content at these sites. This will be accomplished by developing a small fiber optic, grating-based, moisture sensor capable of providing many measurement points. The sensor utilizes a demodulation system capable of providing continuous, autonomous monitoring. Phase I will optimize the moisture sensors for maximum sensitivity and ease of manufacture. Then, eight sensors, will be fabricated and tested, along with the de-modulation software, to provide autonomous monitoring of the sensors.

Commercial Applications and Other Benefits as described by awardee: A distributed sensor system, capable of measuring multiple points of moisture content (or other measurands, i.e. chemicals or gas) autonomously and highly accurately over long periods of time, would be valuable for the monitoring of waste containment sites.

121

Development of a Fiber-Optic Sensor for Nitrate Detection--CC Technology, Inc., 360 North Third South Suite, Laramie, WY 82070; 307-755-6490

Mr. Eugene Watson, Principal Investigator

Dr. Keith Carron, Business Official

DOE Grant No. DE-FG03-99ER82758

Amount: \$100,000

Nitrate, which occurs in groundwater in rural areas due to excess fertilization or waste products, is a health hazard to infants through its reduction to nitrite. Because nitrite binds to hemoglobin and displaces oxygen, it creates the toxic condition known as "blue babies". This project will develop an instrument that can detect nitrate directly in groundwater samples without sample preparation. Phase I will develop a prototype instrument that will be tested at municipal water treatment plants. A nitrate specific binding molecule will be synthesized and placed on a Surface Enhanced Raman Scattering substrate that will enhance the signal of the bound nitrate. This will be tested for longevity, selectivity, and sensitivity. Phase II will develop an in-line instrument that continuously monitors water supplies.

Commercial Applications and Other Benefits as described by the awardee: The initial market should be the 200,000 municipal water supplies that are attempting to comply with clean water acts. Follow-up markets would include nitrate producers that must monitor discharge to comply with regulatory standards.

122

Novel Solid State Electrochemical Sensor--H.V. Setty Enterprises, Inc., 12110 Red Oak Court South, Burnsville, MN 55337-3312; 612-894-2792

Dr. H.V. Venkatesetty, Principal Investigator

Dr. H.V. Venkatesetty, Business Official

DOE Grant No. DE-FG02-99ER82796

Amount: \$93,288

This project will develop a solid state, miniaturized, low cost electrochemical sensor using a nonaqueous gelled electrolyte for the detection and measurement of toxic gases and vapors attributed to subsurface contaminants, such as those present at Department of Energy sites. The sensor will have a micron-size, three-electrode structure and gelled electrolyte capable of a wide voltage window for measuring toxic gases and organic vapors. The Phase I project will design and fabricate the three-electrode cell on a substrate of silicon-oxide on silicon, develop and evaluate thin film gelled electrolyte, package the sensor, and demonstrate its

feasibility. In Phase II, engineering prototypes will be developed for field testing.

Commercial Applications and Other Benefits as described by the awardee: Reliable, low cost, and long life sensors should be useful for environmental monitoring of toxic gases and vapors. Sensors with multigas sensing capability should be useful in industrial processes monitoring and control and for indoor air quality monitoring.

ATMOSPHERIC MEASUREMENT AND SAMPLING TECHNOLOGY

123

Automated Balloon Sonde Launcher for Remote Locations--ADA Technologies, Inc., 304 Inverness Way South, Suite 365, Englewood, CO 80112-5828; 303-792-5615
Dr. John A. Bogner, Principal Investigator
Dr. Martin J. Mastroianni, Business Official
DOE Grant No. DE-FG03-99ER82721
Amount: \$99,989

Balloon-borne radiosondes are widely employed in atmospheric research programs. However, radiosonde launching requires dedicated personnel to be on hand at each launch site to perform all the required tasks involved with launching a sonde. Currently, no simple, compact, rugged launchers, which automate these tasks, are available. This project will develop a launcher meeting the above criteria, that will be able to launch balloon-borne radiosondes, receive their data, and forward that data to a central facility. This launcher will also be unique, in that it is far smaller and more affordable than existing systems, and will be applicable in a variety of novel approaches. For example, the launcher may be adapted in the future to launch balloons from the ocean. Phase I will involve the construction of a prototype launcher that can automatically prepare a sonde for launch, fill and release the

balloon, and forward simulated data to a remote computer by radio modem link. By the end of Phase I, all of these key enabling technologies will have been demonstrated, allowing for a complete launcher to be constructed.

Commercial Applications and Other Benefits as described by the awardee: This launcher should be useful in studies of the atmosphere, which are carried out by several government agencies, including the Department of Energy and National Oceanic and Atmospheric Administration. It should also be useful anywhere routine radiosonde launches are conducted, such as airports and National Weather Service facilities.

124

Development of III-Nitride Ultraviolet Detectors--Avyd Devices, Inc., 2925 College Avenue, Unit A-1, Costa Mesa, CA 92626; 714-751-8553
Dr. Honnavalli R. Vydyanath, Principal Investigator
Dr. Honnavalli R. Vydyanath, Business Official
DOE Grant No. DE-FG03-99ER82748
Amount: \$99,910

High sensitivity ultraviolet (UV) detectors for radiometric instrumentation are needed to monitor atmospheric chemical composition changes. This project will develop a material/device approach that results in III-nitride based UV detectors with state-of-the-art sensitivity and very efficient rejection of longer wavelength radiation. In Phase I, single element and linear arrays of p-i-n detectors will be developed with response times on the order of a 10^{-9} seconds or less, detectivity greater than 1×10^{12} watt⁻¹ or noise-equivalent-power less than 1 pico-watt (pW) for 1 Hz bandwidth, and UV/visible rejection ratio at room temperature of 10^6 or higher. Phase II will optimize the approach and demonstrate multiplexed detector arrays with high reproducibility at a low cost.

Commercial Applications and Other Benefits as described by the awardee: Applications should include missile plume detection for military use, environmental monitoring, automobile engine combustion sensing, remote sensing of earth resources, solar astronomy, and burner monitoring in gas turbines for commercial use.

125

Mercury Cadmium Telluride Detectors for Near Infrared Applications--Avyd Devices, Inc., 2925 College Avenue, Suite A-1, Costa Mesa, CA 92626; 714-751-8553

Dr. Honnavalli R. Vydyanath, Principal Investigator

Dr. Honnavalli R. Vydyanath, Business Official
DOE Grant No. DE-FG03-99ER82747

Amount: \$99,806

Short wavelength infrared detectors, operating at near theoretical limits for radiometric instrumentation, are needed to monitor changes in atmospheric chemical composition. This project will use a material/device approach to develop mercury cadmium telluride (HgCdTe) detectors that are sensitive in the short wave region of the solar radiation and possess state-of-the-art detectivity. Phase I will demonstrate single element and linear arrays of HgCdTe detectors with cut-off wavelength around 2 microns, R₀A performance close to or

in excess of 10^5 ohm-cm², quantum efficiency in excess of 60 percent, and detectivity on the order of 5×10^{11} Jones or higher at 300K. Phase II will optimize the approach and demonstrate multiplexed detector arrays with high reproducibility at a low cost.

Commercial Applications and Other Benefits as described by the awardee: Applications should include detection of hot boxes on railroad cars, process control, measurement of the temperature of brake linings, power lines, cutting tools, welding and soldering operations, detection and monitoring of air pollution, skin thermography for tumor detection, and infrared cell sorting.

126

Optical Fiber Fluorescent Based Water Vapor Sensor--M.L. Energia, Inc., P.O. Box 470, Princeton, NJ 08542-0470; 609-799-7970

Dr. Moshe Lavid, Principal Investigator

Ms. Nira Lavid, Business Official

DOE Grant No. DE-FG02-99ER82821

Amount: \$100,000

High accuracy measurements of atmospheric parameters, particularly water vapor, are required from balloon-borne, disposable, lightweight, low cost, high precision instruments to support atmospheric and climate research. This project will develop a novel fiber sensor for balloon-borne, high accuracy measurements of water vapor concentrations from point of launch to at least 20 km altitude. The concentrations at these elevations are very low, posing a serious challenge. The proposed sensor relies on a thin film containing fluorescent compounds that are sensitive only to the presence of water molecules. By monitoring changes in fluorescence with a fiber optic interface, it is possible to determine the local water vapor in real time. The very low temperatures found at high altitudes are expected to enhance the fluorescence signal and offset the decreased sensitivity typically seen for humidity sensors at very low water vapor concentrations. In Phase I, a single fiber configuration will be employed for both excitation and emission, and a multiwavelength detection method will be used

to provide an internal standard for continuous calibration for better measurement accuracy. The effort will culminate with a successfully tested prototype.

Commercial Applications and Other Benefits as described by the awardee: A fiber optic sensor for moisture measurement that combines rapid response, self-calibration, low cost, and remote monitoring should find commercial applications beyond atmospheric measurements. It also should benefit the food, drug, and chemical industries, where the need for rapid determination of humidity levels is very critical to process optimization and product quality.

127

Low Temperature, High Altitude Humidity Sensor--Nanomaterials Research Corporation, 2620 Trade Center Avenue, Longmont, CO 80503-7551; 303-702-1672

Dr. Peter Mardilovich, Principal Investigator
Ms. Molly M. W. Kostecky, Business Official
DOE Grant No. DE-FG03-99ER82839
Amount: \$100,000

High accuracy measurement of atmospheric water vapor is required from balloon-borne instruments. In particular, humidity sensors require significant improvement in sensitivity, size, weight, and cost. High accuracy must be maintained at very high altitude and at temperatures down to -60°C . This project will develop novel low temperature, high altitude, humidity micro-sensors and sensor arrays that utilize a micro-heater. The approach is based on low-cost, micromachinable, nanoporous ceramic films with tunable chemical composition and pore morphology. In Phase I, micromachinable alumina ceramic films, with morphology tunable at the nano-scale, will be used to produce humidity micro-sensors with high performance in high altitude environment conditions. A prototype humidity sensor array will be constructed and evaluated.

Commercial Applications and Other Benefits as described by the awardee: Any application requiring low-weight, low cost, disposable, high precision humidity sensors should benefit from

this approach. Spin-off applications include micro-sensors for different gases, physical sensors (pressure, temperature), and other microdevices.

128

A Multi-Holographic Filter with a Liquid Crystal Scanner for Surface Optical Reflectance--Physical Optics Corporation, 20600 Gramercy Place, Building 100, Torrance, CA 90501-1821; 310-320-3088

Mr. Kevin Yu, Principal Investigator
Mr. Gordon Drew, Business Official
DOE Grant No. DE-FG03-99ER82855
Amount: \$99,999

Measurement of solar radiation over a wide spectral range is necessary to effectively monitor the earth's atmosphere. Current radiometers capable of measuring light intensity in multiple wavelength bands are bulky, heavy (due to such moving parts as mechanical scanners or rotating arms) and, because of optical filter drift, cannot produce consistent results, especially for long term operation under field conditions. This project will develop a compact, low cost, lightweight Surface Optical Reflectance Meter (SORM) based on a thin stack of environmentally stable reflection holographic filters and a lightweight two-dimensional liquid crystal panel. The system will address such problems as drift, sensitivity, field of view, wide spectral range, and compatibility with the Advanced Very High Resolution Radiometer, and will have a standard 10m meteorological mast. Phase I will conduct system design and analysis, fabricate the key components, and establish proof-of-concept by experimental demonstration. Specially, a narrowband volume reflection holographic filters will be fabricated on thin glass substrates and stacked as one filter module and a scanner with no moving parts.

Commercial Applications and Other Benefits as described by the awardee: The lightweight, compact, and low cost SORM system should have practical applications in remote sensing, environmental monitoring, target recognition, and manufacturing process control. In addition,

liquid crystal scanners and holographic filters can be critical components of helmet-mounted displays, fax machines, and equipment for spectroscopic and nuclear facility monitoring.

129

Self-Calibrating Multi-Mode Filter Spectroradiometer with Measurement Applications for Column Amounts of Ozone, Nitrogen Dioxide, Sulfur Dioxide, and Aerosol Optical Depths--Research Support Instruments, Inc., 5735 Arapahoe Avenue, Suite 2A, Boulder, CO 80303; 978-689-0003
Dr. Donald F. Heath, Principal Investigator
Mr. George E. Caledonia, Business Official
DOE Grant No. DE-FG03-99ER82872
Amount: \$99,978

The accuracy of surface-based spectroradiometric measurements (including zenith sky radiances, hemispheric irradiances, and aerosol optical properties) is limited by long-term drifts in radiometric calibration. A self-calibrating system would provide greater long-term accuracy and reduce instrument operational errors. This project will develop a self-calibrating, multi-mode spectroradiometer and demonstrate its advantages for long-term monitoring. The spectroradiometer will be based upon a National Institute of Science and Technology radiometric scale and will incorporate optical components shown or believed to be stable under extremes of temperature and humidity. In Phase I, the critical optical, detector and self-calibrating features will be evaluated in the laboratory and at a field site. The techniques for zenith oriented measurements will be evaluated against conventional direct sun observations.

Commercial Applications and Other Benefits as described by the awardee: The technology could lead to a new class of spectroradiometric instrumentation which is small, low in cost, and highly accurate. Applications should include the monitoring of long-term changes in tropospheric pollution from surface observations.

130

Low Cost Optical Moisture Sensor for Weather Balloons--Southwest Sciences, Inc., 1570 Pacheco Street, Suite E-11, Santa Fe, NM 87505-3937; 505-984-1322
Dr. Joel A. Silver, Principal Investigator
Dr. Alan C. Stanton, Business Official
DOE Grant No. DE-FG03-99ER82887
Amount: \$100,000

Current water vapor sensors used on weather balloons do not meet the concurrent requirements of rapid response, low cost, high sensitivity, and high accuracy over their full operating range. An accurate, reliable, and inexpensive moisture sensor is needed for balloon-borne meteorological sensing applications. This project will develop a simple, non-laser-based optical method that can meet these objectives at very low cost, comparable to that of capacitive sensors. In Phase I, a laboratory version of the sensor will be constructed and tested in an environmental chamber to simulate balloon ascent conditions. Various cell and modulation methodologies will be investigated to determine the optimal design. Evaluation of electronic design, size, weight and cost considerations will be performed. Phase II will develop and test a prototype and demonstrate its capabilities to meet all desired specifications.

Commercial Applications and Other Benefits as described by the awardee: Applications should include environmental sensing, meteorological measurements, process stream monitoring for the chemical and semiconductor industries, and aviation hazard assessment. This sensor would provide very high sensitivity at low cost to the user.

131

A Cost-Effective Automatic Balloon Launcher--Visidyne, Inc., 10 Corporate Place, South Bedford Street, Burlington, MA 01803-5149; 781-273-2820
Mr. J. Michael Berrigan, Principal Investigator
Mr. John W. Bates, Business Official

DOE Grant No. DE-FG02-99ER82916
Amount: \$99,990

By a costly and labor-intensive procedure, approximately 800,000 balloon-borne radiosondes are hand-launched each year. The development of an automatic radiosonde launcher would replace the manual procedure with a reliable and much less expensive process. This project will design, build, and test the critical components for an automatic radiosonde launcher. Phase I will establish baseline requirements, develop a preliminary design, identify critical subsystems, fabricate and test units, and conduct laboratory and field tests. In Phase II, the new launcher will be fully developed and rigorously tested at a field site under a variety of ambient weather conditions.

Commercial Applications and Other Benefits as described by the awardee: The automatic radiosonde launcher should have a significant cost/benefit advantage over present hand-launch techniques. It should be valuable to both domestic and foreign organizations, particularly in remote locations.

132

A Low Cost Automated Radiosonde Launch System--Yankee Environmental Systems, Inc.,
101 Industrial Boulevard, Turners Falls, MA
01376-1608; 413-863-0200

Mr. William M. Stein, Principal Investigator
Ms. Cynthia A. Cote, Business Official
DOE Grant No. DE-FG02-99ER82920
Amount: \$100,000

Upper atmospheric measurements of temperature, humidity, and wind are required daily at hundreds of locations around the world. These critical measurements are primarily made by radiosondes carried aloft by helium balloons and tracked by ground stations. Currently, the process of radiosonde setup and launch is performed manually by trained human operators, and no mechanism exists to automatically calibrate radiosondes just prior to launch. While one commercially available automated launch system does exist, its \$350,000 price makes it impractical. This project will develop a robust, fault-tolerant launch system that automatically: (1) powers up a radiosonde; (2) checks the RF link; (3) starts data acquisition; (4) performs a calibration of the radiosonde temperature and humidity signals; (5) inflates a balloon and verifies inflation; (6) releases the balloon; (7) verifies that the payload is successfully away; (8) continuously captures data for the duration of flight; (9) transfers data to a central data archive; and, (10) returns to an idle state in preparation for the next launch. Phase I will establish the desired specifications of the proposed launcher and key critical components will be modeled, prototyped, and tested.

Commercial Applications and Other Benefits as described by the awardee: The new launcher would represent a significant improvement in the price vs. performance of launching radiosondes for programs such as the Department of Energy Atmospheric Radiation Measurement program and the National Weather Service. The worldwide market for such a system is nearly one thousand systems (roughly \$30 - \$50 million).

CARBON CYCLE MEASUREMENTS OF THE ATMOSPHERE AND THE BIOSPHERE

133

A Diode Laser Sensor for High Precision Measurement of Terrestrial CO₂ Sources and Sinks--Physical Sciences, Inc., 20 New England

Business Center, Andover, MA 01810-1077;
978-689-0003

Dr. David M. Sonnenfroh, Principal Investigator
Dr. Byron David Green, Business Official

DOE Grant No. DE-FG02-99ER82858
Amount: \$99,996

High precision measurements of the sequestration and emission of CO₂ and other greenhouse gases from ecosystems, as well as from anthropogenic sources, are required for improved climate and climate-change predictions. Existing instrumentation does not provide sufficient sensitivity, temporal response, chemical selectivity, or ability to be routinely used in the field for large area survey measurements. This project will demonstrate a new, room temperature diode-laser-based sensor that will measure CO₂ and H₂O simultaneously and will be easily field deployable for extended periods. In addition, its unique air probe can be replicated to form networks of sensors, controlled by a single central processor, for large area surveys. Phase I will develop, fabricate, and demonstrate a special *in situ* air probe which will provide advantages of true *in situ* sampling (vs. extractive sampling) and which will permit

CO₂ and H₂O to be measured over the same path. This probe will undergo environmental testing and then will be combined with an existing diode laser spectrometer for an outdoor demonstration of high speed, high precision measurements of CO₂. A conceptual design for a prototype, easily-fieldable eddy covariance flux sensor for CO₂ and H₂O will also be developed.

Commercial Applications and Other Benefits as described by the awardee: The sensor should find application in atmospheric field research concerned with quantifying the increasing burden of greenhouse gases in the atmosphere and their impact on global climate change. The sensor should also find commercial application in agricultural venues monitoring plant health and research. The underlying high speed, high precision, multiple trace gas measurement technology has many commercial applications in industrial process control and monitoring, fenceline monitoring, and combustion analysis.

MEDICAL APPLICATIONS

134

Rapid Processing of Positioning Information for Hand-Held Gamma Camera--PEM Technologies, Inc., 5611 Roosevelt Street, Bethesda, MD 20817-6739; 301-564-0835
Dr. Irving Weinberg, Principal Investigator
Dr. Irving Weinberg, Business Official
DOE Grant No. DE-FG02-99ER82852
Amount: \$99,805

Surgeons prefer to use nonimaging gamma probes for intraoperative work instead of conventional, gantry-held, large field-of-view gamma cameras. Unfortunately, the nonimaging gamma probes are of limited assistance in regions of the body with complex three-dimensional anatomy (e.g., head and neck, axilla). This project will develop a low-cost, hand-held gamma camera, which could improve lesion contrast. Modified backprojection algorithms will be applied to achieve nearly real-

time imaging with novel, gantry-less hardware architectures. Phase I will build a prototype, hand-held gamma camera with software that integrates gamma ray acquisition data with gantry-less positioning information. Using hot spot phantoms and motorized positioners to simulate a human operator with no training on the device, the performance of the prototype camera will be compared to conventional planar gamma cameras.

Commercial Applications and Other Benefits as described by the awardee: The product promises to improve on the performance of nonimaging probes without significantly increasing cost. This work also should spur further development of deployable intraoperative gamma camera architectures.

Small Animal SPECT Camera for Quantitative Molecular Medicine--Photon Imaging, Inc., 19355 Business Center Drive, Suite 8, Northridge, CA 91324-3503; 818-709-2468

Dr. Lawrence MacDonald, Principal Investigator
Dr. Bradley E. Patt, Business Official
DOE Grant No. DE-FG03-99ER82854
Amount: \$100,000

Existing gamma cameras do not have sufficient spatial or energy resolution to perform quantitative analysis on new molecular imaging agents in small animals. These new imaging agents offer potential in diagnosing and monitoring neurodegenerative disorders, targeting ligands in the brain, gene expression and regulation, etc. This project will develop a small, solid-state, SPECT (single photon emission computed tomography) camera that offers unprecedented spatial and spectral resolution when used with these agents. Phase I will investigate the technical aspects of building the SPECT system from 5cm X 5cm imaging modules and will include a high-density electronic readout and optimal detector pixel geometry. Better intrinsic performance and geometrical configuration will greatly enhance capability of performing quantitative analysis of nuclear medicine images.

Commercial Applications and Other Benefits as described by the awardee: A large market exists for new solid state detectors, which can replace current vacuum tube technology with better performance, more compact, and less expensive systems.

Compact Gamma-Ray Imager for In-Vivo Gene Imaging--Spire Corporation, One Patriots Park, Bedford, MA 01730-2396; 781-275-6000
Dr. James Toney, Principal Investigator
Dr. Everett S. McGinley, Business Official
DOE Grant No. DE-FG02-99ER82892
Amount: \$99,989

A compact, low-cost, gamma-ray imaging system is needed for studying gene expression in small animals. One possible approach, bulk cadmium-zinc-telluride detector technology, requires tiling of many crystals; therefore it is too costly to be viable for this application. In this project, cadmium-zinc-telluride thin film detectors will be developed that will enable a large-area imaging device to be fabricated on a single semiconductor wafer. In Phase I, cadmium-zinc-telluride thin films will be grown by metalorganic chemical vapor deposition. The electrical properties of the films will be characterized, and growth conditions will be adjusted to produce optimal properties for low-energy gamma-ray imaging.

Commercial Applications and Other Benefits as described by the awardee: The imaging system should be valuable in genetic research. The detector technology also should be applicable to medical x-ray imaging.

Low-Cost, High Resolution and High Sensitivity PET Detector Modules--Tomotronics, Inc., 5 Snake Brook Road, Wayland, MA 01778; 508-653-4051
Dr. Valery G. Zavarzin, Principal Investigator
Ms. Pamela H. Worstell, Business Official
DOE Grant No. DE-FG02-99ER82909
Amount: \$100,000

Positron Emission Tomography (PET) is a functional medical modality with important applications to biomedical research and to clinical practice. In both contexts, the high cost of high-quality instrumentation has markedly slowed the spread of this technology beyond its base in premiere research institutions. Although relatively low-cost coincidence imagers capable of both single-photon emission imaging are becoming more widespread, these devices severely compromise their PET capability in order to retain good single photon imaging capability. This project will build high-performance PET detector modules using relatively inexpensive materials combined in an unconventional and innovative manner. By using wavelength-shifting optical fiber readout

of Cs(Na) scintillator plates, devices with very high spatial resolution and high sensitivity should be able to be produced at low cost. In Phase I, new readout electro-optics and electronics will be implemented that should significantly improve system spatial resolution. The performance of detector modules incorporating these new techniques will then be characterized.

Commercial Applications and Other Benefits as described by the awardee: Initial applications for this technology should be to high-performance single-organ and small-animal PET imagers, each of which constitutes an emerging market. Further applications include large-field and clinical PET instrumentation, which would tap a much broader and rapidly expanding market.

GENOME, STRUCTURAL BIOLOGY, AND RELATED BIOTECHNOLOGIES

138

DNA Diagnostics Using Electrical Detection--
Atom Sciences, Inc., 114 Ridgeway Center, Oak Ridge, TN 37830-6926; 423-483-1113
Dr. Tom J. Whitaker, Principal Investigator
Dr. Tom J. Whitaker, Business Official
DOE Grant No. DE-FG02-99ER82746
Amount: \$99,865

As more diseases are found to have a genetic link, the significance of monitoring mutations in important genes has become increasingly vital. Unfortunately, the present methods used in research settings are unacceptably slow and expensive. This project will develop an inexpensive, compact device to electronically detect hybridized DNA on a genosensor chip. The approach exploits the increase in dielectric thickness that occurs when DNA binds to a thin dielectric attached to a fixed electrode. Under appropriate conditions, the increased thickness, resulting from binding a fraction of a monolayer of DNA, produces a significant, easily measurable, change in capacitance. Phase I will demonstrate detection of DNA-PNA hybridization using a capacitance measurement which includes: creating an array, forming an insulating monolayer on the conductors, attaching at least two PNA (peptide nucleic acid) probe sequences to the insulating monolayer, measuring the change in capacitance at each probe when the target DNA is hybridized, and determining if the addition of fullerenes to the

hybrid would significantly increase the change in capacitance

Commercial Applications and Other Benefits as described by the awardee: Two commercial products are expected to result: a device for measuring hybridization and the genosensor array. Although the arrays are potentially reusable, the low-cost (estimated at less than \$0.50 each) of the arrays makes it likely that they would be disposable. Estimates for the use of genetic diagnostics vary widely, but if each hospital in the U.S. averaged only 10 diagnostics per day, over 20 million arrays would be required annually.

139

Microarrays of Affinity Probes for the Analysis of Gene Products--CombiMatrix Corporation, 887 Mitten Road, Suite 200, Burlingame, CA 94010-1303; 650-697-5115
Dr. Francis Rossi, Principal Investigator
Dr. Donald D. Montgomery, Business Official
DOE Grant No. DE-FG03-99ER82764
Amount: \$100,000

Most human disease results from complex interactions between the products of gene expression, the proteins. The identification and characterization of the gene products and the elucidation of the mechanisms by which they interact to cause disease remains a difficult

scientific problem. This project will develop technology to monitor protein expression levels and to determine protein-ligand interactions for the functional analysis of gene products. A microarray of affinity probes will be used to interrogate protein samples. The binding pattern of the sample to the microarray will be used to quantitate protein expression levels and to elucidate protein-protein interactions. Phase I will assess the feasibility of synthesizing affinity probe microarrays using an active semiconductor chip. An immobilized affinity probe will be used to analyze protein mixtures, and software will be written to analyze the data produced by an affinity probe microarray.

Commercial Applications and Other Benefits as described by the awardee: The technology should benefit the pharmaceutical industry by rapidly identifying drug targets.

140

A Visual Data-Flow Editor Capable of Integrating Data Analysis and Database Querying--CyberConnect Corporation, 131 Hunting Lodge Road, Storrs, CT 06268-1331; 860-429-2666

Mr. Wally Grajewski, Principal Investigator

Mr. Karl Beckert, Business Official

DOE Grant No. DE-FG02-99ER82773

Amount: \$100,000

In order to determine mapping sequence variations or polymorphism between homologous genomic regions, a genome scientist must be able to access genomic data from different sources and use many data analysis and visualization programs. To achieve this, software must be developed to automate tedious and repetitive data handling, database querying, and analysis tasks. This project will develop a data-flow editing environment in which genome scientists with minimal computer training can easily describe data analysis tasks. The software tool will allow the scientist to organize and coordinate individual data retrieval tasks from different data sources, and combine them with data analysis to derive answers to biologically significant

questions. Phase I will develop prototype software to demonstrate the feasibility of a data-flow editing environment that allows for the ease of interaction between data access and data analysis. The approach will be based on a working scenario for determining homology relationships between known DNA sequences from one species and unknown sequences from a taxonomically-related species.

Commercial Applications and Other Benefits as described by the awardee: This software should be immediately usable by the molecular biology and pharmaceutical industries, both of which are becoming more computationally intensive. Since data-flow management problems are not unique to computational biology, the software also should be applicable to other data and computationally intensive areas, e.g., physics, chemistry, engineering, and finance.

141

Commercialization of the GRAIL EXP Gene Discovery System--Genome Informatics Corporation, 1020 Commerce Park Drive, Oak Ridge, TN 37830; 423-220-0043

Mr. Doug Hyatt, Principal Investigator

Dr. Ed Uberbacher, Business Official

DOE Grant No. DE-FG02-99ER82794

Amount: \$99,925

The sequencing of long contiguous regions of human genomic DNA is soon expected at a rate of several million bases per day. Many genes embedded in these sequences are important for applications in genetic medicine, drug design and the environment. However, standard gene finding programs are not capable of accurately locating and describing genes, and a more powerful technology is needed. In this project, previously developed software that combines pattern recognition and homology information will be used to identify, model, and properly parse genes from long stretches of genomic DNA sequence. Because the software is only available as a research code and not available in a stand-alone, user friendly package, a suitable graphical user interface will be built, and various database issues will be resolved to provide a

commercially viable product. Phase I will develop a suitable client server architecture for the system; develop a user-friendly Java graphical interface for workstations and personal computers; develop an application programming interface to embed the program in a user configured pipeline; refine search routines and database structure to enhance the efficiency of the program's database search component; build or find a database of full-length cDNAs; and make provisions for users to include data from in-house, proprietary databases.

Commercial Applications and Other Benefits as described by the awardee: These software tools should allow the sequence data produced by the Department of Energy and other Federal agencies to be used by the private sector for important medical and environmental applications such as diagnostics, drug design, and bioremediation.

142

Versatile Liquid Crystal Tunable Interference Filter for Chromosome Analysis-Physical Optics Corporation, 20600 Gramercy Place, Building 100, Torrance, CA 90501-1821; 310-320-3088

Dr. Tin Aye, Principal Investigator
Mr. Gordon Drew, Business Official
DOE Grant No. DE-FG03-99ER82856
Amount: \$99,997

High resolution, spectral imaging microscopy using multi-probe fluorescence *in situ* hybridization (FISH) has been demonstrated as a potential technique for chromosome analysis. However, current spectral imaging systems are limited in their performance, thereby limiting the number of chromosomes that can be discerned simultaneously. This project will develop a highly versatile, high resolution, wide spectral range, high speed, liquid crystal, tunable interferometric filter (LCTIF), which can overcome the limitations of current spectral imaging techniques used for FISH. Phase I will demonstrate feasibility through analytical design, computer modeling, and experimental fabrication of a proof-of-concept LCTIF device.

In Phase II, a fully operational prototype LCTIF will be developed, which can be immediately applied to DNA mapping and chromosome analysis.

Commercial Applications and Other Benefits as described by the awardee: The full mapping of human DNA requires improved instrumentation. The proposed innovative spectral (color) filter should respond to this need and significantly improve genomic analysis. The LCTIF should be commercially attractive in many spectral imaging applications requiring low material and fabrication costs and superior performance.

143

Fluorescent-Based High Throughput Protein Kinase and Phosphatase Assays--SymBiotech, Inc., 8 Fairfield Boulevard, Wallingford, CT 06492-1890; 203-949-2766

Dr. Edward M. Davis, Principal Investigator
Dr. Edward M. Davis, Business Official
DOE Grant No. DE-FG02-99ER82901
Amount: \$100,000

The analysis of protein requires technologies comparable to those used for the high throughput analysis of DNA. Such technology could be used to assess the protein's bio-activity, biochemical processes, and reaction to external materials. This project will investigate the use of a newly developed fluorescent reagent for detecting and quantifying phosphomonoesters. The reagent will be used under aqueous conditions to follow the activity of kinase and phosphatase, major classes of proteins that control cell function. In Phase I, the phosphomonoester detection reagent will be prepared and used to detect pepsin's phosphoserine residues, follow phosphatase activity, and monitor CaM kinase activity. The feasibility of employing this reagent in high throughput assay formats will be demonstrated. During Phase II, the kinase and phosphatase assays will be developed into a high throughput assay system (e.g., a microarray-based system).

Commercial Applications and Other Benefits as described by the awardee: The development of high throughput assays for screening the activity

of kinase and phosphatase should have application to basic science, drug development, and medical diagnosis.

METAL FORMING

144

A Generic Approach to Improved Semi-Solid Forming of Metals--Chesapeake Composites Corporation, 239 Old Churchman's Road, New Castle, DE 19720-1529; 302-324-9110
Mr. Eric M. Klier, Principal Investigator
Dr. Alexander Brown, Business Official
DOE Grant No. DE-FG02-99ER82763
Amount: \$99,102

The full potential of the semi-solid forming process (with its requirement for a uniform, spherical primary phase throughout) has not been realized due to difficulties in developing technology for the production of large inexpensive feedstock. Furthermore, even with existing semi-solid metal systems, narrow process windows and alloy chemistry restrictions increase process costs and limit performance attributes. This project will develop production technology for semi-solid forming utilizing new proprietary feedstock metals. The approach offers an intrinsic, highly uniform, spherical solid phase, without electromagnetic or mechanical shearing. In Phase I, new aluminum feedstock will be utilized to demonstrate the low cost, semi-solid production of large diameter components with uniform spherical solid phase, an expansion of the semi-solid forming process window, and substantially enhanced physical and mechanical properties compared to existing materials.

Commercial Applications and Other Benefits as described by the awardee: This approach should encourage further growth of semi-solid forming by providing for low cost large diameter billet stock, reduced semi-solid forming costs, extension of semi-solid forming to new alloy systems, and semi-solid formed components with substantially enhanced physical and

mechanical properties. Near term applications for aluminum include automotive brake components, military engine components, electronic packaging, and precision equipment.

145

High-Strain-Rate Superplastic Forging of Aluminum Alloys--Materials Modification, Inc., 2929 P-1 Eskridge Road, Fairfax, VA 22031-2213; 703-560-1371
Mr. Sang H. Yoo, Principal Investigator
Dr. T.S. Sudarshan, Business Official
DOE Grant No. DE-FG02-99ER82825
Amount: \$100,000

Currently, superplastic forming is used only in turbine manufacturing, aerospace and to a limited extent in the automotive industries due to the high cost associated with thermomechanical and recrystallization processes, and a long time normally required to form a near-net-shape part. This project will demonstrate economical synthesis and processing of nanocrystalline aluminum alloys that exhibit high-strain-rate superplastic deformation to overcome such problems. Thermomechanical and recrystallization processes will be eliminated, and the superplastic forming time will be reduced by more than 1000 percent by using our proposed nanotechnology. In Phase I, aluminum, iron, and chromium nanopowders will be synthesized and formed into an Al-Cr-Fe alloy using a high-energy ball milling process. Rapid densification and superplastic forging will be achieved in one step by employing a plasma and pressure compaction technique. Fully dense, near-net-shape parts will be produced in a short cycle time (<10 min) by the unique densification and plastic yielding mechanisms in the process.

Commercial Applications and Other Benefits as described by the awardee: High strain rate superplastic forging is expected to result in economically-viable, near-net-shape forming techniques for the automobile, aerospace, and even semiconductor industries because it leads to high productivity in fabrication of parts with complex shapes.

146

Desktop Prototyping of Metals and Alloys--
Nanomaterials Research Corporation, 2620
Trade Center Avenue, Longmont, CO
80503-7551; 303-702-1672

Dr. Darin Aldrich, Principal Investigator
Ms. Molly M.W. Kostecky, Business Official
DOE Grant No. DE-FG03-99ER82841
Amount: \$100,000

Metal forming accounts for over \$250 billion per year of U.S. economic activity, yet metal forming generates waste and is a time intensive process. Innovations in metal forming technology can significantly reduce the costs and environmental impact of this and downstream industries. This project will reduce both waste and time-to-market through desktop prototyping technology. Low-cost nanoscale powders of metals and alloys will be produced and used. The Phase I will establish that complex shapes can be formed from stainless steel and nickel alloy nanoscale powders.

Commercial Applications and Other Benefits as described by the awardee: Potential markets for the technology include automotive parts and assembly, office machines, computer peripherals, and medical instruments. The technology should also apply to other metal industries, reducing the environmental impact from metal-derived parts manufacturing operations.

147

Semi-Solid Metal Freeform Fabrication--
Semi-Solid Technologies, 130 Brookline Street,
Suite 210, Cambridge, MA 02139;
508-652-8518

Mr. Christopher S. Rice, Principal Investigator
Dr. Stuart B. Brown, Business Official
DOE Grant No. DE-FG02-99ER82882
Amount: \$99,400

In spite of recent advances in materials science, there is no widely commercialized technology for the rapid fabrication of metal components other than standard milling. There is a need for such technology, as the delivery time for metal dies or large-sized, low volume castings can exceed two to three months or more. This project will combine the features of semi-solid metal, a mixture of molten metal and metal particles, with an advanced deposition technique to produce large metal components. The technology will deposit layers of metal "paste" to build up three-dimensional metal parts. Phase I will focus on aluminum, and Phase II will address ferrous alloys. The Phase I project will construct and demonstrate the capability of the technology by depositing shapes from a semi-solid aluminum alloy.

Commercial Applications and Other Benefits as described by the awardee: There are many large components, including special piping, elbows, valves, flanges, and reducers that are made in small quantities with a months-long delivery time. This technology should provide the ability to produce these components within weeks, either as final components or as interim components. In addition, this technology may provide the ability to rapidly produce tool dies.

PROCESSING FOR SURFACE HARDNESS

148

Ultra-Hard Diamond-Like Nanocomposite Coatings for Wear Applications--Advanced Refractory Technologies, Inc., 699 Hertel Avenue, Buffalo, NY 14207-2341; 716-875-4091

Dr. David Kester, Principal Investigator
Dr. Roger Storm, Business Official
DOE Grant No. DE-FG02-99ER82731
Amount: \$99,975

There is a need for coatings which can act as hard, low friction, wear resistant layers. These coatings could significantly increase the lifetime of mechanical parts subject to wear. In addition to high hardness and low wear, these coatings must provide excellent adhesion to metal surfaces. This project will demonstrate the suitability of a new class of thin film coating materials, diamond-like nanocomposites (DLN). With high hardness (>30 GPa), low wear, and low friction, these materials have several advantages over competing coatings, including lower stress, lower friction, and friction independent of humidity level. Phase I will focus on demonstrating that these coatings can be deposited with hardness levels of 35-45 GPa with excellent adhesion. A two or three layered DLN structure will be used. The tribo-chemical mechanisms responsible for the coating's tribological properties will be studied.

Commercial Applications and Other Benefits as described by the awardee: Commercial applications should include low friction coatings for seals; hard, wear resistant coatings for bearings; thin, hard coatings for hard disks; and biomedical coatings. The specific performance benefits to parts coated with DLN include lower wear, lower friction, longer lifetimes, and lower maintenance costs due to less frequent part replacements.

149

Ultra-Hard Nanolayered Coatings for Wear-Resistant Applications--Applied Thin Films, Inc., 1840 Oak Avenue, Evanston Business & Technology Center, Suite 102, Evanston, IL 60201-3642; 847-491-4619

Dr. Ben Zhou, Principal Investigator
Dr. Sankar Sambasivan, Business Official
DOE Grant No. DE-FG02-99ER82745
Amount: \$100,000

The coating of cutting tools can provide major enhancements in tool life and result in substantial economic benefits. Recently, there has been a strong interest in coatings that perform well at elevated temperatures because of the desire to cut at higher rates and to eliminate the waste cooling fluid. For typically used nitride coatings, the hardness decreases rapidly with increasing temperature, thereby decreasing wear resistance. This project will develop nanolayered coatings for this application, which would provide substantial hardness enhancements. Because the nanolayered coatings exhibit strong dislocation confinement, they are expected to have better high-temperature hardness retention than the currently used monolithic coatings. Phase I will investigate a sputter-deposited nanolayered boron based coating. A specific material system will be selected to optimize key properties including hardness, thermal expansion mismatch with the tool, and stability against the work-piece.

Commercial Applications and Other Benefits as described by the awardee: Nanolayer-coated cutting tools have the potential to make dry-cutting a practical alternative to traditional wet cutting methods. Elimination of the cooling fluid would decrease environmental waste disposal costs and lead to potential economic benefits.

Functionally Graded, Nanocrystalline, Multiphase, Boron-and-Carbon-Based

Superhard Coatings--Spire Corporation, One Patriots Park, Bedford, MA 01730-2396; 781-275-7470

Dr. Fereydoon Namavar, Principal Investigator
Mr. Ronald S. Scharlack, Business Official
DOE Grant No. DE-FG02-99ER82891
Amount: \$99,923

Although many important advances have been made in the development of new alloys for engine components and biomedical prostheses, further improvement is sought in order to increase the durability of these materials and reduce the cost and energy consumption during fabrication and operation (by reducing size and weight). Conventional ceramics, while highly wear-resistant, lack the requisite adhesion and toughness for application as protective hard coatings. This project will develop processes to fabricate superhard, tough, adherent, low-friction, protective coatings. The proposed coatings not only will have metallic adherence to metals but also will possess the higher wear resistance and lower friction coefficient of ceramic coatings. Phase I will develop functionally graded, nanocrystalline, metalloceramic (interface region), multiphase (surface region) ceramic coatings which eliminate the adhesion problems associated with ceramic hard coatings on metallic substrates. Ion enhanced deposition will be applied to produce Ti-B-N coatings with hardness as high as 50 Gpa. The resulting structure takes a advantage of the properties of both covalent and metallic materials as well as multiphase ceramics to reduce internal stress and enhance and toughness of the coating.

Commercial Applications and Other Benefits as described by the awardee: The graded, low-friction, nanocrystalline multiphase Ti-B-C-N coatings should find application as protective coatings, in tooling (where the low shock resistance or toughness of ceramic coatings is a significant limitations on their application), and in applications involving shock loading (which

is too severe for non-reinforced ceramic coatings).

Large Area Filtered Arc Deposition of Carbon and Boron Based Hard Coatings--

UES, Inc., 4401 Dayton-Xenia Road, Dayton, OH 45432-1805; 937-426-6900

Dr. Rabi S. Bhattacharya, Principal Investigator
Mr. Francis F. Williams, Jr., Business Official
DOE Grant No. DE-FG02-99ER82911
Amount: \$99,839

Hard, thin, wear resistant coatings can play a vital role in numerous engineering applications. Many such coatings have been developed over the years in the laboratory by using various plasma-based techniques. However, some of these techniques are not easily scalable for applications on actual engineering components. This project will develop a large area filtered arc deposition (LAFAD) technique that generates carbon and boron based hard coatings for engineering applications. This filtered arc technique allows deposition of droplet-free smooth coatings by deflecting the plasma flow in a rectangular electromagnetic filter. The advanced filter design utilized in this equipment provides large area deposition ranging from about 250 mm in width to heights of 300 mm to 2 m or more. In Phase I, the LAFAD technique will be used to develop diamond-like carbon (DLC), nanocrystalline titanium carbide/DLC, and titanium boride/titanium boronitride composite layers. Deposition parameters will be optimized in order to obtain hard and well-adhered coatings on engineering steel substrates. The coatings will be then characterized for hardness, adhesion, microstructure and surface morphology.

Commercial Applications and Other Benefits as described by the awardee: These coatings and coating equipment should find application in engine and machine components (to control wear and corrosion), cutting and machining tools, die casting dies, hard disk media, etc.

Ultra-Hard, Nano-Structured Diamond Thin Films Using Inductively Coupled Plasma--
UHV Technologies, Inc., 113-B West Park Drive, Mount Laurel, NJ 08054-1278; 609-608-0311

Dr. Nalin Kumar, Principal Investigator
Dr. Nalin Kumar, Business Official
DOE Grant No. DE-FG02-99ER82912
Amount: \$99,607

Diamond thin films possess extreme hardness, chemical inertness, low coefficient of friction, high thermal conductivity, and wide band-gap, making them extremely desirable as a next generation material. However, in spite of significant efforts over past 15 years, these films have found very few commercial applications

due to high manufacturing cost, scalability, large grain sizes, and porosity associated with traditional deposition techniques. This project will develop a new deposition method based on inductively coupled plasma and carbon dimer-based chemistry. This approach will produce ultra-smooth, hard diamond coatings over very large substrates. Phase I, will demonstrate the feasibility of the deposition method and assess its commercial viability in the context of scalability and economics.

Commercial Applications and Other Benefits as described by the awardee: Potential commercial applications of the proposed technology include tribological coatings, hard optical coatings, heat sinks for high power electronics, and vacuum microelectronic devices.

MATERIALS JOINING

Friction Stir Welding of High-Melting-Temperature Materials with the Aid of Auxiliary Heating Sources--
Engineering Mechanics Corporation of Columbus, 4181 Maystar Way, Hilliard, OH 43026; 614-850-8792

Dr. Yong-Yi Wang, Principal Investigator
Dr. Gery Wilkowski, Business Official
DOE Grant No. DE-FG02-99ER82785
Amount: \$94,222

Friction stir welding (FSW) is a solid-state joining process which is immune to such welding defects as solidification cracking and porosity in the weld region, defects usually associated with solidification processes. Most successful FSW applications so far have involved low melting temperature materials, notably various types of aluminum alloys. For FSW with high-melting-temperature materials, the tool materials that have been tested are not strong enough to produce more than a few feet of weld without extensive wear or fracture. This project will develop a FWS process with high

melting temperature materials by adding an auxiliary heating source to the FSW process and selecting tool materials that possess superior elevated temperature strength and wear resistance. Phase I will select appropriate auxiliary heating sources and process parameters for FSW of high-melting temperature materials, conduct trial FSW of selected high-melting-temperature materials, and confirm FSW joint quality through mechanical testing and metallurgical examination. In Phase II, better tool materials will be selected, refined process models will be developed with inclusion of auxiliary heating source for process optimization, the FSW joints will be experimentally tested, and prototype welding equipment will be designed.

Commercial Applications and Other Benefits as described by the awardee: The process would eliminate solidification-related welding defects in friction stir welds, and provide less detrimental metallurgical changes and better overall joint performance. Other applications include hard-to-weld materials such as Ni-based

superalloys, Ti alloys, metal composites, and dissimilar materials.

154

Hermetic, Reaction-Bonded Silicon Carbide Tube Joints with Microwave Heating--FM Technologies, Inc., 10529-B Braddock Road, Fairfax, VA 22032-2236; 703-425-5111
Dr. Richard Silbergliitt, Principal Investigator
Dr. Frederick M. Mako, Business Official
DOE Grant No. DE-FG02-99ER82922
Amount: \$100,000

Metal alloy tubes in radiant furnaces, widely used for heat treating of steel, operate in severe environments (including temperatures in excess of 1000 degrees Centigrade) and require replacement every 1-2 years. Expenses associated with replacing these tubes (including both downtime and the cost of the tubes themselves) are a significant portion of the life cycle cost of heat treating furnaces. Reaction bonded silicon carbide tubes last 2-3 times longer than metal tubes. However, the required 10-15 foot lengths are available at a competitive cost only as straight tubes, whereas 80 percent of radiant tubes have U, W, or trident shapes. In this project, long straight lengths will be joined to short U-sections by forming a silicon carbide-based interlayer *in situ* with microwave heating. In Phase I, reaction bonded silicon carbide tube sections will be joined using liquid infiltration and pyrolysis of preceramic polymer slurries with microwave heating. In order to preserve the hermeticity of these silicon-matrix materials, the joining temperature will be less than the melting point of silicon. Joint microstructure, hermeticity, and mechanical strength will be evaluated.

Commercial Applications and Other Benefits as described by the awardee: 100 billion cubic feet of natural gas is consumed each year in approximately 25,000 heat treating furnaces that use primarily metal radiant burner tubes. Replacement with ceramic tubes would drastically reduce or eliminate tube replacement cost and enable savings of almost \$200,000 per

furnace per year through the increased efficiency associated with higher temperature operation.

155

A Novel Solid State Joining Technique for High Thermal Conductivity Aluminum Nitride Components--Sienna Technologies, Inc., 19501 144th Avenue, NE, Suite F-500, Woodinville, WA 98072-6463; 425-485-7272
Dr. Ender Savrun, Principal Investigator
Dr. Canan Savrun, Business Official
DOE Grant No. DE-FG03-99ER82883
Amount: \$99,995

Use of high thermal conductivity aluminum nitride (AlN) components can boost the performance of heat exchangers significantly. To take advantage of AlN, the AlN components must be joined to each other and to metallic members. However, currently available active brazing alloys are not suitable for high temperature applications, and new joining compounds are required to obtain reliable AlN-to-AlN and AlN-to-metal joints. This project will develop a novel solid-state bonding approach for making AlN-AlN joints. Several AlN-TiO₂ compositions will be investigated to develop a reliable reactive joining compound that can also be used to repair cracks on AlN parts in the field. Phase I will determine a reactive composition that can be applied with no external pressure. Mechanical properties, microstructure, and microchemistry of the joints will be evaluated in order to select a final composition for a detailed Phase II study.

Commercial Applications and Other Benefits as described by the awardee: The new joining compound should have applicability to AlN-based ceramic heat exchangers and other thermal components. The reactive compound will be in form of a paste so that it can easily be printed, squeezed, or painted onto the surfaces that require repairing.

Innovative Vanadium Alloy Joining for Fusion Reactor Applications--Surmet Corporation, 33 B Street, Burlington, MA 01803-3406; 781-272-3250

Dr. Suri A. Sastri, Principal Investigator

Dr. Suri A. Sastri, Business Official

DOE Grant No. DE-FG02-99ER82900

Amount: \$100,000

Vanadium alloy is highly attractive as a structural material for future fusion reactors due to its strength, toughness, and chemical compatibility with liquid lithium. However, before it can be practically utilized, a reliable vanadium bonding technique must be developed. This project will develop a novel bonding technique to reliably bond vanadium alloy to itself, to ferritic stainless steels, and to ceramics.

The approach will satisfy the requirements that the fabricated joints preserve vanadium's high strength, high toughness, and chemical compatibility with liquid lithium. In Phase I, vanadium alloy will be bonded to itself, as well as to ferritic stainless steel and to Al_2O_3 . Mechanical testing, microstructural evaluation, and thermal cycling will be performed.

Commercial Applications and Other Benefits as described by the awardee: Successful bonding of vanadium alloys to other low activation structural materials is critical to the success of the U.S. government's clean fusion energy project funded by the Department of Energy. The technology should also have commercial application in the fabrication of structures from components of dissimilar ceramic and metallic materials that can function in severe service conditions.

SUPERCONDUCTIVITY MATERIALS FOR ELECTRIC POWER

High Current Density in Bismuth-2223 Tape and Low AC Loss Wire--American Superconductor Corporation, Two Technology Drive, Westborough, MA 01545; 508-836-4200

Dr. Alex Otto, Principal Investigator

Dr. Tom Rosa, Business Official

DOE Grant No. DE-FG02-99ER82743

Amount: \$100,000

The current densities of high temperature superconducting (HTS) composite tapes are presently adequate for operation of advanced prototype power transmission and magnet applications. However, even in the best tapes, current density improvements of 25 - 50 percent will be required for broad based commercial utilization. Even larger improvements will be required in fine filament, low ac loss wires. This project will develop process steps for attaining high transport currents for low ac loss, small-filament, bismuth-2223 (Bi-2223) oxide-based HTS wires, as well as conventional, power transmission tape. The approach improves

filament density and superconducting oxide texture via major changes in the reaction sequence that forms the Bi-2223 superconductor from the precursor oxides in multi-filament composite wires and tapes. Phase I will establish the feasibility of process steps for greatly boosting J_c in composite superconducting oxide wires, without the need for deformation after Bi-2223 formation starts.

Commercial Applications and Other Benefits as described by the awardee: High current density, low ac-loss HTS wire should enable the development of high field magnets with enhanced performance and >20 K operation for lower cost refrigeration. It should also enable the development of cost effective HTS based transformers with superior efficiency, size/weight and reactance. J_c enhancements in HTS power transmission tape should lead to commercial products in the underground urban conduit retrofit cable business.

Low Cost Bismuth-2223 Conductors for High Temperature Superconducting Transformers--American Superconductor Corporation, Two Technology Drive, Westborough, MA 01545; 508-836-4200
 Dr. Martin W. Rupich, Principal Investigator
 Dr. Tom Rosa, Business Official
 DOE Grant No. DE-FG02-99ER82741
 Amount: \$100,000

The commercialization of High Temperature Superconducting (HTS) wires requires reduction in manufacturing costs and tailoring of properties for specific applications. This project addresses HTS transformers, an application that requires the conductor to meet stringent cost and performance requirements not currently achievable with conventional Bismuth-2223 (Bi-2223) multifilamentary HTS conductors. A new manufacturing process has been investigated for depositing Bi-2223 films onto flexible metal substrates of the type developed for the YBCO "coated conductor" technology. The advantages of this approach include improved current densities, a significant reduction in materials and manufacturing cost, and the ability to tailor conductor properties for specific applications. Phase I will demonstrate a low cost manufacturing process for HTS conductors with specific properties required for use in HTS transformers.

Commercial Applications and Other Benefits as described by the awardee: This new, low-cost manufacturing process for Bi-2223 conductors should enable the commercialization of electrical transformers, motors, generators and other coil based HTS applications. The technology also should allow these HTS based systems to be cost competitive with conventional copper based systems.

Meter Length YBCO Coated Conductor Development--American Superconductor Corporation, Two Technology Drive, Westborough, MA 01545; 508-836-4200

Dr. Cornelius L. H. Thieme, Principal Investigator

Dr. Tom Rosa, Business Official

DOE Grant No. DE-FG02-99ER82740

Amount: \$100,000

Devices such as power transmission cables, motors, and generators, used in high-energy physics experiments and other applications, can be made very compact when run under cryogenic conditions. For further enhancements in power densities, $\text{YBa}_2\text{Cu}_3\text{O}_x$ coated conductors offer unique opportunities because of their very high critical current density at 77K, and excellent in-field properties at 50-65K. So far only short lengths of this conductor have been made using deformation textured substrates. This project will produce YBCO coated conductors in long lengths and high overall critical current densities by manufacturing bi-axially textured Ni and non-magnetic substrates with a sharp, well defined texture along long lengths and across the width, without surface damage. In Phase I, Ni and non-magnetic alloy substrates will be produced in long lengths and analyzed for texture using x-ray pole figures and orientation and mapping at random locations along the length. Surface quality will be determined using high resolution scanning electron microscopy. One meter long lengths will be coated with buffer and metal-organic-deposited YBCO layers, after which the conductor will be tested at 77K using multiple voltage taps. Bad sections will be cut and further analyzed for texture quality of substrate, buffer and YBCO, as well as surface features which might reduce J_c .

Commercial Applications and Other Benefits as described by the awardee: YBCO coated conductors, produced in long lengths and using a cheap non-vacuum deposition process, should be a technically and commercially attractive superconductor with applications in power transmission cables, motors, generators, transformers, high field magnets, and magnets for energy storage, magnetic separation, and current limiters.

Non-Vacuum, Reel-to-Reel Processing of High-Temperature Superconducting Coated Conductors--MicroCoating Technologies, Inc., 3901 Green Industrial Way, Chamblee, GA 30341; 770-457-8400

Dr. Shara Shoup, Principal Investigator
Mr. Jerome J. Schmitt, Business Official
DOE Grant No. DE-FG02-99ER82834
Amount: \$100,000

High-temperature coated superconductors have enormous potential for electric power applications; yet, fabricating the necessary long lengths has proved to be an elusive goal. Vacuum techniques are the leading processes because they yield films with sufficiently high critical current densities; however, they suffer from low throughput and high cost. This project will develop a low-cost, open-atmosphere Combustion Chemical Vapor Deposition (CCVD) technique to deposit epitaxial superconductor coatings onto single crystal and CCVD-buffered textured metal substrates. The CCVD technique is scalable and has

demonstrated the ability to deposit single orientation buffer layers onto textured Ni. Phase I will focus on optimizing the quality of CCVD-deposited $\text{YbBa}_2\text{Cu}_3\text{O}_{7-x}$ (YBCO) on oxide single crystal substrates to obtain a critical current density of at least 1 MA/cm^2 . The CCVD superconductor will then be deposited onto research coupons of practical Rolling Assisted Biaxially Textured Substrates (RABiTS), previously coated with a CCVD buffer layer. A critical current density goal of $100,000 \text{ A/cm}^2$ is expected on the RABiTS substrates. Scaling to multiple meter lengths will be performed in Phase II.

Commercial Applications and Other Benefits as described by the awardee: The CCVD technique should be readily incorporated into a coated conductor wire fabrication facility and offer a lower cost alternative to the expensive vacuum deposition methods currently being researched to manufacture both the buffer layer and the superconductor. This ease of manufacturing should aid in long-length superconductor wire development and broaden the use of coated superconductor wire.

NEUTRON INSTRUMENTATION

An Advanced Cold Moderator Using Solid Methane Pellets--Cryogenic Applications F, Inc., 450 Bacon Springs Lane, Clinton, TN 37716-5311; 423-435-5433

Dr. Christopher A. Foster, Principal Investigator
Dr. Christopher A. Foster, Business Official
DOE Grant No. DE-FG02-99ER82772
Amount: \$99,978

Existing and planned pulsed neutron sources, such as Intense Pulsed Neutron Source (IPNS) and the Spallation Neutron Source (SNS), generate pulses of cold neutrons for materials research. The usefulness of such facilities depends on the efficiency of components that convert the fast neutrons to a cold neutron beam. Although the existing solid methane moderator

for the IPNS has high efficiency, the design cannot be scaled to the high power levels planned for the SNS. An alternative cold moderator, which uses solid methane pellets and was proposed in 1988, is capable of high power operation; however, the technology for producing and transporting the solid pellets has not yet been developed. This project will apply practical pellet fabrication and transport technologies, previously developed for the Department of Energy (DOE) fusion program, to the production of methane pellets. In Phase I, existing pellet fabrication test apparatus, used to develop machines to produce solid deuterium and dry ice pellets, will be upgraded to allow the production of solid methane pellets. An apparatus to cool the methane pellets to liquid helium temperatures will be added to the apparatus. Plans to test a small scale pellet

moderator at a DOE user facility during Phase II will be developed.

Commercial Applications and Other Benefits as described by the awardee: The proposed research should enhance the operation of high power spallation neutron sources, used for materials research, by doubling the output of cold neutrons. The technologies developed should also be useful for the production of other commercially used cryogenic pellets such as dry ice.

162

Supersmooth Neutron Optical Surfaces by Gas Cluster Ion Beam Processing--Epion Corporation, 4 Alfred Circle, Bedford, MA 01730; 781-275-3703

Mr. Lawrence A. Stelmack, Principal Investigator

Dr. Allen Kirkpatrick, Business Official

DOE Grant No. DE-FG02-99ER82787

Amount: \$100,000

Beam guides and neutron scattering instrumentation at the new national Spallation Neutron Source require many large neutron optical components, which are smooth, efficient, stable, and cost-effective. In order to produce neutron optics with low scatter, techniques must be developed for reducing film surface and interface roughness. This project will apply gas-cluster ion beam smoothing techniques to produce neutron optics with high efficiency and low non-specular scatter. Phase I will identify promising gas-cluster ion beam processing methods to support optics requirements for advanced neutron sources. The feasibility of gas-cluster ion beam smoothing will be determined for materials that are currently used for neutron optical substrates and coatings, as well as for promising new materials. Ultimately, both commercial processing services and production equipment will be provided for treating surfaces of neutron optical substrates and coatings needed for neutron research.

Commercial Applications and Other Benefits as described by the awardee: The technology

should enable production of neutron optical devices having higher performance and enhanced cost-effectiveness. Other applications include next-generation optical and electronic device processing, including mirrors for extreme UV lithography and x-ray instruments, as well as electronics.

163

Three-Dimensional Silicon Imaging Array for Cold Neutrons--IntraSpec, Inc., P.O. Box 4579, Oak Ridge, TN 37831-4579; 865-483-1859

Mr. John Walter, Principal Investigator

Mr. John Walter, Business Official

DOE Grant No. DE-FG02-99ER82807

Amount: \$100,000

Cold neutron scattering is rapidly gaining importance as a tool for studying structure in materials. Neutron detection arrays are used with such neutron scattering experiments to reduce counting times and increase accuracy. With the advent of stronger sources of cold neutrons, there is a need for much higher response speeds in these arrays. Existing two dimensional wire arrays are limited to about 40,000 counts/s total with 10 percent dead time, and are further handicapped by ghost images resulting from pile-up problems. Approaching 10^5 counts/s per pixel, with little cross talk, would amount to a revolution in cold neutron physics. This project will combine sub-arrays of silicon pixel detectors with a neutron-to-charged-particle convertor to allow substantially spherical array systems with good efficiency, very high count rate capability, and low image distortion from pile-up. Each sub-array features parallel processing within four hybrid components: a 196 pixel monolithic detector array (7 cm x 7 cm), an ASIC parallel signal conditioning array, a data logic and storage array, and a data transmission integrated circuit. These sub-arrays will be combined to provide a large imaging array.

Commercial Applications and Other Benefits as described by the awardee: These instruments should be able to handle very high count rates without the usual problems of pile-up induced

ghost images. The technology should also prove useful for other applications such as particle physics arrays and x-ray imaging.

164

Solid-State Neutron Detection Materials--
Radiation Monitoring Devices, Inc., 44 Hunt
Street, Watertown, MA 02172-4624;
617-926-1167

Dr. Gerald Entine, Principal Investigator

Dr. Gerald Entine, Business Official

DOE Grant No. DE-FG02-99ER82867

Amount: \$100,000

Neutron detection is one of most challenging tasks encountered in experimental physics - whether it be employed in material analysis, fission/fusion research or dosimetry. Limited interaction mechanisms reduce choices to amongst a few cumbersome, often inefficient, and highly specialized detector types. For efficient detection, a high density of inter-action centers is needed within a practical volume. As yet undeveloped, a solid-state neutron detector would be a technical breakthrough. The primary obstacle lies in the limited number of semiconducting materials that possess sufficiently high neutron cross-sections. This project will evaluate several promising materials to determine a suitable candidate. Simple device structures will be prepared and tested for charge transport, electrical resistivity, and thermal neutron sensitivity. This data will be combined with growth and fabrication prospects to determine each candidate's likelihood for success. A proton accelerator will be used for charge mobility and lifetime evaluations.

Commercial Applications and Other Benefits as described by the awardee: Solid state detection would likely be the most versatile technique for a wide range of neutron sensing tasks. These detectors would be extremely compact and rugged, capable of position sensitive detection, and possibly lead to *direct* pulse height spectroscopy of neutron energy. Outside the laboratory they should benefit radiation dosimetry, monitoring of nuclear materials, oil

exploration, and cancer treatments (e.g., boron neutron capture therapy).

165

A High-Pressure ^3He Neutron Spin Filter--
Science Research Laboratory, Inc., 15 Ward
Street, Somerville, MA 02143-4228;
617-547-1122

Dr. Jonathan Richardson, Principal Investigator

Dr. Jonah Jacob, Business Official

DOE Grant No. DE-FG02-99ER82878

Amount: \$99,891

Polarized neutron scattering (including small angle, reflectometry, and refraction) has been demonstrated to be an invaluable tool in the characterization of magnetic and non-magnetic materials. Current neutron polarization methods are limited to well-collimated, low energy (greater than 25 meV at room temperature) beams, precluding their use as spin analyzers in most cases. To overcome these limits, this project will develop a dense polarized gaseous ^3He spin filter. A reliable apparatus for polarizing ^3He and delivering it in suitable containers ("cells") will be developed and incorporated in a variety of neutron scattering instruments. The system will be able to support several neutron scattering instruments in parallel by polarizing individual cells, each containing up to 1 liter of ^3He that has been polarized to >40 percent in less than an hour. In Phase I, the polarizing capability of an existing ^3He apparatus will be improved, cells will be designed to the specifications of one or more neutron scattering instruments, and the integrated polarization/cell-filling apparatus will be designed. In Phase II, the system will be built, and tests will be conducted at the National Institute of Standards and Technology Center for Neutron Research.

Commercial Applications and Other Benefits as described by the awardee: This technology should allow polarization equipment to be supplied to both existing and future facilities, including nine neutron scattering centers in the U.S. and Canada and over 22 abroad. Also, plans exist for a new \$1.36B scattering facility in

the U.S. called the Spallation Neutron Source. In addition, polarized ^3He can be used for

medical imaging and characterization of material microstructure.

ALTERNATIVE SYNTHETIC PATHWAYS FOR ENERGY EFFICIENT AND ECONOMIC INDUSTRIAL CHEMICAL MANUFACTURE

166

Novel Catalyst for Methane and Carbon Monoxide Conversion--CeraMem Corporation, 12 Clematis Avenue, Waltham, MA 02154-7011; 781-899-4495

Dr. Michael C. J. Bradford, Principal Investigator

Dr. Robert L. Goldsmith, Business Official

DOE Grant No. DE-FG02-99ER82762

Amount: \$100,000

In current commercial practice, natural gas is converted to higher molecular weight hydrocarbons through an indirect route in which the natural gas is first converted to synthesis gas (a mixture of hydrogen and carbon monoxide) and subsequently converted to liquids by available technology such as the Fischer-Tropsch process. Considerable economic benefits would accrue if new catalyst and process technologies could be developed that directly convert natural gas to liquids. This project will develop a novel catalyst for the direct conversion of methane and carbon monoxide to heavy aromatics (such as benzene, xylene and naphthalene), light alkanes, and olefins. The process will be suitable for fixed bed reactor technology and is thus capable of being quickly scaled up to commercial capacity. Phase I will focus on the preparation, characterization, and laboratory scale evaluation of novel multifunctional catalysts for simultaneous conversion of methane and carbon monoxide to higher molecular weight hydrocarbons.

Commercial Applications and Other Benefits as described by the awardee: The technology should significantly increase the utilization of domestic and remote natural gas reserves

because it directly converts the natural gas to higher molecular weight products of substantially higher market value.

167

Hydrophobic Ionic Liquid Biphasic Catalysis--Covalent Associates, Inc., 10 State Street, Woburn, MA 01801-6820; (781) 938-1140

Dr. Alan B. McEwen, Principal Investigator

Dr. K.M. Abraham, Business Official

DOE Grant No. DE-FG02-99ER82770

Amount: \$99,953

The use of homogeneous catalysts could increase industrial efficiencies due to their high selectivity and activity; however, inadequate separation of products has limited their application. Biphasic catalysis with water has been used successfully, but the contamination of water with solvents requires expensive cleaning processes. This project will develop biphasic catalysts based on ionic liquids containing perfluoro organic anions. These materials are highly stable, have no vapor pressure, and will result in an environmentally benign process. Phase I will determine the catalytic activity of several catalysts in these ionic liquids. Specifically, the reaction of carbon monoxide with olefins and the dimerization of olefins will be investigated. Ultimately, the ionic liquid biphasic catalysis will lead to improved catalyst recovery and product separation.

Commercial Applications and Other Benefits as described by the awardee: The development of an environmentally benign process, without organic solvent or solvent-contaminated water by-products, should have immense industrial significance. Specific

processes that would benefit include the upgrade of lightweight alkenes to more important industrial feedstocks through reaction with carbon monoxide (hydroformylation) and dimerization.

168

Pyrolytic-Catalytic Conversion of Methane to Fullerene -- F.S. Lab, 156 Common Street, Belmont, MA 02178-2913; 617-489-2391
Dr. P. H. Fang, Principal Investigator
Dr. Josephine M. Fang, Business Official
DOE Grant No. DE-FG02-99ER82790
Amount: \$100,000

Fullerene can be used in numerous fields, either directly or as a stock material to synthesize diamond. This project will attempt to convert methane to fullerene. The challenge is to establish an effective pathway of synthesis using a combined pyrolytic and catalytic treatment. Phase I will demonstrate the new synthesis process, which will overcome the defects of prevailing processes. Methane will be used as feedstock material to fabricate fullerene economically and ecologically, with scalability for industrial production.

Commercial Applications and Other Benefits as described by the awardee: A manufacturing technology for large-scale production of fullerene, using methane as a raw material, should be both economically and ecologically viable.

169

Oxidative Coupling of Methane in a Catalytic Micro-Channel Membrane Reactor-- InnovaTek, 350 Hills Street, Richland, WA 99352; 509-375-1093
Dr. W. Lloyd Allen, Principal Investigator
Dr. Patricia M. Irving, Business Official
DOE Grant No. DE-FG03-99ER82803
Amount: \$100,000

This project addresses the conversion of methane gas into higher value products. Although catalysis and separation membranes have been studied for the oxidative coupling of methane, the selectivity and rates of conversion to higher-carbons have been low. A novel catalytic membrane for supplying oxygen to the reaction in a highly efficient micro-channel configuration would increase selectivity and conversion to commercially feasible levels. Phase I will fabricate and test Perovskite structures that offer high levels of oxygen permeation and catalytic effectiveness in the oxidative coupling of the methane reaction. Ultimately, a catalytic membrane material will be developed, along with a highly efficient micro-channel reactor capable of commercial reactive efficiency.

Commercial Applications and Other Benefits as described by the awardee: Commercial applications should include the conversion of methane streams into usable, portable feedstocks. Additionally, the unique capability of Perovskite membranes could improve the efficiency of other industrial oxidative processes.

REACTIVE SEPARATIONS

170

SiC-Based Hydrogen Selective Membranes for Catalytic Membrane Reactor Applications--Media and Process Technology, Inc., 1155 William Pitt Way, Pittsburgh, PA 15238-1368; 412-826-3721

Dr. Paul K. T. Liu, Principal Investigator
Dr. Paul K. T. Liu, Business Official
DOE Grant No. DE-FG02-99ER82826
Amount: \$99,987

Catalytic membrane reactors, which have been demonstrated experimentally, offer enhanced

productivity and improved energy efficiency for several key reaction processes in the chemical and refinery industries. However, the lack of material stability in existing membranes has prevented the field implementation of this technology. This project will develop a SiC-based hydrogen selective membrane with an excellent hydrothermal and chemical stability. This membrane would be ideal for use as a membrane reactor to improve capital and operating costs of the water/gas shift reaction in Integrated Gasification Combined Cycle (IGCC) coal-based power production. In Phase I, SiC-based hydrogen selective membranes will be synthesized and characterized, and performance will be evaluated. A SiC-based hydrogen selective membrane will be prepared, and the membrane will be evaluated for its thermal and chemical stability in a simulated IGCC environment.

Commercial Applications and Other Benefits as described by the awardee: In addition to IGCC, the SiC membrane should be utilized in other reactive separation processes, including steam reforming and various dehydrogenation processes.

171

Membrane Reactor Designs for the Production of Butadiene--Membrane Technology and Research, Inc., 1360 Willow Road, Suite 103, Menlo Park, CA 94025-1516; 650-328-2228

Dr. J.G. Wiljams, Principal Investigator
Mr. E.G. Weiss, Business Official
DOE Grant No. DE-FG03-99ER82827
Amount: \$100,000

Seventy percent of U.S. butadiene, a major petrochemical feedstock, is made by dehydrogenation of butane. Because the equilibrium conversion in this reaction is low, a large product separation step is required to separate and recycle unreacted butane. This project will develop a membrane reactor process to increase the conversion and reduce the size of the product separation system. Membrane reactors have been shown to improve the

equilibrium conversion of dehydrogenation reactions, but have not yet been developed to commercial scale because of the lack of suitable membrane modules. In Phase I, membrane modules that are able to perform the required separation will be developed. Membrane reactor designs incorporating these modules will be analyzed using a computer simulation package, and the economic feasibility of the process will be assessed.

Commercial Applications and Other Benefits as described by the awardee: Improved production technology should provide significant cost savings for the production of the important chemical feedstock, butadiene. The technology could also be modified for application in other important dehydrogenation processes.

172

Sonic Assisted Membrane Processing for Separation of Metals from Difficult Chemical Environments--Montec Associates, Inc., P.O. Box 4182, Butte, MT 59702-4182; 406-494-5555

Mr. Steven F. McGrath, Principal Investigator
Mr. Lawrence C. Farrar, Business Official
DOE Grant No. DE-FG03-99ER82836
Amount: \$100,000

The tendency of ultrafiltration membranes to foul while in service has limited their application in industrial settings. This has prevented advanced membrane separation technologies, which offer improvements over conventional processes, from being adopted in industrial practice. One such technology is ligand modified-micellar enhanced-ultrafiltration (LM-MEUF), which offers the possibility of selective extraction and concentration of metals from dilute waste streams. This project will develop a low frequency, transmembrane, sonic back-pulsing device to reduce or eliminate the rate of fouling and concentration polarization of LM-MEUF membranes. Phase I will design and fabricate acoustically optimized membrane modules with a mechanically driven elastic resonator in the center. The formation of fouling deposits on the feed side of the membranes will

be prevented by using acoustic energy. The device will be tested as a separation module in the application of LF-MEUF technology to the selective separation of copper an acid mine drainage stream. A prototype commercial device for use in an industrial setting will be developed in Phase II.

Commercial Applications and Other Benefits as described by the awardee: The proposed technology should have broad application in ultrafiltration membrane technology. Tubular membrane modules in general service should benefit from the incorporation of the sonic backpulsing technology. Also, the demonstration of LF-MEUF to successfully remove metals selectively from a difficult matrix should accelerate the adoption of the technology in metallurgical processing applications.

173

Partial Oxidation Reactor Based on Low-Cost Thin-Film Ceramic Membrane--
NexTech Materials, Ltd., 720-I Lakeview Plaza
Boulevard, Worthington, OH 43085-4733;
Dr. Scott L. Swartz, Principal Investigator
Mr. William J. Dawson, Business Official
DOE Grant No. DE-FG02-99ER82926
Amount: \$100,000

Membrane reactors, based on ceramic electrolyte membranes, utilize oxygen (from air) to convert natural gas into syngas, a feedstock for liquid fuels and chemicals. Commercialization of these systems will require the development of fabrication technology for ceramic tubular membranes with high oxygen permeation rates. Specifically, low-cost manufacturing methods for a membrane structure comprising a dense electrolyte film on a porous tubular support are needed. This project will develop a low-cost manufacturing method for supported, thin-film, electrolyte membranes, along with manufacturing technology for producing large tubular membranes. In Phase I, novel powder processing and fabrication methods will be used to improve mechanical properties and to control the porosity of a cerium-oxide based support

material. A cerium-oxide based electrolyte film will be deposited onto the porous ceria support from aqueous suspensions of nano-scale, ceria crystallites, and the bi-layer membranes will be sintered in order to densify the electrolyte film. The electrochemical performance of these ceria electrolyte films for the partial oxidation of methane will then be evaluated in a small-scale membrane reactor.

Commercial Applications and Other Benefits as described by the awardee: This low-cost, membrane fabrication technology should be applicable to membrane reactors for chemicals and fuels production, to gas-separation membranes for large-scale oxygen production, and to solid-oxide fuel cells for clean and highly-efficient power generation. There is also the potential for on-site conversion of remote natural gas reserves into transportable liquid fuels in both Alaska and the Gulf of Mexico.

174

Simplified, Energy Efficient, Catalytic, Reactive Distillation of Conventional Ethylbenzene Containing Mixed Xylenes to Produce High Purity Para-Xylene Product--
Ozok Systems Incorporated, 2207 Cheshire Drive, Aurora, IL 60504; 630-585-5822
Dr. Dickson E. Ozokwelu, Principal Investigator
Dr. Dickson E. Ozokwelu, Business Official
DOE Grant No. DE-FG02-99ER82850
Amount: \$100,000

Worldwide demand for purified terephthalic acid, the key raw material for polyester, is expected to double from 12 million tons per year in 1995 to 24 million tons per year in 2005. The raw material for making terephthalic acid, para-xylene, serves as the intermediate step between petroleum refining and end-use chemical markets. However, production of this feedstock is energy-intensive, relying either on adsorption or cryogenic crystallization for purification. This project will develop novel catalyst(s) and a simplified process for the reactive separation of commodity chemical para-xylene. The catalyst will selectively alkylate ethylbenzene and other xylene isomers, except para-xylene, and yield

high purity para-xylene product in one reactive distillation step, where the feed is conventional pyrolysis gas or reformates from the refinery. The alkylated products, recovered from the bottom of the distillation column, could be separately treated to make other value added products or de-alkylated to ethylbenzene, ortho- and meta-xylene. Phase I will screen potential catalysts and alkylating agents to determine preferred alkylating agent(s), catalyst, or catalyst combination. Then, the preferred catalyst or catalyst combination will be optimized with respect to various catalyst designs and process variables.

Commercial Applications and Other Benefits as described by the awardee: The process should save the U.S. chemical industry about 105 trillion BTUs of energy in the year 2020. Although the chemical industry sector would be the primary users of this technology, its effect would be felt in almost every industrial sector, since many U.S. industries use polyester end products. The U.S. para-xylene manufacturers would be more competitive than foreign counterparts, and the nation's dependence on imported fossil fuel would be reduced.

175

Economic and Self-Sustaining Production of Saleable Products from Waste Anions Using Phase-Transfer Catalysis--PTC Value Recovery, 900 Briggs Road, Suite 130, Mt. Laurel, NJ 08054-4114; 856-642-2080
Dr. Marc Halpern, Principal Investigator
Mr. Peter J. Joyce, Business Official
DOE Grant No. DE-FG02-99ER82864
Amount: \$89,930

Many chemical anions and neutral compounds are generated as aqueous waste in hundreds of large volume, commercial industrial processes. When these anions and compounds are organic (e.g. phenol derivatives), then significant quantities of organic waste pollute the environment and eventually are converted into the greenhouse gas, CO₂, through incineration or biological treatment. In addition, this waste represents both significant cost (due to treatment) and lost opportunity (because it is an inefficient use of raw materials) for the companies that generate it. This project will use Phase-Transfer Catalysis (PTC) technology to produce a useful and saleable product from waste anions. PTC has already been shown to accomplish this in a cost efficient manner, with *purchased* anions in hundreds of current commercial processes. If the appropriate phase transfer catalyst is present, the targeted species in the aqueous waste stream will react with a complementary organic substrate, to make a desirable and saleable product. In Phase I, three different model systems will be examined to test the applicability of PTC technology using waste anions. The phase-transfer catalysis technology will be demonstrated, and a pilot plant using actual industrial waste streams will be built. Technical and economic information will be obtained on a small but significant portion of waste chemical products: bis-phenol A dianion, acetate, and iodide.

Commercial Applications and Other Benefits as described by the awardee: This technology should generate large savings by recycling previously wasted chemical species that otherwise would have simply generated pollution. This should also reduce the production of greenhouse gases and the energy load by lessening consumption of natural resources.

INNOVATIVE R&D FOR ADVANCED, LOW-EMISSION, ELECTRIC AND HYBRID VEHICLE TECHNOLOGIES

176

Novel Non-Flammable Electrolytes for Lithium Batteries--Cape Cod Research, Inc., 19 Research Road, East Falmouth, MA 02536-4440; 508-540-4400

Mr. R. Scott Morris, Principal Investigator
Ms. Katherine D. Finnegan, Business Official
DOE Grant No. DE-FG02-99ER82756
Amount: \$100,000

Non-flammable electrolytes for Li-ion batteries are needed to ensure the safety of these energy storage devices when used in such unforgiving applications as the electric automotive market. This project will develop flame retardant additives that can improve the fire safety of the standard electrolyte while not compromising the electrolytes's attractive features. Phase I will employ a combination of computer molecular modeling together with a laboratory evaluation of the better candidates as the basis for the designing and evaluating the feasibility of the concept.

Commercial Applications and Other Benefits as described by the awardee: Flame-resistant, stable electrolytes for Li-ion batteries should improve the economic conditions for acceptance of electric vehicles in the market. An increased confidence in the batteries themselves should expand their use in both military and private markets.

177

Flame Retardant Electrolytes for Lithium-Ion Batteries--EIC Laboratories, Inc., 111 Downey Street, Norwood, MA 02062-2612; 781-769-9450

Dr. Dhamasena Peramunage, Principal Investigator
Dr. A.C. Makrides, Business Official
DOE Grant No. DE-FG02-99ER82781

Amount: \$100,000

Safety concerns require flame retardant electrolytes for Li-ion batteries to be used in propulsion of passenger automobiles. In this project, new flame retardant electrolytes for Li-ion cell will be developed by combining the flame retardant properties of organo-phosphate compounds with the beneficial ion solvating properties of carbonate solvents. Phase I will examine two approaches to fire retardancy. In the first, a fire retardant species will be added to an existing Li battery electrolyte. In the second, new electrolytes will be synthesized that combine flame retardancy with other desirable electrolyte features.

Commercial Applications and Other Benefits as described by the awardee: This technology should have application wherever Li battery safety is a general concern, particularly where batteries are in close proximity to people, e.g. electric automobiles, portable electronic devices, telephones, infrared goggles, etc.

178

Diesel Emission Reduction by On-Board Fuel Reformation--Hydrogen Microplasmatron Technologies, LLC, P.O. Box 397161, Cambridge, MA 02139; 781-784-3865

Dr. Daniel L. Jassby, Principal Investigator
Dr. Alexander Rabinovich, Business Official
DOE Grant No. DE-FG02-99ER82923
Amount: \$100,000

Diesel emissions, especially from heavy vehicles, have considerable negative impact on the quality of air in urban areas. The on-board reformulation of diesel fuel is a possible means of decreasing emissions. By converting the diesel fuel into hydrogen-rich gas, emissions from heavy engines may be decreased. This project will demonstrate the use of a plasma

reformer to convert a substantial fraction of the diesel fuel. The challenge is to accomplish this without the substantial energy losses associated with partial oxidation reforming. A plasma reforming system, using exhaust gas recirculation, will be tested in Phase I. The system will be incorporated in an engine test stand (with a DDC 50 heavy duty engine), to evaluate the concept. NO_x, CO, hydrocarbons, and particulate matter emissions will be monitored along with engine performance.

Commercial Applications and Other Benefits as described by the awardee: A successful method of controlling diesel emissions should have large commercial potential for the automobile industry.

179

Nonflammable Lithium-Ion Battery Electrolytes--TechDrive, Inc., 17 W 695 Butterfield Road, Suite A, Oakbrook Terrace, IL 60181; 630-910-3729

Dr. Robert Filler, Principal Investigator
Dr. Robert Filler, Business Official

DOE Grant No. DE-FG02-99ER82905
Amount: \$100,000

Small lithium-ion batteries are now employed in power cellular phones, computers, and cameras. However, before full size lithium batteries can be mass produced for use in electric vehicles, some important safety-related issues, including flammability of electrolytes, must be addressed. This project will develop significantly improved electrolyte systems which exhibit a high degree of non-flammability and higher flash points, while retaining current lithium ion battery technology. In Phase I, specifically designed flame-retardant materials will be prepared that will significantly improve the safety of electric vehicle batteries. The thermal and electrochemical properties of the electrolytes containing flame-retardant compounds will be carefully evaluated.

Commercial Applications and Other Benefits as described by the awardee: Lithium batteries using these new cost-effective electrolyte materials should be environmentally friendly and safer than currently available materials.

COMPUTATIONAL GEOSCIENCES

180

High-Resolution Seismic Imaging of Geothermal Reservoirs with Tomo-Datuming and Migration--3DGeo Development, Inc., 465 Fairchild Drive, Suite 226, Mountain View, CA 94043-2251; 650-969-3886

Dr. Dimitri Bevc, Principal Investigator
Dr. Alexander M. Popovici, Business Official
DOE Grant No. DE-FG03-99ER82720
Amount: \$100,000

Seismic data in volcanic geothermal areas are plagued by near-surface velocity variations that adversely affect processing, imaging and interpretation. These kinematic and amplitude distortions cannot be adequately compensated by conventional static shift methods. This project

will develop a three-dimensional (3-D) method that combines tomographic velocity estimation with wave equation datuming to compensate the data for adverse near-surface effects and allow the imaging of geothermal reservoirs by 3-D migration. The tomographic inversion method combines turning-ray tomography with reflection tomography, complimentary methods that will increase the resolution of the near-surface velocity and insure that the near-surface model is consistent with the deeper reflection events that are of greatest importance for geothermal reservoir imaging. Wave-equation datuming through the tomographically determined near-surface velocity will remove wavefield distortions and greatly improve the subsequent migration step, resulting in improved imaging of geologic structure and accurate reservoir

characterization and monitoring. In the Phase I, the increased resolution of tomo-datuming and migration will be demonstrated in two dimensions before proceeding to 3-D in Phase II.

Commercial Applications and Other Benefits as described by the awardee: The technology should allow seismic imaging and reservoir characterization to be applied in geothermal areas where these methods were previously unusable or inadequate. The technology should facilitate exploration in complex areas, improve geothermal reservoir characterization, and decrease the much higher costs of exploratory drilling and failed water reinjection projects.

181

Imaging the Distribution of Reservoir Properties with Time--Correlations Company,
P.O. Box 730, Socorro, NM 87801-0187;
505-835-5220

Mr. Bruce A. Stubbs, Principal Investigator
Mr. William W. Weiss, Business Official
DOE Grant No. DE-FG03-99ER82769
Amount: \$100,000

The spatial distribution of reservoir properties varies throughout oil and gas reservoirs during the producing period. There is a need to easily visualize the various reservoir parameters as they vary with time to enhance the communication between experts of various disciplines that interpret the information subject to their training. This project will develop a comprehensive tool to visualize the distribution of static and dynamic reservoir properties. The tool will automatically generate geostatistical reservoir models and interactively invoke a simulator to estimate the distribution of the dynamic properties. Computational display algorithms will be developed to seamlessly visualize the various dynamic parameters. The phase I project will design a geostatistical format including upscaling for export to a simulator and modify a simulator code for display of the dynamic property distribution for visualization.

Commercial Applications and Other Benefits as described by the awardee: The ability to

visualize the spatial distribution of reservoir properties should greatly improve the ability of geophysics, geologist, and engineers to focus on a single reservoir description independent of their discipline. The result should be the drilling of fewer non-commercial wells during the development of oil and gas fields. Of the wells drilled in 1996, 25 percent were dry holes that cost \$2.75 billion to drill. Improved visualization of reservoir parameters should reduce this percentage.

182

Irregular Grid Generation and Rapid Three-Dimensional Color Display Algorithm--
StrataMagnetic Software, LLC, 11930 Winwood Lane, Houston, TX 77024; 713-647-0875
Dr. W. Chunling Chin, Principal Investigator
Ms. Yue Hwa Yang, Business Official
DOE Grant No. DE-FG03-99ER82895
Amount: \$100,000

Computer displays of earth images used in oil exploration are expensive and time-consuming to produce. Faster and less expensive graphics would streamline the exploration process, and earth scientists would make faster and more accurate economic decisions in drilling and production. This project will develop irregular grid systems that display reservoir geology more accurately, and fast three-dimensional color earth imaging prototype software, which would improve the reservoir description process. This software would be used to refine customer requirements and define product specifications. In Phase I, the underlying mathematical algorithms, hosted by a working software prototype program and with capabilities fine-tuned to work well with geoscientists, will be developed. The software will allow field personnel to display geological properties and calculate production efficiently.

Commercial Applications and Other Benefits as described by the awardee: Geological display software created for oil and gas explorationists should help describe the reservoir more accurately and make drilling and production more economically efficient.

A Geometry-Based Interactive Pre- and Post-Processor for Reservoir Simulation and Visualization--Thunderhead Engineering Consultants, Inc. (Joint Venture), 2015 Hunting Avenue, Manhattan, KS 66502; 785-587-8492
 Dr. Daniel Swenson, Principal Investigator
 Dr. Daniel Swenson, Business Official
 DOE Grant No. DE-FG03-99ER82908
 Amount: \$99,900

New computational capabilities and software design approaches present an opportunity to simplify and enhance current methods used to create and view geophysical reservoir simulations. Although current technology can be used to solve complex problems, significant investment is required to become proficient in simulator use. This learning hurdle is a barrier to increased usage and application to new problem areas. This project will develop cross-platform, object-oriented, three-dimensional software that allows the analyst to interactively

describe a reservoir and all associated data. The program will then prepare input files for reservoir simulators (initially TOUGH2 and TETRAD). After analyses are complete, the program will read the output files and display information through time. Phase I will develop an operational computer program that demonstrates the ability to interactively specify the information necessary to perform a reservoir simulation. A subset of features will be implemented to generate input files for simulation with TOUGH2 and TETRAD. The subset of features implemented will be sufficient to demonstrate the viability of a geometric model database for use with multiple reservoir simulation codes.

Commercial Applications and Other Benefits as described by the awardee: Computer simulation of geophysical reservoirs and environmental remediation is increasingly important to the nation's energy and environment. This software will allow existing simulators to be accessed by a larger user base.

HIGH PERFORMANCE NETWORKS AND APPLICATIONS

A Differentiated Services Allocation System for the Energy Sciences Network--Aldea Communication, Inc., 7720B El Camino Real, Suite 425, Carlsbad, CA 92009; 760-510-8406
 Ms. Susan Estrada, Principal Investigator
 Ms. Susan Estrada, Business Official
 DOE Grant No. DE-FG03-99ER82831
 Amount: \$85,608

With over 20,000 nationwide users of dozens of unique experimental facilities and high performance computing resources, the Department of Energy (DOE) has a long history of successful network research, advanced network deployment, and advanced applications support. The heavily collaborative and computing nature of these DOE researchers drives the requirements for sophisticated allocation systems for accessing distributed

resources such as supercomputers, high-end storage systems with extremely large scientific data sets, unique on-line facilities, and massive, multidimensional datasets in tele-immersive environments. However, allocation systems for these differentiated network services are not currently available. This project will develop an allocation system for production networks like DOE's Energy Sciences Network (ESnet). Phase I will survey current DOE allocation processes, develop a requirements list for Esnet, and build a prototype allocation system for differentiated services on ESnet.

Commercial Applications and Other Benefits as described by the awardee: Commercial applications for allocations for differentiated services exist in both corporate intranets as well as the public Internet. It is anticipated that this allocation system could provide the basic platform for this service.

Massively Parallel, Optical Fiber to Chip Interconnect and Low Loss Splitter for High Speed DWDM Networking, Communication, and Computing--Ionic Systems, Inc., Unit 417
1430 Tully Road, San Jose, CA 95122-3058;
650-961-4800
Dr. R. M. Kubacki, Principal Investigator
Ms. C. E. Teague, Business Official
DOE Grant No. DE-FG03-99ER82925
Amount: \$100,000

One of the significant advantages of optical data transmission and networking is the ability to add additional wavelengths of optical energy to the same optical path, in order to permit high throughput. One such process, dense wavelength division multiplexing (DWDM), can add many wavelengths to existing fiber optic networks. The very heart of DWDM is the ability to add and then divide out individual wavelengths of light; however, even a minimal amount of splitting reduces signal strength to undetectable levels. This project will use a photo-oxidized plasma deposited organosilicon polymer to fabricate vertically stacked optical microstructures. The vertically stacked waveguide array will provide a low loss optical splitter and a high efficiency interconnect attach from the optical fiber. Although light energy is neither created nor amplified in this device, the efficiency of fiber-to-waveguide coupling permits a far higher percentage of the light leaving the fiber to be used. In Phase I, an initial demonstration will be performed to show the feasibility of plasma-depositing photosensitive polymers with a dual component reaction. At least two optical waveguides will be vertically arrayed and coupled to a single fiber. Their use as a short wavelength optical waveguide interconnect/splitter, with no subsequent etching, will be demonstrated.

Commercial Applications and Other Benefits as described by the awardee: When implemented in the production of high speed telecommunications and networking, this process should offer increased performance to anyone requiring high speed data communication and networking.

Cyberwarfare on the Electricity Infrastructure--Logobots, LLC, 60 East 32nd Street, Suite 203, Chicago, IL 60616;
312-567-3765
Dr. Narayan P. Murarka, Principal Investigator
Dr. V. C. Ramesh, Business Official
DOE Grant No. DE-FG02-99ER82924
Amount: \$100,000

The changes created by deregulation have increased the vulnerability of the electric power grid to cyberwarfare. Decision-makers at utilities and at relevant government agencies need a suitable risk analysis framework in order to devise protective and corrective countermeasures. In this project, threats specific to the electricity infrastructure will be identified and characterized. Then, the potential damage that can be caused by these threats as well as the effectiveness of various protective tools will be quantified using large-scale modeling and simulation. In Phase I, a Java-based prototype of the risk analysis framework will be created. This prototype will include a multi-agent simulation system integrated with access control security software. Decision-makers will be able to see the probability distribution of the extent of damage for each threat, and to see the change in this probability distribution due to the application of one or more protect tools.

Commercial Applications and Other Benefits as described by the awardee: Electric utilities should be able to use the resulting software to assess the vulnerability of their respective systems to cyberwarfare. Government agencies entrusted with national security could use this system to enact policies for protecting the electricity infrastructure. The product and the underlying concepts are generalizable to other critical infrastructures such as banking and transportation.

Holographic Memory Module with Ultra-High Capacity and Throughput--
 MetroLaser, Inc., 18006 Skypark Circle, Suite
 108, Irvine, CA 92614-6406; 949-553-0688
 Dr. James E. Millerd, Principal Investigator
 Dr. Cecil Hess, Business Official
 DOE Grant No. DE-FG03-99ER82833
 Amount: \$99,904

High capacity, high transfer rate, random access memory systems are needed to archive and distribute the tremendous volume of digital information being generated in many applications, for example, the human genome mapping and online libraries. Also, the development of multi-gigabit-per-second networks underscores the need for next generation archival memory systems. This project will develop a novel holographic volume memory that has ultra-high data storage capacity in excess of 10^{12} bits storage and throughput 1 Gbit/second transfer. In addition, the system will be well suited for high security applications because of the way in which the data is encrypted—the stored data can be recalled only with a decoder-key identical to that used at the recording stage. Phase I will extend the theoretical analysis of a three-dimensional memory module and perform experimental tests to validate key aspects of the data storage system. Also, the secure nature of the data storage will be demonstrated, and the performance of the full-scale system will be estimated.

Commercial Applications and Other Benefit as described by the awardee. The system should significantly extend the archival and retrieval data capacity of information systems and can be employed in local or extended networks. Within the government, the memory system would find applications in ground-based computer memory systems and in high security systems. In the consumer market, the high-speed access offers a significant improvement over magnetic media for storing the operating system and application software for personal computers, libraries of films or books, and large databases of navigational information.

Plug-and-Play Phase Conjugate Quantum Cryptography for Secure Private and Public Key Distribution--Physical Optics Corporation,
 20600 Gramercy Place, Building 100, Torrance,
 CA 90501-1821; 310-320-3088
 Dr. Anatoly Vasiliev, Principal Investigator
 Mr. Gordon Drew, Business Official
 DOE Grant No. DE-FG03-99ER82869
 Amount: \$99,995

Quantum cryptography (QC) is a method for secure key exchange over an insecure channel based on the nature of photons. In previously proposed QC systems, time-multiplexed double Mach-Zehnder interferometers with Faraday rotators compensate for phase and polarization distortions. However, all quantum cryptography systems face two major difficulties: the need for continuous alignment of the system and the high noise level of photon counters, which essentially determines the error rate (ER) in the key. This project will develop phase conjugate quantum cryptography (PCQC) devices based on novel high-gain, ferroelectric liquid crystal (FLC) phase conjugate mirrors (PCMs) with a gain factor of 10 to 20 for optical phase conjugation returns over the one-inch area of the device. Phase I will demonstrate the feasibility of the proposed PCQC technique and device by configuring a two-layer PCM, demonstrating improved gain and sensitivity in a two-layer PCM with an FLC SLM, and determining bit-rate/error-rate ratios of the interferometric PCQC system.

Commercial Applications and Other Benefits as described by the awardee: The FLC PCM device should have applications in secure communications, adaptive optics, interferometry, and fiber optic sensors. It also can be used in adaptive interferometers and adaptive optical systems for phase correction in astronomy and surveillance, e.g., by law enforcement, the U.S. military, and the National Aeronautics and Space Administration. Plug-and-Play Phase Conjugate Quantum Cryptography will also support network security as well as such commercial applications as secure information systems and banking (e-mail

and web access, digital cash, cellular communications).

189

Low Cost 10 Gigabits Per Second Optical Links for Gigabit Networks--Princeton Electronic Systems, Inc., P.O. Box 8627, Princeton, NJ 08543-8627; 609-799-5414
Dr. Reza Saedi, Principal Investigator
Dr. Chuni Ghosh, Business Official
DOE Grant No. DE-FG02-99ER82870
Amount: \$99,990

Affordable gigabit networks are necessary for communications at high data rate in the business and scientific world. To make affordable gigabit networks a reality, low cost multi-gigabit communication links are essential. This project will develop 10.6 gigabit per second (Gb/s) links and related subsystems for the front end of multi-gigabit fiber optical networks. This will include developing the links and the clock and clock recovery circuits and the 10.6 Gb/s to 2.48 Gb/s converters using multiplexers and demultiplexers which are the essential subsystems for the gigabit networks. The Phase I project will develop the 10.6 Gb/s transmitter and receivers using high speed lasers and detectors, and design, fabricate and characterize them individually and in a link. The performance will be improved for use in actual systems in Phase II.

Commercial Applications and Other Benefits as described by the awardee. There is tremendous demand for data communications bandwidth for every conceivable scientific and commercial application including Internet applications. The gigabit fiber optical links for high-speed data transmission for local area networks as well as for the gateways for external communications should have a market potential of several hundred million dollars in the near future.

190

CoWorker: An Application Server for Collaborative Work--Tech-X Corporation,

1280 28th Street, Suite 2, Boulder, CO 80303-1758; 303-448-0727

Dr. Svetlana G. Shasharina, Principal Investigator

Dr. John R. Cary, Business Official

DOE Grant No. DE-FG03-99ER82904

Amount: \$99,954

The Department of Energy has an increasing need for remote and collaborative development and execution of computing applications. Currently this is achieved only with difficulty. Joint visualization of data is often carried out only by transferring files using ftp or other protocols followed by printing. Joint editing of files, needed for code development or document generation, is also difficult. This project will develop a client-server system for collaborative visualization, text generation, and code execution. The system will permit many participants to work together. The server, written in C++, will maintain the working versions of the files and act as a central communication point. It will be configurable so that participants in a session would be able to jointly interact with an application. The client, written in Java, would permit the collaborators to interact with the server - editing files, generating or modifying graphics, and executing code with the results visible to all. Phase I will develop prototype joint editing tools and joint graphics markup tools. This would include modifying the server to allow sharing the editing and graphics markup commands.

Commercial Applications and Other Benefits as described by the awardee: There is a growing market for collaboration tools. The tool developed here should be unique in that it would permit many-to-many joint execution of applications and collaborative visualization.

191

Real Time 30 Gigabits Per Second Pattern Analyzer--Conductus, Inc., 969 West Maude Avenue, Sunnyvale, CA 94086-2802; 408-523-9458

Dr. Vsevolod Kaplunenko, Principal Investigator

Dr. Vsevolod Kaplunenko, Principal Investigator
Mr. Ron Wilderink, Business Official
DOE Grant No. DE-FG03-99ER82832
Amount: \$99,842

Further development of gigabit networks, such as optical communications networks, will require increases in both the number of Wave Division Multiplexing (WDM) channels and the speed of each channel up to gigabit rates. However, no conventional tools can provide real time measurements of a single WDM channel at gigabit rates. The so-called sampling approach, typically used for very high speed monitoring of such channels, reproduces the digital signal waveform only as an average of many millions of samples. This project will develop and demonstrate a prototype real-time 30 Gb/s pattern analyzer, which can acquire 30 Gb/s digital signals during the specified time and visualize its pattern on the screen of an advanced oscilloscope at sub-gigabit rates. A low-temperature chip, packaged into a closed-cycle

refrigerator and monitored by a room temperature controller, will use superconductors to reduce the resultant signal rate to a level acceptable for commercial oscilloscopes. Phase I will provide a detailed optimization of the superconducting components, and at least two different superconducting chips will be fabricated to verify the concept. The highest achievable bit-rate at the analyzer input will be measured, as well as the lowest attainable rate at its output. The architecture of the analyzer prototype will be also developed.

Commercial Applications and Other Benefits as described by the awardee: This unique instrumentation should allow for the practical implementation of gigabit technology for applications in optical communications networks. The tool also should ease the testing and building of other high speed applications including, for example, the petaflop computer, which may use gigabit rate digital signal processing.

ADVANCED SENSORS AND DATA ANALYSIS TECHNIQUES FOR NATIONAL SECURITY APPLICATIONS

192

Fluorescence Chemical Sensor for Chemical Warfare—ALTAIR Center, LLC, P.O. Box 214, 48-12 Briarwood Lane, Marlborough, MA 01752-0214; 508-481-6634

Dr. Igor Livitsky, Principal Investigator
Dr. Sergei Krivoslykov, Business Official
DOE Grant No. DE-FG02-99ER82737
Amount: \$99,999

This project will develop a simple and efficient fluorescence chemical sensor employing strong enhancement/quenching of the emission in the presence of the chemical warfare agents. The main principle of signal amplification, as distinct from other luminescence indicators, is based on the antenna effect of the energy transfer/migration process between two chromophores. Specially, a synthesized

fluorescent compound (energy acceptor chromophore), specific to the target molecules (sarin, soman), will be deposited as a thin active layer (20-50Å) on the surface of the other chromophore acting as the energy donor. Fluorescence of the active layer is provided by energy transfer between donor and acceptor chromophores, leading to enhanced signal sensitivity due to the antenna effect. Analyte binding at the active layer should dramatically change both the emissive properties of acceptor molecules and the efficiency of transfer energy. Phase I will synthesize the acceptor chromophores, choose an appropriate donor chromophore, and demonstrate the ability of the binary system to produce strong fluorescence changes in the presence of chemical warfare agents. In Phase II, a prototype chemosensor system for detecting chemical warfare agents

Commercial Applications and Other Benefits as described by the awardee: The technology should provide a small inexpensive sensor for detecting chemical warfare agents. In addition to such immediate applications as individual chemical sensors (like radiation dosimeters), the proposed system should find commercial applications in providing security for public places (airports, subways, government centers) where there is a high risk of terrorist actions.

193

Chemosensor Array for Detecting the Proliferation of Weapons of Mass Destruction--Intelligent Optical Systems, Inc., 2520 West 237th Street, Torrance, CA 90505-5217; 310-530-7130

Dr. Kisholoy Goswami, Principal Investigator
Mr. Robert Lieberman, Business Official
DOE Grant No. DE-FG03-99ER82805
Amount: \$99,995

In the new world order, national security requires a refocusing in the defense against weapons of mass destruction (WMD). Subversion and terrorist attacks now appear to be the most likely origins of WMD attacks. This project will counter this threat by developing compact, lightweight, on-site equipment capable of detecting both chemical warfare agents and explosives in a single unit. The system will be designed to achieve unmatched detection speed, reversibility, accuracy, and sensitivity for detecting the chemical signatures of terrorist weapons. It will integrate four breakthrough technologies: (1) fiber optic long period grating; (2) chemical indicators having affinity for nerve agents, explosives and their precursors; (3) an array of chemosensors; and (4) a proprietary signal processor. Phase I will construct an array of long period gratings on optical fibers, covalently immobilize WMD-sensitive indicators, and fabricate a working model of the combined WMD/explosive sensor, and demonstrate the model's sensitivity and selectivity to explosives and chemical agent simulants.

Commercial Applications and Other Benefits as described by the awardee: In addition to serving anti-terrorist enforcement needs, the proposed system should improve compliance with regulations concerning pollution, tapping both domestic and international markets for pollution sensing and control techniques.

194

Autofocusing Catadioptric Telescope for Lidar Applications--Logicom International, W98 University Drive, Mundelein, IL 60060; 847-566-2528

Mrs. Lucy Wender, Principal Investigator
Mrs. Lucy Wender, Business Official
DOE Grant No. DE-FG02-99ER82814
Amount: \$89,287

The detection and identification of nearby hazardous chemicals is needed without subjecting the operator to significant risk. Objects at ranges of 2-50 meters are illuminated with ultraviolet light (220-400 nm), and images of these objects must be focused by an f/4 telescope system inside a 200 mm diameter circle. This project will develop an autofocusing catadioptric telescope that uses plastic reflectors and a focusing lens system and provides the required image transmission at low production cost. Phase I will develop a working model of the telescope, including an operating autofocus and lens positioning stepper motor actuator. Laboratory tests will also be conducted.

Commercial Applications and Other Benefits as described by the awardee: In addition to the field monitoring of hazardous chemicals, this technology should be applicable to the monitoring of agricultural products for disease or contamination. Other possible applications include near infrared imaging sensors for security applications and production line monitoring for semiconductor substrates.

A Hand-Held Instrument Using an Array-Based Sensor for the Detection of Signatures of Weapons of Mass Destruction-- Lynntech, Inc., 7610 Eastmark Drive, College Station, TX 77840-4023; 409-693-0017

Dr. Anuncia Gonzalez-Martin, Principal Investigator

Dr. G. Duncan Hitchens, Business Official

DOE Grant No. DE-FG03-99ER82818

Amount: \$100,000

The proliferation of weapons of mass destruction has been recognized as one of the most serious national security issues facing the U.S. and its allies. The Federal government and the Department of Energy have recognized that in cooperative and non-cooperative environments, it is necessary to have the capability to detect the production, storage, transportation, and testing of these weapons. A low-cost, reliable, user-friendly hand-held sensor for the detection of vapors associated with the proliferation of weapons of mass destruction would strengthen the U.S. response to threats to national security and world peace. This project will develop an array-based sensor for which the chemical and electrical properties of individual array elements are controlled to allow a unique fingerprint to identify each vapor. Integrated circuits will be developed to control sampling and signal detection and analysis, including pattern recognition. In Phase I, an innovative array-based sensor, using electrically conducting polymers as the elements, will be fabricated on a printed circuit board. Output signals will be integrated into a pattern recognition software for analyte identification. Effectiveness will be evaluated by detecting simulants of chemical vapors associated with the proliferation of weapons of mass destruction in complex operating environments.

Commercial Applications and Other Benefits as described by the awardee: The primary users should be domestic and international agencies responsible for negotiating, verifying and monitoring arms controls treaties. Similar sensors should find wide application in environmental remediation processes (e.g., to

detect the presence of toxic, hazardous, or regulated chemicals in waste effluents, drinking water, and other environmental systems), and in the food, beverage, and perfume industries for the determination of odors and aromas, as well as in the clinical and agronomic industries.

A New Detection System for Determination of Bacterial Pathogens on Contaminated Objects and People-- Lynntech, Inc., 7610 Eastmark Drive, College Station, TX 77840-4023; (409) 693-0017

Dr. Dalibor Hodko, Principal Investigator

Dr. G. Duncan Hitchens, Business Official

DOE Grant No. DE-FG03-99ER82816

Amount: \$100,000

The development of biological agents as weapons has paralleled advances in basic and applied microbiology. Viruses and bacteria, in particular, can be rendered more lethal by genetic engineering techniques, and many toxins can now be mass-produced. Because of this, new detectors are needed that combine the sampling of contaminated objects with the identification of a broad spectrum of biological agents. This project will develop a practical microfluidic device that integrates sampling, concentration, and detection of biological agents found on objects or people. The system utilizes innovative, non-optical detection of the PCR (polymerase chain reaction) amplicons, specific to each pathogen. The approach also will allow further miniaturization, ruggedness, and decreased measurement time for the detector. In Phase I, the new non-optical method for determination of PCR amplicons will be tested in a microfluidic device where sampling, concentration, and on-chip lysis of biological agent surrogates will be performed on a single chip. Detection will be optimized with respect to sampling method, conditions of measurement, and sensitivity of the detection. The interference of inorganic and other biological particles on measurement sensitivity will be determined. In Phase II, a field demonstration of a prototype microfluidic device is planned using surrogates of biological agents.

Commercial Applications and Other Benefits as described by the awardee: The developed method for integrated sampling and detection of biological particles on objects or people should find applications beyond biological warfare, including applications in biomedical testing, the food and pharmaceutical industries, and environmental and forensic bacteriological analysis.

197

Compact Reflector Telescope--Optra, Inc., 461 Boston Street, Topsfield, MA 01983-1290; 978-887-6600

Dr. Michael Hercher, Principal Investigator
Mr. James R. Engel, Business Official
DOE Grant No. DE-FG02-99ER82848
Amount: \$88,763

A lightweight, compact $f/4$ reflective telescope, having a 20 cm to 25 cm aperture and designed for object distances of from 2 meters to 50 meters, is needed for national security applications such as detecting nuclear, chemical, or biological weapons. The telescope is intended for use with a UV spectrometer with a one-degree field-of-view, and is required to have a point spread function of 200 microns or less at a wavelength of 300 nm. The design involves a basic Cassegrain layout with auxiliary quartz relay lenses for making focus adjustments without moving the image plane. Critical design issues to be addressed include accommodating the very large range of object distances by using small internal focusing adjustments and providing a convenient viewing system for focusing and aiming. Phase I will optimize the optical design of the telescope and viewing system; prepare a mechanical design of a complete telescope and viewing system, including interface to the spectrometer; design and construct a full-size mock-up, including the spectrometer; and perform detailed modeling and analysis to demonstrate that the system meets specifications.

Commercial Applications and Other Benefits as described by the awardee: The technology should result in sales of telescopes to

government and industry for stand-off chemical analysis. More generally, similar telescopes would benefit any application requiring high magnification at $f/4$ over a wide range of object distances.

198

Effluent Plume Chemical Analysis Algorithms Using Hyperspectral and Ultraspectral Data--ORINCON Hawaii, Inc., 970 North Kalaheo Avenue, Suite C-215, Kailua, HI 96734; 619-455-5530
Dr. R. David Dikeman, Principal Investigator
Mr. Richard L. Taylor, Business Official
DOE Grant No. DE-FG03-99ER82849
Amount: \$100,000

Chemical detection techniques using mid-wave infrared or long-wave infrared hyper-spectral imagery (HSI), or ultra-spectral point sensors, generate massive data sets that complicate the detection and analysis of chemical plumes. In addition, HSI data sets usually require a long time (days to months) to pull useful information from a scene. In order to benefit non-proliferation activities, new signal processing algorithms are required to detect and classify target chemicals quickly in these massive data sets. This project will develop a two-tier digital signal processing algorithm that can provide substantial improvements in the identification and quantification of chemical compounds from effluent plumes, using hyper-spectral and ultra-spectral data. The first tier uses a principal components analysis (PCA) algorithm to transform and compress the hyper-spectral cube to a set of eigen-images in order to reduce spectral redundancy. The second tier looks down the spectral axis of the uncompressed hyper-cube, and uses a wavelet transform to de-noise and present features to a trained, neural net-based feature extractor, which identifies the chemical constituents of the effluent plume. Phase I will design and develop a trained PCA compression algorithm, a non-trained PCA compression algorithm, and fractal/texture-based image processing algorithms capable of recognizing vapor plumes.

A wavelet-based feature extractor and neural net-based classifier for the analysis and classification of target spectra will also be developed. Finally, comprehensive testing of the efficacy/necessity of the two PCA compression algorithms will be conducted.

Commercial Applications and Other Benefits as described by the awardee: The hyper-spectral processing procedure should be applicable to a multitude of fields, such as medicine and biology, where the signal to noise ratio is low.

199

Fast Analysis of Ultraspectral Measurements of Chemical Plumes--Spectral Sciences, Inc., 99 South Bedford Street, Suite 7, Burlington, MA 01803-5153; 781-273-4770

Dr. Marsha J. Fox, Principal Investigator

Dr. Fritz Bien, Business Official

DOE Grant No. DE-FG02-99ER82889

Amount: \$100,000

Chemical effluent plume detection, is needed for national security applications. Although ultraspectral remote sensing offers great promise, with the capability to identify and quantify species in complex chemical mixtures, the spectral signatures of the plume species are highly corrupted by atmospheric and surface

background emissions. A near real-time approach is sought for extracting plume species spectral signatures from the atmosphere-surface interferences. This project will develop a state-of-the-art computer model and data-processing software for near real-time identification and quantification of chemical species in remote sensing applications of ultraspectral sensors. Phase I will develop and demonstrate the feasibility of new algorithms for extracting plume species transmittance spectra from remotely sensed plume-atmosphere emission spectra. The approach is based on adapting a sophisticated radiative-transfer model for high-resolution, near real-time, plume-atmosphere species retrieval.

Commercial Applications and Other Benefits as described by the awardee: Commercial applications should include detection of hazardous chemical releases, environmental compliance monitoring using fence line and stack plume sensors, and process control measurements in complex chemical environments. This technology also benefits important Federal Government applications involving detection of chemical agent releases, technical intelligence monitoring of chemical production facilities, and detection of illicit drug manufacturing.

ADVANCED RESEARCH IN SUPPORT OF THE COMPREHENSIVE NUCLEAR-TEST BAN TREATY

200

Seismic Monitoring System Calibration Using Ground Truth Database--Multimax, Inc., 1441 McCormick Drive, Largo, MD 20774-5323; 301-925-8222

Dr. W. Winston Chan, Principal Investigator

Dr. W. Winston Chan, Business Official

DOE Grant No. DE-FG02-99ER82837

Amount: \$99,843

In order to verify the nonproliferation of nuclear weapons, a monitoring system must be calibrated to overcome the lack of ground-truth information and uncertainties in regional geological parameters. Because of these uncertainties, the rapid and accurate identification of a suspicious event is currently not feasible. This project will develop advanced seismic analysis technology to compile and analyze ground truth geophysical data essential for event relocation and identification. Phase I will design an innovative processing method and systematic collection

scheme for ground-truth information using data assembled from central China as a test case. These data consist of geological data, historical seismic bulletins, and catalogs published by provincial seismic bureaus in China. Using these data, a tomographic inversion of a three-dimensional crustal velocity model will be performed. A travel-time table associated with various regional phase data, such as phase arrival times and phase amplitudes, will be assembled.

Commercial Applications and Other Benefits as described by the awardee: The ground truth database in central China should be very useful for monitoring the non-proliferation of nuclear weapons. Other possible users include the Nuclear Regulatory Commission for nuclear reactor hazard mitigation; the Federal Highway Administration for bridge and highway designs, and engineering and architectural firms for designing earthquake safety fabrication.

201

Use of Multidimensional Databases and On-Line Analysis Processing for Pattern Recognition in Nuclear Explosion Monitoring--Multimax, Inc., 1441 McCormick Drive, Largo, MD 20774-5323; 301-925-8222
Mr. D. Wilmer Rivers, Jr., Principal Investigator
Mr. Gary Schumaker, Business Official
DOE Grant No. DE-FG02-99ER82838
Amount: \$99,840

Data collected for nuclear explosion monitoring are stored in relational databases as collections of tables. This format is efficient for reading and writing data but is inefficient for analyzing the data to find structures and patterns, e.g., characteristics that distinguish earthquake from explosions. In this project, data will be exported from relational databases (which are two-dimensional since the data are stored as rows and columns) and imported into a multi-dimensional database, which will make it easier to apply "data mining" techniques to find patterns that identify the multivariate measurements for different types of events. In Phase I, a multi-dimensional database schema will be developed for storing nuclear-monitoring data. Data will be installed in a commercially available multi-dimensional database engine. Complex data queries, which cannot easily be processed using relational databases, will be submitted to the multi-dimensional database to search for patterns.

Commercial Applications and Other Benefits as described by the awardee: The ability to perform complex data queries for pattern searches should be useful immediately to the U.S. government for monitoring nuclear explosions. The technology could also be used by small businesses that cannot afford the huge hardware and software systems that are currently available.

ADVANCED RESEARCH AND DEVELOPMENT INTO DETECTION AND CLEARANCE TECHNOLOGIES FOR UNEXPLODED ORDNANCE

202

Automated Hand-Held Unexploded Ordnance Detection, Classification and Discrimination Sensor--AETC, Inc., 8910 University Center Lane, Suite 900, San Diego, CA 92122; 619-450-1211
Dr. Thomas H. Bell, Principal Investigator
Mr. Steven P. Sands, Business Official
DOE Grant No. DE-FG03-99ER82734

Amount: \$93,388

The detection, characterization, and clearance of unexploded ordnance (UXO) are dangerous, tedious, and labor intensive processes. Current techniques for UXO detection are slow, unreliable, and very narrowly focused. Improvement in false alarm rates during clearance operations is central to increased efficiency and reduced cost. This project will

develop automated procedures for target discrimination and classification and incorporate them in a hand-held sensor for buried UXO. A small, portable sensor will operate in a sweep pattern, while an embedded processor acts on the sensor output to precisely locate and characterize the buried target on the spot. In Phase I, test algorithms will be developed for processing hand-held electromagnetic induction sensor data in order to identify unknown targets and discriminate between UXO and clutter. An

evaluation will determine whether or not the processing algorithms can be implemented in an automated, easy-to-use sensor package.

Commercial Applications and Other Benefits as described by the awardee: An effective in-the-field discrimination capability could reduce UXO cleanup costs by as much as 70 percent. The market for this technology includes UXO remediation companies and military Explosive Ordnance Disposal personnel.

APPENDIX A

Alphabetical List of Awardees

<i>3DGeo Development, Inc.</i> 180
Dr. Alexander M. Popovici, Business Official
465 Fairchild Drive
Suite 226
Mountain View, CA 94043-2251
650-969-3886	<i>AETC, Inc.</i>202
Mr. Steven P. Sands, Business Official
8910 University Center Lane
Suite 900
San Diego, CA 92122
619-450-1211
<i>ADA Technologies, Inc.</i> 110, 123
Dr. Martin J. Mastroianni, Business Official
8100 Shaffer Parkway
Suite 130
Littleton, CO 80127-4107
303-792-5615	<i>AIL Research, Inc.</i>19
Dr. Andrew Lowenstein, Business Official
P.O. Box 3662
50 Washington Road
Princeton, NJ 08543-3662
609-452-2950
<i>Advanced Energy Systems, Inc.</i> 53, 97-100
Mr. Anthony Favale, Business Official
27 Industrial Boulevard
Suite E
Medford, NY 11763-2286
516-575-9345	<i>Alameda Applied Sciences Corporation</i>63
Dr. Mahadevan Krishnan, Business Official
2235 Polvorosa Avenue
Suite 230
San Leandro, CA 94577-2249
510-483-4156
<i>Advanced Fuel Research, Inc.</i> 9, 32
Mr. James Markham, Business Official
87 Church Street
East Hartford, CT 06108-3742
860-528-9806	<i>Aldea Communication, Inc.</i>184
Ms. Susan Estrada, Business Official
7720 El Camino Real
Suite 425
Carlsbad, CA 92009-8508
760-929-0580
<i>Advanced Magnet Laboratory, Inc.</i> 68
Dr. Mark W. Senti, Business Official
2730 Kirby Avenue, NE
Building 5
Palm Bay, FL 32905-3402
407-728-7543	<i>ALTAIR Center, LLC</i>192
Dr. Sergei Krivoshlykov, Business Official
1 Chartwell Circle
Shrewsbury, MA 01545-4819
508-845-5349
<i>Advanced Refractory Technologies, Inc.</i> 148
Dr. Roger Storm, Business Official
699 Hertel Avenue
Buffalo, NY 14207-2341
716-875-4091	<i>Altex Technologies Corporation</i>1
Dr. Mehdi Namazian, Business Official
650 Nuttman Street
Suite 114
Santa Clara, CA 95054-2620
408-982-2303
<i>Advanced Resources International, Inc.</i> 33
Mr. Jonathan R. Kelafant, Business Official
1110 North Glebe Road
Suite 600
Arlington, VA 22201-4795
703-528-8420	

AMAC International, Inc. 101
 Dr. Quan-Sheng Shu, Business Official
 Applied Research Center
 12050 Jefferson Avenue
 Suite 348
 Newport News, VA 23606-4323
 757-269-5641

American Superconductor Corporation..... 69, 157, 158, 159
 Dr. Tom Rosa, Business Official
 Two Technology Drive
 Westborough, MA 01581
 508-836-4200

Applied Sciences, Inc...... 111
 Mr. Max L. Lake, Business Official
 141 West Xenia Avenue
 P.O. Box 579
 Cedarville, OH 45314-0579
 937-766-2020

Applied Thin Films, Inc. 149
 Dr. Sankar Sambasivan, Business Official
 1801 Maple Avenue
 Suite 5316
 Evanston, IL 60201
 847-491-4619

Atom Sciences, Inc...... 138
 Dr. Tom J. Whitaker, Business Official
 114 Ridgeway Center
 Oak Ridge, TN 37830-6926
 423-483-1113

Avyd Devices, Inc...... 124, 125
 Dr. Honnavalli R. Vydyanath, Business Official
 2925 College Avenue
 Suite A-1
 Costa Mesa, CA 92626
 714-751-8553

Bader Engineering & Research, Inc...... 112
 Dr. Manny S. Bader, Business Official
 P.O. Box 130228
 The Woodlands, TX 77393
 409-760-2333

Berkeley Ion Equipment, Inc......102
 Dr. M. Wei, Business Official
 3400 De La Cruz Boulevard
 Suite V
 Santa Clara, CA 95054-2609
 408-727-9071

Blasch Precision Ceramics, Inc......24
 Mr. David W. Brobeck, Business Official
 580 Broadway
 Albany, NY 12204-2802
 518-436-1263

Blue Road Research.....120
 Mr. Eric Udd, Business Official
 2555 N.E. 205th Avenue
 Fairview, OR 97024-8600
 503-667-7772

Calabazas Creek Research.....64
 Dr. R. Lawrence Ives, Business Official
 20937 Comer Drive
 Saratoga, CA 95070-3753
 408-741-8680

California Tube Laboratory, Inc.65
 Mr. Peter S. Campbell, Business Official
 125 Aviation Way
 Watsonville, CA 95076-2058
 831-761-1199

Cape Cod Research, Inc......20, 176
 Ms. Katherine D. Finnegan, Business Official
 19 Research Road
 East Falmouth, MA 02536-4440
 508-540-4400

CC Technology, Inc......121
 Dr. Keith Carron, Business Official
 P.O. Box 3112
 Laramie, WY 82071
 307-755-6490

Ceradyne, Inc...... 103
 Mr. Howard George
 3169 Red Hill Avenue
 Costa Mesa, CA 92626
 714-549-0421

CeraMem Corporation..... 25, 34, 166
 Dr. Robert L. Goldsmith, Business Official
 12 Clematis Avenue
 Waltham, MA 02453
 781-899-4495

Chesapeake Composites Corporation 144
 Dr. Alexander Brown, Business Official
 239 Old Churchman's Road
 New Castle, DE 19720-1529
 302-324-9110

CombiMatrix Corporation..... 139
 Dr. Donald D. Montgomery, Business Official
 887 Mitten Road
 Suite 200
 Burlingame, CA 94010-1303
 650-691-5115

Compact Membrane Systems, Inc. 113
 Dr. Stuart M. Nemser, Business Official
 325 Water Street
 Wilmington, DE 19804
 302-999-7996

Composite Technology Development, Inc. 50, 70
 Dr. Naseem A. Munshi, Business Official
 1505 Coal Creek Drive
 Lafayette, CO 80026-2782
 303-664-0394

Conductus, Inc...... 85, 191
 Mr. Ron Wilderink, Business Official
 969 West Maude Avenue
 Sunnyvale, CA 94086-2802
 408-523-9458

Correlations Company..... 181
 Mr. William W. Weiss, Business Official
 P.O. Box 730
 Socorro, NM 87801-0187
 505-835-5220

Covalent Associates, Inc. 167
 Dr. K. M. Abraham, Business Official
 10 State Street
 Woburn, MA 01801-6820
 781-938-1140

Cremat 89
 Mr. Fred Olschner, Business Official
 45 Union Street
 Watertown, MA 02172-2523
 617-926-0661

Cryogenic Applications F, Inc. 161
 Dr. Christopher A. Foster, Business Official
 450 Bacon Springs Lane
 Clinton, TN 37716-5311
 423-435-5433

CyberConnect Corporation..... 140
 Mr. Karl Beckert, Business Official
 103 Moulton Road
 Storrs, CT 06268
 860-429-2666

DAC Vision, Inc. 77
 Mr. James W. Drain, Business Official
 6390 Rose Lane
 Carpinteria, CA 93013
 805-684-8307

Diversified Technologies, Inc. 43, 66, 78, 79, 80
 Mr. Michael A. Kempkes, Business Official
 35 Wiggins Avenue
 Bedford, MA 01730-2314
 781-275-9444

DPD, Inc...... 21
 Ms. Farangis Jamzadeh, Business Official
 2000 Turner Street
 Lansing, MI 48906-4053
 517-349-5653

EIC Laboratories, Inc. 177
 Dr. A. C. Makrides, Business Official
 111 Downey Street
 Norwood, MA 02062-2612
 781-769-9450

- Eltron Research, Inc.**..... 35, 44
Ms. Eileen E. Sammells, Business Official
4600 Airport Boulevard
Boulder, CO 80301-3241
303-440-8008
- Energen, Inc.** 104
Dr. Chad H. Joshi, Business Official
17 D Sterling Road
Billerica, MA 01862-2518
978-671-5400
- Engineering Mechanics Corporation of Columbus** 153
Dr. Gery Wilkowski, Business Official
3518 Riverside Drive
Suite 202
Columbus, OH 43221
614-850-8792
- Envirogen, Inc.** 114
Dr. Ronald Unterman, Business Official
Princeton Research Center
4100 Quakerbridge Road
Lawrenceville, NJ 08648-4702
609-936-9300
- Epion Corporation**..... 162
Dr. Allen Kirkpatrick, Business Official
37 Manning Road
Bellerica, MA 01821
781-275-3703
- EURUS Technologies, Inc.** 71
Mr. John A. Romans
2031 East Paul Dirac Drive
Tallahassee, FL 32310-3711
850-574-1800
- F.S. Lab**..... 168
Dr. Josephine M. Fang, Business Official
156 Common Street
Belmont, MA 02178-2913
617-489-2391
- FARTECH, Inc.**..... 39
Dr. Jin-Soo Kim, Business Official
3146 Bunche Avenue
San Diego, CA 92122-2247
619-455-6655
- FM Technologies, Inc.**..... 54, 154
Dr. Frederick M. Mako, Business Official
10529-B Braddock Road
Fairfax, VA 22032-2236
703-425-5111
- G.H. Gillespie Associates, Inc.**..... 55
Dr. George H. Gillespie, Business Official
P.O. Box 2961
Del Mar, CA 92014-5961
619-677-0076
- Genome Informatics Corporation** 141
Mr. Ed Uberbacher, Business Official
1020 Commerce Park Drive
Oak Ridge, TN 37830
423-220-0043
- Geo-Microbial Technologies, Inc.** 36
Mr. Daniel C. Hitzman, Business Official
East Main Street
P.O. Box 132
Ochelata, OK 74051-0132
918-535-2281
- H.V. Setty Enterprises, Inc.**..... 122
Dr. H. V. Venkatesetty, Business Official
12110 Red Oak Court
South Burnsville, MN 55337-3312
612-894-2792
- Hi-Z Technology, Inc.** 14, 15
Mr. Norbert Elsner, Business Official
7606 Miramar Road
Suite 7400
San Diego, CA 92126-4202
619-695-6660
- Hydrogen Microplasmatron Technologies, LLC** 178
Dr. Alexander Rabinovich, Business Official
P.O. Box 397161
Cambridge, MA 02139
781-784-3865
- HYPRES, Inc.**..... 90, 105
Dr. Elie Track, Business Official
175 Clearbrook Road
Elmsford, NY 10523-1109
914-592-1190

HYTEC, Inc. 86, 87
 Mr. William O. Miller, Business Official
 110 Eastgate Drive
 Suite 100
 Los Alamos, NM 87544-3304
 505-661-0080

InnovaTek 169
 Dr. Patricia M. Irving, Business Official
 350 Hills Street
 Richland, WA 99352
 509-375-1093

Intelligent Optical Systems, Inc. 106, 193
 Mr. Robert Lieberman, Business Official
 2520 West 237th Street
 Torrance, CA 90505-5217
 310-530-7130

International Power Group, Inc. 81
 Mr. David S. White, Business Official
 18250 68th Avenue
 South Kent, WA 98032
 714-803-7940

IntraSpec, Inc. 163
 Mr. John Walter, Business Official
 P.O. Box 4579
 Oak Ridge, TN 37830-4579
 423-483-1859

Ionic Systems, Inc. 185
 Ms. C. E. Teague, Business Official
 Unit 417
 1430 Tully Road
 San Jose, CA 95122-3058
 650-961-4800

Ionwerks 56
 Dr. J. Albert Schultz, Business Official
 2472 Bolsover
 Suite 255
 Houston, TX 77005-2537
 713-522-9880

Jorway Corporation 91
 Mr. Timothy D. Radway, Business Official
 27 Bond Street
 Westbury, NY 11590-5042

L'Garde, Inc. 88
 Mr. Roger Garrett, Business Official
 15181 Woodlawn Avenue
 Tustin, CA 92780-6419
 714-259-0771

Lasergenics Corporation 92
 Dr. Richard Schlecht, Business Official
 6830 Via Del Oro
 Suite 103
 San Jose, CA 95119-1353
 408-363-9791

Linear Measurements, Inc. 5
 Mr. Robert Hatch, Business Official
 4174 Sorrento Valley Boulevard
 San Diego, CA 92121-1407
 619-535-2172

LMC, Inc. 82
 Mr. Lennart J. Lindell
 333 Dietz Avenue
 De Kalb, IL 60115
 815-758-3514

Logicom International 194
 Mrs. Lucy Wender, Business Official
 W98 University Drive
 Mundelein, IL 60060
 847-566-2528

Logobots, LLC 186
 Dr. V. C. Ramesh, Business Official
 60 East 32nd Street
 Suite 203
 Chicago, IL 60616
 312-567-3765

Lynntech, Inc. 115, 195, 196
 Dr. G. Duncan Hitchens, Business Official
 7610 Eastmark Drive
 Suite 202
 College Station, TX 77840-4023
 409-693-0017

MER Corporation 51
 Mr. R. O. Loutfy, Business Official
 7960 South Kolb Road
 Tucson, AZ 85706
 520-574-1980

M.L. Energia, Inc. 40, 126
 Ms. Nira Lavid, Business Official
 P.O. Box 470
 Princeton, NJ 08542-0470
 609-799-7970

Manufacturing and Technology Conversion International, Inc...... 2
 Dr. Momtaz N. Mansour, Business Official
 6001 Chemical Road
 Baltimore, MD 21226-1606
 410-354-0420

Materials and Systems Research, Inc. 6
 Dr. Anil V. Virkar, Business Official
 5395 West 700
 South Salt Lake City, UT 84104-4135
 801-973-1199

Materials Modification, Inc...... 145
 Dr. T. S. Sudarshan, Business Official
 2929 P-1 Eskridge Road
 Fairfax, VA 22031-2213
 703-560-1371

Media and Process Technology, Inc. 170
 Dr. Paul K. T. Liu, Business Official
 1155 William Pitt Way
 Pittsburgh, PA 15238-1368
 412-826-3721

Membrane Technology and Research, Inc. 171
 Mr. E. G. Weiss, Business Official
 1360 Willow Road
 Suite 103
 Menlo Park, CA 94025-1516
 650-328-2228

MetroLaser, Inc. 10, 187
 Dr. Cecil F. Hess, Business Official
 18010 Skypark Circle
 Suite 100
 Irvine, CA 92614-6428
 949-553-0688

Microbeam Technologies, Inc.26
 Ms. Roxanne Benson, Business Official
 1521 24th Avenue, South
 Suite B-2
 P.O. Box 14758
 Grand Forks, ND 58208-4758
 701-772-4482

MicroCoating Technologies, Inc.27, 37, 160
 Mr. Jerome J. Schmitt, Business Official
 3901 Green Industrial Way
 Chamblee, GA 30341
 770-457-8400

Montec Associates, Inc......172
 Mr. Lawrence C. Farrar, Business Official
 P.O. Box 4182
 Butte, MT 59702-4182
 406-494-5555

Multimax, Inc......200, 201
 Mr. Gary Schumaker, Business Official
 1441 McCormick Drive
 Largo, MD 20774-5323
 301-925-8222

Nanomaterials Research Corporation 11, 12, 83, 127, 146
 Ms. Zmolly M. W. Kosteletzky, Business Official
 2620 Trade Center Avenue
 Longmont, CO 80503-7551
 303-702-1672

NexTech Materials, Ltd......28, 173
 Mr. William J. Dawson, Business Official
 720-I Lakeview Plaza Boulevard
 Worthington, OH 43085-4733
 614-842-6608

Omega-P, Inc......57, 58, 67
 Dr. George P. Trahan, Business Official
 202008 Yale Station
 Suite 100
 New Haven, CT 06520
 203-789-1164

Optra, Inc......197
 Mr. James R. Engel, Business Official
 461 Boston Street
 Topsfield, MA 01983-1290
 978-887-6600

ORINCON Hawaii, Inc. 198
 Mr. Richard L. Taylor, Business Official
 970 North Kalaheo Avenue
 Suite C-215
 Kailua, HI 96734
 619-455-5530

Ozok Systems, Incorporated 174
 Dr. Dickson E. Ozokwelu, Business Official
 2207 Cheshire Drive
 Aurora, IL 60504
 630-585-5822

Paulsson Geophysical Services, Inc. 38
 Dr. Bjorn N. P. Paulsson, Business Official
 647 South Palm Street
 Suite G
 La Habra, CA 90631-5794
 562-694-9598

PEM Technologies, Inc. 134
 Dr. Irving Weinberg, Business Official
 5611 Roosevelt Street
 Bethesda, MD 20817-6739
 301-564-0835

Photon Imaging, Inc. 107, 135
 Mr. Bradley E. Patt, Business Official
 19355 Business Center Drive
 Suite 8
 Northridge, CA 91324-3503
 818-709-2468

Physical Optics Corporation 108, 128, 142, 188
 Mr. Gordon Drew, Business Official
 20600 Gramercy Place
 Building 100
 Torrance, CA 90501-1821
 310-320-3088

Physical Sciences, Inc. 133
 Dr. Byron David Green, Business Official
 20 New England Business Center
 Andover, MA 01810-1077
 978-689-0003

Plasma Processes, Inc. 45
 Mr. Timothy McKechnie, Business Official
 4914-D Moores Mill Road
 Huntsville, AL 35811-1558
 256-851-7653

Plastronic, Inc., Subsidiary of Eurus Technologies, Inc. 72
 Mr. Michael Tomsic, Business Official
 2031 East Paul Dirac Drive
 Tallahassee, FL 32310
 850-574-2998

Positive Light, Inc. 59
 Mr. Jeremy Weston, Business Official
 101 Cooper Court
 Los Gatos, CA 95032-7604
 408-399-7744

Powdermet, Inc. 52
 Mr. Andrew J. Sherman, Business Official
 9960 Glenoaks Boulevard
 Suite A
 Sun Valley, CA 91352-1064
 818-768-6420

PowerLight Corporation 22
 Mr. Thomas L. Dinwoodie
 2954 San Pablo Avenue
 Berkeley, CA 94710
 510-540-0550

Precision Combustion, Inc. 29
 Mr. Paul Donahe, Business Official
 410 Sackett Point Road
 New Haven, CT 06473-3106
 203-787-8614

Princeton Electronic Systems, Inc. 189
 Dr. Chuni Ghosh, Business Official
 P.O. Box 8627
 Princeton, NJ 08543-8627
 609-799-5414

Prudent Technologies, Inc. (formerly ZeoTech Corporation) 117
 Mr. Thomas Silverstrim, Business Official
 544 Shadeland Avenue
 Drexel Hill, PA 19026-1420
 215-895-2350

PTC Value Recovery..... 175
Mr. Peter J. Joyce, Business Official
900 Briggs Road
Suite 130
Mt. Laurel, NJ 08054-4114
609-642-2080

**Radiation Monitoring
Devices, Inc..... 93, 109, 164**
Dr. Gerald Entine, Business Official
44 Hunt Street
Watertown, MA 02472-4699
617-926-1167

Radiation Science, Inc..... 41
Dr. Allen S. Krieger
P.O. Box 293
Belmont, MA 02178-0002
617-621-7076

Reaction Engineering International..... 3
Dr. Michael P. Heap, Business Official
77 West 200 South
Suite 210
Salt Lake City, UT 84101-1609
801-364-6925

Research Support Instruments, Inc. 129
Mr. George E. Caledonia, Business Official
5735 Arapahoe Avenue
Suite 2A
Boulder, CO 80303
978-689-0003

Resonant Shock Compaction, LLC..... 116
Mr. Robert E. Pressey, Business Official
2075 South University Boulevard
Box 310
Denver, CO 80210
303-413-1671

Saddleback Aerospace..... 46
Ms. Elizabeth A. Campbell, Business Official
10523 Humbolt Street
Los Alamitos, CA 90720
562-598-3700

SAGE Electrochromics, Inc.....23
Mr. Kenneth Ney, Business Official
2150 Airport Drive
Faribault, MN 55021
507-333-0078

Sandia View Software, Inc..... 60
Dr. Carl R. Stern, Business Official
613 Sandia View Road, NW
Albuquerque, NM 87107
505-345-4147

SatCon Technology Corporation.....16
Dr. James L. Kirtley, Jr., Business Official
161 First Street
Cambridge, MA 02142-1228
617-661-0540

Science Research Laboratory, Inc.....165
Dr. Jonah Jacob, Business Official
15 Ward Street
Somerville, MA 02143-4228
617-547-1122

Scientific Digital Visions, Inc. 94, 95, 96
Ms. Tracy Langlands, Business Official
2 North Second Street
Suite 1215
San Jose, CA 95113-1303
408-289-8492

Semi-Solid Technologies, Inc. 147
Dr. Stuart B. Brown, Business Official
1610 West Dartmouth Avenue
Englewood, CO 80110-1307
508-652-8518

Sienna Technologies, Inc.....155
Dr. Canan Savrun, Business Official
19501 144th Avenue NE
Suite F-500
Woodinville, WA 98072-6463
425-485-7272

Sigma Technologies International, Inc..... 7
Dr. Angelo Yializis, Business Official
10960 N. Stallard Place
Tucson, AZ 85737-9527
520-575-8013

Silicon Designs, Inc. 8
 Mr. John C. Cole, Business Official
 1445 NW Mall Street
 Issaquah, WA 98027
 425-391-8329

Southwest Sciences, Inc. 42, 130
 Dr. Alan C. Stanton, Business Official
 1570 Pacheco Street
 Suite E-11
 Santa Fe, NM 87505-3937
 505-984-1322

Spectral Sciences, Inc. 199
 Dr. Fritz Bien, Business Official
 99 South Bedford Street
 Suite 7
 Burlington, MA 01803-5153
 781-273-4770

Spinheat Limited 4
 Mr. Michael J. Virr, Business Official
 1222 Bronson Road
 Fairfield, CT 06430-2824
 203-259-6101

Spire Corporation 136, 150
 Dr. Everett S. McGinley, Business Official
 One Patriots Park
 Bedford, MA 01730-2396
 781-275-6000

Starmet Corporation 118, 119
 Mr. Donald T. King, Business Official
 2229 Main Street
 Concord, MA 01742
 978-369-5410

StrataMagnetic Software, LLC 182
 Dr. W. Chunling Chin, Business Official
 11930 Winwood Lane
 Houston, TX 77024
 713-647-0875

Supercon, Inc. 73, 74
 Mrs. Elaine Tarkiainen, Business Official
 830 Boston Turnpike
 Shrewsbury, MA 01545-3301
 508-842-0174

Superconducting Systems, Inc. 75
 Ms. Minou Mossavat, Business Official
 90 Rumford Avenue
 Waltham, MA 02453
 781-642-6702

Supergenics 76
 Mr. Bruce A. Zeitlin, Business Official
 1233 Tree Bay Lane
 Sarasota, FL 34242
 941-349-0930

Surmet Corporation 156
 Dr. Suri A. Sastri, Business Official
 33 B Street
 Burlington, MA 01803-3406
 781-272-3250

SymBiotech, Inc. 143
 Dr. Edward M. Davis, Business Official
 8 Fairfield Boulevard
 Wallingford, CT 06492-1890
 203-949-2766

TDA Research, Inc. 30
 Mr. Michael E. Karpuk, Business Official
 12345 West 52nd Avenue
 Wheat Ridge, CO 80033-1917
 303-940-2301

Tech-X Corporation 61, 190
 Dr. John R. Cary, Business Official
 5541 Central Avenue
 Suite 135
 Boulder, CO 80301
 303-448-0727

TechDrive, Inc. 179
 Dr. Robert Filler, Business Official
 17 W 695 Butterfield Road
 Suite A
 Oakbrook Terrace, IL 60181
 630-910-3729

Thermacore, Inc. 31, 47
 Mr. Donald M. Ernst, Business Official
 780 Eden Road
 Lancaster, PA 17601-4275
 717-569-6551

**Thunderhead Engineering Consultants, Inc.
(Joint Venture)..... 183**

Dr. Daniel Swenson, Business Official
1006 Polyntz Avenue
Manhattan, KS 665025459
785-587-8492

Tomotronics, Inc. 137

Ms. Pamela H. Worstell, Business Official
5 Snake Brook Road
Wayland, MA 01778-5013
508-653-4051

TPL, Inc. 84

Dr. William F. Hartman, Business Official
3921 Academy Parkway North, NE
Albuquerque, NM 87109-4416
505-342-4414

UES, Inc. 151

Mr. Francis F. Williams, Jr., Business Official
4401 Dayton-Xenia Road
Dayton, OH 45432-1805
937-426-6900

UHV Technologies, Inc. 152

Dr. Nalin Kumar, Business Official
113-B West Park Drive
Mount Laurel, NJ 08054-1278
609-608-0311

Ultramet 48

Mr. Craig N. Ward, Business Official
12173 Montague Street
Pacoima, CA 91331-2210
818-899-0236

Unique Mobility, Inc. 17

Mr. Donald A. French, Business Official
425 Corporate Circle
Golden, CO 80401-5635

UTRON, Inc. 49

Dr. F. Douglas Witherspoon, Business Official
8506 Wellington Road
Suite 200
Manassas, VA 20109-3915

Visidyne, Inc. 131

Mr. John W. Bates, Business Official
10 Corporate Place
South Bedford Street
Burlington, MA 01803-5149
781-273-2820

Visual Computing Systems Corporation 18

Mr. Robert J. Westerkamp, Business Official
9540 Highway 150
P.O. Box 250
Greenville, IN 47124-0250
812-923-7474

X-Ray Optical Systems, Inc. 13

Mr. David Usher, Business Official
30 Corporate Circle
Albany, NY 12203
518-464-3334

Y.Y. Labs, Inc. 62

Dr. Yan Yin, Business Official
P.O. Box 597
Fremont, CA 94537-0597
510-739-6049

Yankee Environmental Systems, Inc. 132

Ms. Cynthia A. Cote, Business Official
101 Industrial Boulevard
Turners Falls, MA 01376-1608
413-863-0200

APPENDIX B

State List of Awardees

Alabama.....	45
Arizona.....	7, 51
California.....	1, 5, 10, 14, 15, 22, 38, 39, 46, 48, 52, 55, 59, 62, 63, 64, 65, 77, 85, 88, 92, 94, 95, 96, 102, 103, 106, 107, 108, 124, 125, 128, 135, 139, 142, 171, 180, 184, 185, 187, 188, 191, 193, 202
Colorado.....	11, 12, 17, 30, 35, 44, 50, 61, 70, 83, 110, 116, 123, 127, 129, 146, 190
Connecticut.....	4, 9, 29, 32, 57, 58, 67, 140, 143
Delaware.....	113, 144
Florida.....	68, 71, 72, 76
Georgia.....	27, 37, 160
Hawaii.....	198
Illinois.....	82, 149, 174, 179, 186, 194
Indiana.....	18
Kansas.....	183
Maryland.....	2, 134, 200, 201
Massachusetts.....	16, 20, 25, 34, 41, 43, 66, 69, 73, 74, 75, 78, 79, 80, 89, 93, 104, 109, 118, 119, 131, 132, 133, 136, 137, 147, 150, 156, 157, 158, 159, 162, 164, 165, 166, 167, 168, 176, 177, 178, 192, 197, 199
Michigan.....	21
Minnesota.....	23, 122
Montana.....	172
New Jersey.....	19, 40, 114, 126, 152, 175, 189
New Mexico.....	42, 60, 84, 86, 87, 130, 181
New York.....	13, 24, 53, 90, 91, 97, 98, 99, 100, 105, 148
North Dakota.....	26
Ohio.....	28, 111, 151, 153, 173
Oklahoma.....	36
Oregon.....	120
Pennsylvania.....	31, 47, 117, 170
Tennessee.....	138, 141, 161, 163
Texas.....	56, 112, 115, 182, 195, 196
Utah.....	3, 6
Virginia.....	33, 49, 54, 101, 145, 154
Washington.....	8, 81, 155, 169
Wyoming.....	121

APPENDIX C

Grant Application Submissions and Awards Listed by States, Territories, and Possessions

<u>State</u>	<u>Number Submitted</u>	<u>Number Selected</u>	<u>State</u>	<u>Number Submitted</u>	<u>Number Selected</u>
Alabama	13	1	Montana	6	1
Arizona	36	2	New Hampshire	9	0
Arkansas	2	0	New Jersey	37	7
California	229	44	New Mexico	28	7
Colorado	104	17	New York	48	11
Connecticut	53	9	North Carolina	6	0
Delaware	7	2	North Dakota	3	1
District of Columbia	5	0	Ohio	30	5
Florida	13	4	Oklahoma	7	1
Georgia	11	3	Oregon	4	1
Hawaii	2	1	Pennsylvania	28	4
Idaho	4	0	Puerto Rico	4	0
Illinois	30	6	Rhode Island	2	0
Indiana	7	1	South Carolina	7	0
Iowa	3	0	South Dakota	3	0
Kansas	5	1	Tennessee	20	4
Kentucky	3	0	Texas	52	6
Maine	4	0	Utah	16	2
Maryland	26	4	Vermont	1	0
Massachusetts	160	43	Virginia	68	6
Michigan	8	1	Washington	8	4
Minnesota	10	2	West Virginia	1	0
Mississippi	1	0	Wisconsin	3	0
Missouri	1	0	Wyoming	7	1

Although eligible to participate, there were no submissions from Alaska, Louisiana, Nebraska, Nevada, the Virgin Islands, the Commonwealth of Northern Mariana Islands, or the Trust Territory of the Pacific Islands.

APPENDIX D

Subject Index

The Subject Index has two parts: **DOE Program Subjects** and **Crosscutting Subjects**. The numbers that follow each subject are the Award Numbers as they appear in the Table of Contents.

DOE PROGRAM SUBJECTS

Energy Production

Fossil Energy, 24-38

Fusion Energy Sciences, 39-52

Energy Usage

Buildings and Industry, 9-13, 166-175

Electric Vehicles, 14-18, 176-179

High Energy and Nuclear Physics

Accelerator Science and Technology, 53-84, 97-105

Detectors, Instrumentation, and Data Processing, 85-96

Impact on the Environment

Environmental Management, 106-119

Environmental Research, 120-133

Nonproliferation and National Security, 192-204

Renewable Energy

Biomass, 1-4

Geothermal Drilling, 5-8

Photovoltaics and Solar Energy, 19-23

Underlying Energy Sciences

Computational Technology, 180-191

Life and Health Sciences, 134-143

Materials, 144-165

CROSSCUTTING SUBJECTS

Batteries, 176-177, 179
Beams and Beam Diagnostics, 13, 39-40, 54, 60, 62, 102, 105

Catalysts, Chemistry, Electrochemistry, 29-31, 106, 122, 166-170, 174-175, 192-193, 198-199, 201
Corrosion Protection, 26
Data Processing, Networking, Communication, 94-96, 140-141, 184-191, 198-201
Electronic Components, 5, 7, 43, 49, 78, 80-81, 83, 89
Energy Storage, 20-21
Fuel Cells, 24-25, 28
Geophysical Sciences and Drilling, 33, 38, 106
Genetics, DNA, 138-143
Imaging, 38, 41, 109, 134-137, 163, 180-183, 201
Instrumentation, 9, 12-13, 41, 91, 107, 161-165
Laser Technology, 59-59, 85
Materials Development, Processing, 20-23, 27, 36, 44-48, 51-52, 70, 77, 82, 84, 86-87, 92-93, 103, 144-165
Membranes, 32, 34, 37, 113, 170-173
Motors, 14-18
Nanotechnology, 14-15, 148-150, 152
Optical Components, Fiber Optics, Laser, 108, 120-121, 128-130, 162, 185, 189, 194, 197
Pollution Control, 110-119, 178
Scientific Computing, and Simulations, 55, 57, 61, 101, 180-183
Sensors, 6, 8, 10-11, 42, 62, 88, 90, 93, 106, 108, 120-122, 124-127, 130, 164, 192-193, 195-196, 202
Separations Technology, 35, 111-113
Superconducting and Magnet Technology, Gryogenics, 68-76, 97-100, 104
Thin Films and Coatings, 14-15, 35, 50, 148-152, 157-160, 173