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OVERVIEW OF DOE SPACE NUCLEAR PROPULSION PROGRAMS

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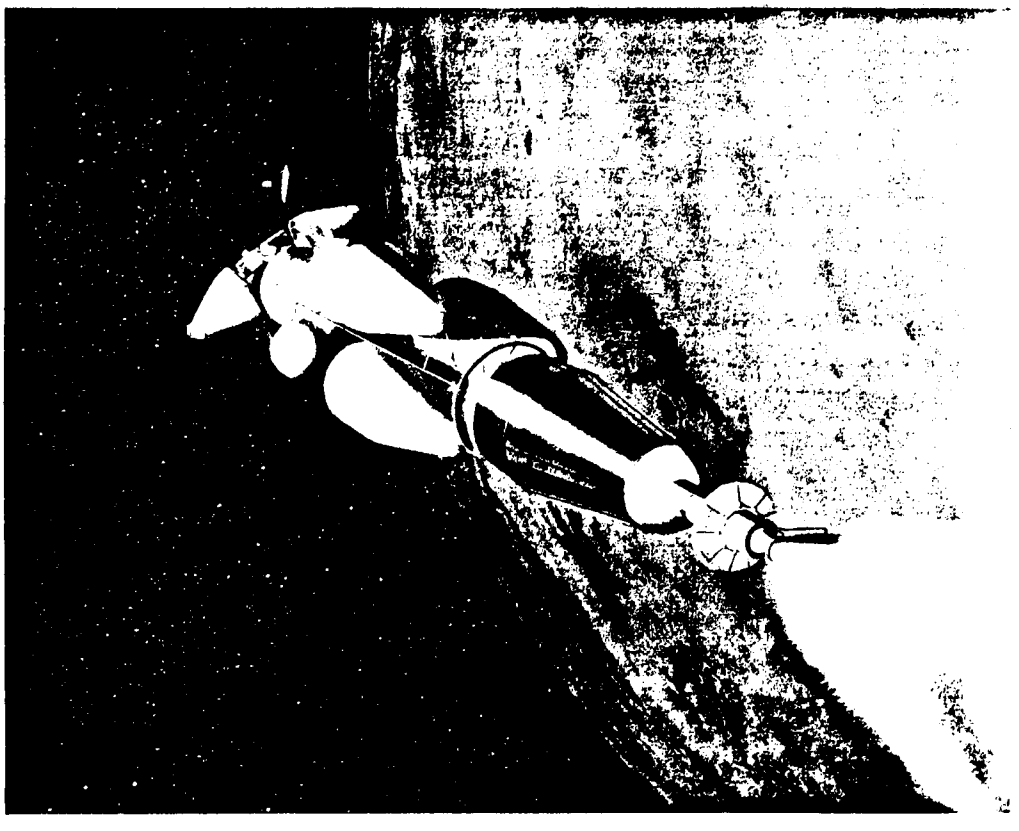


TYPES OF SPACE NUCLEAR PROPULSION

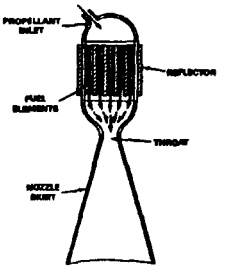
- NUCLEAR THERMAL ROCKETS (NTR)

  DEVELOP THRUST BY USING A NUCLEAR REACTOR TO HEAT A PROPELLANT GAS AND EXPEL IT THROUGH A NOZZLE

  - HIGH SPECIFIC IMPULSE* (>TWICE BETTER THAN BEST CHEMICAL SYSTEMS)
  - HIGH THRUST (FAST ACCELERATION)
  - SHORT LIFETIME (MINUTES TO HOURS)

  PRIMARY NASA OPTION FOR CARGO AND PILOTED MARS MISSION; ALSO, PROMISING CHOICE FOR MANY DOD APPLICATIONS

NUCLEAR THERMAL ROCKET



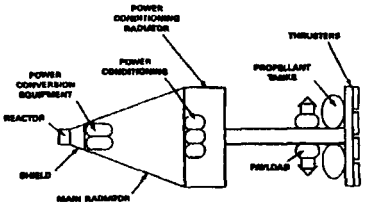
- NUCLEAR ELECTRIC PROPULSION (NEP)

  DEVELOP THRUST BY USING ELECTRICITY PRODUCED FROM HEAT IN A NUCLEAR REACTOR TO IONIZE A PROPELLANT AND ACCELERATE THE CHARGED PARTICLES THROUGH A THRUSTER

  - VERY HIGH SPECIFIC IMPULSE* (>10 TIMES BETTER THAN BEST CHEMICAL SYSTEMS)
  - LOW THRUST (CONTINUOUS ACCELERATION)
  - LONG LIFETIME (MONTHS TO YEARS)

  ENABLING OR SIGNIFICANTLY ENHANCING FOR SEVERAL NASA SOLAR SYSTEM ROBOTIC MISSIONS; NEAR TERM NEP REACTOR SYSTEMS WILL BE BASED ON SPACE REACTORS CURRENTLY UNDER DEVELOPMENT

NEP VEHICLE/SYSTEM SCHEMATIC



- THRUST PRODUCED PER RATE OF PROPELLANT CONSUMPTION

NUCLEAR THERMAL PROPULSION HISTORICAL SUMMARY (ROVER//NERVA)

- 18 YEAR DEVELOPMENT PROGRAM (1955-1973)
  ($1.4 BILLION EXPENDED IN THEN-YEAR DOLLARS)
- 20 REACTORS BUILT AND TESTED
  - REACTOR DESIGN AND DEVELOPMENT - LANL
  - DESIGN AND MANUFACTURE OF ROCKET ENGINE SYSTEMS - WESTINGHOUSE AND AEROJECT
  - TESTING OF ALL REACTORS - NEVADA TEST SITE
- PERFORMANCE DEMONSTRATED

- POWER LEVEL	4100 MWt
- PEAK FUEL TEMPERATURE	2750K
- SPECIFIC IMPULSE (Isp)	850 sec
- START/STOP CYCLES	28
- CONTINUOUS OPERATION	62 MINUTES

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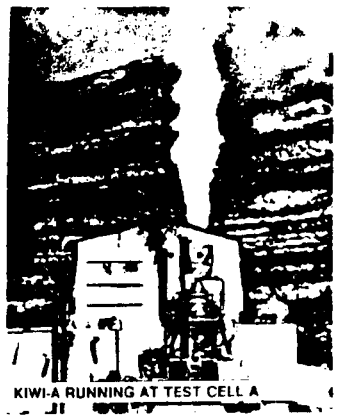
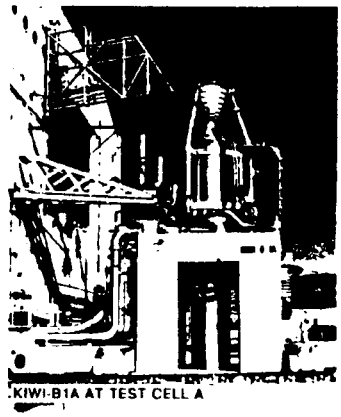
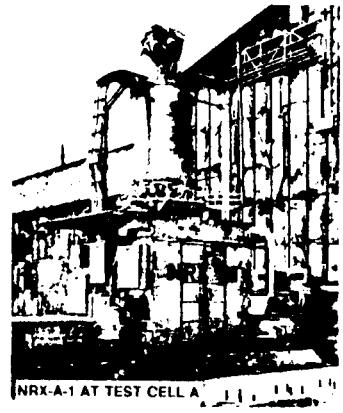
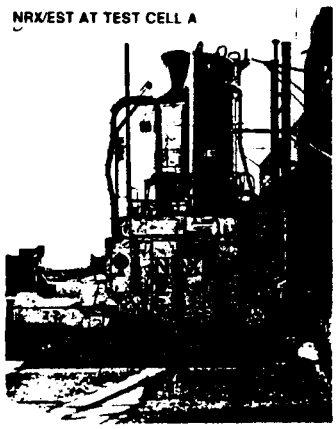
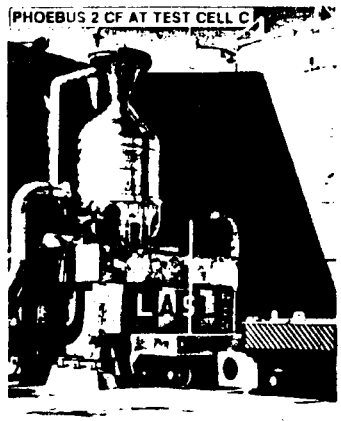
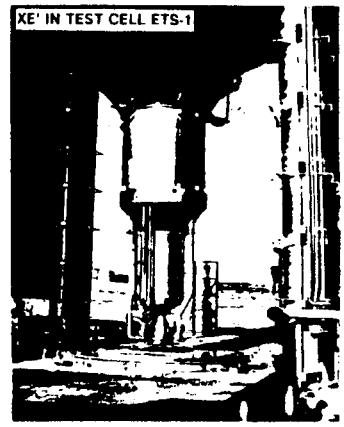

KIWI-A RUNNING AT TEST CELL A


KIWI-B1A AT TEST CELL A


NRX-A-1 AT TEST CELL A


NRX/EST AT TEST CELL A


PHOEBUS 2 CF AT TEST CELL C


XE' IN TEST CELL ETS-1

DOE'S CHARTER FOR THE DEVELOPMENT OF NUCLEAR POWER

- DOE'S CHARTER, ARISING FROM AUTHORITY IN THE ATOMIC ENERGY ACT OF 1954, AS AMENDED, IS TO SUPPORT FEDERAL AGENCIES (DOD AND NASA) IN MEETING THEIR SPECIAL POWER NEEDS FOR BOTH TERRESTRIAL AND SPACE APPLICATIONS

DOE ROLE IN SPACE NUCLEAR PROPULSION

- TRADITIONAL DOE ROLE OF DESIGNING, DEVELOPING, TESTING, AND PROVIDING NUCLEAR SYSTEMS, INCLUDING ENVIRONMENTAL, SAFETY, AND HEALTH ASPECTS
- NASA/DOE MEMORANDUM OF UNDERSTANDING (MOU) FOR ENERGY-RELATED CIVIL SPACE ACTIVITIES
  - SPECIFIC PROVISIONS FOR NUCLEAR PROPULSION
- PROJECT SPECIFIC MOU FOR NUCLEAR PROPULSION
  - DRAFT PREPARED FOR BOTH NASA AND USAF PROJECTS
- NATIONAL SPACE POLICY DIRECTIVE ON SPACE EXPLORATION INITIATIVE
  - NASA, DOD, AND DOE DIRECTED TO CONTINUE TECHNOLOGY DEVELOPMENT FOR SPACE NUCLEAR POWER AND PROPULSION

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DOE SAFETY ROLE IN SPACE NUCLEAR PROPULSION ACTIVITIES

- ENVIRONMENT, HEALTH, AND SAFETY
  - OVERALL POLICY, ALARA
  - OVERSIGHT
  - NEPA PROCESS
  - SAFETY ANALYSIS, REPORTS/APPROVALS
  - PUBLIC SAFETY
  - SAFEGUARDS
  - SITE MONITORING
- NUCLEAR SYSTEM DESIGN, MANUFACTURE, ASSEMBLY, CHECKOUT AND OPERATION
- GROUND TEST FACILITY DESIGN, ACQUISITION, CONSTRUCTION AND OPERATION

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SAFETY APPROACH

- SAFETY IS AN OVERRIDING CONSIDERATION:
  - FOR PROTECTION AGAINST ACCIDENTS
  - FOR PUBLIC ACCEPTANCE
  - FOR BOTH GROUND TESTING AND SPACE OPERATIONS
- ULTIMATE SAFETY OBJECTIVE:
  - MINIMIZE RISK TO PUBLIC AND CREW IN NORMAL AND ABNORMAL OPERATIONS
- NUCLEAR POWER SOURCE LAUNCH APPROVAL PROCESS:
  - BASED ON RIGOROUS SAFETY REQUIREMENTS, EVALUATION AND TESTING
  - CONSIDERS MISSION OBJECTIVES/BENEFITS VERSUS RISKS
  - BASED ON SUCCESSFUL HISTORY OF ISOTOPE AND REACTOR APPLICATIONS BY NASA AND DOD

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NUCLEAR SYSTEM DESIGN, MANUFACTURE, ASSEMBLY, CHECKOUT, AND OPERATION

- NUCLEAR SYSTEM DESIGN STANDARDS, REQUIREMENTS, AND CODES
  - DESIGN SAFETY FEATURES
  - SAFETY TEST REQUIREMENTS AND ANALYSIS
  - PREOPERATIONAL CHECKS AND TESTS
- MANAGEMENT OF FACTORY, SHIPPING, SITE, AND POST TEST OPERATIONS FOR NUCLEAR COMPONENTS AND SYSTEMS
  - FACTORY, SUB-ASSEMBLY TESTING, CRITICALS, ETC.
  - SHIPPING AND ASSEMBLY
  - FACILITY CONTROLS
  - EMERGENCY PLANNING
  - EMERGENCY ACTIONS
  - RECOVERY, CLEANUP, AND DISPOSAL ACTIONS
- NUCLEAR FLIGHT SYSTEM OVERSIGHT (WITH USER AGENCIES)
  - OVERALL POLICY DEFINITION
  - SAFETY REVIEW AND APPROVAL PROCESSES
  - FLIGHT OPERATIONS MONITORING
  - SUPPORT IN POSSIBLE EMERGENCIES
  - NORMAL AND ABNORMAL DISPOSAL OPERATIONS
  - POTENTIAL GROUND RECOVERY OPERATIONS

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GROUND TEST FACILITY DESIGN ACQUISITION, CONSTRUCTION, AND OPERATION

- SITE SELECTION AND MANAGEMENT OVERSIGHT
  - STANDARDS AND CRITERIA
  - SITE PREPARATION AND MAINTENANCE
  - SITE MONITORING
  - SHIPPING/HANDLING OF RADIOACTIVE/HAZARDOUS MATERIALS
  - DECOMMISSIONING AND DISPOSAL
- FACILITY DESIGN AND CONSTRUCTION OVERSIGHT
  - STANDARDS AND DESIGN CRITERIA
  - FUNCTIONAL REQUIREMENTS
  - SAFETY REQUIREMENTS, ANALYSES, AND APPROVALS
  - PREOPERATIONAL CHECKS AND TESTING OF EQUIPMENT AND SYSTEMS
- OVERSIGHT OF OPERATIONS
  - CONDUCT OF OPERATIONS
  - TRAINING REQUIREMENTS
  - TEST PROCEDURE APPROVAL
  - SPECIFIC TEST APPROVAL
  - POST IRRADIATION EXAMINATION
- QUALITY ASSURANCE PROGRAM OVERSIGHT
- SAFEGUARDS AND SECURITY OVERSIGHT

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GROUND TESTING ISSUES

- MAJOR FACILITIES REQUIRED
  - EITHER NEW FACILITIES OR EXTENSIVE MODIFICATIONS TO EXISTING FACILITIES
  - MUST MEET CURRENT ENVIRONMENTAL AND SAFETY REQUIREMENTS (EFFLUENT CONTROL)
  - FACILITY STUDY ESTIMATES $0.5 TO OVER $1B AND 7-10 YEARS EACH
  - DOE SITES WILL BE USED
- TYPES OF FACILITIES
  - FUEL BUNDLE QUALIFICATION
  - ENGINE SYSTEM
- ISSUES
  - SAFETY AND PUBLIC ACCEPTANCE
  - LARGE COST
  - SINGLE NATIONAL TEST COMPLEX VERSUS MULTIPLE COMPLEXES
- EXPERIENCE
  - ROVER/NERVA DESIGN
  - NUCLEAR FURNACE*
    - HAS SHOWN GROUND TESTING CAN BE ACCOMPLISHED THROUGH USE OF A SCRUBBER SYSTEM

*A SMALL (50 MWt) HIGH TEMPERATURE REACTOR USED FOR TESTING NUCLEAR THERMAL ROCKET FUEL ELEMENTS.

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POTENTIAL USE OF CIS FACILITIES

- TWO DOE DELEGATIONS RECENTLY RETURNED FROM A FACT FINDING TRIP TO RUSSIA AND KAZAKHSTAN
  - VISITED SEVERAL NUCLEAR PROPULSION FACILITIES WHICH COULD POSSIBLY BE USED
  - REVIEWED SPACE POWER AND PROPULSION CAPABILITIES
  - STILL COMPILING INFORMATION OBTAINED AND DRAFTING REPORTS
  - MUST CAREFULLY REVIEW AND VERIFY CAPABILITIES
- EXACT DOE ROLE IN USING OR MAKING USE OF FOREIGN NUCLEAR FACILITIES OR TECHNOLOGIES STILL NEEDS TO BE DEFINED
  - INTERNATIONAL AGREEMENTS MAY BE NEEDED
  - ROLE OF U.S. INDUSTRY NEEDS TO BE FURTHER EXPLORED
- TOPIC BEING WORKED

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NUCLEAR PROPULSION DEVELOPMENT NEEDS

- PAST PROGRAM PERFORMANCE NOT ADEQUATE FOR TODAY'S NEEDS
- PERFORMANCE IMPROVEMENTS REQUIRED
  - HIGHER SPECIFIC IMPULSE (900-1000 SEC.)
  - HIGHER THRUST/WEIGHT (25 - 35 TO 1)
  - DIFFERING REQUIREMENTS FOR CIVILIAN AND MILITARY APPLICATIONS (e.g., RUN TIME, RESTARTS)
- NEW DEVELOPMENT PROGRAM NEEDED
  - REESTABLISH OLD TECHNOLOGY AND CONSIDER NEW CONCEPTS

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KEY NEAR-TERM NUCLEAR PROPULSION ACTIVITIES FOR SPACE EXPLORATION

- DEVELOPING AND TESTING OF CANDIDATE NTP FUELS
- EARLY STUDY AND SELECTION OF EFFLUENT TREATMENT SYSTEMS
  - TEST AND QUALIFY PROTOTYPE COMPONENTS AND SUBSYSTEMS
- NUCLEAR FACILITY PRECONSTRUCTION ACTIVITIES
  - INITIATE ENVIRONMENTAL, SAFETY, AND PRELIMINARY DESIGN ACTIVITIES
  - PROCEED TOWARD A SINGLE NATIONAL NUCLEAR PROPULSION TEST COMPLEX
    - - MEETS BOTH NASA AND DOD REQUIREMENTS
- NTP CONCEPTS ASSESSMENTS AND DEFINITION
  - NERVA DERIVATIVE
  - PARTICLE BED
  - CERMET
  - CIS TWISTED RIBBON

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RECENT DOE NUCLEAR PROPULSION ACTIVITIES FOR SEI

- LIMITED ASSESSMENTS OF NUCLEAR PROPULSION CONCEPTS AND ASSOCIATED TECHNOLOGIES
- NUCLEAR FUEL DEVELOPMENT
- FACILITIES EVALUATIONS AND ASSESSMENTS
  - DOE/NASA/USAF NUCLEAR FACILITIES REVIEW
    - - INITIATED STUDIES FOR COMMON FACILITIES
  - PROVIDED FACILITIES INPUT FOR SNTP DRAFT EIS EFFORT
  - CIS FACILITIES VISITS
- PLANNING AND PROGRAMMATIC ACTIVITIES

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SPACE NUCLEAR THERMAL PROPULSION (SNTP) PROGRAM

- USAF TECHNOLOGY DEVELOPMENT PROGRAM TO DEMONSTRATE THE FEASIBILITY AND HIGH PERFORMANCE CAPABILITIES OF A NUCLEAR PROPULSION SYSTEM USING PARTICLE BED REACTOR TECHNOLOGY FOR POSSIBLE U.S. AIR FORCE (USAF) SPACE PROPULSION NEEDS
- USAF PHILLIPS LABORATORY IS PROGRAM MANAGER FOR THE SNTP PROGRAM
- DOE IS RESPONSIBLE FOR THE NUCLEAR DEVELOPMENT PORTION OF THE PROGRAM, INCLUDING NUCLEAR SAFETY OVERSIGHT AND NUCLEAR GROUND TESTING
- SANDIA NATIONAL LABORATORIES ALBUQUERQUE (SNLA) AND BROOKHAVEN NATIONAL LABORATORY (BNL) ARE PRINCIPAL DOE LABORATORIES PARTICIPATING ON THE PROGRAM

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SNTP NUCLEAR PROPULSION EIS ACTIVITIES

- DRAFT EIS
  - ISSUED FOR PUBLIC REVIEW
  - FINAL EIS EXPECTED IN NOVEMBER 1992
  - TWO SITES UNDER CONSIDERATION
    - NEVADA TEST SITE
    - IDAHO NATIONAL ENGINEERING LABORATORY TEST SITE
  - SITE SELECTION ANTICIPATED IN JANUARY 1993

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SUMMARY

- LONG HISTORY OF SUCCESSFUL USE OF NUCLEAR POWER IN SPACE (AND DOE SUPPORT OF THESE SYSTEMS)
- SPACE NUCLEAR THERMAL PROPULSION IS A LONG LEAD DEVELOPMENT ACTIVITY. CONSOLIDATION OF U.S. MILITARY AND CIVILIAN EFFORTS TO THE GREATEST DEGREE POSSIBLE WOULD BE BENEFICIAL.
- DOE WILL HAVE A LEAD ROLE IN DIRECTING THE NUCLEAR ASPECTS OF SPACE NUCLEAR THERMAL PROPULSION PROGRAMS; ACQUIRING AND OPERATING THE GROUND NUCLEAR TEST FACILITIES; AND ASSURING THE SAFETY OF ALL DESIGN, DEVELOPMENT, FABRICATION, TEST, AND OPERATIONS ACTIVITIES

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