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ISOTOPE BRAYTON GROUND DEMONSTRATION TESTING AND FLIGHT QUALIFICATION

REPORT NO. 74-311015-1
DECEMBER 9, 1974

EXECUTIVE SUMMARY

AC03-76SF01123

Prepared for:
UNITED STATES ATOMIC
ENERGY COMMISSION
SPACE NUCLEAR SYSTEMS DIVISION
SOLICITATION NO. SNS-RFP-75-1-CAO

MS 3568-OD

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GENERAL ELECTRIC
COMPANY
SPACE DIVISION
VALLEY FORGE SPACE CENTER
P. O. BOX 8555 PHILADELPHIA, PA. 19101

December 6, 1974

DANIEL J. FINK
VICE PRESIDENT AND
GENERAL MANAGER

Mr. William G. Orr
Vice President and General Manager
AiResearch Manufacturing Company of Arizona
402 South 36th Street
Phoenix, Arizona 85010

Subject: Isotope Brayton Power Conversion System Program

Dear Mr. Orr:

We in General Electric's Space Division are pleased to team with you in support of the AEC's Isotope Brayton System Development and Test Program. Our confidence in the isotope Brayton system is based upon a careful assessment of the several power conversion technologies available and their relative state of maturity, combined with an evaluation of a broad spectrum of user mission requirements.

General Electric has supported NASA in Brayton technology development and in several mission application studies. In addition, we have been a major contractor to the AEC for over a decade - performing in an excellent fashion on such notable programs as SNAP-27 and the current Multi-Hundred Watt (MHW) RTG Program. The Commission has invested well over \$3-million in facilities at GE's Valley Forge location. In addition, General Electric has invested approximately \$100-million in Valley Forge - a facility dedicated to the development and fabrication of spacecraft and their subsystems.

Our program will be managed by Mr. Wayne Prickett who will report to our Advanced Energy Programs organization managed by Mr. B. J. Tharpe. Both Mr. Lee Farnham, General Manager of the Division's Space Systems Department, and I will review the program on a regular basis to be sure the program is proceeding satisfactorily.

I wish to assure you and the Commission of my personal commitment of the Space Division's full support to this proposal to the Atomic Energy Commission. AiResearch and GE have worked as a successful team in past efforts and I believe this relationship can continue and grow for this lengthy and important new effort. We look forward to an increasingly important General Electric role as the program progresses into later flight phases where GE's demonstrated capabilities as a space nuclear power system supplier are crucial.

Sincerely,

Daniel J. Fink

December 5, 1974

TELEDYNE
ISOTOPES
110 WEST TIMONIUM ROAD
TIMONIUM, MARYLAND 21093
TELEPHONE: (301) 252-8220

Mr. W. G. Orr
Vice President and General Manager
AiResearch Manufacturing Company of Arizona
A Division of Garrett Corporation
Post Office Box 5217
Phoenix, Arizona 85010

Dear Mr. Orr:

Teledyne Isotopes is pleased to have the opportunity to participate as a subcontractor to AiResearch Manufacturing Company of Arizona on the Isotope Brayton Power System Proposal, SNS-RFP-75-1-CAO. The Isotope Brayton program will receive full commitment at Energy Systems Division to assure high priority in implementation of all subcontractor responsibilities. We have designated the Isotope Brayton full program status equivalent to our current AEC SNAP-19 Viking and Low Cost High Performance Generator Technology prime systems contractor programs.

Teledyne Isotopes has supported the AEC since 1958 as a prime systems contractor pioneering in the space nuclear power field. Our key program management, technical, and production employees therefore average sixteen years experience in development and production of isotope flight systems and we assure you that this unique capability will be applied to assist AiResearch in successfully meeting Isotope Brayton Power System development objectives.

Sincerely,

ENERGY SYSTEMS DIVISION

P. J. Vogelberger, Jr.

P. J. Vogelberger, Jr.
Vice President and General Manager

pld

AIRESEARCH MANUFACTURING COMPANY OF ARIZONA
A DIVISION OF THE GARRETT CORPORATION

December 4, 1974

U. S. Atomic Energy Commission
Washington, D. C. 20545

Subject: AiResearch Proposal for Development of the
"Isotope Brayton Ground Demonstration System"

Gentlemen:

The Garrett Corporation offers a background of thirty years of gas turbine technology, extensive space systems experience in the Mercury, Gemini, Apollo and Skylab programs, and over fifteen years of closed cycle gas turbine and heat exchanger experience directly applicable to the AEC Isotope Brayton Ground Demonstration System. Our most recent contracts with the NASA will provide the Brayton rotating assembly and recuperator for the Isotope Brayton Ground Demonstration System Program.

Our proposed program includes as subcontractors, the General Electric Space Division and the Teledyne Isotopes Energy Systems Division. These highly qualified contractors will each provide their technical expertise to the isotope heat source requirements. We recommend that both subcontractors' efforts be funded through Phase I. Based on the Phase I analyses and the status of the heat source development at that time, a Phase II recommendation will be made by Garrett.

Our technical team has provided this proposal for Phases I, II, and III and is fully qualified to perform the proposed effort through flight test and production. I have assigned Mr. James McCormick as my manager to direct the program effort. He will head the Garrett/General Electric/Teledyne team that has developed the Brayton Rotating Units, Turbo-Alternator-Compressor, the Mini-Brayton Rotating Units, recuperators, the Multi-Hundred Watt Heat Source, the Apollo and Pioneer space nuclear power hardware, SNAP 3A, and 9A, and numerous other related efforts.

I wish to extend to the AEC the assurance that the Isotope Brayton Ground Demonstration System program will receive the manpower, technology, and managerial expertise required for meeting the program objectives.

Very truly yours,

AIRESEARCH MANUFACTURING COMPANY
OF ARIZONA
A Division of The Garrett Corporation

W. G. Orr
Vice President and Manager

W. G. ORR

INTRODUCTION

THIS DOCUMENT SUMMARIZES THE ORGANIZATIONAL AND TECHNICAL STRENGTHS OF THE GARRETT CORPORATION TEAM THAT WILL BE UTILIZED IN THE FULFILLMENT OF THE UNITED STATES ATOMIC ENERGY COMMISSION PROGRAM FOR THE GROUND DEMONSTRATION TEST OF A 1.3 KW ISOTOPE POWER CONVERSION SYSTEM LEADING TOWARD DEVELOPMENT OF AN ISOTOPE SPACE POWER SYSTEM IN THE 0.5 TO 2.0 KW POWER REGIME: SOLICITATION NUMBER SNS-RFP-75-1-CAO.

WE UNDERSTAND THE IMPORTANCE OF SUCCESSFUL DEVELOPMENT OF A LONG LIVED, HIGHLY RELIABLE, LOW WEIGHT COST EFFECTIVE FLIGHT QUALIFIED POWER SYSTEM FOR USE ON NEAR EARTH TO OUTER PLANET SPACE MISSIONS, SUCH AS THE DOD SURVSATCOM AND FUTURE NASA PROBES, BEGINNING IN THE 1980'S. THE GARRETT/GENERAL ELECTRIC/TELEDYNE COMPANIES DEDICATE THEMSELVES TO SUPPORT THIS PROGRAM WITH THE BEST THEY CAN OFFER IN TECHNICAL TALENT, PROGRAM MANAGEMENT AND FACILITIES. THEY BRING A VAST AMOUNT OF EXPERIENCE AND CAPABILITY TO SUCCESSFULLY ACCOMPLISH DEVELOPMENT OF THE ISOTOPE BRAYTON SYSTEM AND ITS INTEGRATION ABOARD SPACECRAFT.

THE DEDICATION AND PRIORITY PLACED BY THE GARRETT CORPORATION IN THE FULFILLMENT OF THIS IMPORTANT PROGRAM IS EXPRESSED IN THE LETTER ON THIS PAGE SIGNED BY MR. W. G. ORR, CORPORATE VICE PRESIDENT AND MANAGER OF THE AIRESEARCH MANUFACTURING COMPANY OF ARIZONA, A DIVISION OF THE GARRETT CORPORATION.

THE FOLLOWING PAGES OUTLINE THE TECHNICAL APPROACH, PROGRAM ORGANIZATION AND CONTROL, EXPERIENCE, FACILITIES AVAILABLE AND FINANCIAL RESOURCES.

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PROGRAM SCHEDULE

▼ DENOTES PROGRAM MILESTONES

PROGRAM DESCRIPTION

THE COMPLETE SCHEDULE FOR THE PROGRAM IS IN THREE PHASES.

THE FIRST PHASE, LASTING 27 MONTHS, IS FOR THE CONCEPTUAL DESIGN OF THE ISOTOPE BRAYTON FLIGHT SYSTEM AND THE DESIGN AND TEST OF A GROUND DEMONSTRATION SYSTEM. THESE WILL USE, AS A BASELINE DESIGN, THE MULTI HUNDRED WATT-RTG HEAT SOURCE BEING DEVELOPED FOR THE AEC BY THE GENERAL ELECTRIC COMPANY. THE GROUND DEMONSTRATION SYSTEM WILL SIMULATE, AS MUCH AS POSSIBLE, THE ISOTOPE BRAYTON FLIGHT SYSTEM AND WILL UTILIZE COMPONENTS AND TECHNOLOGY BEING DEVELOPED BY THE NASA UNDER CONTRACTS NAS3-18517, NAS3-18029 AND NAS3-18541 FOR THE MINI BRAYTON ROTATING UNIT, RECUPERATOR AND HEAT SOURCE ASSEMBLY. THE GROUND DEMONSTRATION SYSTEM WILL BE PERFORMANCE TESTED AND AN ENDURANCE TEST OF FIVE THOUSAND HOURS WILL BE RUN.

PHASE 2 WILL BE 36 MONTHS IN DURATION DURING WHICH THE ISOTOPE BRAYTON FLIGHT SYSTEM WILL BE DEVELOPED AND FULLY QUALIFIED FOR LAUNCH BY JUNE 30, 1980; INCLUDING TESTING WITH THE ISOTOPE HEAT SOURCE.

PHASE 3 IS THE FOLLOW-ON PRODUCTION PHASE THAT IS BEING ESTIMATED ON THE BASIS OF FOUR ISOTOPE BRAYTON SYSTEM LAUNCHES PER YEAR.

THE SCHEDULE FOR THE COMPLETE PROGRAM IS SHOWN ON THIS PAGE.

PHASE I CONCEPTUAL ISOTOPE BRAYTON FLIGHT SYSTEM

THE ISOTOPE BRAYTON FLIGHT SYSTEM WILL BE CAPABLE OF ANY POWER OUTPUT FROM 0.5 TO 2.0 KW (EOM) FOR A WIDE VARIETY OF MISSIONS WITH MINIMUM REDESIGN AND REQUALIFICATION. A FLIGHT SYSTEM, OPTIMIZED WITH A NOMINAL 4800 WATT (BOM) THERMAL INPUT TO PRODUCE 1.3 KW ELECTRIC OUTPUT, CAPABLE OF OPERATING OVER THE ABOVE RANGE WILL BE CONCEPTUALLY DESIGNED IN PHASE I. THE POWER DELIVERED TO THE SPACECRAFT SHALL BE VARIABLE FROM 0 TO 100 PERCENT OF FULL OUTPUT IN MILLISECONDS BY USE OF A PARASITIC LOAD. REFERENCE VOLTAGE IS 28 VDC $\pm$ 2 PERCENT.

THE FLIGHT SYSTEM WILL HAVE A LIFETIME IN EXCESS OF SEVEN YEARS WITH A MEAN MISSION DURATION (MMD) OF FIVE YEARS. FAILURE MODES IN THE PRELAUNCH, LAUNCH AND OPERATIONAL PHASES WILL BE IDENTIFIED.

THE COST OBJECTIVE FOR THE SYSTEM AT A 1300 WATT ELECTRICAL OUTPUT, ASSUMING \$1,000 PER THERMAL WATT FOR THE GFE HEAT SOURCE, IS \$5,000 PER WATT ELECTRICAL. THE PRESENTLY PROJECTED COST IS \$4,200 PER ELECTRICAL WATT.

THE WEIGHT OBJECTIVE FOR THE TOTAL POWER SYSTEM PRODUCING 1300 WATT ELECTRICAL IS 371 POUNDS (3.5 WATT ELECTRICAL/POUND). AN INITIAL ESTIMATE OF THE WEIGHT OF THIS SYSTEM IS 369 POUNDS.

INTERFACE INVESTIGATIONS WILL BE MADE OF: LAUNCH WITH A VARIETY OF VEHICLES; ON-PAD EXPLOSIVE ENVIRONMENTS; GEOSYNCHRONOUS SINK TEMPERATURE OPERATION; CONTROL OF THERMAL INPUT TO THE SPACECRAFT; MAGNETIC FIELD LIMIT; ON-PAD BIOLOGICAL DOSE LIMIT; RESISTANCE TO NATURAL AND MAN-MADE RADIATION; PACKAGING DESIGN FLEXIBILITY AND; ON-PAD AND IN-ORBIT FUELING CAPABILITY. PRELIMINARY INVESTIGATIONS OF THE ABOVE HAVE ALREADY BEEN MADE AND FMCA WILL BE EMPLOYED TO ASSURE THAT THE AEC RELIABILITY OBJECTIVES ARE MET.

AN INITIAL CONCEPTION OF THIS FLIGHT SYSTEM DESIGNED TO PRODUCE 1.3 KW ELECTRICAL IS SHOWN.

PHASE 1 ISOTOPE BRAYTON GROUND DEMONSTRATION SYSTEM

THE MAJOR EFFORT DURING PHASE 1 IS THE DESIGN AND TESTING OF THE ISOTOPE BRAYTON GROUND DEMONSTRATION SYSTEM (IBGDS) THAT CLOSELY SIMULATES THE CONCEPTUAL IBFS. GOVERNMENT FURNISHED MINI BRU, RECUPERATOR AND HEAT SOURCE ASSEMBLY (HSA) EQUIPMENT WILL BE INTEGRATED WITH A HEAT SINK SIMULATOR AND FLIGHT TECHNOLOGY CONTROL CONCEPTS. AN ELECTRIC ISOTOPE HEAT SOURCE SIMULATOR WILL BE USED TO PROVIDE THERMAL HEAT FOR THE IBGDS. (NOTE: THE MINI BRU AND RECUPERATOR AND HEAT SOURCE ASSEMBLIES ARE CONSIDERED TO BE FLIGHT PROTOTYPE HARDWARE.)

THE PROPOSED SYSTEM SCHEMATIC AND PLANNED TEST INSTALLATION ARE SHOWN. THE SYSTEM CONSISTS OF TWO HSA'S FOR PERFORMANCE TESTING OVER A WIDE POWER RANGE WITH 4800 WATT THERMAL MAXIMUM INPUT. ANALYTICAL CORRELATIONS WILL BE USED TO PREDICT THE ENGINE PERFORMANCE WITH 2400 AND 7200 WATT THERMAL INPUT, BASED ON THE 4800 WATT THERMAL TESTING. A 5000 HOUR ENDURANCE TEST WILL BE RUN.

ISOTOPE BRAYTON GROUND DEMONSTRATION AND FLIGHT SYSTEM PROGRAM ORGANIZATION

PROGRAM ORGANIZATION

GARRETT-AIRESEARCH HAS ESTABLISHED A TEAM OF HIGHLY QUALIFIED MEMBERS TO CONDUCT THE PROPOSED PROGRAM FOR THE ISOTOPE BRAYTON GROUND DEMONSTRATION TESTING AND FLIGHT SYSTEM QUALIFICATION THROUGH ALL THE PHASES. AS EXPRESSED ON PAGE 1, THIS PROGRAM HAS STRONG SUPPORT AND A HIGH PRIORITY WITHIN THE GARRETT CORPORATION.

MR. J. E. MCCORMICK, THE PROJECT DIRECTOR FOR THIS PROGRAM, HAS HAD SEVENTEEN YEARS OF EXPERIENCE IN THE AEROSPACE FIELD WITH FOURTEEN OF THOSE YEARS DIRECTLY RELATED TO THE CLOSED BRAYTON CYCLE FOR SPACE APPLICATIONS. HE IS SUPPORTED BY AN IN-DEPTH ORGANIZATION OF EXPERIENCED ENGINEERING PERSONNEL AND TWO OUTSTANDING COMPANIES; NAMELY, THE GENERAL ELECTRIC COMPANY SPACE SYSTEMS ORGANIZATION AND THE TELEDYNE ISOTOPES ENERGY SYSTEMS DIVISION.

MR. WAYNE PRICKETT WILL MANAGE THE GENERAL ELECTRIC EFFORT AND MR. ROBERT BUXBAUM WILL MANAGE THE TELEDYNE ISOTOPES EFFORT.

JAMES E. McCORMICK—PROJECT DIRECTOR

THE SCOPE OF MR. McCORMICK'S TECHNICAL EXPERIENCE INCLUDES CLOSED BRAYTON SPACE POWER SYSTEM SPACECRAFT INTEGRATION DESIGN STUDIES FOR THE McDONNELL DOUGLAS AND NORTH AMERICAN ROCKWELL NASA SPACE STATION AND BASE STUDIES AND MANAGEMENT OF POWER SYSTEMS HARDWARE AND TEST PROGRAMS (AIRESEARCH 3 KW BRAYTON CYCLE DEMONSTRATOR, NASA MINI BRAYTON ROTATING UNIT AND U.S. NAVY EXPERIMENTAL ENGINE) HE HOLDS AN M.S.M.E. DEGREE FROM THE ARIZONA STATE UNIVERSITY.

PROGRAM PLANNING/MONITORING TECHNIQUES

PROGRAM MANAGEMENT

- PROGRAM MANAGEMENT PROVIDES BOTH THE AUTHORITY AND VISIBILITY TO INTEGRATE ALL PROGRAM ELEMENTS
- ADMINISTRATIVE STAFF SERVES AS FUNCTIONAL MEANS OF INITIATING AND MONITORING PROGRAM CONTROLS
- INTEGRATED CONTROL SYSTEM PROVIDES CORRELATION BETWEEN COST, SCHEDULE AND HARDWARE STATUS
- KEYSTONE TO SUCCESSFUL MANAGEMENT AND CONTROL IS THE PRE-PLANNED DEFINITION OF TASKS AND INTERFACES.
- PLANNING/MONITORING TECHNIQUES INCLUDE:
 - MASTER PROGRAM SCHEDULE
 - PERT NETWORK (INTERNAL CONTROL)
 - WORK BREAKDOWN STRUCTURE
 - COST PERFORMANCE REPORTS
 - CONTRACT DATA ITEM SCHEDULES
 - PERIODIC TECHNICAL DESIGN COORDINATION WITH THE AEC
 - PROGRAM STATUS REPORTS
- SUBCONTRACTOR CONTROLS—MANAGEMENT OF THE GENERAL ELECTRIC AND TELEDYNE ISOTOPES EFFORT WILL BE ACCOMPLISHED BY WEEKLY VERBAL CONTACT WITH THE RESPECTIVE PROGRAM MANAGERS IN ADDITION TO SCHEDULED MEETINGS AND WRITTEN TECHNICAL AND COST REPORTS

CLOSED CYCLE CONTRACTS			
CUSTOMER	DATE	TYPE OF PROGRAM	\$ VALUE
NASA AND USAF	1963 1965	ADVANCED COMPONENT DESIGN DEVELOPMENT AND FABRICATION	638,000
NASA LEWIS	1963 1965	DEVELOP AND CONSTRUCT 10 KWE TWO-SHAFT ENGINE	1,579,000
NASA, NAR MCD-DOUGLAS	1964 1971	SPACE STATION/BASE POWER SYSTEM STUDIES	206,000
NASA HOUSTON	1963 1971	DESIGN-CONSTRUCT-TEST 3 KWE DEMONSTRATOR ENGINE	164,000
NASA LEWIS	1966 1972	DESIGN-CONSTRUCT-TEST 10 KWE SINGLE-SPOOL ENGINE (BRU)	6,491,000
NASA LEWIS	1970 1972	DESIGN-CONSTRUCT-TEST 100 KWE TURBO-ALTERNATOR-COMPRESSOR FOR REACTOR HEAT SOURCE (TAC)	3,118,000
NASA/AEC/USAF/GE	1972 1974	STUDY OF 0.5 TO 2.0 KWE MINI-BRAYTON SYSTEM FOR SATELLITES	128,000
NAVSHIPS NSRDC NAVSEC	1969 1974	STUDY AND DEVELOPMENT OF TWO EXPERIMENTAL PROPULSION ENGINES (CCPS 40-1 & CCPS 10-1)	5,174,000
NAVSHIPS	1970	CONCEPTUAL DESIGN 50 KWE POWER SYSTEM FOR DEEP SUBMERGENCE VEHICLE	50,000
AEC/WECO	1972	DESIGN-CONSTRUCT-TEST 3 KWE DEMONSTRATOR ENGINE FOR USE WITH COGEO HEAT SOURCE	100,000
MARAD	1973	STUDY OF A 9,000 HP ENGINE FOR LNG REFRIGERATION AND A 40,000 TO 80,000 HP SHIP PROPULSION ENGINE	310,000
AECL	1973	STUDY OF A 30 KWE UNDERWATER POWER SYSTEM	25,000
PFE	1973	25 HP REFRIGERATOR RAILCAR GENERATOR SET DEMONSTRATION UNIT	450,000
AGA	1973	10 HP ROOFTOP REFRIGERATION DEMONSTRATION UNIT	750,000
NASA LEWIS	1974	500 TO 2500 WATT MINI-BRAYTON TURBOALTERNATOR AND RECUPERATOR (MINI-BRU)	2,207,000
TOTAL			21,390,000

MINI BRAYTON ROTATING UNIT
NAS 3-18517

BACKGROUND

MINI BRAYTON RECUPERATOR
NAS 3-18029

MDAC SPACE STATION/BASE STUDIES
NAS 8-25140

BRAYTON HEAT EXCHANGER UNIT
NAS 3-10607

MORL RADIOISOTOPE BRAYTON
NAS 1-4479

BRAYTON ROTATING UNIT
NAS 3-9427

GAS GENERATOR
NAS 3-2778

MORL REACTOR BRAYTON
NAS 1-5547

BRAYTON CYCLE DEMONSTRATOR
NAS 9-6116, -10217

BRAYTON CONTROL SYSTEM
NAS 3-10943

NAR SPACE STATION/BASE STUDIES
NAS 9-9953

TURBOALTERNATOR COMPRESSOR
NAS 3-13448, -15687

LAC LUNAR BASE STUDY
NAS 8-20377

GE MINI BRAYTON RTG STUDY
AEC SNSO-6

GARRETT EXPERIENCE

THE GARRETT CORPORATION AND ITS ISOTOPE HEAT SOURCE TEAM MEMBERS HAVE EXTENSIVE EXPERIENCE IN THE DEVELOPMENT AND APPLICATION OF THE TECHNOLOGY REQUIRED FOR THIS PROGRAM.

EXTENSIVE SPACE SYSTEM EXPERIENCE EXISTS WITHIN THE GARRETT-AIRESEARCH DIVISIONS DUE TO STRONG PARTICIPATION IN THE NASA MERCURY, GEMINI, APOLLO AND SKYLAB PROGRAMS.

GARRETT HAS BEEN DEVELOPING SPACE POWER SYSTEMS SINCE 1956 AND HAS LED THE WORLD IN SMALL CLOSED BRAYTON SYSTEM TECHNOLOGY SINCE 1961. THIS SYSTEM IS A DIRECT EXTENSION OF STANDARD GARRETT PRODUCT LINES, INCLUDING SMALL HIGH SPEED TURBOMACHINERY, HEAT EXCHANGERS, ALTERNATORS AND CONTROLS. GARRETT IS PRESENTLY DEVELOPING THE MINI BRAYTON ROTATING UNIT AND THE RECUPERATOR FOR THE PROPOSED PROGRAM UNDER NASA LEWIS RESEARCH CENTER CONTRACTS. A LISTING OF THE DEVELOPMENT PROGRAMS SPECIFICALLY RELATED TO THE CLOSED BRAYTON SYSTEM IS SHOWN.

A VERY SIGNIFICANT ACCOMPLISHMENT OF GARRETT-AIRESEARCH BUILT EQUIPMENT IS THE SUCCESSFUL OPERATION FOR MORE THAN 28,000 HOURS OF THE NASA 10 KW ISOTOPE BRAYTON SYSTEM WITH AN ELECTRICAL HEAT SOURCE AT THE LEWIS RESEARCH CENTER FACILITY.

ELEMENTS TO

SUBSYSTEMS TO

MISSION SUCCESS

GENERAL ELECTRIC EXPERIENCE

OVER TWO DECADES OF UNIQUE
DEMONSTRATED STRENGTHS IN

- NUCLEAR HEAT SOURCES
- HEAT EXCHANGER TECHNOLOGY
- REFRACTORY & SUPERALLOY MATERIALS
- SPACE NUCLEAR POWER SYSTEMS
- NUCLEAR POWER/SPACECRAFT
INTEGRATION
- NUCLEAR SAFETY
- SPACECRAFT
- TOTAL SPACE SYSTEMS MANAGEMENT
- SUCCESSFUL MANAGEMENT OF OVER \$60
MILLION IN SPACE NUCLEAR POWER
CONTRACTS

KEY GENERAL ELECTRIC EXPERIENCES DIRECT-
LY SUPPORTING THE IBFS PROGRAM (JUST A PART
OF THE OVER \$60 MILLION OF GE CONTRACTS IN
SPACE NUCLEAR POWER SINCE 1963) ARE:

- MINI-BRAYTON ERTG STUDY (AEC SNS0-6)
POSITIVE IMPACTS TO IBFS—
HSA/RADIATOR/SPACECRAFT-TO-IBFS
INTERFACES, MISSION OPERATIONS AND
REQUIREMENTS
- HEAT SOURCE ASSEMBLY (HSA)
DEVELOPMENT (NAS3-18541)
POSITIVE IMPACTS TO IBFS—ISOTOPE
HEAT SOURCE INTEGRATION AND SAFETY,
—REFRACTORY HEAT EXCHANGERS
- SNAP 27 PROGRAM (AT(29-2)-2581)
ALL UNITS STILL OPERATING ON MOON
ABOVE SPECIFICATIONS:
POSITIVE IMPACTS TO IBFS—BERYLLIUM
TECHNOLOGY, BI-METALLIC JOINTS, SAFETY
- MHW-RTG PROGRAM (AT(29-2)-2831)
POWER SOURCE FOR DOD LES8/9
SATELLITES AND NASA MARINER PROBE TO
JUPITER/SATURN
POSITIVE IMPACTS TO IBFS—MHW HEAT
SOURCE AND SUPPORT STRUCTURE,
BERYLLIUM TECHNOLOGY, MULTI-FOIL
INSULATION, SAFETY.

GE HAS BUILT, DELIVERED AND FLIGHT
OPERATED A LARGE NUMBER OF AMERICA'S
SPACECRAFT. OF PARTICULAR IMPORTANCE TO
IBFS IS GE'S SUCCESSFUL EXPERIENCE IN MANAG-
ING ALL ASPECTS OF INTEGRATING AND FLYING A
SNAP 19 ON THE WEATHER SATELLITE NIMBUS III.

MISSION AND APPLICATION STUDIES OF
NUCLEAR POWERED SPACE VEHICLES ARE CON-
TINUALLY BEING CONDUCTED AND PROVIDE A
CURRENT IN-DEPTH KNOWLEDGE OF THE FUTURE
NEEDS OF ALL AGENCIES OF THE SPACE-
ORIENTED COMMUNITY. FOR ISOTOPE BRAYTON
POWER SYSTEMS.

MHW HEAT SOURCE
AT(29-2)-2831

HEAT SOURCE ASSEMBLY
NAS3-18541

MINI-BRAYTON SPACECRAFT
AEC-SNS0-6

ASSURANCE WITH GE'S EXTENSIVE EXPERIENCE

SNAP 27 DEPLOYMENT ON MOON
APOLLO 12 MISSION
AT(29-2)-2581

MHW GENERATOR
AT(29-2)2831

MHW POWERED
DOD SPACECRAFT
LES 8/9

MHW POWERED
NASA PROBE TO
JUPITER/SATURN

NIMBUS III
WITH RTG

TERRESTRIAL GENERATOR HISTORY

TELEDYNE ISOTOPES EXPERIENCE

THE TELEDYNE ISOTOPES ENERGY SYSTEMS DIVISION HAVE OVER EIGHTEEN YEARS OF EXPERIENCE IN THE DESIGN, DEVELOPMENT AND PRODUCTION OF RADIOISOTOPE THERMOELECTRIC GENERATORS INCLUDING THE SNAP 3A'S AND SNAP 9A'S FOR THE NAVY NAVIGATIONAL SATELLITES AND THE SNAP 19 GENERATORS ABOARD PIONEER 10 AND 11.

SPACE GENERATOR HISTORY

GARRETT SPACE LABORATORY

OVERALL VIEW OF LABORATORY

LARGE SPACE CHAMBER (WILL ACCOMMODATE
GEMINI-II OR APOLLO-SIZE CAPSULES)

CENTRAL CLEANROOM

HIGH-ALTITUDE
SIMULATION CHAMBER

LARGE SPACE-
SIMULATION CHAMBER

LAUNCH-SIMULATION CHAMBER

GE FACILITIES FOR NUCLEAR SPACE POWER

WELDING CHAMBER—8 FT.
SHOWING Cb-1Zr MANIFOLD

RTG LOADING AND ASSEMBLY STATION

HOT GAS ISOSTATIC PRESSURE
3 FT³ 3000°F 10,000 PSI He

NUCLEAR QUALIFIED VIBRATION
TEST FACILITY
(NIMBUS ON TEST)

NUCLEAR QUALIFIED
39 FT. CHAMBER

GENERAL ELECTRIC FACILITIES

THE SPACE DIVISION OF GENERAL ELECTRIC HAS OVER 2 MILLION SQUARE FEET OF FACILITIES DEDICATED TO SPACECRAFT AND SPACE NUCLEAR POWER ACTIVITIES. THE TOTAL VALUE OF THE FACILITIES APPROACHES \$100 MILLION. AS PART OF THE MODERN AND WELL EQUIPPED MANUFACTURING AND ASSEMBLY, TEST AND QUALITY ASSURANCE, RESEARCH AND DEVELOPMENT, AND COMPUTER AREAS THERE ARE FACILITIES OF PARTICULAR VALUE TO THE IBFS PROGRAM. THESE KEY FACILITIES (SOME HERE PICTURED) PROVIDE SIGNIFICANT ABILITY FOR:

ADVANCED MATERIALS CHARACTERIZATION
REFRACTORY MATERIALS FORMING & JOINING
ISOTOPE HEAT SOURCE HANDLING AND STORAGE
RTG ASSEMBLY
RTG FLIGHT QUALIFICATION
ELECTRIC HEAT SOURCE FABRICATION

MAJOR FACILITIES INCLUDE ONE OF THE MOST VERSATILE COMPUTER PROCESSING COMPLEXES IN THE UNITED STATES. OPERATING AT THE VALLEY FORGE SPACE CENTER IS THE LARGEST SINGLE INSTALLATION OF FULLY INSTRUMENTED SPACE ENVIRONMENT SIMULATION FACILITIES IN THIS COUNTRY. KEY AMONG THESE ARE

SPACE CHAMBER (32' DIA X 54' WITH SOLAR SIMULATION)

3 CHAMBERS (39' SPHERICAL) FOR SPACECRAFT TESTING

1 CHAMBER (12' DIA X 26') FOR SMALL SPACECRAFT

NUMEROUS SMALLER CHAMBERS ARE AVAILABLE.

GENERAL ELECTRIC'S SPACE DIVISION IS CONTINUALLY ADDING TO AND MODERNIZING ITS FACILITIES AND IS UNIQUELY QUALIFIED TO SUPPORT THIS IBFS PROGRAM.

FACILITIES, EQUIPMENT, LABORATORIES GE HAS FORMED AND JOINED THESE MATERIALS				
METALS	ALLOYS			
Cb	Cb-BASE	Ta-BASE	Mo-BASE	W-BASE
Ta				
Mo	Cb-1Zr Cb-103	T-111	Mo-0.5Ti	W-25Re
W	Cb-129Y	90Ta-10W	Mo-TZM	W-25Re-30Mo
Ti	D-43	T-222		

THE GARRETT CORPORATION IS A WHOLLY OWNED SUBSIDIARY OF THE SIGNAL COMPANIES.

MANUFACTURING COMPANIES

SERVICE COMPANIES

THE SIGNAL COMPANIES

THE GARRETT CORPORATION

- ORGANIZED IN 1936
- ELEVEN DIVISIONS AND PRINCIPAL SUBSIDIARIES
- OVER 13,000 EMPLOYEES
- 10TH LARGEST EMPLOYER IN SOUTHERN CALIFORNIA
- 3RD LARGEST EMPLOYER IN ARIZONA
- NEVER A WORK STOPPAGE
- POWER, ENVIRONMENT AND CONTROL SYSTEMS FOR THE TRANSPORTATION EQUIPMENT AND ENERGY CONVERSION INDUSTRIES

- CORPORATE ASSETS \$1,378,032,000
- ANNUAL SALES OF \$1,433,875,000
- 50 YEARS OF GROWTH
- A DIVERSIFIED ENTERPRISE WITH WORLDWIDE OPERATIONS IN THE AEROSPACE AND SURFACE TRANSPORTATION AND INDUSTRIAL FIELDS
- 48 PERCENT OWNER OF AMERICAN PRESIDENT LINES
- 50 PERCENT OWNER OF GOLDEN WEST BROADCASTERS
- 91ST LARGEST CORPORATION IN THE U.S.
- 32,000 EMPLOYEES

FACILITIES

SINCE THE CLOSED BRAYTON CYCLE IS A DIRECT EXTENSION OF THE GARRETT-AIRESEARCH ESTABLISHED PRODUCT LINES, EXTENSIVE FACILITIES WITH FULLY TRAINED AND QUALIFIED PERSONNEL EXIST THAT WILL BE USED IN THE CONDUCT OF THE NUCLEAR BRAYTON TURBINE ALTERNATOR COMPRESSOR PROGRAM. SHOWN ON THIS PAGE ARE A NUMBER OF THESE FACILITIES.

DEVELOPMENT MACHINE SHOP

SHOCK AND VIBRATION TABLE

TYPICAL DIGITAL DATA ACQUISITION CONSOLE

STANDARDS LAB

DEVELOPMENT ASSEMBLY

ELECTRON BEAM WELDING

DEVELOPMENT AND QUAL TEST FACILITIES

MEASURING CLEARANCES WITH CUSTOM DISTANCE PROBES

WHIRL PIT TEST CHAMBER

INSTRUMENTATION LAB

PRECISION SHADOW COMPARATORS

ANOCUT ELECTRO-MACHINING

ENGINE OPERATION LARGE ALTITUDE AND COLD CHAMBER

STRAIN GAUGE INSTRUMENTATION

5 AXIS AIRFOIL PROFILERS

GARRETT FACILITIES

DUE TO THE EXTENSIVE EXPERIENCE IN THE DEVELOPMENT OF CLOSED BRAYTON ENGINES AND ISOTOPE HEAT SOURCES BY THE GARRETT CORPORATION, THE GENERAL ELECTRIC COMPANY, AND TELEDYNE ISOTOPES, IN-DEPTH FACILITIES TO DESIGN AND DEVELOP THE ISOTOPE BRAYTON GROUND DEMONSTRATION AND FLIGHT SYSTEMS ARE IN PLACE AND ARE AVAILABLE FOR THIS PROGRAM. SOME OF THESE FACILITIES ARE SHOWN.