NASA Technical Memorandum 4369

OAST Space Technology
Accomplishments FY 1991

NASA Office for Aeronautics and Space Technology
Washington, D.C.

National Aeronautics and Space Administration
Office of Management
Scientific and Technical Information Program
1992
FOREWARD

The Space Research and Technology (R&T) program conducted by NASA's Office of Aeronautics and Space Technology (OAST) provides technology for future civil space missions to enhance mission safety and reliability, increase productivity and performance, reduce costs of space missions, and provide the technological basis for evermore challenging and beneficial missions in the future.

The program consists of a continuum of space research and technology activities ranging from initial research to the full-scale test of prototype equipment in space. Activities include work that is performed by in-house staff at the NASA Centers, University researchers supported by NASA-funded grants and contracts, and industrial aerospace organizations under contract to NASA. These diverse activities provide advances in technology in all important space disciplines, to meet current and future mission needs, and technology breakthroughs that may revolutionize a technical discipline or mission concept. The work is managed and coordinated by OAST through a process that integrates the best available talent and capability in NASA, industry, and universities into a National civil space research and technology program.

The space R&T program structure includes two major components: the R&T Base, which addresses result-driven research or technology opportunity-driven R&T activities; and the Civil Space Technology Initiative (CSTI), which incorporates a series of focused programs directed at meeting the technology needs identified by civil space mission planners (see diagram below).

This book contains accomplishment highlights of OAST's FY1991 program which was executed at the Langley, Lewis, and Ames Research Centers, the Goddard and Marshall Space Flight Centers, the Johnson Space Center, and the Jet Propulsion Laboratory. Point of contact names listed on the contents page correspond to the individuals (Center or Headquarters) who constructed the charts.

Gregory M. Reck
Director for Space Technology
Office of Aeronautics and Space Technology
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<td>HQ</td>
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FOCUSED PROGRAM
SCIENCE TECHNOLOGY

DEVELOP ADVANCED INSTRUMENT, OBSERVATION, INFORMATION, AND IN SITU MEASUREMENT TECHNOLOGIES TO MAXIMIZE THE RETURN FROM NASA SPACE AND EARTH SCIENCE MISSIONS OVER THE NEXT TWENTY YEARS

- EXPAND CAPABILITY AND REDUCE COSTS THROUGH DISCIPLINARY ADVANCEMENTS WHICH INCREASE SCIENCE INFORMATION RETURN AND SPACECRAFT PERFORMANCE
  - INSTRUMENT
  - OBSERVATION
  - DATA & INFORMATION
  - IN SITU MEASUREMENT

- ENABLE THE NEXT GENERATION OF SPACE SCIENCE MISSIONS
  - ASTROPHYSICS
  - SOLAR SYSTEM EXPLORATION
  - SPACE PHYSICS
  - EARTH SCIENCE
  - LIFE SCIENCES/MICROGRAVITY

Office of Aeronautics and Space Technology
HgZnTe 1 X 270 ARRAY

SHOWN

- MERCURY ZINC TELLURIDE (HgZnTe) 1 X 270 LINEAR ARRAY

OBJECTIVE

- TO DEVELOP HgZnTe INFRARED (IR) MATERIALS AND DEVICES HAVING IMPROVED ROBUSTNESS AND RELIABILITY FOR REMOTE SENSING IN THE FAR-IR (8-20 MICRON) SPECTRAL BANDS

ACCOMPLISHMENT

- DEMONSTRATED HIGH SENSITIVITY AND FAR-IR SPECTRAL RESPONSE ON TWO HgZnTe 1 X 270 ARRAYS (DEVELOPED IN FY90)

- COMPLETED COMPARATIVE VACUUM BAKE OF HgZnTe PHOTOCONDUCTIVE DEVICES WITH HgCdTe (MERCURY CADMIUM TELLURIDE) PHOTOCONDUCTIVE DEVICES
  - HgCdTe RESPONSIVITY DOWN >90% AFTER 1 WEEK AT 100°C; HgZnTe UNCHANGED
  - HgZnTe VACUUM BAKED FOR ANOTHER 21 DAYS WITH NEGLIGIBLE CHANGE

- DEVELOPED IMPROVED (BETTER SURFACE MORPHOLOGY AND FEWER INTERNAL DEFECTS) HgZnTe MATERIALS (DEVICES CURRENTLY IN FABRICATION PROCESS)

BENEFITS

- HgZnTe MATERIALS
  - ENABLE LONGER LIFE DEVICES BY PERMITTING EXTENDED HIGHER TEMPERATURE VACUUM BAKES
  - PERMITS HIGHER TEMPERATURE OPERATION AT 20 MICRONS COMPARED TO STATE-OF-THE-ART HgCdTe, THUS ENABLING LOWER COOLING REQUIREMENTS

APPLICABLE MISSIONS

- EOS ATMOSPHERIC INFRARED SOUNDER (AIRS)
- EOS MODERATE-RESOLUTION IMAGING SPECTROMETER-NADIR (MODIS-N)
- EOS SPECTROSCOPY OF THE ATMOSPHERE USING FAR-INFRARED EMISSIONS (SAFIRE)
SILICON-COMPATIBLE INFRARED SENSORS

**SHOWN**
- 128x128 SiGe/Si HETEROJUNCTION INTERNAL PHOTOEMISSION (HIP) SENSOR ARRAY

**OBJECTIVE**
- DEVELOP NEW INFRARED (2 TO 18 μm WAVELENGTHS) DETECTOR MATERIALS AND DEVICE STRUCTURES WHICH ARE SILICON-BASED, WILL OPERATE AT TEMPERATURES ABOVE 65° K, AND WHICH CAN BE FORMATTED INTO LARGE (i.e. MANY ELEMENT) ARRAYS FOR IMAGING AND SPECTROMETER APPLICATIONS

**ACCOMPLISHMENT**
- DEMONSTRATED 128x128 ARRAY OF HIP DETECTORS, SENSITIVE TO WAVELENGTHS FROM 2 TO 18 μm AT 40°K OPERATING TEMPERATURE

**BENEFITS**
- SENSOR ARRAYS OPERATING ABOVE 65° K DO NOT REQUIRE STORED CRYOGENS WHICH LIMIT MISSION LIFE
- WIDESPREAD COMMERCIAL USE OF KNOWN SILICON TECHNOLOGY (e.g. FOR RADIOS, TVs, COMPUTERS) WILL ENABLE SILICON-COMPATIBLE IR DETECTOR MATERIALS TO BE PRODUCED AT LOW COST

**APPLICABLE MISSIONS**
- EOS AND EOS FOLLOW-ON THERMAL IR INSTRUMENTS (e.g. AIRS, MODIS)
- PLANETARY MISSIONS
SILICON-COMPATIBLE INFRARED SENSORS

- Demonstrated the first SiGe long wavelength infrared sensor (>22 μm) using molecular beam epitaxy
- Fabricated 128 x 128 sensor arrays with a 18 μm cutoff wavelength
SILICON MICROMACHINED INFRARED TUNNEL SENSOR

- NASA - JPL - OAST - RC

SHOWN

- PROTOTYPE TUNNELING INFRARED SENSOR

OBJECTIVE

- TO DEVELOP NEW INFRARED DETECTOR MATERIALS AND DEVICE STRUCTURES WITH EXTENDED WAVELENGTH RANGE (2 TO 18 μm WAVELENGTHS) WHICH ARE SILICON-BASED, WILL OPERATE AT TEMPERATURES ABOVE 65° K, AND WHICH CAN BE FORMATTED INTO LARGE (i.e. MANY ELEMENT) ARRAYS

ACCOMPLISHMENT

- BUILT AND CHARACTERIZED NOVEL SILICON-BASED TUNNELING INFRARED SENSOR
- INITIAL DEVICE DEMONSTRATED PERFORMANCE COMPARABLE TO STATE-OF-THE-ART (SOA) UNCOOLED INFRARED DETECTORS, EXPECT FUTURE DEVICES TO DEMONSTRATE 3-TO-5 FOLD IMPROVEMENT IN SENSITIVITY OVER SOA

BENEFITS

- SILICON-COMPATIBLE IR DETECTORS HAVE POTENTIAL FOR LOW COST, HIGHLY UNIFORM ARRAYS
- ENABLES BROAD-BAND MEASUREMENTS (AS OPPOSED TO OTHER APPROACHES WHICH ARE MORE SUITABLE FOR NARROW, HIGH SPECTRAL RESOLUTION OBSERVATIONS)
  - SENSOR USES EXPANSION OF TRAPPED GAS TO MEASURE ENERGY ABSORBED FROM INCOMING INFRARED RADIATION

APPLICABLE MISSIONS

- EOS AND EOS FOLLOW-ON INSTRUMENTS
- SOLAR PHYSICS MISSIONS
- PLANETARY MISSIONS

SCIENCE FY91
GERMANIUM BLOCKED-IMPURITY-BAND (GeBIB) DETECTOR ARRAYS

SHOWN

- 2x8 ELEMENT GeBIB ARRAY

OBJECTIVE

- TO DEVELOP FAR INFRARED (FIR, 30-250 μm WAVELENGTH) DETECTOR ARRAYS FOR FUTURE ASTROPHYSICS IMAGERS AND SPECTROMETERS, WITH HIGH SENSITIVITY, LOW BACKGROUND NOISE, AND HIGH RADIATION RESISTANCE

ACCOMPLISHMENT

- DEVELOPED AND DEMONSTRATED 2x8 FIR ARRAY
  - PERFORMANCE OF EACH ELEMENT IN ARRAY COMPARABLE WITH PREVIOUS GeBIB SINGLE ELEMENT DETECTORS
  - 50-190 μm WAVELENGTH RANGE AT 1.4°C K OPERATING TEMPERATURE

BENEFITS

- ARRAY CAPABILITY PROVIDES IMPROVED SPATIAL AS WELL AS SPECTRAL RESOLUTION, WHILE PRESERVING SENSITIVITY AND LOW BACKGROUND NOISE OF PREVIOUS SINGLE ELEMENT DETECTORS
- GeBIB DETECTORS, COMPARED TO CURRENT STATE-OF-THE-ART (SOA) SINGLE ELEMENT TECHNOLOGY FOR FIR MEASUREMENTS,
  - ENABLE OPERATION AT HIGHER TEMPERATURES (1.4°C K vs. 0.1°C to 0.3°C K), REQUIRING SUBSTANTIALLY LESS ON-BOARD CRYOGENIC COOLING FLUID
  - ENABLE RADIATION HARDNESS FOR INCREASED SENSITIVITY
  - ENABLE ARRAY FORMAT

(SOA ACHIEVES SENSITIVITY BY EITHER OPERATING AT MUCH LOWER TEMPERATURES OR BY USING A DESIGN THAT IS INTOLERANT OF NATURAL SPACE BACKGROUND RADIATION)

APPLICABLE MISSIONS

- SIRTF
- SMIM
- LDR

SCIENCE FY91
SUPERCONDUCTOR-INSULATOR-SUPERCONDUCTOR (SIS) MIXER ELEMENTS

- NASA - JPL - OAST - RC -

SHOWN

- 2x5 ELEMENT FOCAL PLANE ARRAY OF DIPole ANTENNAS WITH SIS TUNNEL JUNCTIONS (SIS TUNNEL JUNCTIONS TOO SMALL TO BE SEEN IN PHOTO)

OBJECTIVE

- TO DEVELOP HIGH SENSITIVITY, HIGH FREQUENCY SIS MIXER ELEMENTS FOR USE IN SUBMILLIMETER WAVE HETERODYNE RADIOMETERS

ACCOMPLISHMENT

- ACHIEVED MAJOR BREAKTHROUGHS IN 3 AREAS WITH SIS TUNNEL JUNCTION MIXER ELEMENTS
  - DEMONSTRATED SENSITIVITY APPROACHING THEORETICAL PERFORMANCE (FACTOR OF 20 AWAY) AT EXTREMELY HIGH FREQUENCY (500 GHz)
  - DEMONSTRATED CLOSER THEORETICAL PERFORMANCE (FACTOR OF 5 AWAY) AT MODERATE FREQUENCY (200 GHz)
  - DEVELOPED 2x5 ELEMENT SIS FOCAL PLANE ARRAY WHICH WILL ENABLE 2-DIMENSIONAL IMAGING

BENEFITS

- SUBMILLIMETER ASTROPHYSICS OBSERVATIONS ENABLE CRITICAL MEASUREMENTS OF CHEMICAL SPECIES IN DISTANT INTERSTELLAR GAS CLOUDS
- SIS MIXER ELEMENTS PROVIDE THE HIGHEST SENSITIVITY HETERODYNE RADIOMETERS IN THE SUBMILLIMETER WAVELENGTHS

APPLICABLE MISSIONS

- SUBMILLIMETER INTERMEDIATE MISSION (SMIM)
- LARGE DEPLOYABLE REFLECTOR (LDR)

SCIENCE FY91
Nb/AlOx/Nb 230 GHz DIPOLE ARRAY
2-MICRON LASER FOR LIDAR (LIGHT DETECTION AND RANGING)

**SHOWN**
- 2 MICRON SOLID STATE LASER CRYSTAL MOUNTED ON THERMOELECTRIC CHILLER (CRYSTAL IS SMALL CUBE ON TOP)

**OBJECTIVE**
- TO IMPROVE PERFORMANCE OF KNOWN SOLID STATE LASER MATERIALS AND CHARACTERIZE CANDIDATE NEW SOLID-STATE LASER MATERIALS

**ACCOMPLISHMENT**
- DEMONSTRATED IMPROVED PERFORMANCE IN TWO 2-MICRON SOLID STATE LASER MATERIALS
  - IMPROVED EFFICIENCY AND SPECTRAL PURITY IN HOLMIUM, THULIUM DOPED YTTRIUM ALUMINUM GARNET (Ho, Tm: YAG) LASER
  - VERIFIED 13% OVERALL EFFICIENCY OF HOLMIUM, THULIUM DOPED YTTRIUM LITHIUM FLUORIDE (Ho, Tm: YLF) LASER AT ROOM TEMPERATURE

**BENEFITS**
- ENABLES BROAD VARIETY OF OBSERVATIONS OF THE EARTH FROM SPACE, INCLUDING WIND SPEEDS, ATMOSPHERIC TRACE GASSES, AND ACCURATE RANGING TO SURFACES, ICE SHEETS, AND CLOUD TOPS
- MORE RELIABLE, MORE EFFICIENT, REDUCED SIZE AND MASS COMPARED TO STATE-OF-THE-ART LASERS
  - GREATER OUTPUT POWER FOR REDUCED INPUT POWER
  - IMPROVED LIDAR RANGE AND SENSITIVITY FOR MORE ACCURATE MEASUREMENTS

**APPLICABLE MISSIONS**
- 2ND GENERATION EOS LAWS (LASER ATMOSPHERIC WIND SOUNDER)
- FUTURE LIDAR AND DIAL (DIFFERENTIAL ABSORPTION LIDAR) MISSIONS
- PLANETARY MISSIONS

SCIENCE FY91
MICRODYNAMIC COMPONENT TESTER (MCT)

SHOWN

- MICRODYNAMIC COMPONENT TESTER, MCT CAPABILITIES, PASSIVE DAMPER COMPONENT, DAMPER TEST RESULTS

OBJECTIVE

- TO DEVELOP A COMPONENT TESTING CAPABILITY FOR MICROPRECISION SYSTEM COMPONENT PERFORMANCE AT THE NANOMETER LEVEL
- TO GENERATE NANOMETER-REGIME DATA ON THE STIFFNESS OR DAMPING BEHAVIOR OF MICRODYNAMIC STRUCTURES, JOINTS, AND ACTUATORS

ACCOMPLISHMENT

- COMPLETED MICRODYNAMIC COMPONENT TESTER WITH 1.25 NANOMETER DISPLACEMENT AND 20 MICRONEWTONS FORCE RESOLUTION
- DEMONSTRATED LINEAR VISCOUS DAMPING AT 15 NANOMETER RESOLUTION USING THE MICRODYNAMIC COMPONENT TESTER

BENEFITS

- ENABLES VALIDATION OF THE PERFORMANCE OF MICRO-PRECISION SYSTEM COMPONENTS (e.g., STRUCTURAL MEMBERS, JOINTS, DAMPERS, ACTUATORS, NEW MATERIALS) IN THE NANOMETER REGIME
- ENABLES THE GENERATION OF AN EXTENSIVE MICRODYNAMICS DATABASE FOR DESIGNERS OF FUTURE OPTICAL CLASS SPACE SYSTEMS
- REPRESENTS A NATIONAL RESOURCE FOR INVESTIGATORS OF THE MICRODYNAMIC PROPERTIES OF MATERIALS AND COMPONENTS

APPLICABLE MISSIONS

- OSI
- POINTS
- NEXT GENERATION SPACE TELESCOPE
- IMAGING INTERFEROMETER

SCIENCE FY91
LOW-VIBRATION STIRLING-CYCLE COOLER

SHOWN
● TESTING OF ADVANCED VIBRATION CONTROL ELECTRONICS WITH BACK-TO-BACK BRITISH AEROSPACE (BAe) COOLERS ON JPL 6-DEGREE-OF-FREEDOM VIBRATION DYNAMOMETER

OBJECTIVE
● TO REDUCE VIBRATION GENERATED BY STIRLING-CYCLE CRYOCOOLERS TO LESS THAN 0.05 LBS OF FORCE

ACCOMPLISHMENT
● ACHIEVED GREATLY REDUCED VIBRATION OF BRITISH AEROSPACE STIRLING-CYCLE COOLER USING NEW LOW-DISTORTION ELECTRONICS WITH MULTIPLE-HARMONIC NARROW-BAND VIBRATION CONTROL TECHNIQUES

BENEFITS
● 1000X DECREASE IN GENERATED VIBRATION (FROM 2 LBS TO 0.002 LBS)
● REDUCES INSTRUMENT JITTER
● IMPROVES SPECTROMETER RESOLUTION

APPLICABLE MISSIONS
● EARTH OBSERVING SYSTEM (EOS) INSTRUMENTS (AIRS, HRDLS, TES, SAFIRE)
● ADVANCED X-RAY ASTROPHYSICS FACILITY (AXAF)
● HIGH ENERGY SOLAR PHYSICS (HESP) GAMMA-RAY SPECTROMETERS
VIBRATION REDUCTION ACHIEVEMENTS WITH IMPROVED COOLER ELECTRONICS

Original Oxford Electronics

With JPL Low-distortion Electronics and Satcon Narrowband Controller

BACK-TO-BACK BAe COOLERS ON JPL 6-DOF FORCE DYNAMOMETER
ACOUSTO-OPTICAL TUNED FILTER (AOTF)-BASED IMAGING SPECTROMETER

SHOWN

- ACOUSTO-OPTICAL TUNED FILTER (AOTF)-BASED IMAGING SPECTROMETER

OBJECTIVE

- TO DEVELOP BREADBOARD IMAGING SPECTROMETER IN THE VISIBLE AND NEAR INFRARED (IR) RANGE BASED ON AOTF TECHNOLOGY

ACCOMPLISHMENT

- DEMONSTRATED VISIBLE AOTF-BASED IMAGING SPECTROMETER WHICH WAS CONSTRUCTED IN FY90
- CONSTRUCTED AND DEMONSTRATED IR AOTF-BASED IMAGING SPECTROMETER BREADBOARD

BENEFITS

- AOTF-BASED IMAGING SPECTROMETERS, WHEN COUPLED WITH HIERARCHICAL CLASSIFIER SOFTWARE, CAN IDENTIFY SCIENTIFICALLY VALUABLE GEOLOGIC MATERIAL FOR SUBSEQUENT COLLECTION 10-50X FASTER THAN CONVENTIONAL IMAGING SPECTROMETERS
  - ELIMINATES THE MECHANICAL SCANNING
  - STRATEGICALLY SELECTS WAVELENGTHS TO IDENTIFY THE GEOLOGIC MATERIALS
- REQUIRES UP TO 20X LESS MEMORY DUE TO STRATEGIC WAVELENGTH SELECTION

APPLICABLE MISSIONS

- MARS SAMPLE RETURN
- COMET NUCLEUS SAMPLE RETURN
- LUNAR SAMPLE RETURN

SCIENCE FY91
1.2-2.5 MICRON AOTF IMAGING SPECTROMETER BREADBOARD

HgCdTe detector array in liquid nitrogen dewar

Imaging lens
Field lens
AOTF
InS
Foreoptics
OPERATIONS

FOCUSSING PROGRAM

PRECEDING PAGE BLANK NOT FILMED
OPERATIONS TECHNOLOGY

DEVELOP AND DEMONSTRATE TECHNOLOGIES TO REDUCE THE COST OF NASA OPERATIONS, IMPROVE THE SAFETY AND RELIABILITY OF THOSE OPERATIONS, AND ENABLE NEW, MORE COMPLEX ACTIVITIES TO BE UNDERTAKEN

- THE OPERATIONS THRUST SUPPORTS THE FOLLOWING MAJOR ACTIVITIES:
  - IN-SPACE OPERATIONS
  - FLIGHT SUPPORT OPERATIONS
  - GROUND SERVICING AND PROCESSING
  - PLANETARY SURFACE OPERATIONS
  - COMMERCIAL COMMUNICATIONS

- THE FOLLOWING TECHNOLOGY AREAS ARE INCLUDED:
  - AUTOMATION & ROBOTICS
  - INFRASTRUCTURE OPERATIONS
  - INFORMATION & COMMUNICATIONS
  - FLIGHT EXPERIMENTS

Office of Aeronautics and Space Technology
AUTOMATED ASSEMBLY OF SPACE STRUCTURES

**Shown**
- ROBOT ASSEMBLING TETRAHEDRAL TRUSS STRUCTURE IN THE LANGLEY RESEARCH CENTER AUTOMATED STRUCTURAL ASSEMBLY LABORATORY (ASAL)

**Objective**
- TO DEMONSTRATE TELEROBOTIC METHODS FOR IN-SPACE ASSEMBLY OF LARGE SPACE STRUCTURES
- TO CHARACTERIZE ASSEMBLY HARDWARE CONCEPTS, CONSTRUCTION METHODS, AND COMPUTER ARCHITECTURES FOR SPACE OPERATIONS

**Accomplishment**
- DEMONSTRATED AUTOMATED ASSEMBLY AND DISASSEMBLY OF 107-ELEMENT PLANAR TRUSS STRUCTURE
- CHARACTERIZED SYSTEM PERFORMANCE, ASSEMBLY TECHNIQUES, AND TECHNOLOGY LIMITATIONS

**Benefits**
- IDENTIFIES PROBLEMS AND CONSTRAINTS ASSOCIATED WITH IN-SPACE CONSTRUCTION
- POTENTIAL 100% REDUCTION OF EXTRA-VEHICULAR ACTIVITY (EVA) REQUIREMENTS FOR CONSTRUCTION OF SPACE STRUCTURES

**Applicable Missions**
- PRECISION SEGMENTED REFLECTOR
- LARGE APERTURE SPACE OBSERVATORIES
- SPACE STATION FREEDOM

OPERATIONS FY91
ADVANCED TELEOPERATION

SHOWN

- DIAGONAL CUTTERS FOR REMOVING PLASTIC TIE WRAPS ON WIRE BUNDLES DURING SIMULATED SOLAR MAX SATELLITE REPAIR (SMSR) EXPERIMENTS AT THE JPL ADVANCED TELEOPERATION LABORATORY

OBJECTIVE

- TO DEMONSTRATE AND EVALUATE APPLICATION OF DUAL-ARM ADVANCED TELEOPERATION TO SMSR SUBTASKS

ACCOMPLISHMENT

- DEMONSTRATED SIX OF TWELVE SMSR SUBTASKS:
  - CUTTING THERMAL BLANKET
  - UNBOLTING AND REBOLTING MAIN ELECTRONICS BOX
  - CUTTING PLASTIC TIE WRAPS ON WIRE BUNDLES
  - UNPLUGGING AND REPLUGGING ELECTRICAL CONNECTORS
- EVALUATED SYSTEM PERFORMANCE USING ALTERNATIVE CONTROL MODES (POSITION, RATE, MANUAL FORCE FEEDBACK, AUTOMATIC COMPLIANCE CONTROL) AND ALTERNATIVE VISUAL SYSTEMS

BENEFITS

- PROVIDES DATABASE OF ADVANCED TELEOPERATOR PERFORMANCE OF REALISTIC TASKS
- IDENTIFIES SPECIFIC DEVELOPMENT NEEDS FOR SPACE TELEOPERATION TASKS
- IDENTIFIES SPACE SERVICING TASKS AND CAPABILITIES APPROPRIATE FOR ADVANCED TELEOPERATION AS AN ALTERNATIVE TO HUMAN EVA

APPLICABLE MISSIONS

- REMOTE SERVICING AND REPAIR
- REMOTE SURFACE INSPECTION
- REMOTE CONSTRUCTION

OPERATIONS FY91
ASTRONAUT SCIENCE ADVISOR

- NASA - ARC - OAST - RC -

SHOWN
- SLS-1 ROTATING DOME EXPERIMENT (UPPER LEFT), ASTRONAUT SCIENCE ADVISOR USER INTERFACE SHOWING ROTATING DOME DATA ON LEFT AND EXPERIMENT PROTOCOL ON RIGHT (LOWER LEFT), GROUND TESTING OF ASTRONAUT SCIENCE ADVISOR DURING SLS-1 MISSION (LOWER RIGHT)

OBJECTIVE
- DEVELOP ARTIFICIAL INTELLIGENCE (AI)-BASED ADVISORY SYSTEM FOR IN-FLIGHT USE BY ASTRONAUTS WITH SCIENTIFIC SPACE EXPERIMENTS

ACCOMPLISHMENT
- COMPLETED SUCCESSFUL GROUND TEST OF ADVISORY SYSTEM DURING SPACELAB LIFE SCIENCES MISSION (SLS-1)
  - COLLECTED AND ANALYZED REAL-TIME DATA
  - SUGGESTED USEFUL EXPERIMENT PROTOCOL MODIFICATIONS

BENEFITS
- IN-FLIGHT USE WILL IMPROVE SCIENTIFIC RETURN OF SPACE EXPERIMENTS
  - PROVIDES ON-BOARD SCIENTIFIC EXPERTISE AND ADVICE TO ASTRONAUTS IN REALTIME, THEREBY OPTIMIZING EFFICIENCY OF EXPERIMENT
  - REDUCES CUMBERSOME AIR-TO-GROUND COMMUNICATIONS BETWEEN SCIENTIST AND ASTRONAUTS

APPLICABLE MISSIONS
- SHUTTLE MISSIONS
- SPACE STATION FREEDOM

OPERATIONS FY91
Astronaut Science Advisor

- Used for ground support of the "Rotating Dome" Experiment aboard Shuttle Mission SLS-1; July, 1991
- Planned for on-board use by crew on Shuttle Mission SLS-2; May, 1993
AUTOCLASS IV

- A 3-BAND LANDSAT IMAGE (CENTER) SURROUNDED BY FOUR OF THE MANY TERRAIN CLASSES DISCOVERED BY AUTOCLASS IV

OBJECTIVE
- DEVELOP AND APPLY AN ARTIFICIAL INTELLIGENCE (AI)-BASED TOOL FOR AUTOMATIC CLASSIFICATION OF VERY LARGE SCIENTIFIC AND ENGINEERING DATABASES

ACCOMPLISHMENT
- COMPLETED DEVELOPMENT OF AUTOCLASS VERSION IV
  - EXPANDED DATA PROCESSING CAPABILITY FROM SIMPLE SPECTRAL DATA (THE IRAS DATABASE) TO MULTI-CHANNEL VISUAL IMAGES (LANDSAT IMAGES)
- APPLIED AUTOCLASS SYSTEM TO CLASSIFICATION OF LANDSAT IMAGES
  - DISCOVERED MANY NEW TYPES OF GROUND COVER THAT WERE PREVIOUSLY UNKNOWN

BENEFITS
- ENABLES PRELIMINARY ANALYSIS OF LARGE, OFTEN NOISY DATABASES
- AUTOMATICALLY FINDS ACTUAL NUMBER OF CLASSES IN THE DATA
- ENABLES IN-SITU, AUTONOMOUS CLASSIFICATION AS WELL AS INTERACTIVE CLASSIFICATION WITH SCIENTISTS

APPLICABLE MISSIONS
- SPACE SCIENCE MISSIONS (e.g. EOS, GREAT OBSERVATORIES)
- SHUTTLE AND SPACE STATION FREEDOM TELEMETRY ANALYSIS

OPERATIONS FY91
The extended AutoClass implementation was applied to data from Landsat’s Thematic Mapper data from a study area (F.I.F.E.) in Kansas, shown in center panel. For each pixel, information from 7 spectral bands was used to build the class descriptions, including the correlations between the bands.
REAL-TIME DATA SYSTEM (RTDS)

SHOWN
- DATA PROCESSING SYSTEM (DPS) DATA MONITORING AND ANALYSIS TOOL (DDMAT) DISPLAY SHOWING CONFIGURATION AND STATUS OF FIVE SHUTTLE ON-BOARD GENERAL PURPOSE COMPUTERS

OBJECTIVE
- TO DEVELOP SHUTTLE MISSION CONTROL APPLICATIONS USING RTDS, AN ARTIFICIAL INTELLIGENCE (AI)-BASED ADVISORY SYSTEM

ACCOMPLISHMENT
- DEVELOPED A MONITORING AND DISPLAY TOOL (DDMAT) FOR SHUTTLE MISSION CONTROL OPERATIONS

BENEFITS
- PROVIDES EASILY UNDERSTANDABLE GRAPHICS DISPLAY AS COMPARED TO DISPLAY OF 160 INDICATOR LIGHTS AND HEXDECIMAL PARAMETERS (MOST OF WHICH ARE DISCRETE ON/OFF LIGHTS)
- ENABLES AUTOMATIC DIAGNOSIS OF ON-BOARD FAILURES AS COMPARED TO MANUAL ANALYSIS
- POTENTIAL REDUCTION IN NUMBER OF SHUTTLE MONITORING PERSONNEL
- POTENTIAL REDUCTION IN MISSION CONTROLLER TRAINING TIME

APPLICABLE MISSIONS
- SPACE SHUTTLE

OPERATIONS FY91
SPACECRAFT HEALTH AUTOMATED REASONING PROTOTYPE (SHARP)

- SHARP COMPUTER DISPLAY SHOWING GALILEO SPACECRAFT ENGINEERING ANALYSIS

OBJECTIVE
- TO DEVELOP REUSABLE AND PORTABLE ARTIFICIAL INTELLIGENCE (AI)-BASED DIAGNOSTIC SYSTEM
- TO APPLY SYSTEM TO SPECIFIC SPACECRAFT MISSIONS

ACCOMPLISHMENT
- COMPLETED REUSABLE, PORTABLE, AI-BASED SYSTEM (SHARP)
- APPLIED SHARP SYSTEM TO SPECIFIC MISSION SUBSYSTEMS
  - MAGELLAN TELECOMMUNICATIONS
  - GALILEO POWER AND PYRO (EMBEDDED WITHIN ENGINEERING ANALYSIS SUBSYSTEM ENVIRONMENT (EASE) MONITORING SYSTEM)

BENEFITS
- DEMONSTRATES MULTI-MISSION, MULTI-SUBSYSTEM APPLICABILITY OF SHARP DIAGNOSTIC SYSTEM AT HIGH LEVEL OF READINESS
- ENHANCED FAULT DETECTION AND ANALYSIS
  - FASTER, MORE ACCURATE DIAGNOSIS OF SYSTEM HEALTH AND ANOMALIES
- SUPPORTS TECHNOLOGY TRANSFER TO FLIGHT PROJECTS, INCLUDING REQUIREMENTS AND DESIGN FOR FUTURE MULTI-MISSION SPACECRAFT ANALYSIS SYSTEM (MSAS)

APPLICABLE MISSIONS
- VOYAGER
- MAGELLAN
- GALILEO
- CRAF/CASSINI
- PLANETARY MISSIONS

OPERATIONS FY91
SCIENTIFIC ANALYSIS ASSISTANT

- NASA - JPL - OAST RC

SHOWN

- ILLUSTRATION OF MT. PALOMAR SKY SURVEY IMAGE PLATE WITH MACHINE-LEARNING CLASSIFICATION RESULTS

OBJECTIVE

- TO DEVELOP AND DEMONSTRATE ARTIFICIAL INTELLIGENCE (AI) TECHNIQUES TO ASSIST ASTRONOMERS IN AUTOMATED CLASSIFICATION OF ASTRONOMICAL OBJECTS

ACCOMPLISHMENT

- DEVELOPED AI MACHINE-LEARNING ALGORITHMS
  - TESTED ALGORITHMS ON SUBSET OF IMAGE DATA FROM MT. PALOMAR
    - 90.6% ACCURACY IN CLASSIFICATION OF STARS AND GALAXIES

BENEFITS

- ACHIEVES EXPERT HUMAN ASTRONOMER PERFORMANCE
  - ENABLES DRAMATICALLY FASTER PRODUCTION OF SCIENTIFIC CATALOG ENTRIES
    (A FEW DAYS COMPARED TO CURRENT MANUAL METHOD OF 10 YEARS)
  - ENABLES HIGHLY AUTOMATED SKY OBJECT CATALOG PRODUCTION

APPLICABLE MISSIONS

- GROUND AND SPACE-BASED ASTRONOMICAL OBSERVATORIES

OPERATIONS FY91
Scientific Analysis Assistant:
Sky Object Classification Experiment

Mt. Palomar Sky Survey
Photo Image Plate

Subsets of Data Tested

Hundreds of thousands of objects (stars, galaxies) in each image to be classified

Machine Learning Test Results

Machine Learning Algorithms

% Correctly Classified

Human Expert = 91.0 % correct

#1 #2 #3

90 80 70 60

100 90 80 70 60
LOSSLESS DATA COMPRESSOR

- HIGH PERFORMANCE DATA COMPRESSION CHIP SET

OBJECTIVE
- TO DEVELOP SOURCE ENCODING TECHNIQUES TO MAXIMIZE THE SCIENTIFIC INFORMATION RETURN FROM SPACE PLATFORMS WHICH HAVE CONSTRAINED TELECOMMUNICATION BANDWIDTH
- TO USE HIGH PERFORMANCE VERY LARGE SCALE INTEGRATION (VLSI) TECHNOLOGY TO IMPLEMENT SOURCE ENCODING ALGORITHM

ACCOMPLISHMENT
- DEVELOPED SOURCE ENCODING TECHNIQUES
- DESIGNED, FABRICATED, AND TESTED A LOSSLESS DATA COMPRESSION/DECOMPRESSION VLSI CHIP SET WITH SOURCE ENCODING ALGORITHM
- FUNCTIONALLY TESTED VLSI CHIP SET AT 700 MBPS DATA RATE

BENEFITS
- 2X INCREASE IN ON-BOARD IMAGING DATA STORAGE CAPACITY
  - ENABLES INCREASE IN SCIENCE DATA RETURN WITHOUT INCREASE IN BANDWIDTH
- 2X REDUCTION IN DATA TRANSMISSION TIME TO GROUND STATION
- SUPPORTS EXTREMELY HIGH DATA RATE INSTRUMENTS (700 MBPS)

APPLICABLE MISSIONS
- EOS
- SSF
- HUBBLE SPACE TELESCOPE
- SUBMILLIMETER WAVE ASTRONOMY SATELLITE

- SDI
- SATURN ORBITER
- COMET RENDEZVOUS ASTEROID FLYBY

OPERATIONS FY91
A VERY HIGH SPEED LOSSLESS DATA COMPRESSION/DECOMPRESSION CHIP SET

SCIENCE DATA SOURCE

ENCODER

DATAFLOW

DECODER

RECONSTRUCTED SCIENCE DATA

ASIC CMOS CHIP DESIGNED BY MICRO-ELECTRONICS RESEARCH CENTER, U. OF IDAHO

USAGE
- INCREASE ONBOARD STORAGE CAPACITY
- INCREASE TELEMETRY TRANSMISSION BANDWIDTH

CHIP SET FEATURES
- ADAPTIVE TO SCENE STATISTICS
- ACCEPTS VARIABLE QUANTIZATION LEVELS: 4-14 BITS/SAMPLE
- ACCEPTS VARIABLE-RATE SCIENCE DATA: MAX AT 20 MSAMPLES/SEC
- REQUIRES <0.4 W POWER

USERS
- HUBBLE SPACE TELESCOPE REV.
- COMET RANDEZVOUS ASTEROID FLY-BY/SATURN ORBITER/TITAN PROBE
- SMALL EXPLORER/SUB-MILLIMETER WAVE ASTRONOMY SATELLITE
- STRATEGIC DEFENSE INITIATIVE
## IMAGING SPECTROMETER FLIGHT PROCESSOR (ISFLIP)

- **NASA**
- **JPL**
- **OAST**
- **RC**

### SHOWN
- LOSSLESS DATA COMPRESSION CONCEPT, SHOWING THE PROTOTYPE LOSSLESS DATA COMPRESSOR CHIP DEVELOPED FOR THE EOS HIGH RESOLUTION IMAGING SPECTROMETER (HIRIS) INSTRUMENT

### OBJECTIVE
- TO TRANSFER LOSSLESS DATA COMPRESSION TECHNOLOGY FROM A RESEARCH ENVIRONMENT (HIRIS CHIP) TO APPLICATIONS IN FLIGHT PROJECTS BY PERFORMING FEASIBILITY STUDIES FOR POTENTIAL USERS

### ACCOMPLISHMENT
- PERFORMED FEASIBILITY STUDY FOR CRAF/CASSINI
  - EVALUATED DATA SETS FOR CRAF/CASSINI IMAGING SCIENCE SUBSYSTEM
- TRANSFERRED LOSSLESS DATA COMPRESSION TECHNOLOGY TO CRAF/CASSINI IMAGING SCIENCE SUBSYSTEM

### BENEFITS
- 2X INCREASE IN ON-BOARD IMAGING DATA STORAGE CAPACITY
  - ENABLES INCREASE IN SCIENCE DATA RETURN WITHOUT INCREASE IN BANDWIDTH
- 2X REDUCTION IN DATA TRANSMISSION TIME TO GROUND STATION
- SUPPORTS EXTREMELY HIGH DATA RATE INSTRUMENTS

### APPLICABLE MISSIONS
- ALL PLANETARY AND EARTH ORBITING MISSIONS

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**OPERATIONS FY91**
LOSSLESS DATA COMPRESSION/DECOMPRESSION CONCEPT

DETECTOR ARRAY → ORIGINAL → DATA COMPRESSOR → COMPRESSED (~2:1) → SPACECRAFT

BLACK AND WHITE PHOTOGRAPH

EXACTLY RECONSTRUCTED

GROUND

DATA DECOMPRESSOR
HIGH SPEED FIBER OPTIC TRANSCEIVER

Shown

- 3 GBPS TRANSCEIVER BRASSBOARD IN TEST CONFIGURATION

Objective

- TO PROVIDE SPACE-QUALIFIED HIGH-SPEED (3-5 GBPS) FIBER OPTIC TRANSCEIVERS FOR HIGH PERFORMANCE DATA SYSTEM APPLICATION
- TO REDUCE THE OVERALL SIZE AND VOLUME OF THE TRANSCEIVERS WHILE IMPROVING THE OVERALL POWER EFFICIENCY

Accomplishment

- FABRICATED AND TESTED GALLIUM ARSENIDE (GaAs) HYBRID FIBER OPTIC TRANSCEIVER BRASSBOARD TO GREATER THAN 3 GBPS

Benefits

- ENABLING TECHNOLOGY FOR WIDE BAND COMMUNICATIONS NETWORKS
  - ENABLES TRANSMISSION OF DATA AT EXTREMELY HIGH SPEEDS
- 3X REDUCTION IN SIZE OF TRANSMITTER AND RECEIVER
- 30% REDUCTION IN POWER CONSUMPTION

Applicable Missions

- SPACE STATION FREEDOM
- EARTH OBSERVING SYSTEM
- SPACE EXPLORATION INITIATIVE MISSIONS

Operations FY91
DIGITAL AUTOCORRELATOR SPECTROMETER

SHOWN

- 52-CHANNEL, 125 MHz BANDWIDTH DIGITAL AUTOCORRELATOR SPECTROMETER TO BE FLOWN IN JPL / UNIVERSITY OF CALIFORNIA, SANTA BARBARA (UCSB) BALLOON EXPERIMENT IN JUNE, 1992

OBJECTIVE

- TO DEVELOP HIGH SPEED DIGITAL TECHNOLOGIES FOR WIDEBAND, VERY LOW POWER SPECTROMETERS

ACCOMPLISHMENT

- INTEGRATED 52-CHANNEL DIGITAL AUTOCORRELATOR SPECTROMETER (DEVELOPED IN FY90) INTO JPL/UCSB INSTRUMENT FOR INTERSTELLAR OXYGEN MEASUREMENTS
- CUSTOM-DESIGNED AND FABRICATED 32-CHANNEL CORRELATOR CHIP FOR LOW POWER, HIGHER RESOLUTION APPLICATIONS

BENEFITS

- PROVIDES MORE RELIABLE, MORE STABLE, LOWER POWER, SMALLER SIZE, LOWER MASS TECHNOLOGY COMPARED TO STATE-OF-THE-ART ANALOG SPECTROMETERS
- SPECTROMETERS ENABLE OZONE AND OZONE DEPLETION STUDIES FROM THE MEASUREMENT OF RADIO EMISSION LINES FROM MOLECULES IN THE ATMOSPHERE

APPLICABLE MISSIONS

- BALLOON MICROWAVE LIMBSOUNDER SYSTEM (BMLS)
- EOS MICROWAVE LIMBSOUNDER (MLS)
- LARGE DEPLOYABLE REFLECTOR

OPERATIONS FY91
SPACEFLIGHT OPTICAL DISK RECORDER (SODR)

- NASA - LaRC - OAST - RC

SHOWN
- 9-ELEMENT LASER DIODE ARRAY AND GLASS MEDIA COMPONENTS OF SODR;
  SOFTWARE MODEL OF EXPANDABLE ARCHITECTURE; BREADBOARD TESTING OF
  SYSTEM CONTROLLER

OBJECTIVE
- TO DEVELOP COMPONENTS AND SUBSYSTEMS FOR HIGH-PERFORMANCE
  REWRITEABLE OPTICAL DISK RECORDERs

ACCOMPLISHMENT
- DEVELOPED 300 MBPS DIODE ARRAY AND GLASS MEDIA FOR INSERTION INTO SODR

BENEFITS
- ENABLING TECHNOLOGY FOR LARGE SCALE MASS MEMORY SYSTEMS
  - RECORDS FASTER (300 MBPS PER DISK, UP TO 1200 MBPS FOR MULTI-DISK SYSTEM)
  - RECORDS MORE (10 GBYTES PER DISK, UP TO 160 GBYTES FOR MULTI-DISK SYSTEM)
  - MORE RELIABLE STORAGE TECHNOLOGY (NO MEDIA OR HEAD WEAR)
  - EXPANDABLE, RECONFIGURABLE SYSTEM ARCHITECTURE (UP TO 16 DISKS)

APPLICABLE
- SPACE STATION FREEDOM
- EARTH OBSERVING SYSTEM
- PLANETARY ROVERS AND LANDERS
- LEO / GEO MISSIONS
- SPACE EXPLORATION INITIATIVE MISSIONS

OPERATIONS FY91
INTELLIGENT DATA MANAGEMENT

SHOWN

- INTELLIGENT USER INTERFACE TO THE INTERNATIONAL ULTRAVIOLET EXPLORER (IUE) DATA CATALOG

OBJECTIVE

- TO DEVELOP INTELLIGENT USER INTERFACES TO SCIENTIFIC DATABASES SO THAT SCIENTISTS CAN EASILY FIND AND RETRIEVE THE INFORMATION PERTINENT TO THEIR RESEARCH

ACCOMPLISHMENT

- DEVELOPED INTELLIGENT USER INTERFACE TO THE IUE DATA CATALOG

BENEFITS

- ENABLES SCIENTISTS TO QUERY DATABASE USING ENGLISH AND GRAPHICS (COMPARED TO STRUCTURING QUERIES IN THE FORM OF A SPECIALIZED DATABASE QUERY LANGUAGE)

- ENABLES EASIER, FASTER ACCESS TO DATA (IN SECONDS, COMPARED TO MINUTES OR HOURS)
  - SAVES SCIENTISTS' TIME WHICH CAN BE BETTER UTILIZED IN ANALYSIS
  - DECREASES COMPUTING POWER REQUIREMENTS

APPLICABLE MISSIONS

- SPACE-BASED SCIENTIFIC MISSIONS

OPERATIONS FY91
International Ultraviolet Explorer Catalog Query System
ADVANCED DIGITAL SAR PROCESSOR (ADSP)

- NASA - JPL - OAST - RC -

SHOWN
○ SURFACE IMAGE OF VENUS PROCESSED THROUGH THE ADSP-BASED SAR DATA PROCESSING SYSTEM ON MAGELLAN

OBJECTIVE
○ TO DEVELOP COMPUTING TECHNOLOGY TO ENABLE SYNTHETIC APERTURE RADAR (SAR) DATA PROCESSING AT A REAL-TIME RATE

ACCOMPLISHMENT
○ DEVELOPED ADSP WHICH ENABLES SAR DATA PROCESSING FASTER THAN REAL-TIME
○ ADSP ADOPTED BY MAGELLAN PROJECT AS PRIMARY MISSION OPERATIONS SAR DATA PROCESSOR

BENEFITS
○ $10M ESTIMATED SAVINGS OVER DEVELOPING CONVENTIONAL COMPUTING HARDWARE SYSTEM TO PERFORM SAR DATA PROCESSING

○ ENABLES HIGH SPEED DATA PROCESSING FOR VOLUMINOUS DATA
  - ORDER OF MAGNITUDE FASTER DATA PROCESSING COMPARED TO CURRENT SAR DATA PROCESSING SYSTEMS

○ SAR PROCESSING ENABLES REMOTE SENSING CONTINUOUS OPERATION REGARDLESS OF LIGHT (DAY/NIGHT) OR CLOUD COVERAGE (CLEAR/CLOUDY)

APPLICABLE MISSIONS
○ SAR INSTRUMENT MISSIONS (MAGELLAN, SEASAT, SIR-A, SIR-B, SIR-C)

OPERATIONS FY91
SYNTHETIC APERTURE RADAR PROCESSOR

Magellan

SAR Processor

Venus

Venus Surface Characteristics

Office of Aeronautics, Exploration and Technology
ASTRO STAR TRACKER

SHOWN

- ASTRO-1 SHUTTLE MISSION USING STAR TRACKER

OBJECTIVE

- TO DEMONSTRATE CODE R-DEVELOPED (1975-1982) SOLID-STATE STAR TRACKER TECHNOLOGY BASED ON CHARGE COUPLED DEVICES (CCDs)

ACCOMPLISHMENT

- DEMONSTRATED SOLID-STATE STAR TRACKER ON SHUTTLE ASTRO-1 MISSION IN DECEMBER 1990
  - TRACKER ACQUIRED GUIDE STARS FOR ALL 140+ SCIENCE TARGETS

BENEFITS

- CCD TECHNOLOGY MORE RELIABLE (ENABLES STAR ACQUISITION AND TRACKING ANYWHERE IN THE SKY) COMPARED TO IMAGE DISSECTOR TECHNOLOGY (TRACKERS FREQUENTLY FAIL IN ACQUISITION, ESPECIALLY WHEN ONLY FAINT STARTS ARE AVAILABLE)

- CRUCIAL ELEMENT IN SUCCESSFUL OUTCOME OF ASTRO-1 MISSION (ALL 3 PRIMARY TRACKERS FAILED TO ACQUIRE PROPER TARGETS)

APPLICABLE MISSIONS

- MISSIONS REQUIRING HIGH ANGULAR ACCURACY OR FIELD IDENTIFICATION
- MISSIONS REQUIRING TRACKING AND SCANNING

OPERATIONS FY91
PLANETARY SURFACE
FOCUSSING PROGRAM
PLANETARY SURFACE TECHNOLOGY

PROVIDE KEY TECHNOLOGIES FOR ROBOTIC AND MANNED PLANETARY SURFACE EXPLORATION SYSTEMS INCLUDING CAPABILITIES FOR AN OUTPOST ON THE MOON AND EXPLORATION OF THE PLANET MARS

- INCREASE RELIABILITY AND REDUCE RISK; REDUCE DEVELOPMENT AND OPERATIONS COST; AND ENABLE NEW AND INNOVATIVE CAPABILITIES IN THE AREAS OF:
  - ADVANCED SURFACE SYSTEM OPERATIONS ON THE MOON AND MARS
  - TECHNOLOGIES FOR HUMAN SUPPORT DURING VERY LONG DURATION PILOTED MISSIONS IN DEEP-SPACE AND ON PLANETARY SURFACES
AUTONOMOUS MOBILE EXPLORATION ROBOT

- NASA - JPL/CMU - OAST - RC

SHOWN
- AUTONOMOUS MOBILE EXPLORATION ROBOT (AMPER) IN PLANETARY ROBOTICS TEST FACILITY AT CARNEGIE-MELLON UNIVERSITY

OBJECTIVE
- TO DEVELOP A HIGHLY CAPABLE MOBILE ROBOT TESTBED
- TO EVALUATE THE APPLICABILITY OF INNOVATIVE ROBOTIC MORPHOLOGIES (DESIGN APPROACHES) TO PLANETARY SURFACE EXPLORATION IN EXTREME ENVIRONMENTS

ACCOMPLISHMENT
- DEVELOPED THE AMBLER ROBOTIC VEHICLE WITH ASSOCIATED PERCEPTION AND CONTROL SYSTEMS
- DEPLOYED AND EVALUATED AMBLER VIA EXTERNAL AND NOCTURNAL EXPLORATION SORTIES
- DEVELOPED THREE SIGNIFICANT NEW ROBOTIC TECHNOLOGIES
  - DECOUPLED LEG JOINT DESIGN FOR STABLE MACHINE WALKING
  - ACTIVE RANGE SENSING FOR TERRAIN MAP CONSTRUCTION
  - TASK CONTROL ARCHITECTURE (TCA) FOR COORDINATION OF ROBOTIC COMPUTATION TASKS

BENEFITS
- LEGGED DESIGNS OFFER GREATER MOBILITY THAN COMPARABLY Sized WHEELED VEHICLES, PERMITTING EXPLORATION OF A GREATER VARIETY OF EXTREME TERRAINS
- LEGGED VEHICLES ARE HIGHLY EFFICIENT IN TERMS OF POWER UTILIZATION, REQUIRING SMALLER/LIGHTER POWER SYSTEMS
- CONTINUOUSLY LEVEL BODY MOTION OFFERS A STABLE PLATFORM FOR SAMPLING AND SCIENCE PAYLOADS

APPLICABLE MISSIONS
- MARS ENVIRONMENTAL SURVEY (MESUR)
- MARS EXPLORATION
- SCIENCE INSTRUMENT DEPLOYMENT

OPERATIONS FY91
MINI-ROVER TECHNOLOGY

SHOWN
● "ROCKY III" MINI-ROVER TEST VEHICLE DEVELOPED BY JPL INTELLIGENT ROBOTICS LABORATORY

OBJECTIVE
● TO DEVELOP AND DEMONSTRATE A SMALL MOBILE ROVER TO EVALUATE LESS COMPLEX, LESS COSTLY ROVERS FOR PLANETARY EXPLORATION

ACCOMPLISHMENT
● DEVELOPED 20-KILOGRAM CLASS MINI-ROVER WHICH UTILIZES SIMPLE SENSING SYSTEMS AND BEHAVIOR CONTROL ARCHITECTURES TO PERFORM SIMULATED SAMPLE ACQUISITION TASKS
● DEMONSTRATED ROVER SAMPLE ACQUISITION TASK IN JPL ARROYO TEST SITE
   - AUTONOMOUSLY TRAVERSED 20 METERS FROM THE SIMULATED LANDER SITE TO A DESIGNATED SAMPLE COLLECTION LOCATION
   - SENSED AND AVOIDED OBSTACLES HAZARDOUS TO THE VEHICLE DURING THE TRAVERSE
   - IDENTIFIED AND ACQUIRED COLLECTIBLE SAMPLES
   - RETURNED TO SIMULATED LANDER AND DEPOSITED SAMPLES

BENEFITS
● REDUCED SIZE OF VEHICLE PERMITS GREATER SCIENCE/EXPLORATION PAYLOAD CAPABILITY
● REDUCED COMPLEXITY OF VEHICLE LEADS TO INCREASED ROBUSTNESS, AND HOLDS POTENTIAL FOR REDUCED COST OF OPERATIONAL ROVER SYSTEMS

APPLICABLE MISSIONS
● MARS ENVIRONMENTAL SURVEY (MESUR)
● MARS EXPLORATION
● SCIENCE INSTRUMENT DEPLOYMENT

OPERATIONS FY91
STIRLING COLD END MOTERING TEST

SHOWN

- COLD END OF 12.5 kWe/PISTON 1050K STIRLING POWER CONVERTER

OBJECTIVE

- DEVELOP AND DEMONSTRATE A 25% EFFICIENT 12.5 kWe/PISTON 1050K STIRLING POWER CONVERTER WITH COLD END TEMPERATURE OF 525K FOR USE WITH NUCLEAR SPACE POWER SYSTEMS RANGING FROM 25-800 kWe

ACCOMPLISHMENT

- DEVELOPED COLD END PORTION OF THE STIRLING POWER CONVERTER, AND COMPLETED MOTURING TESTS AT A COLD END TEMPERATURE OF 525K

- FIRST TIME DEMONSTRATION OF LOW-POWER-LOSS, SELF-PUMPED, ZERO-WEAR HYDROSTATIC GAS BEARINGS WHICH FUNCTION OVER THE ENTIRE POWER OPERATING RANGE

BENEFITS

- MOTURING TEST VERIFIED DESIGN OF HIGH TEMPERATURE (525K) COMPONENT PARTS (ALTERNATOR, GAS BEARINGS, AND CLEARANCE SEALS)

- INCREASE IN COLD END OPERATING TEMPERATURE FROM 300K TO 525K ENABLES REDUCED SIZE / REDUCED MASS OF RADITRATOR AND THEREFORE REDUCED LAUNCH COSTS WITH INCREASED PAYLOAD POTENTIAL

- STIRLING POWER CONVERSION SYSTEM OFFERS 6X INCREASE IN SYSTEM EFFICIENCY COMPARED TO SP-100 THERMOELECTRICS

APPLICABLE MISSIONS

- LUNAR SURFACE POWER AND ROVER POWER
- MARTIAN SURFACE POWER AND ROVER POWER
- DYNAMIC ISOTOPE POWER SYSTEMS FOR SPACE SCIENCE

PLANETARY SURFACE FY91
SP-100 THERMOELECTRIC MULTICELL

SHOWN
● SP-100 THERMOELECTRIC MULTICELL

OBJECTIVE
● TO DEVELOP A 10-YEAR LIFE, RELIABLE THERMOELECTRIC MULTICELL THAT CAN PRODUCE 13 WATTS (30% IMPROVEMENT IN POWER OUTPUT) AT OPERATING TEMPERATURES OF 1305K (HOT SIDE) AND 863K (COLD SIDE)

ACCOMPLISHMENT
● DEVELOPED ELECTRICAL INSULATOR AND COMPLIANT PAD COMPONENTS OF SP-100 THERMOELECTRIC MULTICELL
● TESTED INSULATOR AND COMPLIANT PAD AT PROTOTYPIC OPERATING CONDITIONS IN AN OPERATING MULTICELL
  - ACHIEVED PREDICTED MULTICELL POWER OUTPUT OF 8.7 WATTS WITH INSULATOR AND COMPLIANT PAD WHILE OPERATING AT TEMPERATURES OF 1300K (HOT SIDE) AND 900K (COLD SIDE)
● COMPLETED AND EXPERIMENTALLY VERIFIED MULTICELL STRESS AND FRACTURE MODELS
● ACHIEVED 15% IMPROVEMENT IN THERMOELECTRIC MATERIAL POWER OUTPUT

BENEFITS
● VALIDATES SP-100 THERMOELECTRIC CONDUCTIVELY COUPLED MULTICELL WHICH IS NEEDED TO MEET APPLICABLE MISSION REQUIREMENTS
● ACHIEVES MORE OUTPUT POWER IN SAME VOLUME
  - 16X INCREASE IN POWER OF THERMOELECTRIC MULTICELL AS COMPARED WITH STATE-OF-THE-ART RADIOISOTOPE THERMOELECTRIC GENERATOR (RTG) UNICOUPLES

APPLICABLE MISSIONS
● ROBOTIC PLANETARY SCIENCE MISSIONS
● LUNAR AND MARS BASE

PLANETARY SURFACE FY91
REGENERATIVE LIFE SUPPORT

SHOWN

- RESULTS OF CARBON DIOXIDE REMOVAL TECHNOLOGY TRADES FOR LUNAR HABITAT SHOWING THE IMPACT OF ALTERNATE TECHNOLOGIES ON THE AIR REVITALIZATION SUBSYSTEM & ON THE ENTIRE LIFE SUPPORT SYSTEM

OBJECTIVE

- MISSION-SPECIFIC LIFE SUPPORT SYSTEMS ANALYSIS OF LONG DURATION EXTRA-TERRESTRIAL MISSIONS FOR LIFE SUPPORT SYSTEM INTEGRATION & TESTBED ACTIVITIES AT JSC AND RESEARCH PROGRAM AT ARC

ACCOMPLISHMENT

- DEVELOPED A RIGOROUS AND FLEXIBLE METHODOLOGY FOR SYSTEM AND TECHNOLOGY TRADES
- COMPLETED LUNAR OUTPOST SYSTEM AND TECHNOLOGY TRADE STUDIES USING SSF BASELINE TECHNOLOGY SET

BENEFITS

- ENABLES MORE ACCURATE AND EFFICIENT PROJECT & PROGRAM PLANNING AND DECISION-MAKING IN TECHNOLOGY DEVELOPMENT AND SYSTEM ENGINEERING
- LUNAR HABITAT SYSTEMS ANALYSIS SHOWS NEW CO2 REMOVAL CONCEPTS (TWO-BED MOLECULAR SIEVE, AIR POLARIZED CELL) OFFER SYSTEM LEVEL WEIGHT SAVINGS OF 400-700 LBS OVER CURRENT CO2 REMOVAL TECHNOLOGIES (ELECTROCHEMICAL DEPOLARIZED CELL, SOLID AMINE, LITHIUM HYDROXIDE)

APPLICABLE MISSIONS

- SPACE STATION FREEDOM
- SHUTTLE ORBITER
- SPACE SUITS
- DOD MISSIONS

PLANETARY SURFACE FY91
Lunar Habitat I - P/C CLLS Tech. Trades
CO₂ Removal Weight Penalties w.r.t 4BMS
TRANSPORTATION

FOCUSSSED PROGRAM
TRANSPORTATION TECHNOLOGY

PROVIDE TECHNOLOGIES THAT SUBSTANTIALLY INCREASE OPERABILITY, IMPROVE RELIABILITY, PROVIDE NEW CAPABILITIES, WHILE REDUCING LIFE CYCLE COSTS

- ENHANCE SAFETY, RELIABILITY, AND SERVICEABILITY OF CURRENT SPACE SHUTTLE

- PROVIDE TECHNOLOGY OPTIONS FOR NEW MANNED SYSTEMS THAT COMPLEMENT THE SHUTTLE AND ENABLE NEXT GENERATION VEHICLES WITH RAPID TURNAROUND AND LOW OPERATIONAL COSTS

- SUPPORT DEVELOPMENT OF ROBUST, LOW-COST HEAVY LIFT LAUNCH VEHICLES

- DEVELOP AND TRANSFER LOW-COST TECHNOLOGY TO SUPPORT COMMERCIAL ELV's AND UPPER STAGES

- IDENTIFY AND DEVELOP HIGH LEVERAGE TECHNOLOGIES FOR IN-SPACE TRANSPORTATION, INCLUDING NUCLEAR PROPULSION, THAT WILL ENABLE NEW CLASSES OF SCIENCE AND EXPLORATION MISSIONS

Office of Aeronautics and Space Technology
NEW CFD TOOLS FOR TURBINE BLADE DESIGN

SHOWN

- COMPUTATIONAL FLUID DYNAMICS (CFD) ANALYSIS OF TWO-STAGE GENERIC GAS GENERATOR TURBINE (GGGT) WITH IDENTIFICATION OF CONTRIBUTING ORGANIZATIONS, AND TRADITIONAL VS. ADVANCED BLADE DESIGNS

OBJECTIVE

- TO ENHANCE AND VALIDATE CFD TOOLS IN ORDER TO USE THEM TO DESIGN TURBINE BLADES

ACCOMPLISHMENT

- ENHANCED EXISTING CFD TOOLS TO ENABLE 3D BLADE ANALYSIS
- VALIDATED NEW CFD TOOLS BY DESIGNING ADVANCED GGGT BLADES (KNOWN TECHNOLOGY)
- APPLIED TOOLS TO SPACE TRANSPORTATION MAIN ENGINE (STME) TURBINE DESIGN
  - CREATED NOVEL DESIGN WHICH PERMITS SINGLE INSTEAD OF TWO-STAGE TURBINES (ONE BLADE ROW INSTEAD OF TWO)

BENEFITS

- ENABLES IMPROVED TURBINE BLADE ANALYSIS FOR FUTURE ENGINE DESIGN
- NEW BLADE DESIGN OFFERS
  - 10% INCREASE IN BLADE EFFICIENCY
  - 55% REDUCTION IN BLADE COUNT
  - ESTIMATED $71M LIFE CYCLE COST SAVINGS

APPLICABLE MISSIONS

- STME FOR NATIONAL LAUNCH SYSTEM OR HEAVY LIFT LAUNCH VEHICLES
- ADVANCED EXPANDER CYCLE ENGINES FOR UPPER STAGES AND OTHER SPACE TRANSPORTATION VEHICLES
- ADVANCED REUSABLE ENGINES FOR ADVANCED MANNED LAUNCH SYSTEM

TRANSPORTATION FY91
CONSORTIUM FOR CFD APPLICATION IN PROPULSION TECHNOLOGY

Turbine Stage Technology Team-Baseline GGGT aerodynamic analyses

SRA
3D N.S. tip. lkg

LeRC
Inverse design code

MSFC
3D N.S

UTRC
2D N.S

ARC
Unsteady 2D N/S

P&W
Multi-stage 3D Euler

Traditional Blade Design

Advanced Concept Blade Design
NEW TECHNOLOGY MAIN COMBUSTION CHAMBER (MCC)

ADVANCED VERSION OF MCC FOR VERIFICATION TESTING IN SPACE SHUTTLE MAIN ENGINE (SSME) TECHNOLOGY TEST BED

TO DEVELOP AND VERIFY ADVANCED MANUFACTURING TECHNOLOGIES THAT WILL YIELD READILY INSPECTABLE AND CERTIFIABLE MCCs WHILE SIGNIFICANTLY REDUCING FABRICATION COST AND TIME

DEVELOPED TWO ADVANCED MANUFACTURING TECHNOLOGIES FOR MCC LINERS: VACUUM PLASMA SPRAY (VPS) AND FORMED PLATELET (FP)
DEVELOPED ADVANCED MANUFACTURING TECHNOLOGY FOR MCC JACKET: PRECISION CASTING
VERIFIED VPS MANUFACTURING PROCESS THROUGH SUCCESSFUL FABRICATION AND TEST OF 40K-LBS-THRUST COMBUSTION CHAMBER

67% REDUCTION IN PRODUCTION COST OF MCC ($1M vs. $3.2M)
67% REDUCTION IN PRODUCTION TIME (50 Weeks vs. 150 Weeks)
INCREASES MCC QUALITY (FEWER WELDS, 100% INSPECTABLE) COMPARED TO STATE-OF-THE-ART SSME (MANY UNINSPECTABLE WELDS)
IMPROVES HEAT TRANSFER WHICH EXTENDS LIFE OF MCC

SSME EVOLUTION
SPACE TRANSPORTATION MAIN ENGINE (STME) FOR NATIONAL LAUNCH SYSTEM OR HEAVY LIFT LAUNCH VEHICLES
ADVANCED EXPANDER CYCLE ENGINES FOR UPPER STAGES AND OTHER SPACE TRANSPORTATION VEHICLES
ADVANCED REUSABLE ENGINES FOR ADVANCED MANNED LAUNCH SYSTEM

TRANSPORTATION FY91
HIGH-ASPECT-RATIO COOLING CHANNEL DESIGNS

SHOWN

- UNFINISHED THROAT CROSS-SECTION OF SUBSCALE HIGH-ASPECT-RATIO COMBUSTION CHAMBER LINER WITH 400 HIGH-ASPECT-RATIO (6.0) COOLING PASSAGES

OBJECTIVE

- TO FABRICATE HIGH-ASPECT-RATIO COOLING CHANNEL
- TO VERIFY AND CHARACTERIZE THE ADVANTAGES OF USING HIGH-ASPECT-RATIO COOLING PASSAGES IN HIGH PRESSURE ROCKET CHAMBERS

ACCOMPLISHMENT

- FABRICATED HIGH-ASPECT-RATIO COOLING CHANNEL IN SUBSCALE THRUST CHAMBER
- VERIFIED AND CHARACTERIZED CHANNEL
  - BETTER COOLING: ACHIEVED 530°F REDUCTION IN HOT GAS SIDE WALL TEMPERATURE COMPARED TO STATE-OF-THE-ART 0.75-ASPECT-RATIO COOLING CHANNELS
  - LONGER LIFE: NO FATIGUE DAMAGE AFTER 440 THERMAL CYCLES
  - LESS COOLANT FLOW REQUIRED: ACHIEVED 200°F REDUCTION IN HOT GAS SIDE WALL TEMPERATURE AFTER REDUCING COOLANT FLOW BY 50%

BENEFITS

- BETTER COOLING ENABLES SIGNIFICANT INCREASE IN COMBUSTION CHAMBER LINER THERMAL FATIGUE LIFE
- LESS COOLANT FLOW ENABLES REDUCED POWER REQUIREMENTS FOR TURBOMACHINERY

APPLICABLE MISSIONS

- SPACE SHUTTLE MAIN ENGINE (SSME) EVOLUTION
- SPACE TRANSPORTATION MAIN ENGINE (STME) FOR NATIONAL LAUNCH SYSTEM OR HEAVY LIFT LAUNCH VEHICLES
- ADVANCED EXPANDER CYCLE ENGINES FOR UPPER STAGES AND OTHER SPACE TRANSPORTATION VEHICLES
- ADVANCED REUSABLE ENGINES FOR ADVANCED MANNED LAUNCH SYSTEM

TRANSPORTATION FY91
LOW COST THRUST CHAMBER CRITICAL TEST

- TRW LOW-COST THRUST CHAMBER ASSEMBLY UNDER TEST AT LeRC ROCKET ENGINE TEST FACILITY AS PART OF THE SPACE ACT COOPERATIVE AGREEMENT

OBJECTIVE

- TO DEMONSTRATE THAT PREVIOUSLY DEVELOPED PINTLE INJECTOR (ROCKET ENGINE COMPONENT) CAN OPERATE STABLY WITH HIGH-ENERGY LIQUID HYDROGEN/LIQUID OXYGEN (LH2/LO2) PROPELLANTS

ACCOMPLISHMENT

- DEMONSTRATED STABLE OPERATION OF PINTLE INJECTOR WITH LH2/LO2 PROPELLANTS IN 16.5K-LBS-THRUST THRUST CHAMBER ASSEMBLY (20 RUNS OF 2 SEC OR LESS AT ACCEPTABLE COMBUSTION EFFICIENCY LEVELS OF 96 PERCENT)

BENEFITS

- PROVIDES LOW-COST EXPENDABLE REPLACEMENT FOR HIGH-COST PROPULSION HARDWARE IN CURRENT EXPENDABLE LAUNCH VEHICLE (ELV) FLEET
- ENHANCES U.S. COMPETITIVE POSITION IN WORLD MARKET

APPLICABLE MISSIONS

- EARTH/ORBIT MISSION EXPENDABLE LAUNCH VEHICLE (ELV) BOOSTER-STAGE AND UPPER-STAGE PROPULSION

TRANSPORTATION FY91
CERAMIC COMPOSITE ENGINE PARTS

OBJECTIVE

- TO DEVELOP FABRICATION PROCESS FOR CERAMIC COMPOSITE COMPONENTS
- TO APPLY CERAMIC COMPOSITE COMPONENTS TO HIGH TEMPERATURE ROCKET ENGINE PARTS

ACCOMPLISHMENT

- DEVELOPED AND DEMONSTRATED FABRICATION METHODS FOR CARBON FIBER/SILICON CARBIDE (C/SiC) MATRIX AND SILICON CARBIDE FIBER/SILICON NITRIDE (SiC/Si$_3$N$_4$) MATRIX MATERIALS
- APPLIED FABRICATION PROCESSES TO HIGH TEMPERATURE ROCKET ENGINE PART (TURBINE BLADE)
  - DEMONSTRATED TURBINE BLADE DURABILITY, RELIABILITY, AND DAMAGE TOLERANCE UNDER SEVERE THERMAL SHOCK CONDITIONS

BENEFITS

- OFFERS HIGH TEMPERATURE CAPABILITY AND STRUCTURAL STRENGTH IN AGGRESSIVE ENVIRONMENTS (THERMAL TRANSIENTS) COMPARED TO STATE-OF-THE-ART SUPERALLOY METAL BLADES
  - DRAMATIC INCREASES ENGINE EFFICIENCY AND PERFORMANCE
  - DRAMATIC INCREASES ENGINE LIFE

APPLICABLE MISSIONS

- ADVANCED REUSABLE ENGINES FOR ADVANCED MANNED LAUNCH SYSTEM (AMLs)

TRANSPORTATION FY91
Fiber Reinforced Ceramic Matrix Composite Airfoil Shapes Survive Severe Thermal Shock

C/SiC

SiC/Si$_3$N$_4$
CERAMIC BALLS FOR LONG-LIFE BALL BEARINGS

- NASA - MSFC - OAST - RP

SHOWN
- SILICON NITRIDE CERAMIC BALLS AFTER 7+ HOURS OF OPERATION IN BEARING TESTER COMPARED TO STANDARD SPACE SHUTTLE MAIN ENGINE (SSME) 440C METAL ALLOY BALLS AFTER 15+ MINUTES OF OPERATION

OBJECTIVE
- TO DEVELOP CERAMIC BALL BEARING FABRICATION PROCESS THAT WILL EXTEND HIGH LOAD BALL BEARING LIFE FROM MINUTES TO MANY HOURS

ACCOMPLISHMENT
- DEVELOPED SILICON NITRIDE BALL BEARING FABRICATION PROCESS
- DEMONSTRATED 7+ HOURS LIFE OF SILICON NITRIDE BALLS IN BEARING TESTER UNDER LOADING CONDITIONS THAT EXCEED THOSE IN SSME

BENEFITS
- INCREASE IN BALL BEARING LIFETIME FROM MINUTES TO SEVERAL HOURS
  - ELIMINATES FREQUENT BEARING CHANGE OUT CURRENTLY EXPERIENCED BY SSME (CHANGEOUTS COST APPROXIMATELY $1M EACH)

APPLICABLE MISSIONS
- SSME EVOLUTION
- ADVANCED REUSABLE ENGINES FOR ADVANCED MANNED LAUNCH SYSTEM

TRANSPORTATION FY91
MSFC BSMT Bearing Tester
Silver Nitride Balls vs. 440 C Balls
57 mm HPOTP Bearing

Unit 3, Build 2
440 C Baseline
10 Min at 30,000 rpm
Average Ball Wear = .14 mm (.0055 in)

Unit 2, Build 12
Silicon Nitride
7 hours, 8 minutes at 30,000 rpm
Average Ball Wear = .018 mm (.0007 in)
NUCLEAR ELECTRIC PROPULSION (NEP)

CONCEPT FOR NUCLEAR ELECTRIC ROCKET APPROACHING MARS ORBIT. A SMALL MARS EXCURSION VEHICLE WOULD DESCEND FROM THIS NUCLEAR ELECTRIC VEHICLE DOWN TO THE PLANET'S SURFACE. AFTER COMPLETING SURFACE EXPLORATION, IT WOULD RETURN TO SPACE AND RENDEZVOUS WITH THE NUCLEAR ELECTRIC SPACECRAFT FOR TRANSIT BACK TO EARTH.

OBJECTIVE

TO DEVELOP AND DEMONSTRATE FOCUSED NEP SYSTEMS TECHNOLOGY WHICH
- COMPLIES WITH SOUND SAFETY AND ENVIRONMENTAL POLICIES
- MEETS MISSION REQUIREMENTS OF USER CODES

ACCOMPLISHMENT

COMPLETED GOVERNMENT/INDUSTRY NEP SYSTEMS EVALUATION
- COMPLETED MISSION STUDIES TO SHOW BENEFITS OF NEP FOR MARS PILOTED MISSION AND ROBOTIC PLANETARY SCIENCE MISSIONS
- DEVELOPED CONCEPT FOR MODULAR 5MW NEP SYSTEM FOR CARGO AND PILOTED MISSIONS

BENEFITS

- ENABLES LOWER MISSION RESUPPLY MASS
- PROVIDES HIGH LEVELS OF ON-BOARD POWER WHICH CAN BE USED BY SYSTEMS OTHER THAN PROPULSION
- PROVIDES WIDER LAUNCH WINDOWS
- ENABLES LOWER DEVELOPMENT COSTS THROUGH COMMONALITY WITH SURFACE NUCLEAR POWER REACTOR

APPLICABLE MISSIONS

- ROBOTIC PLANETARY SCIENCE MISSIONS
- MARS CARGO AND PILOTED MISSIONS

TRANSPORTATION FY91
NUCLEAR THERMAL PROPULSION (NTP)

- CONCEPT FOR NUCLEAR THERMAL ROCKET APPROACHING MARS ORBIT. A SMALL MARS EXCURSION VEHICLE WOULD DESCEND FROM THIS NUCLEAR SPACECRAFT DOWN TO THE PLANET'S SURFACE. AFTER COMPLETING SURFACE EXPLORATION, IT WOULD RETURN TO SPACE AND RENDEZVOUS WITH THE NUCLEAR THERMAL SPACECRAFT FOR TRANSIT BACK TO EARTH.

OBJECTIVE
- TO DEVELOP AND DEMONSTRATE FOCUSED NTP SYSTEMS TECHNOLOGY WHICH
  - COMPLIES WITH SOUND SAFETY AND ENVIRONMENTAL POLICIES
  - MEETS CODE X MISSION REQUIREMENTS

ACCOMPLISHMENT
- COMPLETED GOVERNMENT/INDUSTRY NTP SYSTEMS EVALUATION
  - COMPLETED PRELIMINARY SELECTION OF 3 NTP CONCEPTS FOR FURTHER STUDY (NERVA DERIVATIVE, PARTICLE BED, CERMET)
- DEVELOPED CONCEPT FOR COMMON MODULAR NUCLEAR THERMAL ROCKET STAGE COMPONENTS WHICH SATISFIES LUNAR AND MARS CARGO AND PILOTED MISSION REQUIREMENTS

BENEFITS
- ENABLES SHORTER TRANSIT TIMES
- REDUCES INITIAL MASS INTO LOW EARTH ORBIT (IMLEO) REQUIREMENTS BY 50% COMPARED TO CHEMICAL SYSTEMS
- PROVIDES WIDER LAUNCH WINDOWS
- ENHANCES OPERATIONAL FLEXIBILITY (CREW SAFETY)

APPLICABLE MISSIONS
- ROBOTIC PLANETARY SCIENCE MISSIONS
- MARS CARGO AND PILOTED MISSIONS

TRANSPORTATION FY91
ADVANCED EXPANDER TESTBED (AETB)

SHOWN

- ADVANCED EXPANDER TESTBED CRYOGENIC ENGINE

OBJECTIVE

- TO DEVELOP ENGINE SYSTEM TECHNOLOGY BASE IN PREPARATION FOR DEVELOPMENT OF THE NEXT SPACE OR UPPERSTAGE CHEMICAL ROCKET ENGINE

ACCOMPLISHMENT

- COMPLETED TESTBED CRYOENGINE PRELIMINARY DESIGN

BENEFITS

- VALIDATES COMPONENT AND ENGINE DESIGN AND ANALYSIS
- IDENTIFIES ENGINE SYSTEM EFFECTS (e.g. COMPONENT INTERACTIONS, SYSTEM DYNAMICS, CONTROL LOGICS)
- PROVIDES A "HOST DEVICE" TO EVALUATE ALTERNATE COMPONENTS AND HEALTH MONITORING SYSTEMS IN AN ENGINE ENVIRONMENT

APPLICABLE MISSIONS

- SPACE TRANSFER VEHICLE CHEMICAL PROPULSION ENGINES
- UPPERSTAGE CHEMICAL ENGINES FOR EXPENDABLE LAUNCH VEHICLES

TRANSPORTATION FY91
MULTILAYER INSULATION (MLI) TECHNOLOGY

- INSTALLATION OF FLIGHT TYPE LIQUID HYDROGEN TANK WITH 34 LAYERS OF MLI IN TEMPERATURE CONTROLLED SHROUD PRIOR TO VACUUM TESTS

OBJECTIVE
- DETERMINE THERMAL PERFORMANCE OF AN MLI SYSTEM IN TEMPERATURE RANGE ANTICIPATED FOR LEO AND LUNAR MISSIONS

ACCOMPLISHMENT
- DETERMINED MLI THERMAL PERFORMANCE OVER SPECIFIED TEMPERATURE RANGE
- SIMULATED LUNAR TEMPERATURE PROFILE (FROM SURVEYOR DATA)
- DETERMINED TRANSIENT MLI THERMAL PERFORMANCE DURING SIMULATED LUNAR SUNRISE

BENEFITS
- ENABLES MISSION SPECIFIC PERFORMANCE PREDICTIONS (e.g. 1-2%/month boiloff at lunar surface) VIA VALIDATED MODELS
- 20-30% LAUNCH MASS REDUCTION FOR LUNAR MISSIONS UP TO 6 MONTHS, USING FULLY CRYOGENIC SYSTEM COMPARED TO STATE-OF-THE-ART STORABLE ASCENT AND RETURN

APPLICABLE MISSIONS
- LEO TO GEO TRANSFER MISSIONS
- LUNAR MISSIONS (INCLUDING ASCENT AND RETURN)

TRANSPORTATION FY91
PLATFORMS

FOCUSSLED PROGRAM
SPACE PLATFORMS TECHNOLOGY

DEVELOP TECHNOLOGIES TO INCREASE ON-ORBIT MISSION EFFICIENCY AND DECREASE LIFE CYCLE COSTS FOR FUTURE MANNED AND UNMANNED SCIENCE, EXPLORATION & COMMERCIAL MISSIONS.

- DEVELOP TECHNOLOGIES THAT WILL DECREASE LAUNCH WEIGHT AND INCREASE THE EFFICIENCY OF SPACE PLATFORM FUNCTIONAL CAPABILITIES

- DEVELOP TECHNOLOGIES THAT WILL INCREASE HUMAN PRODUCTIVITY AND SAFETY OF MANNED MISSIONS

- DEVELOP TECHNOLOGIES THAT WILL INCREASE MAINTAINABILITY AND REDUCE LOGISTICS RESUPPLY OF LONG DURATION MISSIONS

- IDENTIFY AND DEVELOP FLIGHT EXPERIMENTS IN ALL TECHNOLOGY AND THRUST AREAS THAT WILL BENEFIT FROM THE UTILIZATION OF SSF FACILITIES

Office of Aeronautics and Space Technology
CONTROLS-STRUCTURES INTERACTION (CSI)

SHOWN
- INITIAL CSI PLATFORM TESTBED SUSPENDED IN THE LABORATORY AT LANGLEY

OBJECTIVE
- TO DEVELOP METHODS TO DESIGN, ANALYZE, AND TEST LIGHTWEIGHT, HIGH-PERFORMANCE, CONTROLLED STRUCTURES
- TO VALIDATE THE TECHNOLOGY WITH GROUND AND FLIGHT DEMONSTRATIONS

ACCOMPLISHMENT
- PERFORMED GROUND-TEST CSI TECHNOLOGY EXPERIMENT WHICH DEMONSTRATED 20-30X INCREASE IN DAMPING
- PERFORMED CSI ANALYTICAL STUDIES WHICH SHOWED SIGNIFICANTLY IMPROVED REMOTE SENSING PRECISION POINTING JITTER FOR LARGE SPACE ANTENNAS

BENEFITS
- FACTOR OF 500 JITTER REDUCTION FOR 20-80M ANTENNAS
- DECREASED INTERACTION AMONG POINTING INSTRUMENTS ON MULTI-PAYLOAD PLATFORMS
- INCREASED POINTING PRECISION

APPLICABLE MISSIONS
- MISSION TO PLANET EARTH
- SPACE STATION FREEDOM ASSEMBLY
- SHUTTLE REMOTE MANIPULATOR SYSTEM OPERATIONS
- ADVANCED COMMUNICATION SPACECRAFT

PLATFORMS FY91
THE PHASE-ZERO EVOLUTIONARY MODEL:
A CONTROLS-STRUCTURES INTERACTION TESTBED
HYBRID-SCALE MODEL OF
SPACE STATION FREEDOM (SSF) CONFIGURATION

SHOWN

- HYBRID-SCALE SSF MODEL (HMB-2, PRECURSOR TO HMB-15)

OBJECTIVE

- TO DEVELOP DYNAMIC GROUND VERIFICATION TESTING METHODS OF LARGE, FLEXIBLE SPACECRAFT VIA SMALLER SCALE MODELS
- TO VALIDATE GROUND VERIFICATION TESTING METHODS BY CORRELATING THEM WITH ON-ORBIT DATA

ACCOMPLISHMENT

- DEVELOPED SCALE MODEL (HMB-2) FOR GROUND VERIFICATION TESTING
  - COMPLETED CRITICAL COMPONENT TESTING AND MODEL UPDATING
  - COMPLETED INITIAL VIBRATION TEST ON SUSPENDED MODEL
- ACQUIRED PARTS FOR HMB-15 SSF CONFIGURATION OF ERECTABLE TRUSS DESIGN (MODULES AND SOLAR ARRAYS)

BENEFITS

- SCALE MODEL ANALYSIS AND TESTING WILL ELIMINATE THE NEED TO TEST FULL-SCALE SPACECRAFT

APPLICABLE MISSIONS

- MISSION TO PLANET EARTH
- SPACE STATION FREEDOM ASSEMBLY
- REMOTE MANIPULATOR SYSTEM OPERATIONS
- ADVANCED COMMUNICATION SPACECRAFT

PLATFORMS FY91
SIMULATED EVA ASSEMBLY OF TRUSS STRUCTURE AND PANELS

NEUTRAL BUOYANCY ENVIRONMENT TESTS FOR PRECISION SEGMENTED REFLECTOR PANEL-TO-TRUSS ATTACHMENT (LEFT) AND PANEL REMOVAL AND REPLACEMENT (RIGHT)

OBJECTIVE

TO EVALUATE IN A SIMULATED WEIGHTLESS ENVIRONMENT:
- PROCEDURES AND HARDWARE FOR THE ATTACHMENT OF PRECISION REFLECTOR PANELS TO A SUPPORT TRUSS STRUCTURE
- A TECHNIQUE FOR THE REMOVAL AND REPLACEMENT OF A DAMAGED PANEL

ACCOMPLISHMENT

EVALUATED TWO DESIGNS OF PANEL ATTACHMENT HARDWARE IN NEUTRAL BUOYANCY ENVIRONMENT OF McDonnell Douglas UNDERWATER TEST FACILITY
DEVELOPED SPECIAL PURPOSE PANEL REMOVAL AND REPLACEMENT TOOL AND DEMONSTRATED ITS UTILITY IN NEUTRAL BUOYANCY

BENEFITS

DEMONSTRATED EFFICIENCY AND EASE OF OPERATIONS IN ATTACHING PRECISION PANELS TO A SUPPORTING STRUCTURE
- PRELIMINARY RESULTS SHOW PANEL ATTACHMENT TIMES OF 1-2 MINUTES AS COMPARED TO PROJECTED TIMES OF 15-30 MINUTES

PANEL REMOVAL AND REPLACEMENT TOOL ENABLES ALL CRITICAL EVA OPERATIONS TO BE PERFORMED FROM BEHIND THE PANEL, THUS MINIMIZING RISK OF PANEL SURFACE DAMAGE
- PRELIMINARY RESULTS SHOW PANEL REMOVAL AND REPLACEMENT TIMES OF APPROXIMATELY 10 MINUTES AS COMPARED TO PROJECTED TIMES OF 1-2 HOURS

APPLICABLE MISSIONS

- LARGE ANTENNA CONSTRUCTION
- LARGE SOLAR COLLECTORS

PLATFORMS FY91
PRECISION SEGMENTED REFLECTOR PANEL-TO-TRUSS ATTACHMENT HARDWARE AND PROCEDURES VERIFIED IN NEUTRAL BUOYANCY TESTS

Panel Attachment

Panel Removal and Replacement

NASA Langley Research Center Structural Mechanics Division
RESEARCH & TECHNOLOGY BASE
SPACE RESEARCH & TECHNOLOGY BASE

CONDUCT RESEARCH TO IDENTIFY, DEVELOP AND VALIDATE HIGH-LEVERAGE CONCEPTS IN KEY TECHNOLOGY DISCIPLINES (TECHNOLOGY PUSH)

- DISCIPLINE RESEARCH
- UNIVERSITY PROGRAMS
- SPACE FLIGHT RESEARCH & TECHNOLOGY
- SYSTEMS ANALYSIS

Office of Aeronautics and Space Technology
PERSONNEL LAUNCH SYSTEM (PLS) BENCHMARK STUDY

- NASA - LaRC - OAST - RS

**SHOWN**
- HL-20 LIFTING BODY PLS MOCKUP

**OBJECTIVE**
- TO ESTABLISH TECHNICALLY & OPERATIONALLY CREDIBLE MANNED EARTH-TO-ORBIT VEHICLE OPTION (PLS) AS A COMPLEMENT TO THE SPACE SHUTTLE

**ACCOMPLISHMENT**
- COMPLETED HL-20 BASELINE CONCEPT DEFINITION
  - DEVELOPED OPTIMUM CONFIGURATION
  - VALIDATED PERFORMANCE PARAMETERS
  - DEFINED DEVELOPMENT RISKS, PRODUCIBILITY, AND OPERABILITY
  - DETERMINED DEVELOPMENT COSTS AND RECURRING COSTS

**BENEFITS**
- ESTABLISHES TECHNICAL/OPERATIONAL VIABILITY OF HL-20 PLS
- ESTABLISHES A LOW DEVELOPMENT RISK OPTION FOR MANNED TRANSPORTATION

**APPLICABLE MISSIONS**
- SPACE STATION FREEDOM PERSONNEL TRANSPORTATION
- SMALL PAYLOAD DELIVERY AND RETURN
- EARTH OBSERVATIONS
- SATELLITE INSPECTION AND SERVICING

AEROTHERMODYNAMICS FY91
R&T BASE
Aerospace America

The Soviet race to the Moon
Simulators will help pick LH winner
Face to Face with Ben Rich
OPTIMIZED PERSONNEL LAUNCH SYSTEM HL-20 DATABASE

- NASA - LaRC - OAST - RF -

SHOWN

- HL-20 LIFTING BODY WIND TUNNEL MODEL

OBJECTIVE

- TO EXPERIMENTALLY DETERMINE AERODYNAMIC/AEROTHERMODYNAMIC PERFORMANCE CHARACTERISTICS OF HL-20 LIFTING BODY CONFIGURATION AT HYPERSONIC TO SUBSONIC SPEEDS
- TO EVOLVE OPTIMUM AERODYNAMIC CONFIGURATION

ACCOMPLISHMENT

- DEVELOPED DATABASE TO DETERMINE PERFORMANCE CHARACTERISTICS
  - 5' MODEL TESTED AT SUBSONIC SPEEDS (MACH .1)
  - 20" MODEL TESTED AT TRANSONIC AND SUPersonic SPEEDS (MACH .3 TO 4.6)
  - 6' MODEL TESTED AT HYPERSONIC SPEEDS (MACH 6 AND 10)
- PROJECTED HL-20 PERFORMANCE IMPROVEMENTS
- EVOLVED OPTIMUM AERODYNAMIC CONFIGURATION
  - DETERMINED STATIC LONGITUDINAL/LATERAL DIRECTIONAL STABILITY, CONTROL AUTHORITY REQUIREMENTS, AND MAXIMUM LIFT-TO-Drag AT VEHICLE LONGITUDINAL TRIM CONDITIONS

BENEFITS

- ESTABLISHES TECHNICAL VIABILITY OF LIFTING BODIES FOR APPLICATIONS IN SPACE TRANSPORTATION SYSTEMS

APPLICABLE MISSIONS

- SPACE STATION FREEDOM PERSONNEL TRANSPORTATION
- SMALL PAYLOAD DELIVERY AND RETURN
- EARTH OBSERVATIONS
- SATELLITE INSPECTION AND SERVICING

AEROTHERMODYNAMICS FY91

R&T BASE
PERSONNEL LAUNCH SYSTEM (PLS)
APPROACH & LANDING SIMULATION STUDY

- NASA - LaRC
- OAST - RC

SHOWN

- HL-20 LIFTING BODY PLS COCKPIT

OBJECTIVE

- TO ESTABLISH HL-20 LOW SPEED FLYING QUALITY RATINGS FOR MANUAL AND AUTOMATIC APPROACH & LANDING ON RUNWAYS UNDER A VARIETY OF NOMINAL AND OFF-NOMINAL CONDITIONS

ACCOMPLISHMENT

- ESTABLISHED HL-20 LOW SPEED FLYING QUALITY RATINGS OF LEVEL 1 (GOOD)
  - PILOTS AND ASTRONAUTS FLEW SIMULATED MANUAL HL-20 APPROACH AND LANDINGS UNDER SEVERAL NOMINAL AND ADVERSE CONDITIONS
  - DEMONSTRATED SIMULATED AUTOMATIC LANDINGS

BENEFITS

- ESTABLISHES TECHNICAL VIABILITY OF HL-20 PLS FOR BOTH MANUAL AND AUTOMATIC LANDINGS

APPLICABLE MISSIONS

- SPACE STATION FREEDOM PERSONNEL TRANSPORTATION
- SMALL PAYLOAD DELIVERY AND RETURN
- EARTH OBSERVATIONS
- SATELLITE INSPECTION AND SERVICING

AEROTHERMODYNAMICS FY91
R&T BASE
CERAMIC MATRIX COMPOSITES

SHOWN
- REINFORCED SILICON CARBIDE COMPOSITE MATERIAL FOR BUILDING THERMALLY PROTECTED SPACECRAFT STRUCTURES

OBJECTIVE
- TO TEST CERAMIC MATRIX COMPOSITE MATERIALS THAT COMBINE HIGH STRENGTH AND TEMPERATURE RESISTANCE IN ORDER TO INTEGRATE INTERNAL VEHICLE STRUCTURE WITH ITS THERMAL PROTECTION SYSTEM
- TO DEVELOP AND TEST COMMERCIAL FABRICATION METHODS FOR THIS INTEGRATED STRUCTURE

ACCOMPLISHMENT
- COMPLETED PHYSICAL PROPERTY TESTING OF CERAMIC MATRIX COMPOSITES SUBJECT TO HIGH TEMPERATURE ATMOSPHERIC REENTRY CONDITIONS
- DEVELOPED A PROTOTYPE COMMERCIAL FABRICATION METHOD FOR THE INTEGRATED STRUCTURE

BENEFITS
- 50% REDUCTION IN VEHICLE STRUCTURE WEIGHT
  - ENABLES INCREASED PAYLOAD POTENTIAL OR REDUCED MISSION WEIGHT
- INCREASE IN RESISTANCE TO ADVERSE FLIGHT ENVIRONMENTS
  - REDUCES VEHICLE MAINTENANCE AND LIFE CYCLE COSTS

APPLICABLE MISSIONS
- NASP
- AEROBRAKE HOT STRUCTURES

AEROTHERMODYNAMICS FY91 R&T BASE
TOP HAT
Thermal Protection System
WIND TUNNEL AIR FLOW DENSITY MEASUREMENTS USING HOLOGRAPHIC INTERFEROMETRY

SHOWN

- Interferometric holograms of the air flow density through the nozzle of the Ames Electric Arc Drive Shock Tunnel (East), a wind tunnel.

OBJECTIVE

- To measure the air flow density in the nozzle of the East facility using holographic interferometry techniques.

ACCOMPLISHMENT

- Converted Electric Arc Driven Shock Tube facility to a shock tunnel by adding a nozzle.
- Completed air flow density measurements through the East nozzle using holographic interferometry.

BENEFITS

- Enabled first ground-based tests of wake flows behind a hypersonic vehicle at realistic flight conditions.

APPLICABLE MISSIONS

- NASP
- Aerobrake missions
MAGELLAN AEROBRAKE MANEUVER GAS FLOW PREDICTIONS

SHOWN

- Temperatures in the flow field about the Magellan spacecraft during the proposed aerobrake maneuver through the atmosphere of Venus

OBJECTIVE

- To make aerobrake maneuver gas flow predictions about the Magellan spacecraft in order to select a heat-minimizing trajectory through the Venus atmosphere (maneuver will circularize the spacecraft orbit to provide enhanced radar imaging resolution)

ACCOMPLISHMENT

- Performed rarefied flow calculations to define a heat-minimizing mission trajectory for Magellan through the atmosphere of Venus

BENEFITS

- Enables heat-minimizing trajectory projections for the Magellan spacecraft (which is not protected from high atmospheric entry temperatures)
  - Ensures spacecraft survivability during proposed aerobrake maneuver

APPLICABLE MISSIONS

- Magellan
Particle Simulation Code
Application to Magellan Spacecraft Aerobraking

Simulation Geometry

Surface Temperature Profile

Flowfield Particle Profile

Flowfield Temperature
ADVANCED CONCENTRATOR PHOTOVOLTAIC SYSTEM

SHOWN

- 12-ELEMENT FLIGHT MODULE CONTAINING MINI-DOME FRESNEL LENS CONCENTRATORS TO BE FLOWN ON PLASMA EXPERIMENT (PEGASUS LAUNCH, NOVEMBER 1992)

OBJECTIVE

- TO DEVELOP LOW-COST SOLAR POWER SYSTEMS WITH REDUCED AREA (HIGH POWER PER UNIT AREA) AND LIGHT WEIGHT (HIGH POWER PER UNIT MASS)

ACCOMPLISHMENT

- DEVELOPED PROTOTYPE SUBMODULE AND DEMONSTRATED >300 W/SQ.M (3X INCREASE OVER SPACE STATION FREEDOM ARRAY POWER PER UNIT AREA)

- DEVELOPED PRELIMINARY PANEL DESIGN USING MINI-DOME FRESNEL LENS CONCENTRATORS WITH 95 W/KG (2X INCREASE OVER STATE-OF-THE-ART RIGID PANEL POWER PER UNIT MASS)

BENEFITS

- ENABLES LOW COST, SMALL AREA (LOW DRAG), HIGH POWER SPACE-BASED SOLAR POWER SOURCE

APPLICABLE MISSIONS

- SPACE STATION FREEDOM
- SPACE PLATFORMS
- ORBIT TRANSFER (HOUSEKEEPING OR SOLAR ELECTRIC PROPULSION)
- HIGH POWER COMMUNICATIONS SATELLITES

SPACE ENERGY CONVERSION

R&T BASE

FY91
HIGH CYCLE LIFE RECHARGEABLE LITHIUM BATTERY

SHOWN
- RECHARGEABLE LITHIUM BATTERY TEST CELL

OBJECTIVE
- DEVELOP RECHARGEABLE LITHIUM BATTERY WITH SPECIFIC ENERGY OF 100 W-h/kg AT CELL LEVEL WITH LIFETIME OF 1000 CYCLES AT 50% DEPTH OF DISCHARGE

ACCOMPLISHMENT
- ACHIEVED (IN-HOUSE) FOR THE FIRST TIME OVER 750 CYCLES AT 50% DEPTH OF DISCHARGE IN LABORATORY TEST CELLS
- DEVELOPED (CONTRACTOR) 'AA' CELL WITH 120 W-h/kg. CELL TESTED TO OVER 900 CYCLES AT 50% DEPTH OF DISCHARGE.

BENEFITS
- DEMONSTRATES FEASIBILITY OF HIGH ENERGY DENSITY RECHARGEABLE LITHIUM BATTERIES
- 3X SPECIFIC ENERGY OF STATE-OF-THE-ART NICKEL HYDROGEN BATTERIES
- MISSION IMPACT:
  - 2X REDUCTION IN WEIGHT
  - 2X INCREASE IN MISSION CAPABILITY USING SAME BATTERY
  - 1/3 REDUCTION IN VOLUME

APPLICABLE
- EARTH ORBITAL SPACECRAFT
- ROBOTIC PLANETARY SPACECRAFT
- PLANETARY ROVERS

SPACE ENERGY CONVERSION
R&T BASE FY91
RECHARGEABLE LITHIUM BATTERY TECHNOLOGY

LI-TIS₂ CELL
NASCAP/LEO SSF DESIGN IMPROVEMENTS

SHOWN

- SAMPLE CALCULATIONS OF ELECTRICAL POTENTIALS AROUND SPACE STATION FREEDOM (SSF) USING NASA CHARGING ANALYSIS PROGRAM FOR LOW EARTH ORBIT (NASCAP/LEO)

OBJECTIVE

- TO DEVELOP 3D COMPUTER MODELLING TECHNIQUES FOR PREDICTING SPACECRAFT ELECTRICAL INTERACTIONS (e.g. GROUND POTENTIAL, PARASITIC CURRENTS, ELECTRICAL SPUTTERING AND ARCING) WITH THE LEO ENVIRONMENT

ACCOMPLISHMENT

- DEVELOPED NASCAP/LEO (3D COMPUTER MODELLING)
  - APPLIED MODEL TO SPACE STATION FREEDOM
    - VERIFIED NEED FOR SPACE PLASMA GROUNDING DEVICE TO PREVENT ARCING AND SPUTTERING
    - SSF PROGRAM OFFICE IMPROVED SPACECRAFT DESIGN CHANGE

BENEFITS

- ENABLES PREDICTIONS OF COMPLEX ELECTRICAL INTERACTIONS WITH THE SPACE ENVIRONMENT
  - REDUCES RISK OF ELECTRICAL ARCING AND SPUTTERING
  - IMPROVES SPACECRAFT RELIABILITY (REDUCES UPSETS BY >90%)
  - 3X INCREASE IN SPACECRAFT LIFETIME (FROM 5 YEARS TO >15 YEARS)

APPLICABLE MISSIONS

- SPACE STATION FREEDOM
- SPACE SHUTTLE MISSIONS
- LEO-ORBITING PLATFORMS (e.g. EOS, COLUMBUS)
- ALL LEO SPACECRAFT

SPACE ENERGY CONVERSION

R&T BASE

FY91
NASCAP/LEO VALIDATION STUDIES
SPACE STATION FREEDOM

COLOR LEGEND

-0.80
-0.70
-0.60
-0.50
-0.40
-0.30
-0.20
-0.10
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
1.00
1.10

MINIMUM POTENTIAL = -6.87E-01
MAXIMUM POTENTIAL = 9.96E-01
1.00 XZ 33.00 1.00 XX 17.00  CUTPLANE OFFSET Y = 10.00

NASCAP/LEO – S-CUBED
SIMULATION – J. HERR, SVERDRUP TECHNOLOGY

CD-90-46907
ADVANCED PHOTOVOLTAIC SOLAR ARRAY
(APSA)

SHOWN
- STOWED APSA ARRAY MOUNTED ON VIBRATION FIXTURE FOR GROUND TESTING

OBJECTIVE
- TO DEVELOP ULTRA LIGHT WEIGHT SOLAR ARRAYS WITH A 10 FOLD IMPROVEMENT IN SPECIFIC POWER (W/KG)

ACCOMPLISHMENT
- DEMONSTRATED VIA VIBROACOUSTIC GROUND TESTING THAT AN ULTRA LIGHT WEIGHT (140 W/KG) SOLAR ARRAY DESIGN CAN SURVIVE A LAUNCH

BENEFITS
- 3-5X IMPROVEMENT IN SPECIFIC POWER OVER CURRENT RIGID-PANEL ARRAYS (HIGHER POWER ENABLES LOWER MASS)
- ENABLES DOUBLING OF MAXIMUM MISSION DISTANCE FROM SUN FROM 1.6 TO 3.2 AU

APPLICABLE MISSIONS
- LEO/GEO COMMERCIAL MISSIONS
- LEO/GEO/INTERPLANETARY SCIENTIFIC MISSIONS
- EOS POLAR PLATFORM
- DOD MISSIONS

SPACE ENERGY CONVERSION
R&T BASE
FY91
HOT ROCKET TECHNOLOGY

SHOWN
- 14 LB FORCE, STORABLE PROPELLANT (NITROGEN TETROXIDE/MONOMETHYL HYDRAZINE) THRUSTERS. ON LEFT: NEW HIGH TEMPERATURE IRIDIUM-COATED RHENIUM CHAMBER. ON RIGHT: STATE-OF-THE-ART (SOA) SILICIDE-COATED COLUMBIUM CHAMBER

OBJECTIVE
- TO DEMONSTRATE REVOLUTIONARY PERFORMANCE IMPROVEMENT (SPECIFIC IMPULSE & CONTAMINATION) FOR STORABLE PROPELLANT PROPULSION SYSTEMS

ACCOMPLISHMENT
- DEMONSTRATED FABRICATION TECHNOLOGIES FOR ULTRA-HIGH TEMPERATURE MATERIALS (800°C ABOVE SOA)
  - OBTAINED SIGNIFICANT (6%) PERFORMANCE IMPROVEMENT OVER SOA
  - FILM COOLING (A MAJOR CONTAMINATION SOURCE) ELIMINATED

BENEFITS
- INCREASED PERFORMANCE PROVIDES 1 YEAR LIFE EXTENSION FOR A SPECIFIC DOD MISSION
- ELIMINATION OF FILM COOLING REDUCES SPACECRAFT CONTAMINATION

APPLICABLE MISSIONS
- STATIONKEEPING, DRAG MAKEUP, APOGEE, OR REACTION CONTROL PROPULSION FOR COMMERCIAL/DOD/NASA SATELLITES
HIGH POWER ELECTRIC PROPULSION

SHOWN
• A MAGNETOPLASMADYNAMIC THRUSTER (MPDT) OPERATING AT OVER 200 KW

OBJECTIVE
• TO DEMONSTRATE MPDT OPERATION AT POWER LEVELS REQUIRED FOR SPACE EXPLORATION INITIATIVE (SEI) PRECURSOR, AND SEI CARGO AND PILOTED MISSIONS

ACCOMPLISHMENT
• CONSTRUCTED HIGH POWER (350 KW) MPDT TEST STAND
• DEMONSTRATED INCREASED MPDT POWER LEVELS (FROM 30 KW TO OVER 200 KW) AT SPECIFIC IMPULSES TO APPROXIMATELY 3700 SECONDS
• DEMONSTRATED 2X INCREASE IN THRUST EFFICIENCY

BENEFITS
• PROVIDES SIMPLE, ROBUST THRUSTER CANDIDATE FOR HIGH POWER ELECTRIC PROPULSION APPLICATIONS

APPLICABLE MISSIONS
• SEI PRECURSOR MISSIONS
• CARGO AND PLANETARY MISSIONS
FOIL BEARING TECHNOLOGY

SHOWN
- TYPICAL FOIL BEARING CONFIGURATION

OBJECTIVE
- TO DEVELOP ADVANCED CRYOGENIC FOIL BEARING TECHNOLOGY TO PROVIDE LONG LIFE, HIGH LOAD CAPACITY, AND GOOD STABILITY

ACCOMPLISHMENT
- TESTED FOIL BEARINGS UNDER WIDE RANGE OF CONDITIONS ANTICIPATED IN APPLICATION
  - PERFORMED 150 START-STOP CYCLES WITH NO NOTICEABLE WEAR
  - DEMONSTRATED STABILITY AT ALL SPEEDS (10-97,000 RPM)
  - ACHIEVED 240 PSI LOAD CAPACITY IN LIQUID HYDROGEN AND 300 PSI LOAD CAPACITY IN LIQUID NITROGEN
- DEVELOPED COMPUTATIONAL FOIL BEARING ANALYSIS TOOL

BENEFITS
- ELIMINATE PUMP SPEED CONSTRAINTS ASSOCIATED WITH ROLLING ELEMENTS
- SIGNIFICANT INCREASES IN BEARING LIFE (POTENTIALLY UNLIMITED LIFE)
- COOLANT REQUIREMENTS SIGNIFICANTLY REDUCED
- IMPROVED BEARING DYNAMIC CHARACTERISTICS

APPLICABLE MISSIONS
- LUNAR MISSIONS
- INTERPLANETARY MISSIONS
- NASP
- EARTH-TO-ORBIT UPPERSTAGE PROPULSION
- LOX, HYDROGEN, AND HYDROCARBON TURBOPUMPS
BRUSH SEAL TECHNOLOGY

SHOWN
● TYPICAL BRUSH SEAL CONFIGURATION

OBJECTIVE
● TO DEVELOP COMPLIANT, DYNAMICALLY STABLE, LONG LIFE, LOW LEAKAGE SEAL TECHNOLOGY FOR CRYOGENIC AND HOT GAS APPLICATIONS

ACCOMPLISHMENT
● DEVELOPED BRUSH SEAL TECHNOLOGY
  - VERIFIED SEAL AGAINST KNOWN LOW LEAKAGE RATES IN GAS MEDIUMS (STEAM, AIR, ARGON, GASEOUS NITROGEN, CARBON MONOXIDE, AND HELIUM)
  - DEMONSTRATED LOW LEAKAGE RATE IN FIRST TESTS IN CRYOGENIC FLUID (LIQUID NITROGEN)

BENEFITS
● 1/3 TO 1/2 REDUCTION IN LEAKAGE RATES COMPARED TO STATE-OF-THE-ART CONVENTIONAL LABYRINTH SEALS

APPLICABLE MISSIONS
● UPPER STAGE PROPULSION SYSTEMS, ELECTRIC POWER SYSTEMS
● EARTH-TO-ORBIT PROPULSION: SPACE TRANSPORTATION MAIN ENGINE
MOLECULAR COMPUTATIONAL FLUID DYNAMICS (MCFD)

SHOWN

- Numerical simulation of small thruster plume expansions into a perfect vacuum (bottom) and a typical experimentally obtainable vacuum (top)

OBJECTIVE

- To develop accurate predictive analysis tools for viscous nozzle flows in order to assess small thruster plume impacts (contamination, thermal and momentum transfer, and communications) and to assess facility effects on plumes

ACCOMPLISHMENT

- Developed numerical codes for analysis of viscous nozzle flows
- Directly compared numerical code results to state-of-the-art continuum code results and to lab experiments
- Evaluated facility effects on ground-based plume measurements

BENEFITS

- Enables accurate prediction of small thruster plume flows (unavailable from SOA plume codes or ground based experiments)

APPLICABLE MISSIONS

- On-board propulsion
TOUGHENED UNI-PIECE FIBROUS INSULATION (TUFI)
THERMAL PROTECTION MATERIAL

SHOWN
○ IMPROVED DAMAGE RESISTANCE OF CURRENT THERMAL PROTECTION MATERIAL TECHNOLOGY

OBJECTIVE
○ TO DEVELOP NEW THERMAL PROTECTION MATERIALS AND SYSTEMS FOR ADVANCED SPACECRAFT AND HYPERSONIC VEHICLES
○ TO DEVELOP ADVANCED COMPUTER MODELING AND TESTING METHODS OF THERMAL PROTECTION SYSTEMS

ACCOMPLISHMENT
○ DEVELOPED NEW THERMAL PROTECTION MATERIAL, TUFI, AND CERTIFIED MATERIAL DURING SIX SPACE SHUTTLE FLIGHTS
○ DEVELOPED MODIFIED TUFI MATERIAL AND DEMONSTRATED MULTIPLE EXPOSURES (VIA ARCJET TESTS) AT 2900°F

BENEFITS
○ 10 TO 1000 TIMES IMPROVED IMPACT RESISTANCE AS COMPARED TO STATE-OF-THE-ART BASELINE REACTION CURED GLASS (RCG) COATING
○ ENABLES EASIER REWATERPROOFING COMPARED TO RCG COATING SYSTEM
○ EASILY ADAPTS TO HEAT SHIELD MATERIALS WITH COMPLEX SHAPES (RCG TOO RIGID)

APPLICABLE MISSIONS
○ SPACE SHUTTLE IN HIGH DAMAGE AREAS
○ PLANETARY PROBES (MESUR, PV PRIME)
○ AEROBRAKES
○ DOD VEHICLES (ATF, B-2, SDIO/SSTO)
○ HYPERSONIC VEHICLES (SWERVE, PEGASUS WING GLOVE)
IMPACT RESISTANCE OF RSI COATING SYSTEMS

SHUTTLE TECHNOLOGY, 1978
RCG - O

CURRENT TECHNOLOGY
TUFI - ▲

0.015 in.

SIGNIFICANT
DAMAGE

0.1 in.

NO DAMAGE

DAMAGE RESISTANCE AS A FUNCTION
OF AREAL WEIGHT
IMPACT = 1.8 x 10^{-2} ft-lb

RELATIVE DAMAGE RESISTANCE

1000

100

10

1

AREAL WEIGHT, lb/ft^2

0

0.2

0.4
ADAPTIVE UNSTRUCTURED MESHES

**SHOWN**
- Comparison of adaptive (top) and nonadaptive (bottom) mesh computations on a thermally-loaded structure. Graph shows accuracy of mesh results compared to actual thermal load. For nonadaptive meshing to achieve same results as adaptive meshing, computer processing time is increased (from 300 to 9400 sec) and mesh size is increased (from 200 to 5200 nodes).

**OBJECTIVE**
- To develop an adaptive meshing technique for transient thermal analysis of structures in order to more accurately calculate the response of the structures to transient thermal loads.

**ACCOMPLISHMENT**
- Developed adaptive meshing algorithm
- Applied algorithm to thermal analysis of a structure with a given thermal load
  - Demonstrated 10x improvement in computational efficiency compared to state-of-the-art nonadaptive methods

**BENEFITS**
- Requires fewer number of computational cycles
  - Reduces computational costs
  - Saves analyst time
- Enables improved solutions in less time with smaller mesh sizes

**APPLICABLE MISSIONS**
- NASP
- Hypersonic Vehicles
- Space Transportation Systems
TRANSIENT ADAPTIVE MESHING IMPROVES ACCURACY AND EFFICIENCY OF PLATE THERMAL ANALYSIS

50,000 Btu/ft²·sec

Speed 2 in/sec

Plate

500

600

Temp, °F

400

300

x

Exact

Adaptive unstructured mesh (200 Nodes; 300 CPU sec)

Nonadaptive structured mesh (5,200 Nodes; 9,400 CPU sec)

Predicted temperatures within 2% of exact solution

Unstructured mesh order of magnitude more efficient
RADIATION RESISTANCE OF NOVEL TIN-CONTAINING POLYIMIDE

SHOWN
- TIN-CONTAINING POLYIMIDE MATERIAL

OBJECTIVE
- TO IMPROVE ATOMIC OXYGEN RESISTANCE OF POLYMER MATERIALS IN THE SPACE ENVIRONMENT

ACCOMPLISHMENT
- DEVELOPED THREE POLYMER MATERIAL SYSTEMS WITH Bis(TRIPHENYL TIN) OXIDE (BTO) MOLECULAR STRUCTURE (POLYETHERIMIDE, POLYSULFONE, AND POLYPYROMELLITIMIDE)
- TESTED MODIFIED POLYMER SYSTEMS AGAINST ATOMIC OXYGEN, ULTRAVIOLET, AND ELECTRON BOMBARDMENT
  - 40% DECREASE IN ATOMIC OXYGEN EROSION RATE
  - NO EFFECT ON POLYMER RESISTANCE TO ULTRAVIOLET AND ELECTRON BOMBARDMENT

BENEFITS
- ENABLES LONGER-LIFE, MORE DURABLE, BETTER PERFORMING SPACECRAFT MATERIALS
- ENABLES MULTIPLE PRODUCT FORMS (FILM, COATING, THICK CASTING, ADHESIVE, OR MATRIX RESIN)

APPLICABLE MISSIONS
- LONG DURATION LOW EARTH ORBIT PLATFORMS AND SATELLITES
- SPACE STATION FREEDOM
- EARTH-RESOURCE-MONITORING PLATFORMS
- LONG DURATION SCIENCE MISSIONS
- DEPLOYABLE STRUCTURES

MATERIALS & STRUCTURES FY91
R&T BASE
EXPOSURES OF POLYETHERIMIDE / BTO FILMS (10% BTO)

- BTO reduces atomic oxygen erosion of polyetherimide by a third.

- Pure polyetherimide and polyetherimide/BTO lose C=O with electron exposure.

- Pure polyetherimide and polyetherimide/BTO show no chemical change with UV exposure.
LONG DURATION EXPOSURE FACILITY (LDEF) SUMMARY

METEOROIDS & DEBRIS (M&D):
- Current M&D Environment Models Inaccurate
- Small Particle Impact Flux Overestimated
- Large Particle Impact Flux Underestimated
- M&D Impacts Are Not Random In Time And Are Directionally Anisotropic (Non-Uniform)
- Detected Beta Meteoroids (Small Particles From Solar Direction) On Spacecraft

IONIZING RADIATION:
- Current Isotopic Model For Trapped Protons In South Atlantic Magnetic Field Anomaly Is In Error By A Factor Of Three
- Discovery of Radioactive 7Be On All LDEF Front Surfaces (10-100X Higher Concentration of Cosmic Radiation By-Product in Upper Atmosphere Than Expected)
- LDEF Has Provided Statistically Significant Ionizing Measurements In Space

CONTAMINATION:
- Silicones Most Prevalent Molecular Contaminant
- UV And AO Exposure Attached Molecular Contamination To LDEF Surfaces
- However, On Some Leading Surfaces, AO-eroded Contamination
- Contamination of Thermal Control Surfaces Increases Solar Absorbance
- Contamination Of Solar Cell Covers Decreases Solar Transmission To Solar Cell
LONG DURATION EXPOSURE FACILITY SUMMARY (cont'd)

MATERIALS:

- UNEXPECTED ENVIRONMENTAL DEGRADATION OF MANY THERMAL CONTROL COATINGS
- SILOXANE-CONTAINING POLYMER FILMS MORE RESISTANT TO ATOMIC OXYGEN (AO) EROSION THAN TEFLOWN
- UNCOATED POLYMER-MATRIX COMPOSITES NOT RESISTANT TO ATOMIC OXYGEN EROSION
- 1000 ANGSTROM ALUMINUM COATING ON STAINLESS STEEL SUBSTRATE IS STABLE MIRROR/REFLECTOR SURFACE FOR INFRARED APPLICATIONS
- FIBER-REINFORCED ALUMINUM-MATRIX COMPOSITES EXTREMELY STABLE
- OXIDATION OF ALL THIN METALLIC FILMS (EXCEPT TIN AND PLATINUM) SHOWED EVIDENCE OF AT LEAST SLIGHT OXIDATION
- OPTICAL PROPERTIES OF GLASSES AFFECTED IN UV SPECTRAL REGIONS ONLY (DEGRADATION FROM SILICONE CONTAMINATION)

SYSTEMS:

- PASSIVE STABILITY/ VISCOUS DAMPER FUNCTIONED WELL
- BATTERIES AND WIRING HARNESSES PERFORMED WELL
- SILVER AND COPPER COATINGS ON OPTICAL SURFACES WERE OXIDIZED (REDUCES EFFICIENCY). DIELECTRIC AND METALLIC COATINGS WERE DELAMINATED BY THERMAL EFFECTS
LONG DURATION EXPOSURE FACILITY (LDEF) IONIZING RADIATION

- NASA - LaRC - OAST - RM

SHOWN

● BERYLLIUM 7 (COSMIC RADIATION BY-PRODUCT) DISTRIBUTION AROUND LDEF

OBJECTIVE

● TO ANALYZE LDEF IONIZING RADIATION DATA AND COSMIC RADIATION BY-PRODUCTS IN ORDER TO REFINING ENVIRONMENT, ATMOSPHERIC TRANSPORT, AND SPACECRAFT SHIELDING MODELS

ACCOMPLISHMENT

● ANALYZED LDEF IONIZING RADIATION DATA

  - DISCOVERED BERYLLIUM 7 ON ALL LDEF LEADING SURFACES (ABSENT ON THE TRAILING SURFACES DUE TO LDEF FIXED ATTITUDE)

BENEFITS

● ENABLES REFINEMENT OF ATMOSPHERIC TRANSPORT MODELS (10-1000 X HIGHER CONCENTRATION OF COSMIC RADIATION BY-PRODUCT IN UPPER ATMOSPHERE THAN EXPECTED)

● FURTHER UNDERSTANDING OF COSMIC RAY BOMBARDMENT AND ASSOCIATED ATMOSPHERIC PROCESSES ENABLES REFINEMENT OF SPACECRAFT SHIELDING REQUIREMENTS

APPLICABLE MISSIONS

● LOW EARTH ORBIT MISSIONS

MATERIALS & STRUCTURES FY91
R&T BASE
LDEF (Total Spacecraft)

Acquired Radioactivity

![Graph showing activity vs. side number](image)

- **Activity** ($10^3$ Counts/s per Detector)
- **Side No.** (See Inset)

**Inset**: LDEF Side No. (1-12)

**Legend**:
- Trailing Edge
- Leading Edge
- $^7$Be

Graph indicates a peak in activity near the leading edge.
LONG DURATION EXPOSURE FACILITY (LDEF) METEOROID AND DEBRIS

- NASA - LaRC

OBJECTIVE

- TO ANALYZE LDEF METEOROID AND DEBRIS DATA IN ORDER TO REFINE AND SIGNIFICANTLY IMPROVE CONFIDENCE IN SPACECRAFT METEOROID AND DEBRIS MODELS

ACCOMPLISHMENT

- OBTAINED SAMPLES OF METEOROID AND DEBRIS IMPACT DAMAGE ON TYPICAL SPACECRAFT SURFACES
- ANALYZED LDEF METEOROID AND DEBRIS DATA AND IDENTIFIED ERRORS IN EXISTING METEOROID AND DEBRIS MODELS:
  - SMALL PARTICLE FLUX, OVER PREDICTED
  - LARGE PARTICLE FLUX, UNDER PREDICTED
  - ANISOTROPIC DIRECTIONALITY, UNDER PREDICTED

BENEFITS

- ENABLES MORE ACCURATE PREDICTIONS OF METEOROID/DEBRIS FLUX IMPACT DAMAGE
- ENABLES MORE EFFICIENT DESIGNS FOR METEOROID AND DEBRIS SHIELDING

APPLICABLE MISSIONS

- SPACE STATION FREEDOM
- EARTH OBSERVING SYSTEM
- SPACE EXPLORATION

MATERIALS & STRUCTURES FY91

R&T BASE
MULTI-FLEXIBLE BODY DYNAMIC MODELING TOOLS

SHOWN

- SPACE STATION COMPUTATIONAL CONTROLS WORKSTATION WITH THE PARALLEL PROCESSING UNIT

OBJECTIVE

- TO DEVELOP INNOVATIVE TECHNIQUES, SOLUTION ALGORITHMS, SOFTWARE, AND HARDWARE ARCHITECTURES TO FORM A COMPUTATIONAL CONTROL WORKSTATION THAT UTILIZES THE ADVANTAGES OF PARALLEL PROCESSING COMPUTATIONS

ACCOMPLISHMENT

- DEVELOPED AND DEMONSTRATED ORDER-N MULTI-FLEXIBLE BODY DYNAMIC MODELING TOOLS ON A PARALLEL COMPUTATIONAL CONTROLS ANALYSIS WORKSTATION

BENEFITS

- QUANTUM LEAP IN SIMULATION TECHNOLOGY
- ENABLES REAL-TIME SIMULATION OF FLEXIBLE BODY MODELS FOR SPACE STATION ASSEMBLY
- PROVIDES ULTRA-FAST PARALLEL PROCESSING ARCHITECTURE IN DESKSIDE ENVIRONMENT
- PROVIDES CONSISTENT USER FRIENDLY INTERFACE AND STATE-OF-THE-ART POST-PROCESSING OPTIONS
- ENABLES USERS TO UNDERSTAND AND PERFORM ANALYSIS FASTER THROUGH ANIMATION OF MOTION

APPLICABLE MISSIONS

- SPACE STATION FREEDOM

INFORMATION & CONTROLS FY91 R&T BASE
PHOTONIC DEVICES FOR PLANETARY LANDER

SHOWN
- TYPICAL MARS TERRAIN IMAGE AND SEQUENCE OF STEPS TO MEASURE LOCATION OF LANDING SITE IN THE IMAGE

OBJECTIVE
- TO DEVELOP OPTICAL PATTERN RECOGNITION TECHNOLOGY FOR AUTONOMOUS PLANETARY LANDING TO ALLOW CLOSED-LOOP LANDER CONTROL AND MEASUREMENT OF LANDER VELOCITY

ACCOMPLISHMENT
- DEMONSTRATED CONTROL OF PLANETARY LANDER MOCKUP USING PHOTONIC DEVICES (BINARY PHASE-ONLY FILTERS)

BENEFITS
- 10X SMALLER LANDING AREA FOOTPRINT THAN PREVIOUS LANDERS
- SAFE SET DOWN 10X CLOSER TO INTERESTING TERRAIN FEATURES
- 16% SCALE DISTORTION TOLERANCE BETWEEN SUBSEQUENT IMAGES
- MEASUREMENT OF VELOCITY USING ONLY LANDER CAMERA

APPLICABLE MISSIONS
- MARS ROVER SAMPLE RETURN (MRSR)
- MARS ENVIRONMENTAL SURVEY (MESUR)
Terrain Recognition for Lander Guidance

Landing sequence:

1. Select landing site
2. Lander descent
3. Take new image
4. Make contour map
5. Correlate with filter made from previous image
6. Make new filter from site centered on correlation peak
7. Guide lander to recenter over target site

Applications

- Mars Rover Sample Return Lander footprint reduction.
- Mars Environmental Survey Lander velocity and altitude measurement.
EXTRAVEHICULAR ACTIVITY (EVA) EXTRAVEHICULAR MOBILITY UNIT (EMU)
ELECTRONIC CUFF CHECKLIST

SHOWN

- EVA EMU ELECTRONIC CUFF CHECKLIST

OBJECTIVES

- TO DESIGN, DEVELOP, AND TEST A FUNCTIONAL PROTOTYPE OF AN EXTRAVEHICULAR MOBILITY UNIT (EMU) ELECTRONIC CUFF CHECKLIST

ACCOMPLISHMENTS

- DEVELOPED FUNCTIONAL PROTOTYPE OF EXTRAVEHICULAR MOBILITY UNIT (EMU) ELECTRONIC CUFF CHECKLIST FOR POTENTIAL USE AS REPLACEMENT TO CURRENT PAPER PROCEDURAL CHECKLIST

BENEFITS

- SIGNIFICANTLY IMPROVES ASTRONAUT EVA PRODUCTIVITY
  - 20X LARGER DATABASE (>200 PAGES)
  - LESS CUMBERSOME TO USE
  - LESS TIME-CONSUMING TO ASSEMBLE (10X FASTER)
  - UP-TO-DATE WITH CURRENT TRAINING PROCEDURES
- BETTER CONFIGURATION MANAGEMENT CONTROL BY UTILIZING ACCESS-CONTROLLABLE ELECTRONIC DATABASE

APPLICABLE MISSIONS

- SPACE STATION FREEDOM
- SPACE SHUTTLE
VIRTUAL ENVIRONMENT FACILITY

SHOWN
- VIRTUAL ENVIRONMENT DISPLAY FOR TELEOPERATIONS AND TELEROBOTIC PLANNING

OBJECTIVES
- TO DEVELOP VIRTUAL ENVIRONMENT TECHNOLOGY FOR NASA MISSIONS IN ORDER TO PROVIDE A UNIQUE MEANS OF EMMERGING THE USER IN A REAL OR HYPOTHETICAL SIMULATION SUCH THAT THE USER EXPERIENCES OBJECTS AND SITUATIONS AS IF THEY WERE REAL

ACCOMPLISHMENTS
- DEVELOPED SOFTWARE TO DEMONSTRATE VIRTUAL REALITY CONTROL OF TELEROBOTIC MANIPULATOR
- DEVELOPED SOFTWARE TO DEMONSTRATE USE OF VIRTUAL REALITY FOR AEROTHERMODYNAMIC APPLICATIONS

BENEFITS
- PROVIDES QUICK PROTOTYPE WHICH CAN BE EASILY TESTED TO REFINE CONCEPTS AND IDEAS
- ENABLES MISSION ANALYSIS AND TRAINING AT VERY LOW COST WHICH WOULD OTHERWISE REQUIRE EXPENSIVE REAL WORLD FACILITIES (SUCH AS A WIND TUNNEL OR LARGE-SCALE MOCKUP OF A LUNAR SURFACE)
- ENABLES IMPROVED TELEOPERATION PLANNING, ASTRONAUT MISSION TRAINING, AND ADVANCED AEROTHERMODYNAMIC ANALYSIS

APPLICABLE MISSIONS
- SPACE STATION FREEDOM
- SPACE EXPLORATION INITIATIVE MISSIONS

HUMAN SUPPORT FY91
R&T BASE
Virtual Environment Display for Teleoperations & Telerobotic Planning

Virtual Workplace

Real Workplace

Video

Ethernet
AMT MOBILE COMMUNICATIONS

- NASA - JPL - OAST - RC -

SHOWN

- SMALL REFLECTOR ANTENNA TRACKING A PSEUDO SATELLITE SIGNAL USING MECHANICAL DITHERING

OBJECTIVE

- TO DEVELOP AN ANTENNA FOR LAND-MOBILE SATELLITE COMMUNICATIONS AT Ka-BAND

ACCOMPLISHMENT

- DEVELOPED ADVANCED COMMUNICATION TECHNOLOGY SATELLITE (ACTS) MOBILE TERMINAL (AMT) SMALL REFLECTOR ANTENNA AND DEMONSTRATED TRACKING OF A PSEUDO SATELLITE SIGNAL

BENEFITS

- SMALL REFLECTOR ANTENNA IS LOW-PROFILE, ROBUST, AND LOW-COST FOR LAND-MOBILE APPLICATIONS
- PROVIDES SIGNIFICANT SIMPLIFICATION OF RF ELECTRONICS THROUGH USE OF TRACKING BASED ON MECHANICAL DITHERING VERSUS PSEUDO-MONOPULSE

APPLICABLE MISSIONS

- SPACE EXPLORATION INITIATIVE MISSIONS
- ROVER MISSIONS
HIGH EFFICIENCY Ka-BAND (32 GHz)
TRAVELLING WAVE TUBE AMPLIFIER (TWTA) FOR CASSINI

- NASA - LeRC - OAST -

SHOWN

- PRELIMINARY TECHNOLOGY TRAVELING WAVE TUBE AMPLIFIER (TRAVELLING WAVE TUBE ON RIGHT, BRASSBOARD ELECTRONIC POWER CONDITIONER ON LEFT)

OBJECTIVE

- TO IMPROVE EFFICIENCY AND RF OUTPUT POWER OF A 32 GHz LOW-POWER (10 WATTS) TRAVELING WAVE TUBE AMPLIFIER IN ORDER TO MEET THE COMMUNICATIONS REQUIREMENTS OF THE CASSINI MISSION TO SATURN

ACCOMPLISHMENT

- IMPROVED TWTA EFFICIENCY AND RF OUTPUT POWER

BENEFITS

- 2X IMPROVEMENT IN EFFICIENCY (40%) COMPARED TO CURRENT STATE-OF-THE-ART SPACE QUALIFIED TWTA (20%)
- 2X IMPROVEMENT IN RF OUTPUT POWER FROM 5 WATTS TO 10 WATTS
- Ka-BAND OFFERS IMPROVED COMMUNICATIONS FROM DEEP SPACE
- ENABLES TRANSMISSION TO EARTH OF ALL CASSINI MISSION DATA (X-BAND SYSTEM CAPABLE OF TRANSMITTING ONLY 1/3 OF MISSION DATA)

APPLICABLE MISSIONS

- CASSINI
- LUNAR/MARS MISSIONS
- SOLAR PROBE

SPACE COMMUNICATIONS FY91 R&T BASE
FIRST TERAHERTZ FOCAL PLANE ARRAY

SHOWN
- 16x16 (256 ELEMENT) 0.8 THz FOCAL PLANE ANTENNA ARRAY

OBJECTIVE
- TO DEVELOP REMOTE SENSING TECHNOLOGIES IN THE TERAHERTZ REGION OF THE ELECTROMAGNETIC SPECTRUM

ACCOMPLISHMENT
- DEVELOPED FIRST SQUARE ANTENNA ARRAY OPERATING NEAR THE TERAHERTZ RANGE (0.8 THz) FOR INTEGRATION INTO SENSOR SYSTEM

BENEFITS
- TERAHERTZ ARRAY TECHNOLOGY WILL ENABLE REMOTE SENSING OF CRITICAL CHEMICAL SPECIES
  - FOR THE STUDY OF THE MAKE-UP OF DISTANT INTERSTELLAR GAS CLOUDS
  - FOR THE STUDY OF OZONE AND OZONE DEPLETION IN THE UPPER ATMOSPHERE OF THE EARTH

APPLICABLE MISSIONS
- UPPER ATMOSPHERE EARTH SCIENCE MISSIONS
- SUBMILLIMETER ASTROPHYSICS MISSIONS
MICRO-SENSOR FOR FLOW MEASUREMENTS

- NASA - UNIVERSITY OF CINCINNATI - OAST - RS

**SHOWN**
- MICRO-SENSOR FOR FLUID VELOCITY MEASUREMENTS, ON A HUMAN FINGERTIP

**OBJECTIVE**
- TO DEVELOP TECHNOLOGIES FOR MONITORING AND VERIFYING THE HEALTH AND PERFORMANCE OF SPACE VEHICLES AND PROPULSION SYSTEMS

**ACCOMPLISHMENT**
- DEMONSTRATED MICRO-SENSOR THAT CAN BE ADAPTED OVER FULL RANGE OF ENGINE ENVIRONMENTS
  - AT HIGH TEMPERATURES (e.g. FOR COMBUSTION CHAMBERS)
  - AT CRYOGENIC TEMPERATURES (e.g. FOR PUMP AND FUEL LINES)
- DEVELOPED NOVEL BRAZING TECHNIQUE FOR ATTACHING SENSOR TO ENGINE INTERIOR

**BENEFITS**
- SMALL SENSOR SIZE ALLOWS ACCURATE MEASUREMENT WITHOUT DISRUPTING FLUID FLOW
- BRAZING TECHNIQUE ENABLES SENSOR-ENGINE ATTACHMENT IN SECONDS vs. TENS OF HOURS FOR STATE-OF-THE-ART ATTACHMENT TECHNIQUES
- SENSOR CAN BE USED TO MEASURE FLOW OF ANY LIQUID OR GAS (e.g. FOR PROPULSION, LIFE SUPPORT, CRYOGENIC COOLING FLUID)

**APPLICABLE MISSIONS**
- PROPULSION SYSTEMS
- ANY MISSION USING FLUIDS THAT REQUIRE REAL-TIME, NON-INTRUSIVE MONITORING

UNIVERSITY SPACE RESEARCH FY91 R&T BASE
CO₂-TO-OXYGEN DEMONSTRATION PLANT

- NASA - UNIVERSITY OF ARIZONA - OAST - RS

**SHOWN**
- THE CO₂-TO-OXYGEN TEST SYSTEM

**OBJECTIVE**
- TO DEVELOP TECHNOLOGIES FOR THE PRODUCTION OF OXYGEN, HYDROGEN, AND OTHER VOLATILES, METALS, GLASS/ CERAMICS, AND COMPOSITES FROM LUNAR REGOLITH AND THE MARTIAN ATMOSPHERE

**ACCOMPLISHMENT**
- DEMONSTRATED ZIRCONIUM-BASED TEST CELL TO SEPARATE OXYGEN FROM CARBON DIOXIDE
  - GENERATED MORE THAN 10 GRAMS/DAY
- CONDUCTED EXTENSIVE TESTS ON SINGLE CELL SYSTEM AND LIMITED TESTING OF 16 CELL SYSTEM

**BENEFITS**
- ENABLES IN SITU GENERATION OF OXYGEN FROM MARTIAN ATMOSPHERE
  - USEFUL FOR LIFE SUPPORT, BUT GREATEST BENEFIT IS FOR OXYGEN-BASED PROPULSION SYSTEM REFUELING
- ENABLES SIGNIFICANT REDUCTION IN EARTH-TO-ORBIT MASS REQUIREMENTS OF LONG-TERM MARS MISSIONS

**APPLICABLE MISSIONS**
- MARS EXPLORATION MISSIONS
- MARS COLONIZATION MISSIONS

UNIVERSITY SPACE RESEARCH FY91 R&T BASE
ORBITAL ACCELERATION RESEARCH EXPERIMENT (OARE)

- NASA = LaRC
- OAST
- RX

SHOWN
- ORBITER PERIODIC DRAG ACCELERATION MEASUREMENTS OVER 3 1/2 ORBITS DURING STS-40 MISSION

OBJECTIVES
- TO DETERMINE AERODYNAMIC FORCES ACTING ON THE SHUTTLE ORBITER ON-ORBIT AND DURING THE HIGH-ALTITUDE (FREE-MOLECULAR AND TRANSITIONAL FLOW) PORTION OF ATMOSPHERIC ENTRY

ACCOMPLISHMENTS
- DEMONSTRATED CAPABILITY TO SENSE AERODYNAMIC FORCES (MICRO-G ACCELERATION LEVELS) AT SHUTTLE ORBITAL ALTITUDES

BENEFITS
- ENABLES VALIDATION OF STATE-OF-THE-ART DESIGN TECHNIQUES (3D RAREFIED FLUID FLOWS, ORBITAL DRAG AND ORBITAL DECAY PREDICTIONS) FOR VEHICLES THAT WILL OPERATE AT HIGH ALTITUDES WITHIN THE ATMOSPHERE AND IN LOW-EARTH ORBIT

APPLICABLE MISSIONS
- SPACE STATION FREEDOM
- ADVANCED SPACE TRANSPORTATION

SPACE FLIGHT FY91
R&T BASE
SHUTTLE INFRARED LEESIDE TEMPERATURE SENSING (SILTS)

SHOWN

• TYPICAL TEMPERATURE VARIATION OVER ORBITER LEESIDE (UPPER SURFACE) FUSELAGE DURING STS-40 ENTRY

OBJECTIVES

• TO OBTAIN HIGH-SPATIAL-RESOLUTION MEASUREMENTS OF SHUTTLE ORBITER LEESIDE SURFACE TEMPERATURE DURING ENTRY

ACCOMPLISHMENTS

• OBTAINED HIGH-SPATIAL-RESOLUTION MEASUREMENTS OF ORBITER LEESIDE SURFACE TEMPERATURE USING A SCANNING INFRARED RADIOMETER LOCATED ATOP ORBITER VERTICAL TAIL (STS-35 AND STS-40)

BENEFITS

• ENABLES VALIDATION OF STATE-OF-THE-ART DESIGN TECHNIQUES (3D FLUID FLOWS) TO BE APPLIED TO ADVANCED HYPERSONIC VEHICLES

APPLICABLE MISSIONS

• ADVANCED SPACE TRANSPORTATION
SILTS LEESIDE FUSELAGE TEMPERATURE DATA

TYPICAL IMAGE DATA

CENTERLINE DISTRIBUTION

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STTS-40
Mach = 8.7
Altitude = 48.7 km
\( \alpha = 37.5 \text{ deg} \)

Temperature

Increasing Temperature

\( x / L \)
MIDDECK 0-GRAVITY DYNAMICS EXPERIMENT (MODE)

- MIT STUDENTS SHOWING THE MCDONNELL DOUGLAS PROVIDED STRUCTURAL TEST ARTICLE

OBJECTIVE
- TO MEASURE MECHANICAL DYNAMICS OF A JOINT TRUSS STRUCTURE AND THE SLOSH DYNAMICS OF FLUIDS IN MICROGRAVITY ENVIRONMENT

ACCOMPLISHMENT
- DEVELOPED AND FLIGHT QUALIFIED A SHUTTLE MIDDECK DYNAMIC TEST FACILITY
- FLOWN SUCCESSFULLY ABOARD STS-48, SEPTEMBER 12-16, 1991
  - OBTAINED APPROXIMATELY 300 MILLION MEASUREMENTS
  - COMPLETED STRUCTURAL AND FLUID DYNAMICS TESTS

BENEFITS
- FIRST SHUTTLE MIDDECK TEST FACILITY CAPABLE OF INDUCING KNOWN DISTURBANCES IN TEST ARTICLES AND MEASURING THEIR DYNAMIC RESPONSES
- STRUCTURAL AND FLUID DYNAMICS MEASUREMENT TESTS INDICATE
  - FEASIBILITY OF LESS CONSERVATIVE SPACECRAFT DESIGN
  - GREATER VISCOSITY EFFECTS THAN MODELS PREDICTED

APPLICABLE MISSIONS
- FUTURE TRANSFER VEHICLES FOR FUEL DEPOTS
- PRECISION STRUCTURES OR SPACECRAFTS
- LARGE FLUID MASS FRACTION SPACECRAFT
- PLANETARY SPACECRAFT
- SPACE STATION FREEDOM

IN-STEP FY91
TANK PRESSURE CONTROL EXPERIMENT (TPCE)

- NASA - LeRC - OAST - RX -

**SHOWN**
- Tank Pressure Control Experiment

**OBJECTIVES**
- Investigate fluid dynamics and thermodynamics of jet mixing as a means of pressure control
- Obtain data for validation of ground-based empirical models and computer codes

**ACCOMPLISHMENTS**
- Flown successfully aboard STS-43, Aug 2, 1991
- Verified that jet-induced fluid mixing technology is an effective pressure control technique for low-gravity cryogenic tanks
- Obtained excellent video data for comparison of fluid dynamics with drop tower results and preliminary computational results
- Obtained extended low-G temperature/pressure data for determination of fluid mixing times

**BENEFITS**
- Enables the use of lighter weight cryogenic tanks for space platforms & advanced transportation systems
- Video and data results enable accurate upgrading and validation of ground-based empirical models and computer codes

**APPLICABLE MISSIONS**
- Future space transportation systems, depots, satellites, and installations that utilize cryogenic fluids

IN-STEP R&T BASE FY91
The program consists of a continuum of space research and technology activities ranging from initial research to the full-scale test of prototype equipment in space. Activities include work that is performed by in-house staff at the NASA Centers, University researchers supported by NASA-funded grants and contracts, and industrial aerospace organizations under contract to NASA. These diverse activities provide advances in technology breakthroughs that may revolutionize a technical discipline or mission concept. The work is managed and coordinated by OAST through a process that integrates the best available talent and capability in NASA, industry, and universities into a National civil space research and technology program.