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ROCKET ENGINE OPERATIONS - NUCLEAR

Revised Work Statement

MASTER

(RN-PD-0009 - ENCL. (1))

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SUPPLEMENT IV TO APPENDIX B
CONTRACTUAL WORK STATEMENT

The following work statement specifies the work to be performed during the contract period from October 1, 1963, through September 30, 1964.

Using both KIWI-B and general reactor technology in developing the NERVA nuclear rocket engine, the contractor shall exert his best efforts in the execution of the following research and development work in this contract period. This work supplements work performed in previous periods extending from July 10, 1961, through September 30, 1963. The following work statements are identified by task, subtask and sub-subtask numbers.

TASK 1. ENGINE DEVELOPMENT

With the objective of developing the NERVA engine through PFRT and RIFT flight engine configurations on a timely basis, the contractor shall, during this contract period, design and integrate the entire engine system based on the hot-bleed cycle, prepare and update specifications, fabricate test hardware, and perform development testing and analysis as described below.

Subtask 1.1 Engine System

Perform design, analysis and development tasks on the NERVA engine and its interfaces with test stands, support equipment and flight vehicle as follows:

Sub-subtask 1.1.0 Engine Systems Integration, Design and Documentation

A. Engineering

- (1) Update and maintain the layout, assembly and installation drawings of the NERVA Block I Engine to the extent necessary to support component and test stand interface activity.
- (2) Revise and maintain flow schematics and planning parts lists for the NERVA Block I Engine to the extent necessary to support component and test stand interface activity.
- (3) Upgrade and modify the design and drawings of all the pressure vessel and reactor gages and match plates fabricated during Contract Year 1963 as required to conform to the latest NRX assembly configurations.
- (4) Complete the design criteria for the ETS-1 test stand adapter, thrust structure, and the propellant supply line from the supply

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Sub-subtask 1.1.0 (Con't.)

tank to the TSOV including the facility shut-off valve and flow meter. Complete the design and release fabrication drawings for the associated adapter match plates prior to February 1, 1964. Upgrade and maintain the engine interface control drawing current with the latest engine design.

- (5) Perform those design efforts on the NERVA engine interface required to support the engine and stage test stand facilities.
- (6) Upgrade and revise the engine systems data book. Issue supplemental data each quarter.
- (7) Upgrade the NERVA engine weight and balance document. Issue revisions in March and September, 1964.
- (8) Complete Revision D (including the reactor specification) to AGC 10095 NERVA FX engine model specification and submit for approval.

B. Fabrication

- (1) Upgrade and modify master pressure vessel and reactor gages and match plates fabricated during Contract Year 1963 as required to conform to the latest NRX assembly configurations.

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 1.1.1 LRP Technical Administration

A. Engineering - Not applicable

B. Fabrication

- (1) Provide engineering administration for NERVA fabrication at LRP.

C. Testing

- (1) Provide engineering administration for NERVA testing at LRP.

D. Tooling

- (1) Provide engineering administration for NERVA tooling at LRP.

Sub-subtask 1.1.2 Cold Flow Development Test System (CFDTS)

A. Engineering

- (1) Maintain current the CFDTS test plan until such time as the test specification is issued.
- (2) Prepare and issue the CFDTS test specification. Prepare the detail procedures for conduct of the CFTDS test program.

B. Fabrication

- (1) Complete the fabrication of all unique test hardware associated with the CFDTS, and complete the assembly of the CFDTS.

C. Testing

- (1) Complete the installation of the CFDTS and conduct check-out tests in accordance with the approved test plan and specification.

D. Tooling - Not applicable

Sub-subtask 1.1.3 Non-nuclear Engine Acceptance Test System (NNEATS)

A. Engineering

- (1) Define the acceptance tests of the E-engine assemblies sufficiently to establish the facility and equipment requirements in-plant and at NRDS.

B. Fabrication

- (1) No fabrication is planned for this contract period.

C. Testing

- (1) No testing is planned for this contract period.

D. Tooling - Not applicable

Sub-subtask 1.1.4 - Open

Sub-subtask 1.1.5 - Mockup. No work in this contract period.

Sub-subtask 1.1.6 - Open

Sub-subtask 1.1.7 Interface Mockups

A. Engineering

- (1) Complete the report on the feasibility study and test program for the pressure vessel/closure mockup.

B. Fabrication - Not applicable

C. Testing

- (1) Complete the tests on the pressure vessel/closure mockup to determine fit and functional capability in accordance with the development test plan.

D. Tooling - Not applicable

Sub-subtask 1.1.8 NRX Integration, Test Planning and Test Engineering

A. Engineering

- (1) Monitor program schedules for NRX-A system design, fabrication, assembly, and test. Manage the integration of activities related to configuration control drawings, non-nuclear hardware assembly test, and system test plans and specifications.
- (2) Prepare, issue, maintain and control the following configuration control drawings for NRX-A1 through NRX-A8 reactors:
 - a. Interface Control Drawings as required to define and control the interface between the nuclear and non-nuclear subsystems for use in subassembly design.
 - b. NRX-A Final Assembly Drawings. This drawing shall contain the parts list and reference to the applicable procedures necessary for the assembly of the reactor subassembly to the pressure vessel-nozzle subassembly.
 - c. Installation Drawings. These drawings include reference to system level final assembly and mate-up procedures and specify the electrical and mechanical installation details at points of attachment (interfaces) between the test article and the test car/test facility.
- (3) Prepare non-nuclear assembly drawings and drawings of unique hardware required for non-nuclear acceptance tests for NRX-A2 through NRX-A8. Provide configuration and design change controls for the non-nuclear assembly drawings.
- (4) Prepare, issue (after SNPO-C approval), and maintain test plans for NRX-A1, A2, A3, A4, A5, A6, and A7; and test specifications for NRX-A1, A2, A3, A4 and A5.

Sub-subtask 1.1.8 (Con't.)

- (5) Review the following test procedures for NRX-A1, A2, A3 and A4:
 - a. Receiving-Inspection procedures
 - b. Mating of reactor, pressure vessel, nozzle and test car
 - c. Control room operating procedures
 - d. Disassembly procedures
 - e. Post-operative examination procedures
- (6) Provide technical liaison to assure compatibility of the test hardware and test documents with program requirements, to facilitate the preparation of NRX-A configuration control drawings and to coordinate the requirements for non-nuclear GSE.
- (7) Provide two (2) reactor project engineers for the NRX-A program. They shall be responsible for specific NRX-A assemblies through the engineering, fabrication and testing programs.
- (8) Review test requests, coordinate requirements for instrumentation, pre-test assembly and post-test disassembly and examination, and other test engineering services as required.
- (9) Prepare and issue test data analysis reports for NRX-A1 and A2.

B. Fabrication

- (1) Assemble non-nuclear subsystems of the A1, A2, A3, A4 and A5 test articles in accordance with applicable assembly drawings.
- (2) Rework and maintain the unique hardware required for the acceptance testing of NRX-A1 through A-4 non-nuclear assemblies. Modify unique hardware as required for the acceptance testing of NRX-A5 non-nuclear assemblies to include provision for the use of the end-item reflector and shield.

C. Testing

- (1) Perform acceptance tests on NRX-A1, A2, A3, A4 and A5 non-nuclear assemblies and components in accordance with the approved acceptance test specifications, and deliver NRX-A1, A2, A3 and A4 to NRDS

D. Tooling - As required

Sub-subtask 1.1.9 NERVA/RIFT Coordination

A. Engineering

- (1) Maintain technical liaison and coordination between the NERVA Engine and RIFT stage programs. In addition, conduct specific support studies related to the engine-to-engine interfaces as follows:
 - a. Conduct mechanical design effort in the engine-stage interface area as requested by SNPO-C.
 - b. Complete layout drawings depicting in detail all service connections including structural and propellant connections.
 - c. Establish criteria specified in (b) above for the physical, operating and environmental requirements of each connector.
 - d. Review high pressure pump discharge shutoff valve designs of other programs and determine the feasibility and associated development times of using this type of shutoff valve in lieu of the currently designed low pressure pump suction shutoff valve.

B. Fabrication - Not applicable.

C. Testing - Not applicable.

D. Tooling - Not applicable.

Subtask 1.2 Propellant Feed System (PFS)

Sub-subtask 1.2.0 System Assembly

A. Engineering

- (1) Provide overall administration of the PFS subtask and coordinate activities with other engine systems. Compile PFS data and information for inclusion in the Engine Data Book and engine safety reports, for coordination with the RIFT contractor, for coordination with the radiation effects test program with respect to planning and scheduling of tests, and for coordination with engine and system analyses activities.
- (2) Update the layout of the PFS and analyses of the engineering requirements in order to maintain component criteria and to support the RIFT contractor.

- (3) Coordinate engineering effort with the pneumatic system subtask in order to insure consistent performance requirements for seals and disconnects. Complete the design of a static tester for seals and disconnects.
- (4) Prepare PFS test plan for radiation effect test program. Initiate planning and coordination of requirements for a PFS radiation effects tests at the NARF facility. Prepare and maintain up-to-date the test installation and fabrication drawings for the PFS radiation effect test article.
- (5) Coordinate PFS requirements with the CFDTs planning activities and render assistance in the interpretation of test data.
- (6) Issue test plans, acceptance test specifications, and procedures for seal and remote disconnect tests.
- (7) Compile and publish seal and remote disconnect test results. Analyze test data obtained from the tank shut-off valve (TSOV) - pump suction line - turbopump assembly (TPA) (Mark III) test systems.

B. Fabrication

- (1) Fabricate four test rigs for seals and flanges. Purchase seals and remote disconnect flanges for testing in Contract Year 1964.

C. Testing

- (1) Perform life, ease of operation, proof and burst pressure, allowable loads, and allowable loads on seals and remote disconnect flange designed for the Block I E-engine.
- (2) Complete tests of the TSOV-pump suction line - Mark III TPA System in conjunction with TPA development testing conducted in sub-subtask 1.2.3 to determine TPA performance at various TSOV inlet pressures.
- (3) Complete system testing with the Mark IV TPA as outlined in test series described in sub-subtask 1.2.3.

D. Tooling

- (1) Furnish the required tooling, which consists of QC inspection gages for each size of the propellant feed system joints.

Sub-subtask 1.2.1 Lines and Disconnects

A. Engineering

- (1) Complete analysis and issue report on pump suction line contour study to optimize pump inlet flow conditions.

Sub-subtask 1.2.1 (Con't.)

- (2) Complete layout drawing of preliminary Block I E-engine lines.
- (3) Release drawings of the prototype lines and disconnects for the PFS radiation effect test article.

B. Fabrication

- (1) Complete fabrication of the pump suction line assembly initiated in the previous contract period.
- (2) Complete fabrication of the turbine exhaust line assembly for CFDTs which was initiated the previous contract period.

C. Testing - Not applicable

D. Tooling

- (1) Furnish one set of tooling for the turbine exhaust line.

Sub-subtask 1.2.2 Valves

I Tank Shut-off Valve (TSOV)

A. Engineering

- (1) Complete detail fabrication drawings of the Configuration 2B (remote capability) TSOV. Evaluate Configuration 2B TSOV seals, pilot valve, solenoid, potentiometers, and the disconnect actuator for incorporation into the E-1 engine valve design and issue report delineating results.
- (2) Issue detailed test plans for both laboratory and radiation effects testing of TSOV. Analyze and issue reports on results of laboratory testing and RET 905.
- (3) Update acceptance test specifications to reflect development testing results.
- (4) Coordinate engineering requirements of the TSOV with other test systems.

B. Fabrication

- (1) Complete the fabrication of TSOV potentiometers, solenoids, disconnects and disconnect actuators for laboratory and component radiation effect testing.
- (2) Complete fabrication of four (4) Configuration 2A TSOV's-- one for CFDTs, one for support of other testing, and two for R&D.

Sub-subtask 1.2.2 (Con't.)

C. Testing

- (1) Perform laboratory thermal shock, icing, and actuating timing tests of the Configuration 2A TSOV. Complete initial assembly and initial series of dry functional and vibration, leak, endurance, and actuating timing tests of the Configuration 2B TSOV.
- (2) Complete acceptance tests of pilot valves, potentiometers and solenoids and an assembled TSOV for component RET.
- (3) Perform proof leak, functional and other tests to develop TSOV components including TSOV disconnects, TSOV disconnect actuators, and TSOV PV to assure their availability when required with the TSOV.

D. Tooling

- (1) Rework one set of tooling for the TSOV.

II Reactor Cooldown Valve (RCDV)

A. Engineering

- (1) Update acceptance test requirements to reflect development testing results.
- (2) Issue detailed test plans for both laboratory and radiation effect testing. Analyze and issue reports on effect of laboratory test and radiation effects test (RET) 905.

B. Fabrication

- (1) Complete the fabrication of four (4) RCDV's including completion of two units initiated in CY '63.

C. Testing

- (1) Perform RCDV component development tests including electrical and torque test of actuator and electrical tests of position indicator.
- (2) Complete RCDV initial development tests including proof, leak, and functional tests to evaluate seals, various part configurations, and effects of tolerances.
- (3) Complete acceptance tests of a RCDV for component radiation effect test.

D. Tooling

- (1) Rework one set of tooling for the RCDV.

III. Turbine Power Control Valve (TPCV)

A. Engineering

- (1) Modify or redesign the Configuration 2 valve depending upon results of tests.
- (2) Issue detailed test plans for laboratory, hot H₂O₂ gas, hot H₂ gas and radiation effects testing of the TPCV. Analyze and issue reports on the results of the laboratory testing, hot gas testing, and RET 905.
- (3) Update acceptance test specifications to reflect development testing results and coordinate engineering requirements of the TPCV with other test systems.
- (4) Evaluate TPCV body, seals, bearings, and actuator for incorporation into the E-1 engine valve design and issue report delineating results.

B. Fabrication

- (1) Complete the fabrication of five (5) TPCV's: one for CFDTS, one for NRX-A, and three for research and development.

C. Testing

- (1) Perform hot gas operational, leak, bearing evaluation, and ambient seal leak tests on Configuration 2 TPCV.
- (2) Perform evaluation tests of the TPCV - pneumatic actuator assembly in both ambient and hot gas operational tests.
- (3) Perform hot gas endurance tests on the TPCV to evaluate seals, bearings, and valve operational capabilities.
- (4) Complete ten minutes accumulated endurance tests in hot hydrogen gas at FX design conditions, on one valve assembly without internal rework.

D. Tooling

- (1) Rework one set of tooling for the TPCV.

IV. Purge and Emergency Cooldown Check Valves

A. Engineering

- (1) Evaluate test results of initial check valve designs and initiate redesigns directed toward the E-1 engine design requirements.
- (2) Coordinate engineering requirements of check valves for use in the CFDTS.
- (3) Analyze and issue reports on results of laboratory testing and RET 905.

B. Fabrication

- (1) Fabricate purge and emergency cooldown valves to support component development, CFDTS, and RET.

C. Testing

- (1) Perform ambient and low temperature laboratory tests on the purge and emergency cooldown valves.
- (2) Complete acceptance tests of valves for CFDTS.

D. Tooling - No major tooling is required.

Sub-subtask 1.2.3 Turbopump Assembly (TPA)

A. Engineering

- (1) Complete and release final assembly drawings of the MARK IV Mod 2 TPA. Complete and publish the design report on Mark IV Mod 2 TPA. Complete and issue acceptance test specifications for the Mark IV Mod 2 TPA. Complete and issue revision of remote disassembly procedure for the Mark IV Mod 2 TPA.
- (2) Complete test plans for component thrust balance system tests and analyze and issue report on test results.
- (3) Coordinate the TPA development with the PFS development and other test systems.
- (4) Prepare and issue detailed test plans for each series of TPA component and assembly tests and coordinate with SNPO-C. Analyze test data for each test series and publish results in test reports. Coordinate formats for test plans and test reports with SNPO-C. There shall be two Mark III and four Mark IV test series plus acceptance testing of the TPA for CFDTS.

Sub-subtask 1.2.3 (Con't.)

- (5) Complete and issue a report evaluating the results of CY '63 Mark III TPA testing.
- (6) Conduct radial and backward swept impeller pump analyses including investigations of available data and concepts. Complete and issue a report on recommendations for best choice pump configurations (based on available water test results) for LH 2 TPA testing.
- (7) Coordinate design of TPA components to insure compliance with remote handling equipment.
- (8) Perform materials studies, stress analyses, and thermal analyses on TPA components and incorporate results as required.

B. Fabrication

- (1) Complete the fabrication of six (6) Mark IV TPA's: one for CFDTS, one for delivery to Lewis Research Center within 30 days after completion of 10-minute endurance demonstrations, and four for research and development. In addition, complete the fabrication of components (to assembly point) sufficient to assemble three TPA's.
- (2) Initiate the fabrication of eight Mark IV Turbopumps to be completed early in the following contract period with the objective of maintaining TPA development program continuity.
- (3) Complete fabrication of backward swept impellers and impellers incorporating different inducer designs.

C. Testing

- (1) Complete two inlet system test series with the Mark III TPA consisting of:
 - a. C-7 tests for documentation of pump performance (ΔP vs Q) at high NPSP (TSOV inlet) and a 4 psi NPSP or less (TSOV inlet) for FX and reduced speeds from stall to facility maximum Q/N.
 - b. Five tests in H-6 with objectives of-
 1. Checking out the new H-6 facility
 2. Demonstrating TPA operation to satisfy existing engine start-up requirements
 3. Documenting TPA performance during unbled starts so as to be applicable to system analyses and simulations.

Sub-subtask 1.2.3 (Con't.)

- (2) Complete three inlet system test series with the Mark IV TPA. The objectives of the test series shall be as mutually agreed upon and shall be selected from the following test series objectives:
 - a. Documentation of pump performance (ΔP vs. Q) at high NPSP (TSOV inlet) and at 4 psi NPSP or less (TSOV inlet) for FX and reduced speeds from stall to facility maximum Q/N .
 - b. Unbled starts with the objectives of:
 1. Demonstrating TPA operation to satisfy existing engine start-up requirements
 2. Documenting TPA performance during unbled starts so as to be applicable to system analyses and simulations.
 - c. Establishment of required bearing coolant flow.
 - d. Evaluation of steady state and transient thrust balance system
 - e. Demonstration of overspeed and overtemperature capability as defined in NDC-58.
 - f. Documentation of turbine performance
 - g. Determination of TPA breakaway torque characteristics.
- (3) Complete 10 minute demonstration of the Mark IV Mod 2 TPA at FX conditions but at higher than design NPSP (10 psi max).
- (4) Complete three series of water pump development tests, one of which is with a backward-swept impeller, with objectives and test planning coordinated with SNFO-C.

D. Tooling

- (1) Provide one set of new tooling and rework and/or modify existing tooling as required for the Mark IV configuration turbopump assembly.

Sub-subtask 1.2.4 TPA Bearing Development

A. Engineering

- (1) Provide liaison between the bearing engineering activities, turbopump activities, and subtask 1.9 and update criteria for bearings.
- (2) Coordinate bearing development with the turbopump development. Prepare detailed test plans for the bearing program for each test series and coordinate with SNFO-C. Analyze test data for each test series and publish results in test reports.

Sub-subtask 1.2.4 (Con't.)

- (3) Coordinate the designing of bearings to insure compliance with remote handling requirements. Perform material studies, stress analysis, and thermal analysis and incorporate results as required.
- (4) Modify the high speed bearing tester design (electric motor driven) to accept the Mark IV TPA bearing configuration.

B. Fabrication

- (1) Fabricate research bearing sets and TPA bearing components for use in the development program.
- (2) Fabricate candidate bearings to support the radiation effects testing program outlined in Subtask 1.9.

C. Testing

- (1) Complete two bearing test series plus acceptance testing of four (4) bearing testers for RET. Complete the bearing test program consisting of:
 - a. The effects of load on life at full speed
 - b. Clearances required for unbled starting and the required endurance
 - c. The effect of non-radiation testing on bearings previously tested in a radiation environment.
 - d. Drive energy versus cooldown time
 - e. Bearing coolant flow, thrust requirements and shaft fit requirements
 - f. Overspeed capability as defined in NDC-58
- (2) Demonstration of satisfactory operation of a set of control bearings of the same part number at load and speed corresponding to testing in a radiation environment.
- (3) Perform tests of roller and ball bearing sets in a radiation environment at no less than 23,000 rpm, 2000 lb. radial and 2000 lb. axial load (or at a more critical axial load condition) with LH₂ cooling, for target endurance times as follows:

MK III bearings - 5 minutes (on one set)

MK IV bearings - 10 minutes (on one set)

Sub-subtask 1.2.4 (Con't.)

- (4) Demonstration of accumulated roller and ball bearing endurance (one bearing set) at loads and speeds at or above that corresponding to the TPA FX power, and with LH₂ cooling in a non-radiation environment with the Mark IV bearings for 90 minutes endurance time.
- (5) Perform non-radiation bearing tests on bearings available from previous tests in a radiation environment.
- (6) Demonstrate 5 minute Mark IV bearing non-radiation endurance at or above design conditions before first Mark IV TPA test.

Subtask 1.3 Engine Reactor Subassembly Integration

A. Engineering

- (1) Provide program integration through review and assessment of all aspects of the nuclear subsystem program, including mechanical and functional matching. Establish nuclear component and subassembly requirements based on overall system requirements and analysis.
- (2) Provide program integration through management supervision of such items as GSE, GFE and STE requirements, NRDS support requirements and remote handling requirements.
- (3) Assure overall program integration by providing necessary program guidelines for the nuclear subsystem in the preparation of program plans, cost proposals and budget documents consistent with SNPO-C guidelines. Review and revise such program plans, as required, so as to provide an overall integrated program.
- (4) Provide management supervision to the AGC engineering efforts in the related nuclear subsystem areas to assure an overall integrated program and elimination of any duplication of effort.
- (5) Review major items to be purchased by the nuclear subcontractor and submit recommendations to SNPO-C regarding technical approval of such procurement items.
- (6) Evaluate and review on a continuing basis, the integration of the nuclear subcontractor's effort into the overall program and transmit comments to SNPO-C. This evaluation and review shall include the mechanical design of the reactor.
- (7) Provide AGC representation at the nuclear subcontractor's facility as required to perform the foregoing functions.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Subtask 1.4 Thrust Chamber Assembly (TCA)

The overall objective of this work is to develop the Thrust Chamber Assembly (TCA) for the NERVA engine, including the nozzle assembly, pressure vessel, thrust structure, gimbal assembly, and the ducting from the pump and to the turbine. In this contract period, develop as the principal effort those TCA components which are required for the CFDTS and the NRX-A test series.

Supply pressure vessels, propellant inlet lines, and nozzles to the NRX-A program. Continue scale model and development testing on the major TCA components for the E-engine. Demonstrate a life-time equivalent to five 100-sec-duration runs at NERVA design throat heat flux and wall temperature using hydrogen-oxygen as propellants with the prototype NERVA nozzle and skirt. Continue TCA dynamic testing.

Maintain technical liaison with program participants as a continuing effort during this program for the coordination of TCA activities.

Wherever applicable throughout this subtask, detailed test plans and specifications shall be submitted to SNPO-C for review prior to the initiation of testing. Topical and informal reports covering test results and analyses shall be prepared and submitted to SNPO-C as appropriate. These test plans, specifications, topical, and informal reports shall be according to a mutually agreed upon format.

Sub-subtask 1.4.0 Assembly

A. Engineering

- (1) Provide technical direction, coordination, and review of all TCA sub-subtasks on a continuing basis to ensure that the work programs meet the objectives for the period of contract year 1964.
- (2) Conduct stress and dynamic analyses for design purposes and correlation with experimental results from dynamic testing on a continuing basis during the contract period.
- (3) Determine structural requirements for TCA dynamic testing and cold flow development tests.
- (4) Conduct structural analyses of design modifications in the nozzle, thrust structure, gimbal, pressure vessel, turbine inlet line, and pump discharge line.
- (5) Complete the design modifications to TCA series I test tooling in preparation for series II testing at the close of the contract year.

B. Fabrication

- (1) Modify TCA test tooling as required to be compatible with series II test hardware.

C. Testing

- (1) Complete the TCA series I testing and series II dynamic (vibration and shock) testing programs during the contract period, in accordance with mutually agreed upon objectives. Utilize test results from the programs to modify TCA component designs.

D. Tooling

- (1) Provide special TCA inspection gauges for alignment purposes.

Sub-subtask 1.4.1 Nozzle and Extension Development

A. Engineering

- (1) Analyze test results from hot bleed NERVA nozzle component development testing and incorporate any design changes warranted into the nozzle design.
- (2) Update the design of the regeneratively cooled turbine inlet line and the pump to nozzle propellant feed line utilizing results from nozzle simulation firings.
- (3) Evaluate test analyses for the nozzle extension and incorporate any necessary changes into the design.
- (4) Conduct heat transfer analyses of the nozzle and nozzle extension and introduce the results from simulation firings to determine more accurately gas side and coolant side heat transfer coefficients.
- (5) Conduct heat transfer analyses using the results obtained from hot firings to confirm the previous analysis of the hot bleed port system including the regeneratively cooled turbine inlet line.
- (6) Design a new injector-to-nozzle adapter and modify existing adapter designs to accommodate development and acceptance LO₂/LH₂ simulation testing of NERVA nozzles. Incorporate the pressure vessel type mating interface in the new design. Replace the stainless steel nozzle flange-to-adapter joint with forged aluminum type 6061-T6.
- (7) Perform injector design effort with the objective of eliminating face plate failure and extending the duration for the Pressure-Fed Nozzle Test System (PFNTS).

- (8) Continue the nozzle aluminum jacket structural improvement program.

B. Fabrication

- (1) Complete the fabrication of seven hot bleed nozzles, five skirts, and two skirt to diffuser adapters.
- (2) Complete the fabrication of five regeneratively cooled turbine inlet lines and four pump to nozzle propellant inlet lines.
- (3) Complete the fabrication of five nozzles of alternate designs.
- (4) Complete the fabrication of two injectors and three nozzle to injector adapters for nozzle simulation fire testing.
- (5) Complete the fabrication of one thrust chamber Thrust Support Structure.
- (6) Rework hardware fabricated under this sub-subtask as necessary for continued testing.

C. Testing

- (1) Perform development testing of the nozzle extension (skirt) with a diffuser duct.
- (2) Conduct injector development tests to verify the design objectives.
- (3) Conduct simulation tests utilizing hydrogen-oxygen as propellants on nozzles, pump to nozzle propellant inlet lines, and regeneratively cooled turbine inlet lines. Determine the structural integrity, heat transfer characteristics and operational characteristics of these components utilizing test data.
- (4) Demonstrate a life-time equivalent to five 100-second-duration runs at NERVA design throat heat flux and wall temperature using LO₂/LH₂ as propellants with a prototype NERVA nozzle and nozzle extension to an area ratio of 25 to 1 at conditions mutually agreed upon by AGC and SNPO-C.

D. Tooling

- (1) Provide new tooling as necessary for the alternate design nozzles and nozzle to injector adapters.

- (2) Provide handling equipment to adequately protect nozzle parts in a fragile or final stage of assembly.
- (3) Provide new casting patterns or modify existing patterns as required.
- (4) Rework existing tooling as required.

Sub-subtask 1.4.2 Thrust Structure and Gimbal

A. Engineering

- (1) Conduct heat transfer, stress, weight, and dynamic analyses, in support of thrust structure and gimbal design.

B. Fabrication

- (1) Complete the fabrication of one upper and lower thrust structure for CFDTs.

C. Testing

- (1) Conduct thrust structure structural tests in accordance with the series II Test Plan.
- (2) Determine the natural frequency of vibration by dynamic testing.

D. Tooling

- (1) Provide thrust structure and gimbal tooling as required for component design changes and to facilitate fabrication.

Sub-subtask 1.4.3 Pressure Vessel

A. Engineering

- (1) Update the preliminary E-engine pressure vessel design as a result of test and manufacturing experience.
- (2) Modify as required, the pressure vessel seals based on the results of the seal development test program.
- (3) Conduct heat transfer analyses for transient and steady state conditions in support of design and stress analyses.

B. Fabrication

- (1) Complete the fabrication of five aluminum NRX-A pressure vessels, including all seals, bolts, and washers required.

- (2) Provide four additional sets of aluminum pressure vessel forgings.

C. Testing

- (1) Perform component development structural testing (limit load survey) of an aluminum pressure vessel.
- (2) Test the pressure vessel seals at cryogenic as well as ambient temperatures and evaluate the sealing capabilities under operating pressures.
- (3) Conduct a burst test of a prototype aluminum pressure vessel using LN₂.
- (4) Perform acceptance proof tests on each pressure vessel.

D. Tooling

- (1) Rework vendor tooling for pressure vessel fabrication as required by design changes.

Sub-subtask 1.4.4 Roll Control Assembly

No effort this contract year.

Sub-subtask 1.4.5 Reactor Nozzles

A. Engineering

- (1) Update the design of NRX-A nozzles and propellant feed lines to accommodate both the Aerojet and the Rocketdyne RN-6 nozzles for the NRX-A test series.

B. Fabrication

- (1) Complete the fabrication of five NRX-A nozzles and three nozzle propellant feed lines.
- (2) Provide tubes for three additional NRX-A nozzles.

C. Testing

- (1) Perform development proof testing on NRX-A nozzles in accordance with test plans.
- (2) Conduct acceptance tests on the end-item NRX-A nozzles and propellant feed lines as mutually agreed upon.

D. Tooling

- (1) Rework nozzle tooling as required.

Sub-subtask 1.4.6 Applied Research Program

A. Engineering

- (1) Conduct the following TCA materials development program:
 - (a) Perform detailed metallurgical evaluation of the cast jacket material and establish heat transfer characteristics for the tubing-jacket interface.
 - (b) Perform detailed metallurgical evaluation on selected braze alloys to establish values of brazing parameters and to establish fabrication techniques for the nozzle tube bundle assembly.
 - (c) Investigate materials as required for the thrust structure, gimbal, and the gimbal-to-upper and lower thrust structure joints, the nozzle-to-pressure vessel cylinder joint, and the closure-to-pressure vessel cylinder joint.
 - (d) Continue the pressure vessel mechanical properties laboratory test program. Investigate 6061-T6 aluminum forged plate material. Investigate welded plate of 6061-T6 aluminum. Test material taken from pressure vessel forgings throughout the estimated NERVA temperature range. Continue and maintain a file of the latest data on physical and mechanical properties of candidate TCA materials.
- (2) Continue the scale model heat transfer program as follows:
 - (a) Update the nozzle and bleed port data correlations.
 - (b) Establish the thermal design criteria for the NERVA nozzle and bleed port.
 - (c) Perform design, and data analysis of nozzle bleed port and core exit effects tests, liquid side heat transfer tests, and full scale nozzle cooldown tests.

B. Fabrication

Fabricate the following scale model test program hardware:

- (1) Four different reactor core outlets (or bottom support plate) designs and six different bleed port diluent injector systems for the Nozzle Bleed Port and Core Exit Effects Tests.

- (2) An adaptor with hot gas inlet connection, hydrogen rich combustion gas generator, and test assembly for the full-scale nozzle cooldown test.

C. Testing

Conduct the following test program:

- (1) Perform tests to investigate the effect of four different reactor core outlet designs on heat transfer in the nozzle cylindrical section and bleed port. Perform tests to investigate bleed port hot gas-diluent mixing characteristics of different diluent injection systems.
- (2) Perform liquid side heat transfer tests under isothermal flow conditions and with heat addition to hydrogen at supercritical pressures and temperatures greater than 100°R.
- (3) Perform full-scale nozzle cooldown tests to investigate cooldown conditions over a wide operating range.

D. Tooling - Not applicable.

Subtask 1.5 Engine Controls

Continue the analysis and development of the control system for the NERVA engine and the control systems for the NRX reactor tests.

Sub-subtask 1.5.0 Control System Integration

A. Engineering

- (1) Plan and organize a program for the further development of the control systems for the NERVA engine and the NRX reactor.
- (2) Issue a program plan for the development of the engine control system for the FX engine and to submit to SNPO-C for review.
- (3) Integrate the development of the control system components, including actuator, control sensors, signal amplifiers, system amplifiers, switching circuits, programmers, power supplies, harnesses, connectors and neutronic instrumentation systems for control.
- (4) Manage and coordinate the development work of subcontractors applying efforts to controls development, and measure their effectiveness in meeting program goals and objectives.
- (5) Complete an updating of the design criteria, functional specifications and performance specifications of the engine control system, including the programmer, and the reactor subloop and control instrumentation and submit to SNPO-C for approval.
- (6) Complete the preliminary design of the engine control system, including the programmer, reactor subloop and control sensors, based on the above approved specifications.
- (7) Issue summary control system design report.

B. Fabrication

- (1) Complete the fabrication and acceptance testing of a breadboard model of the reactor control subloop utilizing available components from other sub-subtasks as required, for later use in a breadboard model of the engine control system.

C. Testing

- (1) Test updated breadboards of the reactor control system to determine component development problems, response, accuracy, limitations, and malfunction protection capabilities.

D. Tooling - Not applicable

Sub-subtask 1.5.1 - Controls Analysis

A. Engineering

- (1) Issue a report on the refinement studies of the control system startup requirements.
- (2) Issue an interim report on engine control system malfunction analysis and compensation studies.
- (3) Conduct computer studies to determine the effect of malfunction of the reactor and control system and issue report.
- (4) Analyze NRX-A3, NRX-A4 and NRX-A5 reactor dynamic control performance by means of analog computer studies and issue report of predicted control performance.
- (5) Perform analysis of the NRX-A cold gas startup control system and issue a report.
- (6) Conduct analog computer studies of engine control concepts and issue evaluation reports.
- (7) Perform control system evaluation by the tie-in of control system amplifiers and actuators with the analog computer simulation of the engine system and issue a report.
- (8) Analyze NRX-A test results to improve the analog models and to update the control system design.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 1.5.2 Actuators

A. Engineering

- (1) Issue updated actuator design criteria and specifications.
- (2) Issue an evaluation report on the design and testing of a piston-type turbine power control valve actuator.
- (3) Issue an evaluation report on the design and testing of the gear motor type Turbine Power Control Valve (TPCV) actuators.

Sub-subtask 1.5.2 (Con't.)

- (4) Complete the design of a prototype TPCV actuator and high frequency drive amplifier.
- (5) Issue an evaluation report on the design and testing of the Gen II drum control actuator.
- (6) Issue the specifications for the NRX-A4 through NRX-A8 drum actuators.

B. Fabrication

- (1) Complete the acquisition of six Gen II drum control actuators initiated in the previous contract year.
- (2) Complete the acquisition of four TPCV actuators initiated in the previous contract year.

C. Testing

- (1) Demonstrate continuous operation of the TPCV actuator at simulated NERVA radiation conditions with a target time of 30 minutes.
- (2) Demonstrate continuous operation of the control drum actuator at simulated NERVA radiation conditions with a target time of 30 minutes.
- (3) Demonstrate continuous operation of the control drum actuator critical components (piston rings, potentiometer, torque motor, servo-valve) at as near as practical simulated NERVA conditions of temperature, pressure, and radiation with a target time of 30 minutes.
- (4) Conduct operational tests of TPCV and drum control actuators in the simulated NERVA environmental conditions of temperature, vibration and vacuum.

D. Tooling - Not applicable

Sub-subtask 1.5.3 Electronics Development

A. Engineering

- (1) Issue updated requirements and specifications for the NERVA engine electronic components.
- (2) Complete the preliminary design of the NERVA engine flow control sub-system electronic components.
- (3) Complete the preliminary design of the NERVA engine reactor control sub-system electronic components.

Sub-subtask 1.5.3 (Con't.)

B. Fabrication

- (1) Fabricate electronic sub-assemblies as required to produce a working breadboard model of the NERVA engine control system.
- (2) Fabricate individual electronic sub-assemblies as required for operational testing of components.

C. Testing

- (1) Conduct dynamic performance tests on breadboard models of NERVA engine control system electronic components.
- (2) Demonstrate dynamic performance and minimal drift within specifications for not less than 50 hours of continuous testing of the NERVA engine control system components to include but not be limited to switching circuits, comparators, control and signal amplifiers, etc.

D. Tooling - Not applicable

Sub-subtask 1.5.4 Harness and Connectors

A. Engineering

- (1) Complete a study layout of the E-engine harnesses showing harness routing and attachment concepts.
- (2) Complete component study layouts of the required remote disconnects in the E-engine harness configuration.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 1.5.5 - Open

Sub-subtask 1.5.6 Programmer

A. Engineering

- (1) Issue updated design requirements for the E-engine programmer.
- (2) Complete the preliminary design of the E-engine programmer.

B. Fabrication

- (1) Fabricate a breadboard programmer for use in a working model of the E-engine control systems.
- (2) Fabricate breadboard programmer modules as required for computer tie-in and dynamic performance tests.

C. Testing

- (1) Demonstrate programmer performance under expected electrical variations.
- (2) Demonstrate dynamic performance within specifications for not less than 50 hours of continuous testing.

D. Tooling - Not applicable

Sub-subtask 1.5.7 NRX Control System

A. Engineering

- (1) Issue the reactor control requirements for NRX-A3, A4 and A5 tests.
- (2) Modify NRX reactor control systems design as required.

B. Fabrication - Not applicable

C. Testing

- (1) Conduct evaluation and checkout tests as required.

D. Tooling - Not applicable

Subtask 1.6 Countermeasure Systems

Perform the design, fabrication, testing and evaluation directed toward the development of an anticriticality poison wire safety subsystem and a post operational safety subsystem having bifunctional capability and which are capable of being integrated into the NERVA engine, detailed as follows:

Sub-subtask 1.6.0 Countermeasure Assembly

A. Engineering

- (1) Maintain liaison and coordination with related efforts on the Safety Program (Subtasks 2.5 and 2.7) radiation and effects on explosive program (Subtask 1.9), and with other organizations (including AGC subcontractors, Aberdeen Proving Grounds, Picatinny Arsenal, Watervliet Arsenal, and Los Alamos Scientific Laboratory) to effectively coordinate the various related and subsystem safety system efforts within themselves and with the overall engine system program.
- (2) Provide the technical direction, coordination, analysis and review on a continuing basis in order to effect and facilitate the design, analysis, fabrication and test work necessary to provide a program that will result in a demonstration of system feasibility for a non-ejectable type bifunctional (Anticriticality-Post Operation) destruct system and an Anticriticality Poison Wire Safety Subsystem which can be integrated into the NERVA engine and the RIFT vehicle.
- (3) Perform the analysis and evaluation of the requirements of Special Test Equipment (STE) and Government Furnished Equipment (GFE) and materials necessary for the support of all portions of the work concerned with the countermeasures system program.
- (4) Perform the analysis and evaluation of the requirements of the Garfield Flats Test Facility at Hawthorne, Nevada for support of the testing and development portion of the countermeasures system program and perform the work as required for continued development of this facility.
- (5) Provide analysis and review directed toward the investigation and development of engine safety features, including such areas as passive reactor disassembly and mechanical safety devices, malfunction sensor and control interlocks.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 1.6.1 Supporting Research Program

A. Engineering

- (1) Perform the design, analysis and evaluation required for instrumentation of sub-scale and full scale simulated and loaded Post Operational Destruct System (PODS) tests to determine time of arrival and pressure load data.
- (2) Perform the design analysis and evaluation required for the development of correlation data relating the crude fuel element material simulants to the actual fuel element core material.
- (3) Prepare report on results of (2) above. Correlation data between simulated and loaded materials will be shown in this report.

B. Fabrication

- (1) Fabricate the various explosive charges, sub-scale targets, fixtures and associated hardware required for conducting tests related to the supporting research program.
- (2) Provide piezoelectric crystals with associated wiring harness to provide instrumentation pickups for time of arrival and pressure measurements in both full scale and sub-scale targets simulative of the engine cross sections.
- (3) Fabricate various explosive charges simulative of PODS projectiles as required to support the testing effort.

C. Testing

- (1) Conduct tests required for development of instrumentation to determine time of arrival and pressure load data.
- (2) Conduct tests to determine time of arrival and pressure load data for simulated and actual reactor core material in both sub-scale post operative destruct systems and full scale post operative destruct systems.
- (3) Conduct explosive fragmentation tests on various sub-scale models to determine correlation data relating simulant core materials with actual engine materials.

D. Tooling - Not applicable

Sub-subtask 1.6.2 - Open

Sub-subtask 1.6.3 - Open

Sub-subtask 1.6.4 Reactor Poison System Research and Development

A. Engineering

- (1) Perform the design, analysis and evaluation to determine the optimum type, number, and distribution of poison wire arrangement for an anticriticality poison wire system.
- (2) Perform the analysis and evaluation of the mechanical feasibility of the anticriticality poison wire system for integration into the NERVA engine that will provide for the installation and mechanical removal of poison wires from the NRX-A Block I reactor configuration.
- (3) Prepare a report describing preliminary evaluation of the installation and mechanical feasibility of the removal of the wires from the NRX-A Block I configuration based on existing start-up and control specifications including but not limited to analytical determination of vibration and take off "G" loads.
- (4) Perform the analysis and evaluation of the means of effecting rapid removal of the poison wires by the employment of techniques involving hydraulic, pneumatic, spring, or explosively actuated mechanisms.
- (5) Prepare a report describing the conceptual pull mechanisms and associated controls that will accomplish poison wire removal.
- (6) Prepare a report describing the conceptual pull mechanisms and associated controls designed to remove the poison wires from the NRX-A Block I reactor configuration, based on existing start-up and control specifications.
- (7) Provide the design, analysis and evaluation of mounting techniques for a poison wire system including the pull mechanisms and associated controls and perform preliminary weight determinations and stress and vibration analysis for such a system. The design objective is that the pull mechanisms and associated controls shall be capable of being upgraded to meet flight requirements.
- (8) On the basis of test results, evaluate and improve as appropriate the most promising pull mechanism concepts and support structures. Assess the tentative feasibility of the poison wire pull mechanism, mounting structure and control system based on the test program results.

Sub-subtask 1.6.4 (Con't.)

- (9) Prepare a topical report describing the feasibility of the poison wire system, incorporating conceptual designs of pull mechanisms and associated controls, and the poison wire systems integration into and removal from the NERVA engine. Prepare preliminary engineering drawings and specifications for inclusion with this report. This report shall summarize the physical properties (i.e., structural requirements, weight analysis, stress and vibration analysis) of the conceptual poison wire system.

B. Fabrication

- (1) Fabricate mock-ups and other associated hardware required for the demonstration of mechanical feasibility of the anticriticality poison wire system, determination of the pull forces required and the investigation of a means for effecting rapid removal of the poison wire.
- (2) Fabricate test mock-up, jigs, fixtures, and feasibility demonstration pull mechanisms in support of the poison wire testing program. Fabricate support fixtures and a breadboard control system.

C. Testing

- (1) Conduct tests to determine the mechanical feasibility of the anticriticality poison wire system and the pull forces required, and to demonstrate techniques for effecting the rapid removal of the poison wires.
- (2) Perform testing with hardware designed under Item A 7 above and a breadboard control system.

D. Tooling

Provide as required.

Sub-subtask 1.6.5 Post Operational Destruct System (PODS)

A. Engineering

- (1) Perform the design, analysis and evaluation for integration of the PODS into the NERVA engine design. The preliminary design objectives shall include a system phase and a component phase. The system design shall be for the Mark D concept based on the use of 4 projectiles. The preliminary design work shall result in engineering drawings and analysis which include the following:

- a. Overall assembly of the system
- b. Integration of the system into the engine
- c. Major components (i.e., projectile, launcher, control and firing.)
- d. Tabulation of weights, moments of inertia and centers of gravity of the major components and of the assembled system.
- e. Stress and vibration analysis for this system.
- f. Structural loads imposed on the engine by the assembled system during flight.
- g. Reaction forces imposed on the engine by the operation of the projectile launchers.

It is not the objective for the contract period to produce an optimized system or optimized components.

However, the functional relationships between components, the spatial relationships, the requirements for linkages or communications between components and the effects upon overall system performance of changing the performance must be studied and tentatively established in order to create a meaningful preliminary system design.

- (2) Determine the preliminary shielding and/or cooling requirements for the PODS due to the radiation environment.
- (3) Perform the anticriticality modes analysis including the determination of the following:
 - a. Circumstances of booster failure which would prevent the Mark D system from functioning reliably and effectively.
 - b. Possible modification in the source and the type of command signal given to the control and firing unit of the Mark D system which could overcome these circumstances..
 - c. Firing system sequencing for anticriticality mode.
 - d. Number of projectiles to be used in anticriticality mode.
 - e. Disposal of remaining projectiles, if any.
- (4) Publish a report on the basis of the above analysis, evaluating the suitability of the Mark D system for use in the anticriticality mode.
- (5) Design of the PODS projectile, which includes the explosive charge, initiator, casing and nose.
- (6) Perform the preliminary design of the PODS launcher system, which includes the launcher tube, propellant and fuse.

Sub-subtask 1.6.5 (Con't.)

- (7) Perform the design and evaluation of a breadboard control and firing system. The evaluation will be primarily analytical.
- (8) Develop procedures for sampling a statistically significant portion of the core fragments. Use a widespread array of sampling devices on the test pad. Develop a statistically valid arrangement of these devices and specify the meteorological conditions under which tests can be performed.
- (9) Publish a special technical report prior to conducting the initial full scale fragmentation experiment during Contract Year 1964, which specifies and analyzes the recovery and sampling procedures.
- (10) Issue a test plan and addenda as required for PODS tests at Garfield Flats, in accordance with agreed upon procedures.

B. Fabrication

- (1) Fabricate explosive charges and full scale simulated engine targets required for evaluation of a post-operation destruct system having bifunctional capability.
- (2) Fabrication shall include at least the following:
 - a. Full scale targets simulative of engine cross-section segments.
 - b. Full scale simulated engines, with and without configuration core material.
 - c. Explosive charges simulative of the high explosive portion of proposed projectiles.
 - d. Full scale targets simulative of engine forward closure section.
 - e. Projectile initiation train assemblies.
 - f. Launch tube assemblies
 - g. Fuse assemblies
 - h. Control and firing system breadboard model
 - i. Projectile assemblies
 - j. Associated test stands, handling fixtures, etc.

Sub-subtask 1.6.5 (Con't.)

C. Testing

- (1) Perform tests to include experimental studies of core fragmentation, projectile penetration, propellant evaluation, and control and firing systems. The following specific experiments shall be performed:
 - a. One (1) full scale test to verify the selection of projectile casing design.
 - b. Three (3) full scale tests to study the radial, longitudinal and lateral distribution of the projectile charges.
 - c. One (1) full scale test to verify the projectile distribution and in addition study the effects of projectile time delay extremes.
 - d. One (1) full scale test to evaluate the effects of dynamic launch of a single projectile on resulting core fragmentation.
 - e. One (1) full scale test to evaluate the effects of dynamic launch of at least two projectiles on resulting core fragmentation.
- (2) Perform projectile design tests, based upon design evaluation activity to be conducted at Aberdeen Proving Grounds (APG), of the following:
 - a. Inert-loaded projectiles against simulated engine forward closures for penetration evaluation, muzzle velocity and angle of impact.
 - b. Inert-loaded projectiles to determine base charge fuse functioning characteristics. Perform initiator design tests for evaluation of mechanical, pyrotechnic, and/or electric type fuses.
- (3) Perform launch tube design tests to include the following types:
 - a. Closed breech type tubes to determine design characteristics such as muzzle configuration, breech block configuration, gas check, release mechanism.
 - b. Re-coilless type tubes to determine design characteristics, such as muzzle configuration, gas check and release mechanism.
 - c. Composite type tubes to determine design characteristics such as muzzle configuration, gas check and release mechanism.
 - d. Perform tests to evaluate the selected propellant based upon APG results, in the most suitable launch tube design.
- (4) Perform tests on a control and firing system breadboard model to determine response times, required inputs and outputs and functioning relationships of the various components.

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Sub-subtask 1.6.6 Engineering Safety Features

A. Engineering

- (1) Perform the analysis and evaluation related to the passive disassembly of an uncooled engine re-entering the atmosphere and suggest design modifications for enhancing this disassembly.
- (2) Publish a report on the analysis and evaluation of passive reactor disassembly.
- (3) Perform the analysis and evaluation to determine the adequacy of safety features, the mechanical safety devices, and malfunction sensors currently incorporated in the NERVA engine design. The study of engine safety features will include, but not be limited to, the following considerations:
 - a. Evaluate engine design in terms of the limits and conditions which must be maintained to provide safe operation of the engine.
 - b. Evaluate the provisions for alternate control of the engine under various types of malfunction conditions during ground testing.
 - c. Investigate safety features (locks and interlocks, reactor cutback provisions, coolant flow safety provisions, etc.) required to assure safe control of the engine during normal operation, and assess the ability of these devices to assure compliance with applicable safety criteria.
 - d. Investigate safety features required to detect reactor or engine malfunction conditions (excessive reactor period, inadequate coolant flow, excessive temperature, mechanical failure, etc.).
- (4) Perform the analysis and evaluation to define the operational and functional relationships existing among the mechanical safety devices and malfunction sensors, including applications of the controlled interlocks. The study will include but not be limited to the following:
 - a. Analyze and evaluate the operational and functional interrelationships of the various safety devices and malfunction sensors for compliance with safety criteria.
 - b. Evaluate and delineate the malfunction conditions under which a malfunction detector and discrimination circuit system should initiate the destruct sequence.
 - c. Investigate techniques and features to be employed in discriminating between a malfunction condition requiring destruction of the engine and an abnormal condition from which recovery by the control system can be permitted.

Sub-subtask 1.6.6 (Con't.)

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Subtask 1.7 Pneumatic Power Supply (PFS)

Sub-subtask 1.7.0 Pneumatic Power System Assembly

A. Engineering

- (1) Perform system design analyses to upgrade the component design criteria. Complete and issue a report on the computer program simulating the pneumatic system to determine the effects of system size variations and of different mission profiles.
- (2) Perform engineering effort relating to the CFDTS program, to integrate a pneumatic power system into the test assembly.
- (3) Complete the test plans for non-radiation and radiation effects tests on a breadboard pneumatic power system of the E-Block I engine configuration. Perform evaluation of the breadboard E-Block I pneumatic power system tests.
- (4) Initiate test planning for non-radiation tests on a breadboard pneumatic power system including storage bottles.
- (5) Update layout of a pneumatic power system including storage bottles based on development test evaluation and FX system studies.
- (6) Complete the design criteria defining the seal venting and coolant system components.

B. Fabrication

- (1) Complete the fabrication and assembly of a breadboard E-Block I pneumatic power system consisting of configuration I components. This pneumatic system will include all components required to supply actuation and coolant gas and seal venting for the E-Block I engines.
- (2) Complete the fabrication and assembly of a breadboard pneumatic power system including storage bottles. This system will be assembled from configuration I pneumatic system components.

C. Testing

- (1) Complete the first series of tests on the breadboard E-Block I pneumatic power system.
- (2) Complete acceptance testing of the pneumatic power system for CFDTS.

Sub-subtask 1.7.0 (Con't)

D. Tooling

- (1) No major tooling is required.

Sub-subtask 1.7.1 Pneumatic Power System Components

A. Engineering

- (1) Complete the design studies on all components required for the pneumatic power system defined for the E-Block I engine.
- (2) Perform evaluation of component tests performed on configuration I components. These components shall be limited to components of the pneumatic power system defined for the E-Block I engine. Prepare and issue reports covering the developmental test series performed during this contract period.
- (3) Perform design studies on the components of the E-Block I engine coolant supply and venting systems defined by system analysis work.
- (4) Evaluation of the pneumatic power system radiation effects test results will be initiated.

B. Fabrication

- (1) Complete the procurement of pneumatic power system components initiated in the previous contract period including test stand pneumatic connectors, check valves, shutoff valves, regulators, filters, relief valves, burst diaphragms, remote disconnects, seals and bellows. Complete the fabrication of a prototype tank and heat exchanger.
- (2) Complete the fabrication of pneumatic power system components for the CFDTS program initiated in the previous contract period. Components unique to the pneumatic system on CFDTS will be funded and procured under sub-subtask 1.1.2 and will include a back pressure regulator, filter, check valve, shutoff valve, lines and fittings, bellows, connectors and disconnects.

C. Testing

- (1) Perform development testing at vendor and LRP development laboratories on the configuration I pneumatic power system components.
- (2) Complete the radiation effects tests on configuration I pneumatic power system components required for the E-Block I engines.

Sub-subtask 1.7.1 (Con't)

- (3) Complete acceptance tests on configuration I pneumatic power system components for the E-Block I engine required for radiation effects tests on pallet 905.

Subtask 1.8 Systems Analysis

Sub-subtask 1.8.0 Integration and Technical Management

A. Engineering

- (1) Provide over-all administration and coordination of all systems analyses for all systems pertinent to the NERVA engine program. These systems shall include, but are not limited to:

CFDTS

Component development test systems

Acceptance test systems

NRX (hot and cold flow)

E-Engine

FX-Engines

- (2) Submit to SNPO-C a format for the NERVA Systems Analysis Data Book. Update, maintain, and distribute the NERVA Systems Analysis Data Book.

B. Fabrication - Not applicable.

C. Testing - Not applicable.

D. Tooling - Not applicable.

Sub-subtask 1.8.1 Non-nuclear Development Test Systems

A. Engineering

- (1) Complete and report pre-test analyses of CFDTS to establish desirable test conditions.
- (2) Complete and report data analysis model for CFDTS.
- (3) Issue CFDTS data analysis report.
- (4) Analyze component test systems to determine facility/component interactions. Issue memorandum reports of these analyses.

B. Fabrication - Not applicable.

C. Testing - Not applicable.

D. Tooling - Not applicable

Sub-subtask 1.8.2 NRX Systems Analysis

A. Engineering

- (1) Complete and report the test plan analyses of NRX-A1, A2, A3, A4, and A5.
- (2) Complete and report the pre-test analyses of NRX-A1, A2, A3.
- (3) Complete and issue data analysis reports for NRX- A1, A2, and A3.

B. Fabrication - Not applicable.

C. Testing - Not applicable.

D. Tooling - Not applicable.

Sub-subtask 1.8.3 E-Engine Systems Analysis

A. Engineering

- (1) Complete and report E-Engine system analysis model.
- (2) Complete and report steady state and transient analyses of operating map and constraints for start, shutdown, and scram of E-Engine.
- (3) Complete and issue report on Data Analysis Method for E-Engines.

B. Fabrication - Not applicable.

C. Testing - Not applicable.

D. Tooling - Not applicable.

Sub-subtask 1.8.4 FX-Engine Systems Analysis

A. Engineering

- (1) Conduct transient and steady state analyses of the FX-Engine as required to update engine specifications due to component changes.

B. Fabrication - Not applicable.

C. Testing - Not applicable.

D. Tooling - Not applicable.

Subtask 1.9 Radiation Effects Program

Sub-subtask 1.9.0 Integration and Technical Management

A. Engineering

- (1) Plan, design, coordinate, and review radiation effects tests which will evaluate NERVA mechanical components, electrical components, instrumentation and materials. In addition, the radiation tests pertaining to fuel materials and the counter measure system will be reviewed and coordinated. This work includes scheduling tests, preparing test procedures, designing and fabricating test fixtures, reviewing and approving STE requirements, and performing pre-irradiation and post-irradiation test analyses.
- (2) Prepare and submit to SNPO-C the following:
 - a. Program planning details for GD/FW operations for this contract period.
 - b. Program planning details for PBRF operations for this contract period.
 - c. The Radiation Effects Data Book twice during this contract period.
 - d. The preliminary subtask 1.9 radiation effects program for the next contract period.
 - e. Test plans for all radiation effects tests for this contract period.
 - f. Preliminary test specifications to both SNPO-C and test facility eight weeks before the scheduled test date.
 - g. Final test specifications to both SNPO-C and test facility four weeks before the scheduled test date.
 - h. Preliminary test reports no later than 45 days after completion of the following tests:
 1. GTR tests 7A, 8-9, 10 thru 19
 2. ASTR tests 1 through 8
 3. PBRF cycles 5 through 21

Sub-subtask 1.9.0 (Con't.)

- i. Final test reports no later than 90 days after completion of the following tests:
 - 1. GTR tests 4,7,7A, 8-9, 10 through 17
 - 2. ASTR tests 1 through 7
 - 3. PBRF cycles 5 through 19
- j. A report summarizing the NERVA nuclear environment.
- k. A report summarizing the nuclear heating and activation of NERVA engine components.
 - 1. The Radiation Effects Compendium (Report 2510) supplements.
- m. A projected long range radiation effects test schedule to be used by REON and SNPO-C for planning purposes.
- (3) Coordinate and assist in the preparation of the proposed NARF propellant feed system radiation effects tests.
- (4) Coordinate and evaluate the work at GD/FW and AGC-Downey concerning the effect of radiation on LN_2 and LH_2 .
- (5) Coordinate and approve the installation and checkout of special test equipment items for radiation testing at GD/FW.
- (6) Assist in the preparation of program planning details for NARF radiation effects tests on the propellant feed system at GD/FW.
- B. Fabrication - Not applicable
- C. Testing - Not applicable
- D. Tooling - Not applicable

Sub-subtask 1.9.1 Countermeasure Radiation Effects Program

A. Engineering

- (1) Provide liaison and coordination with the work being performed by Picatinny Arsenal, GETR Facility, AGC-Downey and all other subcontractors or GFE efforts related to the irradiation of explosives for NERVA.
- (2) Analyze irradiation test data and prepare summary reports of these data which will indicate the effects of radiation on explosives for both Phase I and Phase II experimental work.
- (3) Design capsules for irradiating explosives as required.
- (4) Assist in the engineering design of the irradiation experiments.

Sub-subtask 1.9.1 (Con't.)

B. Fabrication

- (1) Fabricate irradiation test capsules and test fixtures as required.

C. Testing

- (1) Perform pre-irradiation and post-irradiation tests as defined in a mutually agreed upon plan.

D. Tooling

- (1) As required.

Sub-Subtask 1.9.2 Radiation Analysis and Data Book

A. Engineering

- (1) Maintain the Radiation Effects Data Book on a current status and prepare for submittal to SNPO-C twice during contract year.
- (2) Provide engineering support to all Subtask 1.9 activities to determine the compatibility of test specifications or applicability of test information to the NERVA requirements.
- (3) Perform the necessary analysis to predict the neutron and gamma fluxes within the engine envelope and prepare a summary report for submittal to SNPO-C.
- (4) Calculate the heat generation and induced activation in the engine components during a NERVA engine test and prepare a summary report for submittal to SNPO-C.
- (5) Perform the necessary analytical and experimental studies to identify the problem associated with irradiation LN₂ and LH₂ and its influence upon future radiation tests and upon NERVA reactor experiments and submit two summary reports to SNPO-C.

B. Fabrication

- (1) Fabricate test capsules and fixtures for the LN₂ and LH₂ tests.

C. Testing

- (1) Perform experimental studies concerning the effect of radiation on LN₂ and LH₂ in accordance with a mutually agreed upon plan.

D. Tooling

- (1) As required.

Sub-subtask 1.9.3 Special Test Equipment for GD/FW Radiation Testing

Provide special test equipment for both GTR and ASTR radiation testing at GD/FW. The special test equipment required for test operations scheduled at GD/FW includes but is not limited to the following:

- (1) Equipment for fabricating and checking out test assemblies prior to shipment to GD/FW.
- (2) Fabrication and/or procurement of supporting test equipment for the propellant feed system required for test operations scheduled at GD/FW.

Sub-subtask 1.9.4 Instrumentation Radiation Effects Program

A. Engineering

- (1) Plan and design instrumentation radiation effects tests, assist in the selection of components for testing, design test fixtures, prepare test procedures, assist in the checkout of test assemblies, coordinate radiation effects tests, and analyze test results.
- (2) Provide technical assistance in the conduct of the following instrumentation tests identified as follows during Contract Year 1964:

GTR 10 through 14, 16, 17, 19, 20
PBRF 8 through 22
NRDS 1

B. Fabrication

- (1) Provide test pallets, compatible test assemblies and/or fixtures and incorporate components and instrumentation selected for radiation effects testing into the test assemblies or fixtures so provided.

C. Testing

- (1) Perform pre-irradiation reference tests as required under paragraph A-2.
- (2) Checkout all components, test fixtures, and test assemblies prior to shipment to test facilities.
- (3) Perform pre-irradiation and post-irradiation tests.

D. Tooling

- (1) As required.

Sub-subtask 1.9.5 Components Radiation Effects Program

A. Engineering

- (1) Plan and design component radiation effects tests, assist in the selection of components for testing, design test fixtures, prepare test procedures, assist in the checkout of test assemblies, coordinate radiation effects tests, and analyze test results.
- (2) Provide technical assistance in the conduct of the following component radiation effects tests during Contract Year 1964:

ASTR 2 through 8
GTR 11, 12, 14, 16, 17, 19, 20
- (3) Provide engineering and design services for the preparation and evaluation of test procedures and test specifications for the propellant feed system radiation effects tests. In addition, provide technical assistance for specifying the PFS data acquisition equipment and STE items for GD/FW.

B. Fabrication

- (1) Provide test pallets, compatible test assemblies and/or fixtures and incorporate the components selected for radiation effects testing into the test assemblies or fixtures so provided.

C. Testing

- (1) Perform pre-irradiation reference tests as required under paragraph A-2.
- (2) Checkout all components, test fixtures, and test assemblies prior to shipment to test facilities.
- (3) Perform pre-irradiation and post-irradiation tests.

D. Tooling

- (1) As required.

Sub-subtask 1.9.6 Materials Irradiation Effects Tests

A. Engineering

- (1) Plan and design structural materials, and fuel materials radiation effects tests; prepare test procedures; select materials for test; design test specimens and fixtures; assist in the test assembly checkouts; coordinate radiation tests; and analyze test results.

Sub-subtask 1.9.6 (Con't)

- (2) Provide technical assistance and coordination of materials programs being carried out under other subtasks and by other contractors for the NERVA program.
- (3) Provide technical assistance for the conduct of the following irradiation tests:
 - a. Tensile strength of various materials at cryogenic temperature (GTR-15).
 - b. Thermal conductivity of materials at cryogenic temperatures. (GTR-18)
 - c. Tensile and shear tests of materials at cryogenic temperature (GTR-21).
 - d. Fuel materials for diffusion and burn-up studies at GETR/PBRF (15 capsules).
- (4) Conduct non-nuclear screening tests of NERVA candidate materials and submit a summary report to SNPO-C.
- (5) Prepare and submit to SNPO-C a fuel material irradiation summary report.
- (6) Plan future materials tests, both nuclear and non-nuclear, and submit to SNPO-C for review and approval prior to hardware procurement.
- (7) Maintain the Materials Data Book in a current status and submit to SNPO-C twice during contract year.

B. Fabrication

- (1) Provide cryostats and test pallets as required by the radiation effects program planning documents.
- (2) Provide specimens of the materials selected for radiation effects testing.
- (3) Provide test assemblies or fixtures which are compatible with the cryostats, test pallets, and test reactor interfaces.

C. Testing

- (1) Conduct screening tests of materials planned for the NERVA engine.
- (2) Conduct non-irradiation reference tests on materials to support the NERVA design and development requirements.

Sub-subtask 1.9.6 (Con't)

- (3) Checkout all component test fixtures, and assemblies prior to shipment to test facilities.
- (4) Provide technical assistance for the conduct of pre-irradiation reference tests and analysis.
- (5) Provide technical assistance for the conduct of irradiation tests on fuel materials at the GETR facility and/or the PBRF facility.

D. Tooling

- (1) As required.

Sub-subtask 1.9.7 Pre-irradiation Test STE - No work this contract period.

Sub-subtask 1.9.8 Plum Brook Support

A. Engineering

- (1) Provide technical assistance for the installation and checkout of W-1 cryogenic test loop at PBRF.
- (2) Schedule, coordinate, prepare test operation procedures, and provide technical assistance for the performance of all NERVA tests at PBRF.
- (3) Design irradiation test fixtures where required.
- (4) Provide engineering assistance in the incorporation of test components and instrumentation into test assemblies.
- (5) Provide engineering assistance in the performance of pre-irradiation checkout of all tests scheduled for PBRF.
- (6) Provide assistance for taking data before tests, during tests, and after tests.
- (7) Provide assistance for performing all required post irradiation analysis and all hot-cell work.
- (8) Prepare and submit preliminary test reports to SNPO-C within 45 days of test completion.
- (9) Provide assistance to maintain and repair both the W-1 cryogenic loop and the W-2 water-cooled test loop.

Sub-subtask 1.9.8 (Con't)

B. Fabrication

- (1) Fabricate test fixtures, test capsules, and assemblies for performing radiation effects tests at PBRF.
- (2) Maintain and repair both the W-1 cryogenic loop and the W-2 water-cooled test loop.

C. Testing

- (1) Perform checkout tests of all components or assemblies scheduled for test at PBRF.
- (2) Conduct pre-irradiation checkout of systems.
- (3) Perform irradiation tests. This project shall be responsible for all phases of the test program excluding those services provided by Plum Brook.
- (4) Conduct post-irradiation tests.
- (5) Perform analysis of test components and conduct hot-cell activities.

D. Tooling

- (1) As required.

TASK 2. Engine Support Systems and Functions

Subtask 2.1 - Remote Handling Equipment

Sub-subtask 2.1.0 - Integration and Technical Management

A. Engineering

- (1) Provide the coordination and review necessary to assure the proper development and integration of remote handling equipment in the NERVA Program and the coordination of pertinent NERVA operations requirements with the RIFT contractor. This effort shall include, but not be limited to the following:
 - (a) Systems analysis and review of test plans.
 - (b) Integration of remote handling equipment documentation and operational parameters.
 - (c) Establishment of facility-equipment compatibility requirements.
 - (d) Direction of subcontractor activities and coordination and liaison between subcontractors, SNPO-C, SNPO-N, and other subtasks.
 - (e) Engineering studies, cost estimates and schedules.
 - (f) Progress reports and special topical reports, as required.
 - (g) Spares provisioning lists and program requirements document support.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 2.1.1 - Overhead Positioning System (OPS)

A. Engineering

- (1) Complete the design of the OPS, including that effort required to support the NRX Program in the E-MAD Building.
- (2) Provide engineering and management required for OPS procurement, fabrication, and delivery to NRDS, for E-MAD facility wiring required for the OPS and for preparations to Commerce Assmbly and installation of the OPS in the E-MAD Building during the first quarter of the next contract period. Complete the acceptance test specifications, operating and maintenance instructions, and recommended spare parts list as required for the OPS.

Sub-subtask 2.1.1 (Continued)

B. Fabrication

- (1) Complete the fabrication, assembly, shop test, and delivery of the OPS.
- (2) Complete E-MAD OPS facility wiring (junction box terminal to terminal) based on an E-MAD availability for this purpose by June 1, 1964.

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 2.1.2 - Floor Mounted Handling System (FMHS)

A. Engineering

- (1) Provide engineering and management to complete the various items of the FMHS to support NRX E-MAD operations. These items include:
 - (a) FMHS Busrail subsystem.
 - (b) Remote dolly.
 - (c) Mobile carriage.
 - (d) Turntables
- (2) Complete final design of these items including mechanical, electrical and control systems.
- (3) Provide operation and maintenance instructions, spares provisioning lists and program requirements support.

B. Fabrication

- (1) Complete fabrication and deliver to NRDS the remote dolly, mobile carriage, and turntables required for the NRX program.
- (2) Complete the procurement and/or fabrication of the major elements of the FMHS busrail extension system. Complete the floor mounted handling system facility wiring (junction box terminal to terminal) in the E-MAD Building, assuming availability of the E-MAD Building for this purpose by June 1, 1964.

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 2.1.3 - NRX Support Equipment

A. Engineering

- (1) Prepare, maintain, and modify as necessary the remote handling equipment portion of the Block I Operation Support Plan (OSP) for NRX-A2, and Addenda for NRX-A3, and NRX-A4 reactors and integrate OSP inputs from other subtasks as required. Develop and issue the preliminary Block II (hot) operational support plan. Develop, issue, and maintain a separate Operation Support Plan for NRX-A5 (cold flow).
- (2) Provide the functional requirements and design criteria for post mortem equipment for Block I and A6 reactors.
- (3) Complete the design modifications of existing NRX hot disassembly and post mortem equipment, to support the NRX-A2, A3, A4, and A6 reactors based upon no major modifications to reactor design.
- (4) Complete a study of the use of the OPS and FMHS equipment for disassembly of NRX reactors.
- (5) Complete the design of the NRX-A2, A3, and A4 post mortem equipment based upon no major modification to reactor design.
- (6) Provide the acceptance test specifications, operations and maintenance instructions, recommended spare parts list, and program requirement support as necessary for all delivered hardware.
- (7) Assist in the checkout of remote handling and post mortem equipment for the NRX reactor disassembly in the MAD Building.
- (8) Identify, specify, and design the post operative equipment required for use in facilities other than R-MAD or at Los Alamos Scientific Laboratory.
- (9) Complete the design of mechanical modifications of existing NRX test cars for NRX-A2 thru NRX-A5 reactors and commence design modifications for NRX-A6. Follow modification of test cars and associated hardware and evaluate test car performance.
- (10) Complete the electrical criteria, design modifications, wiring diagrams, and schematics for integration of the NRX-A2 thru NRX-A5 reactors to the test cars. Coordinate the test car interface with the test facility and ACFI for NRX-A1 thru NRX-A5.

Sub-subtask 2.1.3 (Continued)

- (11) Maintain liaison with LASL, SNPO-C, SNPO-N, and NTO and direct the design and equipment fabrication effort of ACFI.
- (12) Complete a study to identify additional or duplicate NRX equipment requirements which will result from concurrent NRX operation in R-MAD and E-MAD.
- (13) In connection with item (1) under Fabrication, it is recognized that the support equipment list may require substantial change due to changes in reactor or remote handling technology. Both parties agree that such substantial changes will warrant a change in scope and therefore warrant a change in estimated cost. Complete the development of functional requirements and design criteria and commence preliminary design for post mortem equipment necessary to support NRX reactor systems in E-MAD.

B. Fabrication

- (1) Complete the fabrication, delivery, and acceptance testing of the NRX-A2 and additional required or modified NRX-A2, A3, and A4 remote handling and post-mortem equipment consistent with the Block I Operation Support Plan and in accordance with the associated support equipment list and amendments thereto as approved by SNPO-C.

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 2.1.4 - NERVA Exhaust System (NEX)

A. Engineering

- (1) Complete the equipment specifications for the NES duct trailer and continue analysis of NES system requirements to ascertain additional NES support equipment required.
- (2) Provide engineering and management and complete the preliminary and detail design of the NES trailer.

B. Fabrication

- (1) Initiate fabrication of the NES duct trailer to assure verification of the duct trailer at NRDS in the second quarter of the next contract period.

Sub-subtask 2.1.4 (Continued)

- C. Testing - Not applicable
- D. Tooling - Not applicable

Sub-subtask 2.1.5 - Support Equipment - Engine

A. Engineering

- (1) Maintain current the remote handling portion of the E-1 Engine operational support plan current with E-1 engine development and integrate the OSP inputs from other subtasks as required.
- (2) Provide the functional requirements and design criteria for E-Engine remote assembly, disassembly, and post operative equipment as required to support facility criteria, design, and construction requirements. Complete the equipment specifications and design of the intercell transfer system and hot cell material transfer system as required for use with the NRX program and eventual use with the E-Engine program.

B. Fabrication

- (1) Initiate procurement and fabrication of the intercell transfer system and hot cell material transfer system consistent with completion of delivery, installation and vendor verification by March 1965.

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 2.1.6 - Engine Installation Vehicle (EIV), Manned Control Car (MCC), and Locomotive

A. Engineering

- (1) Complete the engineering required to support locomotive modifications. Provide the necessary engineering and management for procurement, fabrication, and assembly of the EIV and MCC and integration of these components with the locomotive.

Sub-subtask 2.1.6 (Continued)

B. Fabrication

- (1) Complete the fabrication, delivery, and assembly of the EIV and MCC.
- (2) Complete the modification and delivery of the locomotive in accordance with specification AGC 10126C.
- (3) Complete the facility electrical wiring installation terminal to terminal as required for the EIV operations in the E-MAD Building.

Sub-subtask 2.1.7 - Facility Support Equipment

A. Engineering

- (1) Complete the equipment specification and detail design and provide engineering and management for design, procurement and fabrication of the Waste Disposal System.

B. Fabrication

- (1) Procurement and fabrication of the waste disposal equipment will be started on a schedule consistent with the delivery, installation and verification at NRDS on July 1965.

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 2.1.8 - Test Stand Equipment

A. Engineering

- (1) Continue the analysis of ETS-1 complex to ascertain requirements for additional equipment.
- (2) Complete and issue the results of a test stand malfunction study to determine the types and quantities of remote handling equipment required to recover from a major engine malfunction.

Sub-subtask 2.1.8 (Continued)

(3) Provide liaison with Argonne National Laboratory in support of the Engine/test stand maintenance studies. Based on information available from the ANL studies being conducted, complete and issue a report evaluating the functional requirements for equipment which may be used for engine/test stand maintenance.

(4) Complete the study of on-stand maintenance for ETS-1.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 2.1.9 - Launch Operations Equipment

No work in this contract period.

Subtask 2.2 Ground Support Equipment (Checkout and Test)

Sub-subtask 2.2.0 Integration and Technical Management

A. Engineering

- (1) Provide the coordination and the review necessary to assure proper development and integration of checkout and test equipment in the NERVA program and the coordination of pertinent NERVA operations requirements with the RIFT contractor. This effort shall include, but not be limited to, the following:
 - (a) System operations analysis and review of test plans.
 - (b) Integration of checkout and test equipment documentation and operational parameters.
 - (c) Establishment of facility-equipment compatibility requirements.
 - (d) Direction of subcontractor activities and coordination and liaison between subcontractors, SNPO-C, SNPO-N, and other subtasks.
 - (e) Engineering studies, cost estimates, and schedules.
 - (f) Progress reports and special topical reports as required.
 - (g) Spares provisioning lists and program requirement documentation support.

B. Fabrication - Not applicable.

C. Testing - Not applicable.

D. Tooling - Not applicable.

Sub-subtask 2.2.1 Non-Nuclear Development Test System (NNDTS)

A. Engineering

- (1) Conduct engineering and management necessary to evaluate checkout and test equipment capabilities of the existing facilities to meet CFDTs testing requirements to ascertain additional equipment requirements.

Sub-subtask 2.2.1 (Continued)

- B. Fabrication - Not applicable
- C. Testing - Not applicable
- D. Tooling - Not applicable

Sub-subtask 2.2.2 Open

Sub-subtask 2.2.3 NRX Equipment

A. Engineering

- (1) Prepare, maintain, and modify as necessary the checkout and test equipment portion of Block I operation support plan for NRX-A2 and addenda for NRX-A3, and NRX-A4 reactors. Develop and issue the preliminary Block II (hot) operation support plan. Develop, issue, and maintain a separate operation support plan for NRX-A5 (cold flow).
- (2) Provide the functional requirements and design criteria for new checkout and test equipment for NRX-A3 through A6.
- (3) Complete design modifications of existing NRX checkout and test equipment as required to support the NRX-A3 through NRX-A6 reactors.
- (4) Prepare preliminary designs or equipment specifications for NRX-A3 through A6 checkout and test equipment.
- (5) Perform a study of the effects of concurrent NRX operations in the R-MAD and E-MAD on equipment provisioning.
- (6) Complete the design of the checkout and test equipment for NRX-A3 through NRX-A5.
- (7) Complete the acceptance test specifications, operating and maintenance instructions, and the recommended spare parts list for all delivered hardware.
- (8) Provide technical follow-up for the installation, test, and application of checkout and test equipment required for the NRX program.

B. Fabrication

- (1) Complete the fabrication, modification, delivery, and

Sub-subtask 2.2.3 (Continued)

acceptance testing of the additionally required NRX-A2 through NRX-A5 checkout and test equipment consistent with the Block I Operation Support Plan and in accordance with the associated support equipment list and amendments thereto as approved by SNPO-C.

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 2.2.4 Open

Sub-subtask 2.2.5 Engine Equipment

A. Engineering

- (1) Maintain the checkout and test portion of the E-1 engine operational support plan current with the E-1 engine development.
- (2) Provide the functional requirements and design criteria for the E-Engine checkout and test equipment as required to support facility criteria, design, and construction requirements.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 2.2.6 Checkout and Control Trailer

A. Engineering

- (1) Up-grade the functional requirements and the design criteria for the checkout trailer.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 2.2.7 Open

Sub-subtask 2.2.8 - Test Stand Equipment

A. Engineering

- (1) Up-grade the design criteria for the engine simulator.
Up-grade the remote engine control system functional requirements and design criteria.
- (2) Commence the preliminary design of the remote engine control system.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 2.2.9 - Launch Operations Equipment

No work in this contract period.

Subtask 2.3 - Ground Support Equipment - Logistics, Transport, and Maintenance

Sub-subtask 2.3.0 - Integration and Technical Management

A. Engineering

- (1) Provide coordination and review necessary to assure proper development and integration of the logistics, transport, and maintenance equipment in the NERVA Program and the coordination of pertinent NERVA operations requirements with the RIFT contractor. The definition of equipment will include storage and shipping containers. This effort shall include, but not be limited to, the following:
 - (a) Systems operations analysis and review of test plans.
 - (b) Integration of logistics, transport and maintenance equipment documentation and operation parameters.
 - (c) Establishment of facility-equipment compatibility requirements.
 - (d) Direction of subcontractor activities and coordination and liaison between subcontractors, SNPO-C, SNPO-N, and other subtasks.
 - (e) Engineering studies, cost estimates, and schedules..
 - (f) Progress reports and special topical reports as required.
 - (g) Spares provisioning lists and program requirements documentation support.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 2.3.1 - Radioactive Materials Storage Equipment

A. Engineering

- (1) Complete the design criteria and the final design of the equipment to be utilized for graveyard storage of NRX-A2, NRX-A3, and NRX-A4 reactor components including core materials and metal parts.

Sub-subtask 2.3.1 (Continued)

B. Fabrication

- (1) Complete the fabrication delivery and acceptance testing of the storage containers for the NRX-A1 through A-4 consistent with the Block I Operation Support Plan and in accordance with the associated support equipment list and amendments thereto as approved by SNPO-C.

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 2.3.2 - Open

Sub-subtask 2.3.3 - NRX Support Equipment

A. Engineering

- (1) Prepare, maintain, and modify as necessary the logistics, transport, and maintenance portion of the Block I operation support plan for NRX-A2 and addenda for NRX-A3 and NRX-A4 reactors. Develop and issue the preliminary Block II (hot) Operation Support Plan. Develop, issue, and maintain a separate Operation Support Plan for NRX-A5 (cold flow).
- (2) Complete the designs or modifications as required for the NRX reactor shipping, receiving, cold assembly, and maintenance equipment to support NRX operations at WANL and NRDS, Cold Flow Development Test System, and intermediate shipping.
- (3) Complete design modifications of existing NRX logistics, transport and maintenance equipment as required to support the NRX-A2 through NRX-A6 reactors based upon no major modifications to the reactor design.
- (4) Provide the functional requirements and design criteria for new NRX logistics, transport, and maintenance equipment for Block I and Block II through NRX-A6.
- (5) Provide preliminary design of equipment specifications for Block I and Block II through NRX-A6 logistics, transport, and maintenance equipment.

Sub-subtask 2.3.3 (Continued)

- (6) Complete the design criteria and the design of new Block I and NRX-A5 logistics, transport, and maintenance equipment.
- (7) Complete a study to identify additional or duplicate NRX equipment requirements which will result from concurrent NRX operations in the R-MAD and the E-MAD.
- (8) Provide the engineering and assistance required for the installation and checkout of logistics, transport, and maintenance equipment at NRDS.
- (9) Maintain liaison with LASL, SNPO-C, and SNPO-N and direct the design, equipment, and fabrication at ACFI.
- (10) Provide engineering support for the design, modification, procurement, installation, and checkout of reactor assembly equipment required at WANL for major reactor subassemblies.
- (11) Complete the acceptance test specifications, operations and maintenance instructions and recommended spare parts list as required for all delivered hardware.

B. Fabrication

- (1) Complete the fabrication, modification, delivery, and acceptance testing of the additionally required NRX-A2 through A5 logistics, transport and maintenance equipment consistent with the Block I and A5 Operation Support Plan, and in accordance with the associated support equipment list and amendments thereto as approved by SNPO-C.

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 2.3.4 - Open

Sub-subtask 2.3.5 - Engine Support Equipment

A. Engineering

- (1) Maintain the logistics, transport, and maintenance portion of the E-1 Engine Operation Support Plan current with the E-1 engine development.

Sub-subtask 2.3.5 (Continued)

- (2) Provide the functional requirements and design criteria for E-Engine logistics, transport, and maintenance equipment as required to support facility criteria, design, and construction requirements.
- (3) Complete the preliminary designs or equipment specifications for the Cold Flow Development Test System equipment.
- (4) Complete the design of CFDTs equipment.

B. Fabrication

- (1) Complete the fabrication, delivery, and acceptance testing of the Cold Flow Development Test System equipment.

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 2.3.6 - Open

Sub-subtask 2.3.7 - Open

Sub-subtask 2.3.8 - Open

Sub-subtask 2.3.9 - Launch Operations Equipment

No work in this contract period.

Subtask 2.4 Instrumentation

The full program objective for this subtask is to plan, select, develop, design, test, fabricate and/or procure, and calibrate the diagnostic and control instrumentation components and systems suitable for accurately measuring the diagnostic and control parameters as required in the NERVA engine, subsystem, reactor, and components for both ground and ultimately the flight development test programs in the NERVA high radiation flux and extreme temperature environment.

The work in this contract period shall include the following:

Sub-subtask 2.4.0 Instrumentation Systems

A. Engineering

- (1) Monitor and coordinate the development and testing of the instrumentation required by the various NERVA engine, reactor, component and subsystem development and test programs. Continuously integrate the design of the diagnostic and control instrumentation system with its associated data acquisition system. Maintain liaison with various activities in this country, pertaining to the development of significant and pertinent instrumentation.
- (2) Write, update and issue quarterly the NERVA Instrumentation Data Book which shall include the following:
 - a. Measurement requirements of the various NERVA engine and development systems.
 - b. Development Program Plans of the various instrumentation components under development.
 - c. Progress of the Instrumentation Component Development Programs.
- (3) Prepare, maintain up-to-date and issue monthly to SNPO-C preliminary drafts of sections of the NERVA Instrumentation Data Book, as required, for recording the progress of the Development Program Plans and the Component Development History and Evaluation for the instrumentation systems and components being developed, designed, procured, and tested.
- (4) Prepare or update and issue to SNPO-C by November 15, 1963, a Development Program Plan for the NERVA Instrumentation Data Book describing the program to be followed during the

Sub-subtask 2.4.0 (Continued)

contract period for each development item. Each Development Program Plan in the NERVA Instrumentation Data Book shall be updated monthly, and a draft of each Development Program Plan shall be submitted to SNPO-C by the first of each month containing a description of the results of the work performed during the past monthly report period and a statement of the work planned and problems to be investigated during the next monthly report period.

- (5) A Development Program Plan for next contract period shall be prepared for each development item to be continued or initiated and submitted to SNPO-C by July 1, 1964.
- (6) Submit to SNPO-C on the first of each month an Instrumentation Procurement Status Report.

- B. Fabrication - Not applicable.
- C. Testing - Not applicable.
- D. Tooling - Not applicable.

Sub-subtask 2.4.1 Cold Flow Development Test System (CFDTS) Instrumentation

Based on the established test schedules, and on the measurement and performance requirements established by the NERVA Analysis, Design, Test and Development Programs and as recorded in the NERVA Instrumentation Data Book plan, select, specify, design the instrumentation system installation and procure instrumentation components whose test results indicate their capability to satisfactorily perform when used in the instrumentation systems of the Cold Flow Development Test System (CFDTS).

A. Engineering

- (1) Select and issue specifications for the instrumentation components for procurement.
- (2) Complete the design of the instrumentation system installation.

B. Fabrication

- (1) Procure and/or fabricate instrumentation components, such as transducers, wiring, and connectors, for the Cold Flow Development Test System.

Sub-subtask 2.4.1 (Continued)

C. Testing

- (1) Acceptance test and calibrate the CFDTIS instrumentation components. Testing and evaluation of instrumentation as required to indicate their capability to meet the non-nuclear performance specifications shall be performed under Sub-subtask 2.4.6.

D. Tooling - Not applicable.

Sub-subtask 2.4.2 NRX Instrumentation

Based on the established test schedules, and on the measurement and performance requirements established by the NERVA Analysis, Design, Test and Development Programs and as recorded in the NERVA Instrumentation Data Book plan, select, design instrumentation systems and procure components whose test results indicate their capability to satisfactorily perform when used in the diagnostic and control instrumentation systems in the following development systems:

- (a) NRX-A3.
- (b) NRX-A4.
- (c) NRX-A5.
- (d) NRX-A6.
- (e) NRX-A7.

A. Engineering

- (1) Provide support, guidance, and instrumentation design details as required, to the mechanical design activity in determining the location and installation of instrument transducers and associated cables or tubing in Block I, II, NRX Reactor Instrumentation Systems.
- (2) Prepare and issue procurement specifications for all instrumentation system components.
- (3) Prepare and issue installation specifications for all instrumentation system components.
- (4) Prepare and issue test procedure specifications for post-operative evaluation of instrumentation system components for each NRX reactor system test.
- (5) Prepare and issue specifications for calibration and checkout of instrumentation.

Sub-subtask 2.4.2 (Continued)

- (6) Prepare and issue Measurement Requirement Lists for NRX Reactors.
- (7) Provide engineering liaison in support of Sub-subtask 1.1.8 to provide information required for preparation of assembly and disassembly procedures.
- (8) Prepare and issue instrumentation component acceptance test results for inclusion in the Instrumentation Data Book.
- (9) Prepare and issue post-mortem test and evaluation report on instrumentation for each NRX reactor system test.
- (10) Provide support and guidance to the facility design and test planning groups for coordination of the instrumentation system with the facility data acquisition system.

B. Fabrication

- (1) Procure and/or fabricate diagnostic and control instrumentation such as transducers, wiring, and connectors, for the NRX-A3, -A4, -A5, -A6, and -A7.

C. Testing

- (1) Complete the calibration and the acceptance testing of instrumentation components for NRX-A3, NRX-A4, NRX-A5, and NRX-A6 instrumentation system to determine that they meet the performance specifications.

D. Tooling - Not applicable.

Sub-subtask 2.4.3 E-Engine Instrumentation

No work in this contract period.

Sub-subtask 2.4.4 Mechanical Component Irradiation Test Instrumentation

The instrumentation components required for the Mechanical Component Irradiation Tests shall be specified, designed, procured, and acceptance-tested for the following pallets to fulfill the request by the cognizant component subtask:

902	908
903	911
904	915
905	917
906	918
Control Pallet #1	
Control Pallet #2	

A. Engineering

- (1) Select and issue specifications for transducers and transducer mountings.
- (2) Provide liaison with the irradiation test facility on instrumentation problems.
- (3) Prepare and issue to Subtask 1.9 instrumentation calibration data and instructions for use of the instrumentation.
- (4) Prepare and issue a post-mortem report which shall include the performance analysis of the instrumentation for each test pallet.

B. Fabrication

- (1) Provide instrumentation for the mechanical component irradiation test pallets.

C. Testing

- (1) Perform calibration and acceptance testing of the instrumentation components.

D. Tooling - Not applicable.

Sub-subtask 2.4.5 - Nuclear Instrumentation Development

Conduct development of nuclear instrumentation channels, as required, to measure reactor power level and reactor period for NERVA NRX reactor ground tests, and directed toward ultimate use in flight type reactors. These instruments shall be developed to provide signals to the Reactor Control System as specified by the Reactor Control Design Group and recorded in the NERVA Instrumentation Data Book. The nuclear instrumentation channels shall include such items as the neutron sensors, preamplifiers, signal amplifiers, power supplies, cables and connectors and other components as required.

A. Engineering

- (1) Provide engineering support to the testing and evaluation of the first generation of the developmental models of the neutron detectors and define the problem areas.
- (2) Prepare and issue an evaluation report on the first generation of neutron detectors.
- (3) Provide engineering support to the testing and evaluation of the first generation of the preamplifiers and amplifiers and determine the problem areas.
- (4) Prepare and issue a report on the evaluation of the first generation of developmental models of preamplifiers and amplifiers.
- (5) Prepare and issue a Developmental Program Plan to be followed in the development of second generation of neutron detectors.
- (6) Prepare and issue a Developmental Program Plan for the development of second generation of preamplifiers and amplifiers.
- (7) Complete the re-design of the second generation of neutron detectors.
- (8) Initiate the construction of the second generation of neutron detectors.
- (9) Complete the preliminary design of the second generation of preamplifiers and amplifiers for guidance in the development of the basic circuitry of these items.
- (10) Perform studies as required to develop the basic circuits for the second generation of preamplifiers and amplifiers.
- (11) Design cables and connectors as required for interconnecting the neutron detectors preamplifiers and amplifiers.
- (12) Evaluate and up-date the nuclear environmental information in the proposed detector locations in the engine by analyses of NRX nuclear radiation level calculations and measurements. Prepare and issue a report on this study.

Sub-subtask 2.4.5 (Continued)

- (13) Conduct studies and investigations on alternate approaches for measurement of the NERVA reactor power level and reactor period. Prepare and issue a report on any studies conducted.

B. Fabrication

- (1) Provide first generation neutron detectors as required to support the development program.
- (2) Initiate the fabrication and/or procurement of the second generation of neutron detectors.
- (3) Provide first generation preamplifiers and amplifiers as required to support the development program.
- (4) Provide basic circuitry as required to support the design of the second generation preamplifiers and amplifiers.
- (5) Provide cables and connectors as required for interconnecting the neutron detectors, preamplifiers, amplifiers and test equipment.

C. Testing

- (1) Complete the testing and evaluation of the first generation of the development models of the neutron detectors to define the problem areas.
- (2) Complete the testing and evaluation of the first generation of the preamplifiers and amplifiers to define the problem areas.
- (3) Perform testing on basic circuitry as required to support the design of the second generation preamplifiers and amplifiers.
- (4) Perform testing as required on cables and connectors for interconnecting the neutron detectors, preamplifiers, amplifiers and test equipment.
- (5) Perform environmental tests and support nuclear irradiation tests as required on experimental and developmental models of neutron detectors, preamplifiers, amplifiers, and cables and connectors.

D. Tooling

- (1) Provide tooling as required for the fabrication of nuclear instrumentation components.

Sub-subtask 2.4.6 Non-Nuclear Instrumentation Development

Based on the measurement and performance requirements established by the NERVA Analysis, Design, Test and Development programs, and as recorded in the NERVA Instrumentation Data Book, evaluate, design, develop,

Sub-subtask 2.4.6 (Continued)

and evolve methods of calibration for instrumentation system components. Plan, prepare and implement qualification tests and methodology directed toward providing instruments whose test results indicate their capability to satisfactorily perform when used in the diagnostic and control instrumentation systems in the NERVA engine, subsystem and component tests.

A. Engineering

- (1) Prepare and submit to SNPO-C on or before November 15, 1963, a Development Program Plan describing the program in detail to be followed during this Contract Period for each development item, and subject to prior written approval from SNPO-C for each Development Program Plan initiate or continue the development of that item. (Work may be continued on existing development programs for a reasonable period of time pending receipt of approval from SNPO-C). The Development Program Plans shall be suitable for inclusion in the NERVA Instrumentation Data Book. The following development items shall be included in the Development Program Plans:
 - a. Temperature transducers to measure thrust chamber temperature for control purposes.
 - b. Pressure transducers to measure thrust chamber pressure for control purposes.
 - c. Cables and connectors as required for the instrumentation systems.
 - d. High-precision cryogenic temperature transducers required for turbopump development testing.
 - e. Accelerometers for making vibration measurement of components within the NRX pressure vessel such as core elements, reflector, shield and control drums.
 - f. Pressure transducers for making pressure and differential pressure measurements of the coolant at locations within the NRX reactor pressure vessel such as reactor inlet and outlet plenums, inner and outer reflectors and the shield.

Sub-subtask 2.4.6 (Continued)

g. Temperature transducer as follows:

1. Thermocouples for measuring temperature of fuel elements and structural elements of the NRX reactor.
2. Miniature resistance temperature thermometers for measuring cryogenic temperatures such as the inlet and outlet gas temperatures to the nozzle and reflector.

h. Strain gages for measuring strains in such locations as in the NRX core support plate, tie rods, fuel elements and control drums.

i. Displacement transducers for measuring relative displacement between component parts of the NRX core structure.

j. Such other instrumentation as required to meet the NERVA engine system, subsystem, and component development and test programs.

(2) Plan, design, prepare specifications and procedures for calibration, evaluation, performance and qualification tests in nuclear and non-nuclear environments, as required, to indicate whether the selected candidate transducers and instrumentation components are capable of meeting the measurement and performance requirements as recorded in the NERVA Instrumentation Data Book when used in the diagnostic and control instrumentation systems in the NERVA engine, subsystem and component test programs. The following work shall be included during this contract period:

- a. Prepare and submit to SNPO-C on or before November 1, 1963 a list of Test Plans for nuclear irradiation of instrumentation planned for this contract period. Each Test Plan listed shall include the types of instrumentation and the test objectives. This list shall be used for planning purposes to schedule test facilities and prepare cost estimates and manpower requirements. This list of Test Plans shall represent all the planned nuclear irradiation tests for the diagnostic and control instrumentation program. Detailed description of each Test Plan is to be recorded in the Radiation Effects Testing, AGC Report No. 2510.

Sub-subtask 2.4.6 (Continued)

- b. Prepare and issue Test Specifications data to Subtask 1.9 for the nuclear irradiation testing of the diagnostic and control instrumentation. The Test Specifications shall include the transducer code number to identify the corresponding item in the Instrumentation Data Book. The intended application for each test article that is NRX, MCIT or other applications shall be noted in the Test Specification. Detailed description of the Test Specifications is to be recorded in the Radiation Effects Testing, AGC Report No. 2510.
- c. REON shall perform a continuing review and approve each Test Specification for instrumentation to assure that the test item is required to meet a measurement requirement recorded in the NERVA Instrumentation Data Book and that unnecessary duplication of testing is not planned or performed by LRP and WANL.
- d. Prepare and issue to SNPO-C by July 1, 1964 a list of Test Plans, for nuclear irradiation of instrumentation, planned for the contract year starting October 1, 1964. The Test Plans shall contain the same type of data furnished for the preceding contract period. This list shall be for planning the test facilities and schedules and preparation of cost estimates and manpower requirements for the next contract period.
- e. Prepare and issue to SNPO-C on or before November 1, 1963 a list of non-nuclear performance and environmental tests planned for the contract period, to be used for planning purposes to plan test facilities and to prepare cost estimates and manpower requirements. This list of non-nuclear tests shall include the proposed application of each test article that is intended for use in the NRX-A2, MCIT or other applications.
- f. REON shall perform a continuing review of the non-nuclear testing program planned for the NERVA Instrumentation Program at LRP and WANL to assure that the test item or test data is needed to meet a measurement requirement recorded in the NERVA Instrumentation Data Book, and that unnecessary duplication of testing is not planned or performed by LRP and WANL.

Sub-subtask 2.4.6 (Continued)

- g. Prepare and issue to SNPO-C by July 1, 1964 a list of non-nuclear performance and environmental tests planned for the next contract period. This list shall be for planning the test facilities and preparation of cost estimates and manpower requirements for the next contract period.
 - h. Analyze and evaluate the results of the nuclear and non-nuclear testing and select for further development those transducers and components demonstrating the best performance and potential.
 - i. Design the test fixtures required for the nuclear irradiation tests. These test fixtures are to be compatible with the pallets, cryostats or test chambers being provided by subtask 1.9 of the test facility.
 - j. Design the test fixtures as required for the conduct of the non-nuclear performance and environmental tests.
 - k. Supply technical details for revision and updating of procurement specifications to eliminate or reduce causes of failure in types of transducers which have undergone tests.
 - l. Consult with vendors to determine transducer design improvements suggested by test results and prepare specifications for procurement of more highly developed units for use in further tests.
- (3) Conduct studies of the instrumentation requirements for the NERVA engine system, subsystem and component development and test programs to ascertain that instrumentation is available to meet the requirements or that plans are being implemented to provide the required instrumentation on a time schedule to meet the requirement. Prepare and issue a report to SNPO-C on each study performed.
 - (4) Provide support and guidance to the WANL Component Test Program by coordinating the measurement requirements of the various tests with those defined for the NRX-A Reactor Tests to insure comparability of diagnostic data. Also provide technical support to this activity in the specification and selection of instrumentation for tests in this program.
 - (5) Analyze, prepare and issue test reports and data from the development and test programs for inclusion in the NERVA Instrumentation Data Book.
 - (6) Conduct NERVA Instrumentation Design Reviews every three months commencing December, 1963.

Sub-subtask 2.4.6 (Continued)

- (7) Prepare and issue to SNPO-C within one month of each Design Review meeting a report which shall include the technical data presented and recommendations for studies, tests, development or other action to be made in the succeeding period.

B. Fabrication

- (1) Fabricate and/or procure instrumentation components and test fixtures as required for conduct of non-nuclear performance and environmental testing and nuclear radiation testing.

C. Testing

- (1) Perform non-nuclear performance and environmental tests on candidate instrumentation components for the purpose of selecting instrumentation or determining if the selected instrumentation is capable of meeting the measurement requirements as recorded in the NERVA Instrumentation Data Book.
- (2) Monitor nuclear irradiation tests performed under Subtask 1.9.

D. Tooling

- (1) Provide tooling as required for the fabrication of instrumentation components and test fixtures.

Subtask 2.5 Ground Operations Safety

The purpose of this subtask is to provide an operational safety program in accordance with AEC regulations which will protect the health and safety of personnel (both employees and the general public) and will minimize danger to life and property from both nuclear and non-nuclear hazards associated with all activities performed under this contract. The program will include the following:

- (1) Accident analysis.
- (2) The preparation of safety analysis reports and other safety documentation.
- (3) The review and evaluation of facility designs, proposed tests and operations, and training programs.
- (4) The performance of health, safety, fire protection, and reactor safety inspections.
- (5) Field safety support to the NERVA test operations at Nevada.

The program has been formulated to assure compliance with all legal, regulative, and contractual requirements for safety applicable to work performed under Contract SNP-1.

Sub-Subtask 2.5.1 Safety Analysis and Review

A. Engineering

Overall management and technical direction of the NERVA operational safety program shall be provided under this sub-subtask.

- (1) Assure safety in the design, manufacture, handling, shipping, and assembly and disassembly of components.
- (2) Perform periodic reviews and inspections of participating organizations to assure compliance with approved safety plans and procedures, and with additional restrictions which may be imposed by health, safety, or fire protection regulations or requirements of the Atomic Energy Commission.
- (3) Review and investigate unusual incidents or occurrences affecting safety. Coordinate the preparation and submittal of all incident reports and implement recommendations resulting from investigations.
- (4) Formulate operational safety policy as required for the NERVA program.

Sub-subtask 2.5.1 (Continued)

- (5) Establish guiding principles and approaches for safety analyses.
- (6) Assure maximum incorporation of safety features in the design and in the test operation of the NRX and the NERVA engines.
- (7) Assist and provide data to the test site personnel in order to assure the safe handling and operation of NRX assemblies and components.
- (8) Specify safety and shield design criteria in support of design and operation of NRDS facilities and equipment.
- (9) Provide facility safety reviews and evaluations. Provide recommendations for design approval (from the standpoint of safety) for any planned or proposed NRDS facilities and equipment. Recommend modifications to facilities and equipment which may affect safety of the operation.
- (10) Provide technical assistance to site organizations on major safety problems.
- (11) Audit the safety, training, and occupational health programs at each site or plant.
- (12) Prepare and submit periodic safety reports and documentation required by AEC regulation.
- (13) Perform nuclear-accident, radiological-hazards, and shielding analyses in support of the safety program.
- (14) Establish a system of inspection for the periodic review and evaluation of nuclear hazards associated with NERVA test operations.
- (15) Assure that all nuclear operations are performed in accordance with SNPO-C approved procedures for the handling of SS materials.
- (16) Conduct analyses and prepare and submit for approval all required hazards and safety evaluations and reports for test facilities, critical experiments, shipping, assembly and disassembly operations, and test cell experiments. The following reports shall be included:
 - a. Control procedures for fuel fabrication, cluster assembly, storage and shipping.
 - b. Control procedures and safety evaluations required for fuel and core shipping procedures.

Sub-subtask 2.5.1 (Continued)

- c. Safety Analysis Reports and Operating Limits required for low-power critical experiments at WANEF.
 - d. NRX-A Safety Analysis Report.
 - e. Supplemental safety documentation in Operating Limits and Safety Evaluation Reports required to obtain approvals for NRX-A2, NRX-A3, and NRX-A4 tests.
- B. Fabrication - Not applicable
- C. Testing - Not applicable
- D. Tooling - Not applicable

Subtask 2.6 Reliability and Quality Assurance

A. Engineering

- (1) Implement the latest revision of REON Reliability and Quality Assurance Program Plan, Report No. 2487.
- (2) The methods of implementing the quality and reliability requirements of NPC-200-2 and NPC-200-3 are described in REON Report No. 2487.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Subtask 2.7 Flight System Safety

Sub-subtask 2.7.1 Accident Analysis

A. Engineering

- (1) Postulate and evaluate hazards associated with normal and abnormal operations of the flight engine during ground handling, launch, RIFT flight, early operational flight, and post-operational disposal, maintaining consistency with the current status of the engine development program. Use trajectory data from Lockheed Missiles and Space Company and/or Marshall Space Flight Center and maintain liaison with appropriate government agencies and contractor organizations. Utilize available information on failure modes and effects and probability of failure including those developed under Subtask 2.6.
- (2) Provide criteria and requirements for and evaluate the effectiveness of engine countermeasure systems and safety features.
- (3) Identify and evaluate critical areas within the flight safety program where additional or increased effort is required.
- (4) Provide status reports on results of NERVA flight safety evaluation study.
- (5) Develop an experimental test plan to predict the degree of compaction and fragmentation of a NERVA reactor impacting with land. Formulate an analytical model to predict the degree of compaction and fragmentation.
- (6) Continue to investigate the shutdown mechanisms during reactor excursions. Investigate the physical effects of very fast transients on NERVA fuel. Study fission-product release due to excursions as a function of energy deposition and reactor period.
- (7) Continue to study the effects of high-energy electrical-pulse heating of fuel material to determine the fragmentation and vaporization threshold energies as a function of deposition times. In addition, the amounts of down-channel vapor deposition will be studied.
- (8) Derive an improved analytical model incorporating results from analytical and experimental programs on reactor excursions; formulate an integrated excursion analysis; evaluate the shutdown mechanisms and energy release fragment distribution and fission-product release for all types of excursions.

Sub-subtask 2.7.1 (Con't)

- (9) Conduct analyses, evaluate data, and prepare the required reports associated with RIFT safety review program, including requirements for the anticriticality destruct system.
 - (10) Issue interim report on electrical heating experiments.
 - (11) Publish summary report on TREAT excursion testing.
 - (12) Issue interim report on reactor compaction.
 - (13) Issue report on integrated excursion analysis computer program.
 - (14) Issue interim report on NERVA flight safety evaluation study.
- B. Fabrication - Not applicable.
- C. Testing
- (1) Perform non-nuclear experiments on possible conditions of core compaction and fragmentation which will include a series of tests using one-ninth to one-third scale simulated models of NERVA cores.
 - (2) Perform reactor excursion experiments using the TREAT and TRIGA reactors. These experiments will involve irradiation samples of NERVA fuel under various reactor operating conditions such as transient and integrated power. The irradiated fuel samples will then be analyzed for physical effects and fission-product release.
 - (3) Continue the experimental program on the effect of high-energy electrical-pulse heating of fuel material. This will consist of a series of experiments in which samples of NERVA non-fueled and fueled elements will be subjected to electrical pulses of various time durations and energy inputs.
- D. Tooling - Not applicable.

Sub-subtask 2.7.2 Source Term Studies

A. Engineering

- (1) Perform the required coordination of the experimentally and analytically derived radiation hazards source-term program. Assure that valid data and concepts are used.

Sub-subtask 2.7.2 (Con't)

- (2) Provide liaison and coordination with the Nuclear Vehicle Projects Office, Lockheed Missiles and Space Company and other appropriate agencies.
- (3) Conduct analyses, evaluate data, and prepare the required reports and presentations to fulfill obligations associated with the RIFT safety program.
- (4) Provide representation to the Rover Flight Safety Panel.
- (5) Perform analytical studies to determine the mass loss as well as the re-entry time of re-entering engine fragments and components. This task will incorporate available data from other government agencies and associated contractors. Experimental oxidation and burnup data obtained under this contract shall be incorporated into the analytical studies which will lead to the development of a generalized re-entry code.
- (6) Formulate a test program to evaluate the history of an intact reactor during re-entry utilizing scale models in wind tunnel and plasmajet facilities. This will include determining attitude of the reactor, aerodynamic heat input to the reactor, post-operational heat generation, and ablation. The formulation of an analytical model to describe the re-entry behavior will be initiated.
- (7) Develop an analytical model treatment for fission-product diffusion and correlate this treatment with experimental results. Incorporate fission-product diffusion rate data, obtained from this contract and other laboratories into the fission-product inventory code. Specify fission-product data to be obtained from the reactor/engine ground-testing program. This information will be used as a confirmation of the basic diffusion model. Specify precondition procedures for reducing fission-product inventory based on analytical and experimental results.
- (8) Continue the development of an integrated source-term computer program and provide source-term information through a central information center based on data obtained from the NERVA Flight Systems Safety Program and from all other laboratories and organizations performing pertinent work.
- (9) Modify the fission-product inventory code for the purpose of incorporating it into the source-term program. Continue the development of a materials activation code based on best available information.

Sub-subtask 2.7.2 (Con't)

- (10) Revise, on a continuing basis, the functional requirements of the post-operational destruct system in terms of particle size, ballistic parameters, and spatial distribution of destruct debris.
- (11) Issue report on the effect of additives on the re-entry burnup of fuel.
- (12) Issue report on the study of the characterization requirements for engine fragments from PODS.
- (13) Issue interim report on materials activation code using available input data.
- (14) Complete analytical study and issue report on code for re-entry burnup of arbitrarily-shaped fuel particles.
- (15) Issue status report on in-house source term program.
- (16) Issue first interim report on intact reactor re-entry.
- (17) Issue second series report on analytical and experimental fission - product diffusion work.
- (18) Issue status report on fission-product inventory code including diffusion.
- (19) Issue interim report on experimental and analytical non-fuel burnup work.
- (20) Issue interim report on operation criteria for maximum diffusion of fission products.
- (21) Issue status report on source term program incorporating available data and projecting future program plans.
- (22) Issue second interim report on intact reactor-re-entry.

B. Fabrication - Not applicable

C. Testing

- (1) Perform simulated re-entry burnup experiments on reactor engine components. In addition, obtain oxidation rate data on these materials under conditions similar to those encountered during re-entry.

Sub-subtask 2.7.2 (Con't)

- (2) Perform wind-tunnel tests to evaluate the tumbling characteristics and ballistic parameters of scale models of a re-entering reactor. Perform simulated re-entry tests of scale models in a plasmajet facility to determine modes of breakup of the reactor.
 - (3) Specify in-pile irradiation and perform post-irradiation experiments on NERVA fuel to determine the rate of release of fission products as a function of temperature, pressure, fission-product inventory, sample cladding, and geometry. Design and assemble irradiation capsules for the above program. Actual irradiations and hot-cell examinations are covered under Sub-subtask 1.9.6.
 - (4) Complete re-entry burnup and diffusion studies on fuel.
- D. Tooling - Not applicable.

Subtask 2.8 Training

A. Engineering

Continue the NERVA Training Program to provide specialized indoctrination, familiarization, capability, and qualification to appropriate operational personnel to meet operational aspects of the NERVA Program. The effort shall include, but not necessarily be limited to, the following:

- (1) Coordinate and monitor on-the-job training.
- (2) Coordinate and monitor "shop" and/or "factory" training for key personnel requiring operating familiarization with equipment for NRDS including E-MAD conducted by sub-contractors to AGC.
- (3) Present the "Test Cell "A" Indoctrination Course" at least 3 times during CY 1964.
- (4) Complete preparations for and present the "Cryogenics for Nuclear Rocket Applications Course" at least 6 times during CY 1964.
- (5) Coordinate and administer Health and Safety Training for NERVA operational personnel. (Instructors and preparation of instructional materials are to be supplied under sub-subtask 2.5.2).
- (6) Deliver NERVA program orientation lectures at LRP.
- (7) Provide radiation safety training to LRP personnel directly connected with the NERVA effort, as required by California Law.
- (8) Conduct a training and qualification program, including records and documentation of all trainees.
- (9) Complete and issue a Nuclear Physics Course Handbook.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Subtask 2.9 Assistance to LASL

A. Engineering

Provide technical assistance to the Los Alamos Scientific Laboratory at Los Alamos at a level of assignment mutually agreeable to the contractor and SNPO-C.

B. Fabrication - Not applicable.

C. Testing - Not applicable.

D. Tooling - Not applicable.

TASK 3 NRDS SUPPORT

Subtask 3.1 NERVA Exhaust System (NES)

Continue research and development on the NERVA exhaust system (NES) to provide the following:

A. Engineering

- (1) Provide the engineering for scale model tests to provide parametric data on the behavior of the NES subsystems. Continue updating of analytical models which help to predict behavior and interaction of the components when coupled as an exhaust system. Data and analysis obtained thereby shall provide design criteria for the exhaust system configurations that are suitable for RIFT and other future facilities.
- (2) Provide the engineering for scale model tests directed toward uprating the ETS-1 NES to a full pumping system.
- (3) Provide the engineering for scale model tests as required to determine the effects of final design changes on the ETS-1 NES performance.
- (4) Provide the engineering for scale model tests for the NERVA exhaust system to provide design criteria for the preliminary design of the ETS-2 NES.
- (5) Provide technical assistance to SNPO-C, as required, including technical assistance in directing and coordinating the architect-engineer during final design and fabrication of the ETS-1 NES duct.
- (6) Complete the integration support and analysis efforts started in the previous contract period for the NES subsystems covering the operational and safety requirements for the ETS-1 NES. These efforts include (a) acceptance tests and plans, (b) handling and shipping plans, (c) use and operational analysis, (d) interface configuration control, and (e) malfunction analysis.
- (7) Continue designing the test planning for the steam generator system for ETS-1.
- (8) Plan and establish criteria for using a temporary instrumentation and controls system at NRDS for development testing of the steam generator system.

Subtask 3.1 (Continued)

- (9) Provide I & C design criteria and engineering support of the permanent I & C for the steam generator system and related diagnostic hardware in ETS-1.
- (10) Provide preliminary mechanical design, and stress and heat transfer analyses of the ETS-2 duct and truss. Provide assistance to SNPO-C, as required, and technical direction and coordination to the architect-engineer for the ETS-2 NES.
- (11) Provide design, analyses, and studies to establish the integrated physical and operational criteria of the NES subsystem at ETS-2. This effort shall include review of the ETS-1 data to determine its applicability to ETS-2.
- (12) Provide engineering support and direction during the subscale thermal cycle test program.
- (13) Establish criteria for the conducting of a test program using an uncooled duct in conjunction with the steam generator.
- (14) Evaluate by analysis the extent of radioactive contamination of the duct caused by fission product plate-out.
- (15) Provide design of temporary steam exhaust line for NRDS steam generator tests.

B. Fabrication

Complete the fabrication of the following hardware for development purposes:

- (1) Scale model hardware as required in support of the research and development program.
- (2) Scale model hardware as required for the supporting test program.
- (3) Provide temporary I & C for steam generator tests.
- (4) Provide permanent I & C transducers for steam generator.
- (5) Uncooled sheet metal duct and associated equipment.
- (6) Complete the fabrication of a steam generator for ETS-1.
- (7) Fabricate or procure temporary steam exhaust line for NRDS steam generator tests.

Subtask 3.1 (Continued)

C. Testing

- (1) Continue scale model research and development test program.
- (2) Complete scale model supporting test program.
- (3) Complete the thermal cycle test program.

D. Tooling - Not applicable.

Subtask 3.2 ETS-1

Sub-subtask 3.2.0 Integration and Technical Management

A. Engineering

- (1) Provide technical support for the integration, coordination, planning and dissemination of information necessary for the development and activation of the ETS-1 facility complex to provide a test capability consistent with the requirements of the NERVA program.
- (2) Provide updated operational parameters where necessary for design completion and construction of all remaining facility items of the ETS-1 Complex.

Sub-subtask 3.2.1 Design Review

A. Engineering

- (1) Conduct review of the remaining architect-engineering designs and construction drawings and specifications for functional, operational, and safety adequacy as set forth below. The remaining design packages requiring review of preliminary, final, or revised drawings and specifications are:
 - a. Fire Protection System
 - b. Change House
 - c. Engine Compartment Shields
 - d. NES Duct Vault Door
 - e. Modification and additions required by the NES and NES support equipment
- (2) Evaluate and report to SNPO-C on the facility design, construction changes and/or modifications indicated as a result of engine development changes and/or facilities construction deficiencies.
- (3) Conduct review of modification design, construction drawings, and specifications for functional, operational, and safety adequacy. The modifications and additions presently identified are:
 - a. LH₂ storage dewar diking
 - b. Additional high pressure gas bottles and manifolding
 - c. A higher capacity CH₄ header system
 - d. Tunnel modifications to provide for ETS-1/ETS-2 I&C integration.

Sub-subtask 3.2.2 NES Facility Modification

A. Engineering

- (1) Provide engineering support for the development and integration of the NES, NES support equipment, NES steam generator, and NES sheet metal duct.
- (2) Coordinate this effort with the construction, activation, and checkout activities.
- (3) Prepare criteria for ETS-1 facility modifications required to support ETS-1 steam generator and sheet metal duct tests.
- (4) Review and coordinate Architect-Engineer efforts up to and including preparation of drawings and specifications for ETS-1 facility modifications to accommodate the equipment identified in A(1) as required to assure functional operation and safety adequacy.

Sub-subtask 3.2.3 Interface/Integration and Control

Define and integrate all facility interfaces with other systems as follows:

A. Engineering

- (1) Prepare criteria, preliminary design studies, and interface/integration control drawings for the integration of the facility I&C system with other systems.
- (2) Prepare I&C control drawings for the conduct of the NES sheet metal duct and steam generator tests.
- (3) Prepare NERVA Design Criteria Interfaces (NDS) as required to support long lead facility design procurement for typical systems as Remote Engine Controls and Engine Compartment Shields.
- (4) Review and coordinate the following with facility designs:
 - a. Run tank-to-engine propellant supply line system
 - b. Engine adapter system assembly
 - c. The coupling design for test-stand thrust structure system assembly
 - d. The remote coupling mechanisms between these systems
- (5) Monitor and coordinate with facility designs the interface control drawings for the thrust structure and propellant supply line system.

Sub-subtask 3.2.3 (Continued)

- (6) Provide support as necessary to supply information for or ascertain effects on facility interfaces, interferences, installation, and operational requirements with respect to engine/adaptor/EIV system installation and recovery.
- (7) Prepare and maintain interface/integration control drawings for the NES, NES support equipment, and NES development test systems.

Sub-subtask 3.2.4 Facility-to-Thrust Structure Systems Development

A. Engineering

- (1) Provide thermodynamic, fluid, operational, and safety systems analyses as applicable; provide appropriate NERVA Design Criteria (NDC), preliminary design, and long lead item procurement specifications for the facility-to-thrust structure systems. These systems include the following:
 - a. LE_2 , GH_2 , GH_3 , and GN_2 engine emergency cooldown systems
 - b. Engine compartment and engine purge systems
 - c. Engine actuator gas back pressure and supply systems
 - d. Remote interface disconnect drive systems
 - e. Emergency cooldown bleed and chill system
 - f. I&C test stand-to-engine harness system

Sub-subtask 3.2.5 ETS-1 Facility Activation Plan

A. Engineering

- (1) Prepare and submit an outline defining the broad scope of the ETS-1 facility complex activation plan and develop the basic master activation network.
- (2) Submit the details of the activation plan for those elements of the ETS-1 facility complex which require initiation of activation during this contract period.
- (3) Submit the preliminary ETS-1 activation plan for the entire period from Beneficial Occupancy DATE (BOD) through initiation of test article installation in accordance with the approved outline submitted under item A(1). The activation plan shall be in sufficient detail to allow test site preparation of

Sub-subtask 3.2.5 (Continued)

detail procedures for each major element of the activation network and will recommend and define activities to be performed by cognizant NRDS groups.

Sub-subtask 3.2.6 Engineering Support

A. Engineering

- (1) Update the operational countdown schedule as required to assess the integrated facility operational, functional, and safety characteristics and to provide guidelines for operational planning.
- (2) Perform appropriate critical failure analysis of the facility systems to ascertain the operational safety of facility systems and the existing functional mode of the presently designed and constructed EIS-1 facility. Submit a preliminary facility operational malfunction study report.
- (3) Provide engineering support for the development of the Program Requirements Documents and applicable portions of the Operational Support Plan.

Subtask 3.3 ETS-1 Instrumentation and Control (I&C) System

A. Engineering

- (1) Provide technical direction, over-all preliminary designs, general specifications, and technical definitions of components of the Instrumentation and Control (I&C) System for ETS-1 at NRDS such that a separate contractor will be enabled to design in detail, procure, fabricate, install, and check out the I&C System. Maintain technical liaison with the separate I&C Facility contractor and approve all final procurement specifications, drawings, checkout procedures and quality control procedures (and changes thereto) issued by separate I&C Facility contractor. The contractor shall retain engineering responsibility for the I&C System for ETS-1 and shall maintain over-all engineering surveillance. The I&C design shall be based on Instrumentation and Control System Design Criteria - Test Cell ETS-1, NRDS, as revised 1 June 1962, as modified by Overall Preliminary Design Package Volume I and Volume II, AGC Report No. 2410, dated November 1962, and as further modified by revisions, supplements, or addenda to these documents that are formally approved by SNPO-C in writing.
- (2) The Government reserves the right to direct the contractor to issue, revise, or revoke any technical direction and/or approval which the contractor may have exercised pursuant to this clause. The contractor shall comply with any such direction given by the Government.
- (3) Monitor and maintain surveillance of the ETS-1 I&C contractors reliability and quality control systems, procedures, reports, and performance. Perform frequent audit checks to ensure compliance with applicable requirements.

Subtask 3.4 ETS-2

Sub-subtask 3.4.0 Integration and Technical Management

A. Engineering

- (1) Provide technical support for the integration of ETS-2 into the ETS-1/ETS-2 complex at NRDS to accommodate the NERVA Engine Test Program.
- (2) Provide assistance, as required, in updating engine requirements and facility criteria, clarifying the requirements, evaluating and recommending facility process system and Instrumentation and Control (I&C) interfaces system with ETS-1.

Sub-subtask 3.4.1 I&C System Design Criteria

A. Engineering

- (1) Prepare and submit an outline for approval by SNPO-C for the ETS-2 I&C criteria in sufficient detail to depict the scope and content of the criteria relative to the operational, functional, safety and integration requirements of the ETS-2 I&C System into the ETS-1 I&C complex.
- (2) Initiate preparation of the I&C design criteria upon SNPO-C approval of the outline. The criteria document shall be prepared with the guiding objective that a separate design contractor can prepare a detail design, suitable for obtaining, on a fixed-price-basis, the fabrication, procurement, installation, checkout and testing of the I&C Systems.
- (3) Submit a draft of the I&C criteria for approval four months after receipt of SNPO-C approval of the outline.
- (4) Publish the I&C criteria one month after official receipt of SNPO-C comments, assuming no major revisions to the document are required.
- (5) Provide continuing coordination with SNPO-C, engine, and other facility system groups to establish the I&C requirements in such areas as engine measurement and control, exhaust system, and engine-facility process systems.

Sub-subtask 3.4.1 (Continued)

- (6) Prepare and submit with the draft criteria preliminary cost estimates and schedules for the design, fabrication, procurement, installation, and testing of the ETS-2 I&C system as described in the criteria.

Sub-subtask 3.4.2 Technical Support - I&C System Design Phase

No work in this contract period.

Sub-subtask 3.4.3 Technical Support - I&C System Fabrication/Procurement/Installation Phase

No work in this contract period.

Sub-subtask 3.4.4 Facility Design Review

A. Engineering

- (1) Review all Architect-Engineer conceptual designs and study reports, such as:
 - a. Facility siting plan;
 - b. Test stand concept;
 - c. Run tank diameter determination study; and,
 - d. Hazard and safety reports,for consistency with NERVA operational, functional, safety, and test requirements.
- (2) Conduct reviews of radiation flux plots for accuracy and compliance with the time versus intensity criteria.
- (3) Conduct engineering reviews of Architect-Engineer designs, released drawings, and specifications, to ensure compliance with the basic criteria and functional, operational, and safety adequacy to accomplish the NERVA Engine Test Program.

Sub-subtask 3.4.5 Engine/Facility Interface Integration and Control

A. Engineering

- (1) Provide technical assistance in the preparation of engine/run tank interface design, and in the resolution of facility systems-engine interface problems.

Sub-subtask 3.4.5 (Continued)

- (2) Obtain, evaluate, and transmit to SNPO-C preliminary information on the run tank bottom design to enable the design work to proceed until a definite tank bottom design has been established.
- (3) Assist in determining preliminary outline dimensions for a tank bottom assembly to allow assessment of the tank bottom and tank outlet design by the Architect-Engineer.
- (4) Prepare the tank bottom shut-off valve criteria and establish its design concept in order to support the Architect-Engineer design effort.
- (5) Assist in defining the NES/facility interface criteria and in the integration of the NES into ETS-2.
- (6) Assist in the preparation of criteria for the integration of the remote engine control system, the GSE checkout system, the engine compartment shields, and the ETS-1/ETS-2 interface.

Sub-subtask 3.4.6 Activation Planning

No work in this contract period.

Sub-subtask 3.4.7 Engineering Support

A. Engineering

- (1) Provide support in the preparation of long-term support requirements estimates needed for the preparation of the Program Requirements Document.
- (2) Conduct studies to assess the effects of NES model studies and engine operational parameters as to their effect on the facility requirements and design characteristics.

Subtask 3.5 E-MAD Facility Complex

Sub-subtask 3.5.0 Integration and Technical Management

A. Engineering

- (1) Provide technical assistance to SNPO-C for integration, coordination, planning, review and dissemination of information necessary to evaluate and develop the E-MAD facility and allied facilities of the E-MAD Complex for assembly, disassembly, maintenance, post-operative evaluation, and test capabilities in the NERVA Program.
- (2) Provide updated operational parameters, requirements and recommendations related thereto as required by the program development and schedules.

Sub-subtask 3.5.1 E-MAD Design Review

A. Engineering

- (1) Conduct design review of Phase I construction changes and "as-built" drawings, Phase II bid packages, specifications, construction changes and "as-built" drawings and "CY 1964 Modification" construction packages as released by SNPO-C.

Sub-subtask 3.5.2 Wall-Mounted Handling System

A. Engineering

- (1) Conduct review of the wall-mounted handling system designs, plans, and specifications, including design reports and operational and maintenance manuals.

Sub-subtask 3.5.3 Equipment Interface Coordination

A. Engineering

- (1) Provide assistance, coordination and liaison as required to assure equipment compatibility with the E-MAD Facility.
- (2) Prepare and maintain facility/equipment interface control drawings as required on the basis of equipment design availability.
- (3) Conduct specific studies and/or liaison to assure compatibility and/or define modifications that may be required on existing or planned NRX equipment to be transferred and/or installed in E-MAD.

Subtask 3.5 (Continued)

Sub-subtask 3.5.4 Special Equipment Integration and Retrofit Building (SEIRB)

A. Engineering

- (1) Provide design criteria, conceptual design, cost estimates, and schedules for the SEIRB, and submit a preliminary criteria report. This building is a consolidation of the Critical Parts Storage, Engine Transport System, Maintenance, and NRX Test Car Build-Up facilities.
- (2) Conduct review of all drawings, specifications, and reports associated with the above facility to assure operational, functional, and safety compatibility.

Sub-subtask 3.5.5 Engineering Liaison and Analysis

A. Engineering

- (1) Perform engineering liaison in support of operational safety and hazards studies.
- (2) Provide engineering support as required for assessment of facility/engine/NRX malfunction studies.
- (3) Perform appropriate radiation evaluation and shielding studies as required to develop the operation parameters necessary to establish functional utilization of the E-MAD Complex.
- (4) Perform engineering liaison and coordination with NTO in support of the Program Requirements Document and the Operation Support Plan and dissemination of data to subcontractors.

Sub-subtask 3.5.6 Activation Plan

A. Engineering

- (1) Prepare and submit an outline defining the broad scope of the E-MAD Facility complex activation plan and develop the basic master activation network.
- (2) Prepare the details of the activation plan for those elements of the E-MAD Facility complex which require initiation of activation during this contract period. Complete final cold area activation plan.

Sub-subtask 3.5.6 (Continued)

- (3) Submit the preliminary E-MAD activation plan details for all hot areas of the E-MAD Facility in accordance with the approved outline submitted under Item A(1). The activation plan shall be in accordance with SNPO-C, supplied BOD dates, and shall be in sufficient detail to allow test site preparation of detail procedures for each major element of the activation network, and will recommend and define activities to be performed by cognizant NRDS groups.

Subtask 3.6 Reactor Development Facility

Sub-subtask 3.6.0 Integration and Technical Management

A. Engineering

- (1) Provide technical support for the integration, coordination, review, and dissemination of information necessary for the development and modifications of the Test Cell "A" Facility complex to provide a test capability consistent with the requirements of the NERVA-NRX Program.
- (2) Update operational parameters and requirements as required by the program development and schedule.

Sub-subtask 3.6.1 Test Cell "A" (Mechanical)

A. Engineering

- (1) Coordinate, provide and/or review requirements, design information, analyses and specifications of mechanical and fluid systems modifications as proposed for functional, operational, and safety adequacy of Test Cell "A" for use as a NERVA Reactor Development Facility.
- (2) Provide engineering studies, conceptual layouts, requirements and budgetary cost estimates necessary to support Test Cell "A" modifications required for the NRX reactor development test program. Proposed modifications and additions currently defined are:
 - a. Emergency Cooldown Reserve System
 - b. Relocation of Liquid Hydrogen Propellant Line
 - c. Helium Gas Line Modification
 - d. Neutronic Room and Positioners
 - e. Hydraulic System Improvements
- (3) Provide a review and define requirements for facility modifications necessary to support full power-full duration runs and restart capabilities.
- (4) Evaluate LASL modifications such as the Single Phase Propellant Feed System to assure that NERVA-NRX test objectives and operational, functional, and safety requirements are met.

Sub-subtask 3.6.1 (Continued)

- (5) Evaluate the facilities capabilities to support NRX-A test plans and specifications as described by reactor run profiles programmed for NRX-A 1964 and early 1965 reactor tests.

Sub-subtask 3.6.2 Design Criteria (Mechanical)

A. Engineering

- (1) Provide facility modification design criteria for the mechanical and fluid systems of Test Cell "A" (as defined in sub-subtask 3.6.1, Items a, b, c, d, and e) as approved by SNPO-C. Design criteria shall be prepared for the design of the proposed changes and for procurement of materials and equipment for required modifications.

Sub-subtask 3.6.3 Test Cell "A" (Instrumentation and Control)

A. Engineering

- (1) Coordinate, provide and/or review requirements, design, information, analyses and specifications of instrumentation and control systems modifications as proposed for functional, operational, and safety adequacy of Test Cell "A" for use as a NERVA Reactor Development Facility.
- (2) Provide engineering studies, conceptual layouts, schematics, budgetary cost estimates and justifications of Test Cell "A" instrumentation and control (I&C) modifications required for the NRX reactor development test program.
- (3) Define modifications and/or additions which may be required for separation of Test Cell "A" and Test Cell "C" instrumentation and control.
- (4) Prepare preliminary I&C requirements for facility modifications necessary to support full power - full duration tests and restart capabilities. Examples of proposed modifications and additions currently defined are:
 - a. Additional PAM/FM and Wideband Magnetic Tape Recorders.
 - b. Tape Control Console
 - c. Timing System
 - d. TV and Communication Systems
 - e. D.C. and 400-Cycle Power Supplies
 - f. Test Cell "A" Control Console

Sub-subtask 3.6.3 (Continued)

- (5) Conduct an evaluation of existing facility I&C systems to determine operational and functional adequacy for support of the NRX program. The following items are identified as examples for which improvements are being considered:
 - a. Low Level Multiplexers
 - b. D.C. Amplifiers
 - c. Signal Conditioners
 - d. Quick-Look Data Reduction
 - e. A.C. Transducer Demodulation Equipment
- (6) Perform evaluation of Test Cell "A" electronics room adaptability to accommodate NRX-A-2, A-3, A-4, and A-5 reactors. Prepare appropriate instrumentation and wiring termination data as required for test set-up for NRX-A-2, A-3, and A-4 reactors.

Sub-subtask 3.6.4 Design Criteria (Instrumentation and Controls)

A. Engineering

- (1) Provide design criteria for modifications to instrumentation and controls systems of Test Cell "A" (as exemplified in 3.6.3, and as approved by SNPO-C). Design criteria shall be prepared for the design of proposed changes and for procurement of materials and equipment for required modifications.

Sub-subtask 3.6.5 Design Review

A. Engineering

- (1) Conduct review of engineering schematics, design, drawings, and specifications of current modifications to Test Cell "A" to determine technical concurrence and consistency with the NRX operational, functional, and safety requirements.
- (2) Perform review for those modifications which require design effort resulting from design criteria as approved by SNPO-C.

Subtask 3.6 (Continued)

Sub-subtask 3.6.6 Engineering Support

A. Engineering

- (1) Conduct field liaison to give technical assistance and consultation as required to support field efforts in facility checkout and utilization.

Subtask 3.7 Radiation Effects Facility

A. Engineering

- (1) Provide technical assistance to SNPO-C, as required, in completing and upgrading the operational requirements for facilities, instrumentation and controls, and services during the final design and construction of the radiation effects facility located at General Dynamics, Fort Worth, Texas.
- (2) Review instrumentation and control design drawings to assure the functional, operational, and safety adequacy of the systems to support the Propellant Feed System Test program.
- (3) Conduct reviews of Architect-Engineer designs, reports, construction drawings, and specifications to assure the functional, operational, and safety adequacy of the radiation effects facility.
- (4) Provide through SNPO-C liaison, monitoring and design review, and approval of the data acquisition system (GFE) to be installed at NARF in support of the PFS test program.
- (5) Assist as required in the preparation of plans for and guidance of the checkout and activation of the radiation effects facility.
- (6) Define interface control and integration of the Propellant Feed System control system with the facility and the interlocks necessary to effect emergency shutdown of the reactor and facility process systems.

Subtask 3.8 NRDS Radioactive Material Complex

A. Engineering

- (1) Provide technical assistance to SNPO-C as requested to define and/or update the operational requirements for the NRDS Radioactive Materials Complex.
- (2) Prepare criteria document(s) delineating the over-all facility requirements defined in Item (1). Basic documents will be developed for Facility Complexes:
 - a. Decontamination Facility and Warm Parts and Equipment Storage Facility.
 - b. Radioactive Waste Disposal Facility, High Activity Parts Storage Area, and the Spent Fuel Storage Facility.
- (3) Submit preliminary drafts of these criteria documents for SNPO-C review.
- (4) Publish approved final drafts of these criteria, following incorporation of SNPO-C comments and subsequent addenda.
- (5) Conduct operational, functional, and safety reviews of the Architect-Engineer designs, reports, construction drawings, plans, and specifications.
- (6) Provide assistance in resolving design deficiencies, and developing modifications in problem areas.
- (7) Provide engineering assistance to define the requirements for Government-furnished equipment and services in support of preparation of the Program Requirements Document.
- (8) Assist in defining the requirements for special support equipment to be identified in Operational Support Plans.

Subtask 3.9 Future NERVA Development Facility Requirements

A. Engineering

- (1) Provide technical assistance to SNPO-C as required to define and/or update the operational requirements for development of facilities in support of the NERVA engine.
- (2) Initiate a study to define the operational requirements and basic criteria for a third engine test stand with future vehicle capability based on SNPO-C integrated NERVA/RIFT guidelines.
- (3) Perform REON/SNPO-C engineering liaison with the RIFT program organization to obtain information needed for solution to Item (2).
- (4) Prepare and submit for approval an outline of the basic facility criteria document to be developed as a result of Item (2), approximately seven weeks after receipt of SNPO-C guidelines.
- (5) Prepare and submit a preliminary draft of the basic criteria document for review by SNPO-C three months after receipt of outline approval.
- (6) Submit a revised draft of the basic criteria document one month after receipt of SNPO-C comments resulting from review of Item (5) above, based on no major modifications to the basic draft. Participate in a formal review of this draft with all cognizant groups.
- (7) Publish the formal basic criteria document 45 days after receipt of integrated comments from SNPO-C as a result of review of Item (6) above. It is assumed that only nominal modifications will be required as a result of the integrated comments.
- (8) Based on SNPO-C consolidated NERVA/RIFT guidelines and schedules covering the time period through PERT and flight acceptance of RIFT vehicle, conduct a study to develop information and data relative to the adequacy of the present and planned NRDS facilities to support the NERVA program and/or to identify the additional facilities needed.
- (9) Based on SNPO-C consolidated NERVA guidelines and schedules (as defined in Item (8)), conduct a study to develop information and data relative to the adequacy of present non-nuclear development facilities at AGC-Sacramento plants to support the

Subtask 3.9 (Continued)

NERVA program. This study will include facilities for non-nuclear component and system development and acceptance testing.

- (10) Submit a preliminary topical study report, based on Items (8) and (9).
- (11) For purposes herein, the Basic Criteria Document required by Items (2) through (7) is broadly defined as a document containing the following:
 - a. Basic integrated engine/stage operational requirements and objectives.
 - b. Facility/stage/engine mechanical interface criteria.
 - c. Handling and safety requirements.
 - d. I&C requirements.
 - e. Over-all facility functional description and concept layouts.
 - f. Preliminary siting considerations including budgetary cost estimates.

Subtask 4.1 Program Planning and Control

A. Engineering

- (1) Provide for the planning, monitoring, evaluation, control, and continuous surveillance of the total NERVA Program from the standpoints of correlating schedules and costs.
- (2) Utilize and implement the PERT system in accordance with the NASA-PERT Handbook, dated 30 October 1962.
 - a. The networks shall be developed and continuously updated to clearly define and integrate the work program for the following subtasks: 1.1, 1.2, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.1, 2.4, 2.7, 3.1, 3.2, 3.5, 5.1, 5.2, 5.3, 5.8, 5.9, 8.0, 8.2, and 8.4.
 - b. Integrated end-item oriented networks shall be prepared and maintained for the NRX-A1, NRX-A2, NRX-A3, NRX-A4, NRX-A5, NRX-A6, NRX-A7, NRX-A8 reactors, CFDTS, and reactor component development test program.
 - c. The networks shall include constraining requirements from all supporting subtasks as well as the constraints between test programs.
 - d. Insofar as possible, program milestones shall be selected from and shall be identified on the networks. To the maximum extent possible, a discrete terminal event for all activity streams shall be shown on the networks to explicitly identify the point of accomplishment for the 1964 Contract Year.
 - e. The event designated as the start of test shall be the reference event for assessing criticality of all activities associated or interrelated with the end-item oriented networks.
 - f. The reference event for assessing criticality for those activities not associated or interrelated with end-item oriented networks shall be the discrete terminal event which explicitly identifies the point of accomplishment for the 1964 Contract Year.
 - g. In the event of a major program change, revised and integrated subtask networks shall be submitted to SNPO-C within forty-five (45) days from contractual agreement on the program change.
 - h. All new WANL networks will be conveyed to SNPO-C concurrently with the submittal to REON.

Subtask 4.1 (Continued)

(3) Prepare the continuously submit biweekly status reports to SNPO-C.

a. The activities to be reported shall be jointly selected from the subtask and end-item oriented network by SNPO-C and REON. The biweekly status reports for the activities defined in these networks shall be prepared and submitted, as required, to be received by SNPO-C on alternate Monday mornings (the reporting date).

b. Both the WANL and REON biweekly status reports shall include (1) all necessary computer input data and (2) a narrative report.

1. Computer input data shall be submitted in accordance with the NASA Form 577 format and shall include the following information:

(a) Status of all activities whose expected completion date was passed during a given biweekly report period; if activity was completed, the actual completion date shall be stated; if activity was not completed, the reestimated activity time shall be stated.

(b) Deleted activities.

(c) New activities.

2. The narrative report shall include the following:

(a) Explanation of increased activity time estimates, decreased activity time estimates, and logic changes since the previous report for all activities on positive slack paths of one week or less, and any negative (critical) slack paths.

(b) Management action undertaken to effect schedule recovery relative to slippages reported in the previous report.

(c) Actions planned to be taken as a result of the information obtained and incorporated in the current report to correct any further potential slippages.

c. The current and complete biweekly WANL report including all computer input data, narrative report, and computer printout X

Subtask 4.1. (Continued)

shall be submitted in its entirety to SNPO-C concurrently with the submittal to REON.

- d. All WANL computer input data shall be current as of the Thursday preceding the reporting date.
 - e. All REON computer input data shall be current as of the Wednesday preceding the reporting date.
- (4) Perform review and evaluation of integrated program status bi-weekly. Biweekly reports shall be prepared by REON and conveyed to SNPO-C on or before the Monday following the reporting date.
- (5) Develop revised, expanded, and integrated subtask networks in sufficient detail to clearly define the total recommended program plan for the next contract period.
- a. Networks defining the work program for the following sub-tasks shall be prepared: 1.1, 1.2, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.1, 2.4, 2.7, 3.1, 3.2, 3.5, 8.0, 8.2, 8.4, and 8.6.
 - b. Integrated end-item oriented networks for all the Block III reactors shall be prepared.
 - c. The subtask and end-item oriented networks shall be submitted concurrently with the recommended program plan for the next contract period. Discrete terminal events for all activity streams shall be shown on the networks to explicitly identify the point of accomplishment for the 1965 Contract Year.
- (6) Submit critical item reports, supplemental schedule and status data to SNPO-C at such intervals as directed by the Contracting Officer. A reasonable time will be allowed for the preparation of these reports and data.
- (7) Submit status reports for those activities defined in the SNPO-C Management Networks for the NRDS activities being performed by the Contractor.
- a. These reports shall be submitted in the sequence and frequency established by SNPO-C.
 - b. The status reports shall not be submitted more often than biweekly.

Subtask 4.1. (Continued)

- (C) Update and submit to SNPO-C test stand utilization charts for the following LRP facilities: C-6, C-7, D-3, G-7, H-4, H-4A, H-5, H-6, and the vibration stand.
- a. The facility utilization charts shall be updated biweekly and will be conveyed to SNPO-C concurrently with the bi-weekly PERT status reports.
 - b. Charts shall include and identify facility modifications, test setups, checkout, number of tests, serial number of test hardware, etc.

Subtask 4.2 Fiscal Control

- (1) Provide financial management for budgeting, analysis, and fiscal control of the NERVA program.
- (2) Prepare and submit an informal monthly progress letter, with a cost section in the format discussed and agreed upon for the forthcoming contract year showing fund expenditures, on the 22nd day of each month following the end of the period covered. The number of copies are to be as directed by the Contracting Officer.

Subtask 4.3 Technical Reports

A. Informal Monthly Progress Report

- (1) Prepare an informal monthly progress report in two sections:
 - a. Submit an "Informal Monthly Progress Letter" by the 17th day of each month following the end of the period covered. This letter shall present the technical progress during the month of the report.
 - b. Submit a "Reliability and Quality Assurance Supplement to Monthly Progress Letter" by the 22nd day of each month following the end of the period covered. This supplement shall present the accomplishments in reliability and quality assurance made during the month of the report.

The following reports shall have the general format used for reports during the previous contract period. The number of copies shall be as directed by the Contracting Officer.

B. Special Technical Reports

- (1) Special technical reports from the contractor and subcontractors shall be prepared to describe significant technical accomplishments.

C. Summary Technical Report

- (1) A summary technical report shall be prepared to describe the technical work performed from 1 October 1963 through 30 September 1964, and shall be delivered by 15 November 1964.

D. Performance Evaluation Reports

- (1) Periodic reports shall be submitted on evaluation of subcontractor performance at such time and in such manner and form as the Contracting Officer shall direct.

E. Subcontractor Reports

- (1) Subcontractor reports shall be submitted as requested by the Contracting Officer.

F. Summary Motion Picture

- (1) Summary motion pictures shall be submitted, summarizing and documenting the significant items of technical progress

Subtask 4.3 (Continued)

from 1 October 1963 through 30 September 1964 that can be portrayed by motion pictures. Films shall be prepared according to the requirements of the Contracting Officer but the total time for all films shall not exceed 60 minutes. The final summary motion picture shall be completed by 15 November 1964.

G. Program Planning Documents

- (1) Program planning documents shall be submitted, defining the engine development program and associated tasks, as needed to support program redirections.
- (2) A budget estimate for Fiscal and Contract Years 1965 and 1966 shall be submitted according to AEC and NASA budget formats, as submitted in the previous contract term, by 15 April 1964 or 60 days after final program guidelines for this purpose are received from the Contracting Officer, whichever is the later date.
- (3) A program plan for Contract Year 1965, including estimated costs, shall be submitted 60 days after final program guidelines for this purpose are received from the Contracting Officer. This program plan shall have essentially the same format as that for the previous contract term.

Subtask 4.4 - Central Data System

A. Engineering

- (1) Establish and maintain a central source of engineering, scientific, and program control data and documentation using electronic data processing and microfilming equipment for efficient storage and retrieval of NERVA data.
- (2) Develop and issue final criteria for the following:
 - a. Reliability and quality assurance data system
 - b. Support equipment data system
 - c. Test data storage and retrieval system
 - d. Information storage and retrieval system for reports, documentation, and important correspondence.
- (3) Complete the implementation of the support equipment data system.
 - a. System shall include provisioning lists and schedules, support equipment program plan and program planning master scheduling report.
 - b. Support equipment provisioning lists shall be issued monthly.
- (4) Initiate the implementation of the reliability and quality assurance data system.
- (5) Provide monthly indices of drawings, specifications, and standards developed in the NERVA Program.
- (6) Submit monthly to SNPO-C the microfilm aperture cards of drawings, specifications, and standards developed in the NERVA Program.

Subtask 4.5 Subcontract Management

- (1) Prepare, review, and process proposal requests, evaluate bids, and negotiate and prepare subcontract documents, amendments, and supplementary agreements thereto, in conformance with the terms and conditions of the prime contract.
- (2) Administer subcontracts, including the administration of subcontractors' technical progress, quality assurance, reliability, and cost according to the terms and conditions of the subcontract.
- (3) Monitor subcontractors' procurement systems and, with other REON organizational elements, consent to orders placed by subcontractors.

Subtask 4.6 Special Program Services

- (1) Provide special equipment and services to meet specific requirements of the NERVA Program.
- (2) Engage nationally known consultants to participate in meetings of the NERVA Advisory Group. Rent office computer and special peripheral computer equipment.
- (3) Monitor continuously all technical activities being carried out under this contract for the detection of new technology being generated. Conduct a search to determine what utilization can be made of this technology in other programs or in commercial applications. Submit quarterly summary reports.

TASK 5. SPECIAL TEST EQUIPMENT

Subtask 5.0 Special Test Equipment - WANL and Plum Brook

Prepare and submit in timely manner, all engineering, procurement and other data necessary to properly evaluate the necessity of acquiring special test equipment to be used in the nuclear subsystem development program, and which has been described and approved in an applicable test plan. Such data shall include the specific test program for which the item of equipment is intended, cost and where required, design, installation and activation plans. No procurement action for such equipment shall be initiated by the contractor until prior approval has been obtained. The equipment contemplated under this subtask is described in WANL document WP(J)-022.

Sub-Subtask 5.0.0 Nuclear Subsystem Special Test Equipment

A. Engineering

- (1) Install and activate equipment for environmental testing of actuator components and assemblies.
- (2) Install and activate special test assemblies for irradiation testing.
- (3) Install and activate equipment for mechanical tests including structural, temperature gradient and bottom support tests.
- (4) Install and activate equipment for component flow tests including liquid H₂ vaporizing systems and plugged core tests.
- (5) Install and activate equipment for reactor preassembly and proof critical tests.
- (6) Install and activate equipment for reactor transient flow analysis and tests.
- (7) Install and activate equipment for the NRX-B Component Test Program.
- (8) Install and activate equipment for flexible critical experiments as described in WP(J) 022 (project 8930, Add-on #3) and Change Order 1 to Mod. 8.

B. Fabrication - As required

C. Testing - As required

D. Tooling - As required

Sub-Subtask 5.0.1 Nuclear Subsystem Special Test Equipment - NASA

A. Engineering

- (1) Install and activate equipment for control component development tests.
- (2) Install and activate equipment for Plum Brook follow and support.
- (3) Install and activate equipment for non-nuclear instrument development testing.

B. Fabrication - As required

C. Testing - As required

D. Tooling - As required

Subtask 5.1 (AGC-LRP) Test Zone C Special Test Equipment

I. Test Stand C-6

A. Mechanical

- (1) Fabricate and install GH_2 piping and mixing chamber including orifices, flanges and pipe fittings.
- (2) Provide continuing test setup modifications to accommodate test hardware configuration changes.
- (3) Complete the fabrication of supersonic diffuser and closure for Test Stand C-6.

B. Instrumentation and Controls

- (1) Augment the instrumentation system for hot bleed nozzle development program including Resistance Temperature Transmitter (RTT) transducers.
- (2) Provide continuing test setup modifications to accommodate test hardware configuration changes.

II. Test Stand C-7

A. Mechanical

- (1) Provide continuing test setup modifications to accommodate test hardware configuration changes.
- (2) Complete the fabrication of a LH_2/LO_2 gas generator for use in support of TPA testing.
- (3) Complete the fabrication and installation of valves for TPA hot gas drive system.
- (4) Complete the fabrication and installation of vacuum jacketed LH_2 piping from overhead vessel on Test Stand C-6 to Test Stand C-8, including bleed purge and pipe supporting system for NRX-A cold flow testing ("Conversion kit" for Test Stand C-6 to accomplish NRX-A cold flow acceptance tests).
- (5) Complete the activation of the TPA hot gas drive system.

B. Instrumentation and Controls

- (1) Procure and install transducers for TPA development program.

Subtask 5.1 (continued)

- (2) Provide continuing test setup modifications to accommodate test hardware configuration changes.
- (3) Complete the procurement and installation of conduit and cabling to provide additional electrical control system capability for TPA testing on Test Stand C-7.
- (4) Complete the procurement and installation of instrumentation equipment for Test Stands C-6, C-7 including test position sub-select modules, and remove and relocate existing data acquisition system cabling and conduit.
- (5) Complete the procurement and installation of temperature and pressure transducers for TSOV vessel.
- (6) Complete the activation of the NRX-A cold flow test system and TSOV vessel electrical controls and Instrumentation systems.

Subtask 5.2 (AGC-LRP) Cryogenics Lab (Test Zone A) Special Test Equipment

A. Mechanical

- (1) Fabricate or procure STE component and system replacement spares.
- (2) Fabricate and install gimbal tester.
- (3) Fabricate and install turbine speed probe tester for modified turbine drive bearing tester.
- (4) Modify the bearing tester and provide spares including one tester and two motors.
- (5) Fabricate and install pneumatic supply system mockup.
- (6) Fabricate and install special vibration test fixtures including specially designed magnesium alloy casting.
- (7) Fabricate and install spin test drive adapters for NERVA pump components spin test.
- (8) Fabricate and install component test setup to adapt to NERVA valves and other laboratory test bay interfaces.
- (9) Provide continuing test setup modifications to accommodate test hardware configuration changes.
- (10) Complete the fabrication and installation of two (2) high-speed-bearing-testers, including spare parts, for the Cryogenics Laboratory; and five (5) high-speed-bearing testers for the Radiation Effects test program.
- (11) Complete the fabrication and installation of special hardware test carts and fixtures.
- (12) Complete the fabrication and installation of a turbine-power control-valve cold flow test system.
- (13) Complete the fabrication and installation of a piping system (LH₂) from the portable trailer to the test-specimen conditioning chambers.
- (14) Complete the fabrication and installation of a side-by-side hardware checkout and testing setup.

Subtask 5.2 (Continued)

- (15) Complete the fabrication and installation of special LH₂ containers for use in cryogenic temperature conditioning non-metallic and metallic tensile specimens.

B. Instrumentation and Controls

- (1) Procure and install transducers and flow measurement apparatus including gauges, flow nozzles, and orifices.
- (2) Procure and install patch cords and boards.
- (3) Provide system instrumentation operational amplifiers and controls for interconnection with data acquisition instrumentation for automatic shutdown of high speed tests.
- (4) Provide continuing test setup modifications to accommodate test hardware configuration changes.
- (5) Complete the procurement and installation of transducers including torque, pressure, position, and temperature transducers.
- (6) Complete the procurement and installation of a special hydrogen leak measurement apparatus.

Subtask 5.3 (AGC-LRP) Test Zone H Special Test Equipment

A. Mechanical

- (1) Fabricate and install special work platforms in Test Zone H shop.
- (2) Fabricate and install special work platforms for CFDTS and ejector test system including ejector supporting structure.
- (3) Fabricate and install ejector GN₂ piping system, including valves, regulators, and flanges.
- (4) Fabricate and install special ducting to adapt the simulator interface and ejector inlet.
- (5) Fabricate and install heat exchanger supply and distribution piping.
- (6) Fabricate or procure STE component and system replacement spares for test stands H-4, H-5, and H-6.
- (7) Activate TPCV, nozzle test system (with and without diffuser) CFDTS, and hot H₂ heat exchanger for test stands H-4, H-4A, H-5, and H-6.
- (8) Provide continuing test setup modifications to accommodate test hardware configuration changes.
- (9) Complete the fabrication of two (2) gas generators for the support of turbopump-assembly testing and TPCV tests.
- (10) Complete the fabrication and installation of a 48" x 48" two-stage, main load ejector.
- (11) Complete the fabrication and installation of a 36" x 36" two-stage, turbine exhaust line ejector.
- (12) Complete the fabrication and installation of a hot hydrogen heat exchanger, including heating source.
- (13) Complete the fabrication and installation of a special turbine-power-control-valve test fixture, including hot gas supply and carry-off ducting.
- (14) Complete the fabrication and installation of a nozzle adapter water coolant supply system.

Subtask 5.3 (Continued)

- (15) Complete the fabrication and installation of valves for TPA hot gas drive system.
- (16) Complete the fabrication and installation of a 125-psi, 250-gallon, vacuum jacketed LH₂ TSOV vessel, including bleed, vent, and purge systems, TSOV supporting structure and work platforms.
- (17) Complete the structural reinforcement of Test Stands H-4, H-5, and H-6 to accommodate potential hot gas facility blast over-pressures.
- (18) Complete the modification of the Test Stand H-5 CFDTs suction line to accommodate ETS-1 suction line configuration.
- (19) Complete the fabrication and installation of a special 105,000-gallon 100-psi LH₂ run vessel.
- (20) Complete the fabrication and installation of a special 100,000-gallon, 75-psi vacuum insulated catch vessel.
- (21) Complete the fabrication and installation of the diffuser and engine chamber vessel.
- (22) Complete the fabrication and installation of the diffuser positioning equipment and support structure.
- (23) Complete the fabrication and installation of LH₂ run and catch vessel vent systems.
- (24) Complete the fabrication of special TPA and simulator handling equipment.
- (25) Complete the fabrication and installation of the test equipment positioning system hydraulic actuation equipment.
- (26) Complete the fabrication and installation of test stand vacuum insulated LH₂ piping systems, including transfer line to catch vessel.
- (27) Complete the fabrication and installation of the deflector plate in Test Stand H-5.

Subtask 5.3 (Continued)

B. Instrumentation and Controls

- (1) Procure and install remaining instrumentation systems associated with the CFDTS.
- (2) Procure and install electrical controls for 10 lb/sec. hot H₂ facility.
- (3) Procure and install electrical controls for ejector test system.
- (4) Procure and install transducers for TPA, TPCV, and nozzle development test programs.
- (5) Activate the test stand installations for CFDTS, hot H₂ heat exchanger, TSOV vessel, and hot gas diversion valve.
- (6) Provide continuing test setup modifications to accommodate test hardware configuration changes.
- (7) Complete the removal and relocation of the analog computer from test zone "C" to test zone "H".
- (8) Complete the procurement and installation of analog computer checkout equipment.
- (9) Complete the procurement and installation of an X-Y plotter for pre-checking function generators on the analog computer.
- (10) Complete the procurement and installation of signal conditioning equipment amplifiers, digital data system, patching system, cabling and conduit for the CFDTS.
- (11) Complete the procurement and installation of pressure and temperature transducers for TSOV vessel.
- (12) Complete the electrical controls for Hot Gas diversion valving and TSOV vessel.
- (13) Complete the fabrication and installation of the transducer simulator system.
- (14) Complete the fabrication and installation of the environmental pressure transducer calibration system.
- (15) Complete the fabrication and installation of a cryogenic reference junction.

Subtask 5.3 (Continued)

- (16) Complete the installation of transducer calibration equipment.
- (17) Complete the fabrication and installation of additional drop boxes and electrical controls for vessel VH-12 and TPCV test system (PFNTS).
- (18) Complete the fabrication and installation of the high frequency measuring system including amplifiers.
- (19) Complete the fabrication and installation of test stand terminal and drop boxes.
- (20) Complete the fabrication and installation of the remote valve control system including RSV boxes, purge panels, patch sequence, and wiring.
- (21) Complete the fabrication and installation of the time distribution system.
- (22) Complete the procurement of resistance temperature transmitters.
- (23) Complete the procurement of mass flow meters.
- (24) Complete the procurement of strain gage pressure transducers.

Subtask 5. (AGC-Azusa) Special Test Equipment

- (1) Complete the acquisition of the required analog computer components and complete the expansion of the PACE computer installation as mutually agreed upon.
- (2) Complete the acquisition of stock spare parts for the PACE analog computer installation as mutually agreed upon.

Subtask 5.5 (AGC-Downey) Special Test Equipment

A. Engineering

- (1) Provide all the necessary planning, design and procurement of the special test equipment (STE) required in support of work on the engine countermeasures system, Subtask 1.6, detailed as follows:

a. Electronic Instrumentation and Controls

1. Procure special electronic instrumentation and controls for recording velocity and shock transmission in tests involving high explosive systems.
2. Design special circuits used in systems employing electronic instrumentation.
3. Provide modifications as required to accommodate continuing test hardware configuration changes.

b. Photographic and Optical Equipment

1. Procure special photographic and optical equipment required to record particle size, velocity, and distribution data resulting from the fragmentation of the various sub-scale and full-scale targets by explosive means.

c. Mechanical Equipment

1. Procure test stands and support towers as required for supporting and mounting the various targets used in the explosive destruct system test programs.

B. Fabrication

- (1) Provide the necessary fabrication and installation of the STE required, detailed as follows:

a. Electronic Instrumentation and Controls

1. Fabricate special circuits used in systems employing electronic instrumentation.
2. Install consoles for instrumentation and firing control.
3. Install electrical components in mechanical test equipment.

Subtask 5.5 (Continued)

b. Photographic and Optical Equipment

1. Install and inspect the special photographic and optical equipment used to record the explosive events at the Downey facility, Chino Hills facility, and the Garfield Flats test facility.

c. Mechanical Equipment

1. Fabricate test stands and support towers as required for supporting and mounting the various targets used in the explosive destruct system test programs.
2. Install and modify the instrumentation cubicles and camera barricades as required for firing control and data recording of various explosive tests.

C. Testing

- (1) Activate and calibrate special electronic instrumentation, and photographic and optical equipment.

D. Tooling - Not applicable

Subtask 5.6 Open.

Subtask 5.7 Open.

Subtask 5.8 (AGC-LRP-SRP) Miscellaneous Laboratories Special Test Equipment

A. Mechanical

- (1) Fabricate and install vibration drive, shock, transverse, axial, and stabilizing adapters. (SRP Vibration Lab.)
- (2) Fabricate and install exciter base plate support. (SRP Vibration Lab.)
- (3) Provide continuing test setup modifications to accommodate test hardware configuration changes. (Sacramento plants.)

B. Instrumentation and Controls

- (1) Procure and install low frequency drive units. (SRP Vibration Lab.)
- (2) Provide continuing test setup modifications to accommodate test hardware configuration changes. (Sacramento plants.)

Subtask 5.9 (AGC-LRP) Engineering Laboratories Special Test Equipment

A. Mechanical

- (1) Fabricate and install LN₂ leak test vessel. (Component and Structures Lab.)
- (2) Fabricate and install TSOV component test setup. (Component and Structures Lab.)
- (3) Provide continuing modifications to accommodate test hardware configuration changes. (Component and Structures Lab.)
- (4) Complete the fabrication and installation of an extension to the existing LN₂ piping system for low temperature conditioning. (Electrical Lab.)
- (5) Complete the fabrication and installation of special vibration equipment and fixtures. (SRP Vibration Lab.)

B. Instrumentation and Controls

- (1) Fabricate and install fatigue test cryostat. (Materials Lab.)
- (2) Fabricate and install component test setup. (Electrical Lab.)
- (3) Provide continuing modifications to accommodate test hardware configuration changes. (Electrical Lab.)
- (4) Complete the procurement and installation of a high sensitivity temperature calibration equipment including a special helium operated cryostat capable of producing temperatures from 24°K to 40°K.

TASK 6 GOVERNMENT PROPERTY

The objective of this task is to provide non-nuclear test set-ups capable of testing the NERVA engine components and subsystems consistent with the technical design, procurement, fabrication, installation, and activation of Government property exemplified in the following listing, consistent with the technical objectives imposed.

Subtask 6.1 (AGC-LRP) Test Zone H

No work in this contract period.

Subtask 6.2 (AGC-LRP) Test Zone A

A. Mechanical

- (1) Fabricate and install GN₂ heating system for engine component purge system.
- (2) Procure and install vibration exciter and shock tester.
- (3) Procure and install spin test drive motors for TPA component tests.
- (4) Fabricate and install burst chamber for engine component leak test.
- (5) Fabricate and install bearing and seal assembly equipment including vacuum oven, flow bench, and hydraulic press.
- (6) Procure and install power tube bender.
- (7) Procure glove boxes, blowers, absolute filters, hoods, and accessory hardware for handling irradiated materials.
- (8) Complete the fabrication and installation of the LN₂ distribution piping system extension to the environmental conditioning chambers.

B. Instrumentation and Controls

- (1) Procure LH₂ leak rate sampling unit.
- (2) Procure He leak detector.
- (3) Procure and install LH₂ leak alarm system.
- (4) Procure and install test bay movie camera and controls.
- (5) Procure and install instrumentation calibration and checkout equipment.

7.

Subtask 6.2 (Continued)

- (6) Procure and install data recording and sampling equipment for bearing test program.
- (7) Modify acquisition of thermocouple data to accommodate expanded bearing test program.
- (8) Procure and install radiological monitoring instrumentation for supporting the safety program.
- (9) Complete the procurement and installation of a strain-gauge indicator, a frequency converter, five (5) power supplies, an electrical spot welded, an oscilloscope, a low frequency function generator, and a residual gas analyzer.
- (10) Complete the procurement and installation of the data acquisition system (portions not considered STE).

Subtask 6.3 Open

Subtask 6.4 (AGC-LRP) Development Fabrication Facility

A. Mechanical

- (1) Procure and install aluminum ac welders.
- (2) Procure and install cleaning equipment and clean-work stations.
- (3) Procure and install electrical connector welding machine.
- (4) Procure and install hydraulic assembly press.

Subtask 6.5 Garfield Flats Test Facility, Hawthorne, Nevada

Provide the design, planning, and procurement and/or fabrication, installation (utilizing government furnished Hawthorne Naval Ammunition Depot support where practical) and activation of the following items as part of the continued development of the Garfield Flats test facility at Hawthorne, Nevada, in support of the test and development phase of the engine countermeasures system, Subtask 1.6, for contract year 1964:

(1) Security Guard Services

Renew the contract for security guard service for the period 1 October 1963 through 30 September 1964.

(2) Trailer Rental Service

Renew the contract for trailer rental through contract year 1964 until the compound area building is sufficiently complete for occupancy.

(3) Test Sampling Apparatus

Procure and install a system to catch and retain debris from various test firings.

(4) Instrumentation Barricade

Construct a steel shelter, in the test pad area, similar to the shelter for the firing panels at the test site. The proposed barricade shall be 15 feet square by 8 feet high.

(5) Guard House

Procure and install a prefabricated 8 foot by 12 foot building for housing the security guard. This building shall be equipped with telephone communications to the test site barricades and the compound area building.

(6) Electrical Power Installation

Provide a power distribution line from Mina, Nevada, to the test site. The power line shall include a substation with transformers to supply the needs of the test facility.

(7) Telephone Installation

Provide a telephone communications system for on-site communications and external toll communications. This installation shall be integrated with the power line installation.

Subtask 6.5 (Continued)

(8) Assembly Building

Construct a 40 foot by 60 foot concrete block building. The building shall have a concrete floor and shall include heating and air conditioning. The building shall contain space for offices, assembly, storage, sanitation, and shower facilities.

(9) Compound Fencing

Procure and install a 1180 foot chain link fence with a 20 foot gate around the 300 foot square compound area.

(10) Security Lighting

Procure and install a security lighting system around and in the compound area in accordance with security specifications for storage of SS materials.

(11) Outer Perimeter Fencing

Procure and install a five strand barbed wire fence on steel posts around the SNPO-C approved perimeter of the Garfield Flats Test Site near Hawthorne, Nevada.

(12) Water Installation

Provide a water well and procure and install the necessary plumbing and equipment for the compound area buildings.

(13) Test Pad Power Distribution

Procure and install, electrical power lines for test pad controls and instrumentation, in closed channels set into the ground near ground level.

TASK 7 NRDS OPERATIONS

Subtask 7.0 - NRDS General Support

A. Engineering

- (1) Provide the necessary administrative and engineering personnel and services to support the NERVA test operations at NRDS. These shall include overall management, procurement, receiving, accounting, budgets, communications, traffic control, clerical, reproduction, library, and other applicable services.
- (2) Project management shall be in accordance with the approved organization chart delineating prime and major sub-contractor personnel to the level of department managers.
- (3) Direct the overall planning and scheduling of all NERVA activities at NRDS pertaining to the test program, facilities and test equipment.
- (4) Formulate and prepare the program requirements document (PRD) in accordance with the specified milestones.
- (5) Provide liaison with REON/WANL/SNPO-C/SNPO-N associated with (3) above.
- (6) All staffing at NRDS shall be in accordance with the approved manning chart.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Subtask 7.1 Test Cell "A" Operations

A. Engineering

- (1) Provide on-site test engineering necessary to insure compliance with the test objectives and requirements detailed in the NRX-A1, A2, A3 and A4 test specifications. This shall consist of the following tasks:
 - a. Prepare, issue and maintain facility Standard Operating Procedures (SOP).
 - b. Prepare, issue and maintain all other procedures required by the test specifications.
 - c. Prepare and issue the eight hour, three day and final data reports.

Subtask 7.1 Test Cell "A" Operations (continued)

- (2) On or about 1 January 1964, assume Test Cell "A" "facility management" responsibility. "Facility management" is defined as the authority for personnel and space assignments, setting schedules, controlling maintenance and modifications of the facility, defining facilities spares requirements and ensuring that these spares are provided through appropriate channels.

B. Fabrication - Not applicable

C. Testing

- (1) Provide personnel to conduct NRX-A1, A2, A3 and A4 test programs and complete subject tests in accordance with the approved test specification.
- (2) Conduct routine essential maintenance on the following systems with the available test operating team:
 - a. Cryogenic
 - b. H.P. gas and compression
 - c. Hydraulics
 - d. Neutronics
 - e. Controls
 - f. Vacuum
 - g. Flare
 - h. Control air
 - i. Process water
- (3) Provide the technical supervision of Pan American Airways personnel in their conduct of maintenance and operation including the following systems. The contractor shall issue work orders for the performance of this work.
 - a. Reactor shed
 - b. Plant air
 - c. Utility water
 - d. Deluge water

Subtask 7.1 Test Cell "A" Operations (continued)

- e. Fire protection
- f. Sewage disposal
- g. Heating, ventilating and air conditioning
- h. Data acquisition
- (4) Utilize government services (Pan American Airways and Edgerton, Germeshausen & Grier) starting in February, 1964, for the operation of control, neutronics and data acquisition systems. Subsequent to July 1, 1964, provided "operational separation" of Test Cells A and C has been achieved, utilize government furnished services (Pan American Airways) for operation of the data acquisition system.

Subtask 7.2 Test Cell "C" Operations

No work in this contract period.

Subtask 7.3 R-MAD and Post Mortem Operations

A. Engineering

- (1) Coordinate all engineering activities associated with NRX operations at R-MAD
- (2) Provide on-site test engineering necessary to insure compliance with the test objectives and requirements detailed in the NRX-A1, A2, A3 and A4 test specifications. These shall include the following tasks:
 - a. Prepare, issue and maintain Standard Operating Procedures (SOP)
 - b. Prepare, issue and maintain all other procedures required by the test specifications.
 - c. Assist in preparation of the final data reports.

B. Fabrication - Not applicable

C. Testing

- (1) Complete the assembly of the NRX-A1, A2, A3 and A4 test assemblies.

Subtask 7.3 R-MAD and Post Mortem Operations (continued)

- (2) Complete the disassembly of the NRX-A1, A2 and A3 test assemblies. Conduct the post operative examination of NRX-A1, A2 and A3 as required by the test specifications.
- (3) Conduct all other operations required by the NRX-A1, A2, A3 and A4 test specifications.

D. Tooling

- (1) Provide engineering design and special tooling and jigs required for NRX operations in R-MAD, including field modifications to special handling equipment.

Subtask 7.4 ETS Operations

A. Engineering

- (1) Monitor on-site activities during the latter phase of engineering and construction in preparation for activation. Assist in defining operational requirements of the ETS-1 Activation Plan.
- (2) Assume ETS-1 "facility management" responsibility as each system receives engineering and construction final acceptance.
- (3) Prepare the necessary procedures and checklists for conducting the tests shown in paragraph C Testing.
- (4) Prepare other procedures and checklists required to support the ETS-1 Activation Plan as defined in Subtask 3.2 for those activities occurring early in Contract Year 1965.

B. Fabrication - Not applicable

C Testing

- (1) Provide technical supervision of Pan American personnel in the installation of approved minor modifications to correct construction deficiencies or incorporate improvements.
- (2) Provide on-site test engineering and other personnel to conduct operational checks, and to perform routine essential maintenance on the following systems:

Subtask 7.4 ETS Operations (continued)

- a. Cryogenic
 - b. Propane
 - c. Gas and compression
 - d. Fire protection
 - e. Vacuum
- (3) Provide on-site test engineering and supervision of Pan American personnel for work on all other systems except the I&C. The contractor shall issue work orders for the performance of this work.
 - (4) Complete the GHe and LN₂ checkout of the cryogenic systems prior to May 24, 1964.
 - (5) Complete the checkout of systems required for steam generator tests such that test operation can start on July 1, 1964.

D. Tooling - Not applicable

Subtask 7.5 E-MAD Operations

Sub-Subtask 7.5.1 Engine Operations

No work in this contract period.

Sub-Subtask 7.5.2 NRX Operations

A. Engineering

- (1) Conduct operations planning and establish personnel requirements.
- (2) Monitor on-site activity during the latter phase of engineering and construction in preparation for activation. Assist in defining operational requirements of the E-MAD activation plan as defined in Subtask 3.5.
- (3) Assume E-MAD "facility management" responsibility as each construction increment receives "engineering and construction final acceptance."

Sub-Subtask 7.5.2 NRX Operations (continued)

- (4) Monitor and/or supervise on-site activities associated with assembly and installation of special handling equipment.
- (5) Initiate preparation of necessary procedures and checklists for conducting tests on those mechanical and electrical systems installed in the cold areas. Procedures which are necessary to initiate cold area activation in Contract Year 1964 shall be completed.
- (6) Initiate preparation of other procedures required to support the activation plan for those activities occurring early in Contract Year 1965.
- (7) Provide engineering surveillance for personnel familiarization and qualification during the vendor in-plant special equipment assembly and shop tests.
- (8) Provide engineering liaison to REON/WANL/LRP for special equipment design and provisioning requirements.
- (9) Provide engineering support for development of Program Requirements Documents.

B. Fabrication - Not applicable

C. Testing

- (1) Provide on-site test engineering, conduct operational checks, and perform routine essential maintenance necessary to insure facility (cold area) compatibility with the operational requirements detailed in the E-MAD Activation Plan.
- (2) Initiate checkout tests of E-MAD Cold Areas in June, 1964.

Subtask 7.6 Graveyard and Storage Operations

No work in this contract period.

TASK 8. NRX-A NUCLEAR SUBSYSTEM DEVELOPMENT

In the portion of the Work Statement for Tasks 8 and 9, reference is made to certain reactor components and subassemblies by code number. A listing of these components and subassemblies and the corresponding code numbers is contained in a separate classified document titled "List of Major Reactor Components and Subassemblies for Use With Supplement IV to Appendix B, Contractual Work Statement, Contract SNP-1", dated October 28, 1963, duplicate copies of which are in the possession of both the contractor and the Government, and is hereby incorporated by reference into this contract. Wherever code numbers are used in this Work Statement for Tasks 8 and 9 in connection with reactor components and subassemblies, such numbers are identified on the list described above against specific components and subassemblies.

Subtask 8.0 NRX-A Block I Nuclear Subsystem Engineering

The Nuclear Subsystem designation NRX-A Block I reactors shall denote the following: NRX-A1 Cold Flow Reactor, NRX-A2, A3 and A4 Hot Test Reactors.

Provide layouts, detailed designs and design support and evaluate the mechanical design and performance of the NRX-A Block I reactors and their modifications and replacement shields. This design is to be based on flight environment requirements and is to serve as a basis for development of the reactor to a qualified flight status.

Perform thermal and fluid flow design of the NRX-A Block I reactors, replacement shields and their modifications; develop analytical techniques required to carry out the thermal and fluid flow design; specify and analyze component tests required to verify or support the thermal and fluid flow design; specify the thermal and fluid flow requirements, capabilities and performance of the as-manufactured reactors; and specify the requirements for, and analyze the results of, thermal and fluid flow testing of integral reactors.

Perform the nuclear design and analysis of the NRX-A Block I reactors, develop design methods, as needed, to predict nuclear characteristics of the reactors, and prepare nuclear specifications of the reactor components.

Complete the analysis of the radiation environment of the operating NRX-A Block I reactor subassembly, determine the heating rates and activation of components used in its operation; and support studies of facilities, shielding and handling of components within facilities; continue evaluation of the analytical methods used to compute radiation fields and heating rates; develop detailed radiation heating distribution throughout all components within the pressure vessel; and complete detailed nuclear analysis of the shield replacement unit.

Complete the required mechanical tests covering static, vibration and shock tests of the Block I reactor components, core and full reactor, under conditions simulating the combined loads of flight, shipping and operating environments to verify, to the extent possible, the design parameters and to demonstrate design margins. Furnish data and analysis of component physical properties to the design groups and complete qualification tests of final designs. These tests shall, to the extent feasible, demonstrate, prior to committing to hot test, the capability of the Block I reactor components to operate under at least as severe conditions as those anticipated during hot testing.

Complete the tests necessary for verification of the flow capabilities of Block I reactor components under various environmental conditions; to develop methods for rapid and accurate measurement for fluid flow; to measure fluid flow in reactor fuel assemblies and components under various environmental conditions; to investigate and evaluate the types of vibrations which may result from hydrogen coolant flow phenomena; to evaluate flow instabilities, and to determine the effectiveness of the reactor lateral support and seal system.

Subtask 8.0 - continued

Complete the experimental evaluation of the corrosion rates and thermal gradients of the Block I reactor core components under controlled environmental conditions; determine the basic parameters affecting corrosion; determine the effects of corrosion on heat transfer; determine the corrosion rates and the temperature gradients of the support blocks; and, determine the effects of corrosion and thermal gradients on an integrated fuel cluster.

Perform low power nuclear tests of pre-assembled NRX-A Block I reactors to determine core reactivity, required shim content, calibration of control drums, and power distribution.

Sub-Subtask 8.0.0 Reactor Mechanical Design

A. Engineering

- (1) Complete the required modifications of the design of all NRX-A Block I reactors and replacement shields based on stress and dynamic analysis, component testing and analysis, KIWI testing, Phase I reactor vibration tests and NRX-A1 cold flow tests; complete and issue all detail design drawings and design reports for the NRX-A Block I reactors.
- (2) Complete the steady state and transient stress analysis of reactor and replacement shield components for all NRX-A Block I reactors. Evaluate the effect of design modification on component stresses; define allowable temperatures and temperature gradients; investigate the adequacy of analytical techniques for stress analysis and develop improved techniques; provide support to design groups to increase the probability of survival of graphite components; issue stress analyses reports for all NRX-A Block I reactors.
- (3) Determine, up-date and issue shipping and reactor test environments to be used for design; analyze and report data from shipping and reactor tests; define response of reactor components to environment; investigate fluid flow paths, such as fueled element interspace gaps, which may influence core dynamic behavior; establish and issue vibration test objectives and compare test results with analytical predictions.
- (4) Provide design support as required for procurement, inspection, and acceptance of reactor hardware, including the following:

Sub-Subtask 8.0.0 (continued)

- a. Evaluate processes submitted by vendors for compliance with drawing requirements, such as welding, fabrication, cleaning and forging processes.
 - b. Establish non-destructive test standards for inspection of graphite and beryllium parts.
 - c. Assist in the development of new materials and processes and fabrication techniques, by exploring and evaluating changes which will fulfill design and procurement objectives.
- (5) Define and specify objectives of component test programs required to substantiate the adequacy of all NRX-A Block I reactors and replacement shield mechanical designs on a continuing basis; evaluate, analyze and report the effect of component test results and analysis on these designs; determine and specify all tests required to verify reactor and shield designs, design concepts and design assumptions.
 - (6) Evaluate and coordinate design changes requested by other groups such as Reactor Analysis or Manufacturing Engineering; define engineering parts requirements for each reactor assembly including the NRX-A Block I reactors, Phase I vibration reactor and rebuild, the G-3 plugged core and the CFDTS test reactor.
 - (7) Maintain and periodically issue up-dated master design layouts for all NRX-A Block I reactors, Phase I vibration reactor and rebuild, the G-3 plugged core and CFDTS test reactor to evaluate changes requested by vendors and other groups such as Manufacturing Engineering.
 - (8) Determine and specify NRX-A2, A3 and A4 reactor test data requirements and accuracies for mechanical design development purposes.
 - (9) Determine and issue operative and post-operative mechanical analyses reports on the NRX-A1, A2 reactors, Phase I vibration reactor and rebuild and the G-3 plugged core reactor.
 - (10) Incorporate ground handling and flight environment data into NRX-A Block I design specifications on a continuing basis.
 - (11) Study, define and release instrumentation requirements for NRX-A2, A3 and A4 reactors and replacement shields, Phase I vibration reactor and rebuild, and the G-3 plugged core, and establish and issue detailed design drawing modifications required for instrumentation of these assemblies.

Sub-Subtask 8.0.0 (Continued)

- (12) Maintain liaison with Los Alamos Scientific Laboratory on all aspects of reactor mechanical design.
- (13) Coordinate reactor and shield pressure vessel interfaces and mechanical requirements with Aerojet-General on a continuing basis to ensure compatibility with the engine.
- (14) Complete and issue the required design modifications, stress analysis and detailed design drawing and instrumentation revisions for G-3 plugged core, Phase I vibration reactor and rebuild, and the CFDTs test reactors.
- (15) Design bearings and test fixtures as required to support development testing of flight-type control drum bearings.

B. Fabrication - As required

C. Testing

- (1) Perform limited development testing of flight-type control drum bearings, and other testing as required.

D. Tooling - As required

Sub-Subtask 8.0.1 Reactor Thermal and Fluid Flow Design

A. Engineering

- (1) Complete the analytical determination of the thermal and fluid flow characteristics of the NRX-A2, A3 and A4 reactors and replacement shields over the full operating range for both steady state and transient conditions.
- (2) Determine the cooling requirements of mechanical structures and investigate the effects of mechanical modifications.
- (3) Complete specifications for the component and reactor assembly experiments required to verify or determine the thermal and fluid flow characteristics and capabilities of the reactors.
- (4) Complete analysis of the available heat transfer and fluid flow data from component, reactor and basic experiments and incorporate selected data into the reactor design calculations to be issued in reactor design report supplements.
- (5) Complete specifications for the orificing of NRX-A2, A3, and A4 reactors.
- (6) Complete the determination of thermal and fluid flow operating capabilities and characteristics of NRX-A2, A3, and A4 reactors and issue reports describing the determinations.

Sub-Subtask 8.0.1 (continued)

- (7) Insure the adequacy of the fuel element specifications for core thermal and fluid flow performance.
- (8) Complete the analysis of NRX-A Block I reactor hot channel factors, on the basis of inspection data from the fuel manufacturing operation and laboratory tests, and determine statistically the effect of these data on reactor performance.
- (9) Develop methods as required to carry out the design and analysis of NRX-A Block I reactors.
- (10) Study, define and prepare the necessary instrumentation list required for proper execution and acquisition of data for NRX-A2, A3, A4 and G-3 reactor tests and specify the instrumentation range and accuracy required.
- (11) Prepare NRX-A3, A4 and G-3 test requests.
- (12) Prepare and issue NRX-A2, A3 and A4 reactor design report supplements.
- (13) Prepare and issue NRX-A1, A2 and A3 reactor test performance prediction report.
- (14) Complete and issue reports on analysis of NRX-A1, A2 and A3 reactor test results.
- (15) Complete and issue supplemental reports on analysis of NRX-A1 and A2 test results.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-Subtask 8.0.2 Reactor Nuclear Design

A. Engineering

- (1) Determine and specify the NRX-A3 and A4 fuel element loading distribution and the resulting power distribution in the reactor core, predict nuclear parameters required for the design of the reactor subassembly.
- (2) Prepare reactor fuel element nuclear specification requirements for NRX-A3 and A4.

Sub-Subtask 8.0.2 (continued)

- (3) Predict and specify reactivity parameters and their respective uncertainties for all NRX-A Block I assembled cores and monitor fuel element fabrication for NRX-A2, A3 and A4 reactors to assess material reactivity effects.
- (4) Compute and specify reactivity coefficients and all other kinetic parameters necessary for control system design and accident analysis.
- (5) Prepare and issue detailed test plans for the NRX-A2, A3 and A4 reactor nuclear tests to be performed at WANEF.
- (6) Provide theoretical support to and analyze and report results of the NRX-A2, A3 and A4 reactor nuclear experiments at WANEF and the NRX-A2 and A3 reactor tests at NRDS.
- (7) Prepare detailed test plans for NRX-A2, A3 and A4 reactor nuclear tests to be performed at NRDS.
- (8) Develop and issue standard design methods of computation for nuclear design associated with NRX-A Block I reactors.
- (9) Evaluate and up-date design methods by comparing test results with predictions.
- (10) Design and issue specification requirements of poison systems for criticality control of assembled reactors.
- (11) Review, analyze and report on design changes and variations for their effects on the reactor nuclear characteristics.
- (12) Review applicable reactor test procedures for compatibility with reactor nuclear characteristics.
- (13) Coordinate and review nuclear calculations performed for criticality control during assembly, shipping, handling, and storage.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-Subtask 8.0.3 Shielding and Radiation Analysis

A. Engineering

- (1) Complete the computation of detailed radiation heating patterns, fast neutron flux, gamma dose rate and activation of all components of the NRX-A Block I reactor subassembly. Heating distributions shall be developed for both reactor startup and shutdown as well as steady state conditions.
- (2) Prepare test request and analyze test data from planned radiation measurements at NRDS.
- (3) Review facility shielding and provide radiation information required for studies of reactor subassembly handling during NRDS operations.
- (4) Perform analysis required to evaluate manufacturing variation requests and design changes.
- (5) Develop improved methods of computation as required for NRX-A Block I radiation analysis.
- (6) Evaluate design methods by comparing test results with predictions.
- (7) Prepare and issue reactor design report supplements for NRX-A2, A3, and A4.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-Subtask 8.0.4 Mechanical Analysis and Testing

A. Engineering

- (1) Evaluate the results of tests conducted.
- (2) Prepare required reports and data summaries.

B. Fabrication

- (1) Provide test fixtures and equipment as required to accomplish project objectives.

C. Testing

- (1) Determine standard physical properties of reactor components W-1 and W-2 under reactor operating temperature ranges. Determine static and dynamic Young's Modulus, shear modulus, internal damping, and fatigue strength. Provide basic design

Sub-Subtask 8.0.4 (Continued)

- information on stress limits for the actual fuel element components. Investigate response of W-3 components to their environmental conditions. Issue a final report.
- (2) Complete tests and analysis of Block I W-8 support parts to demonstrate that these components and the associated W-5 parts meet design requirements. Obtain results from static and cyclic loadings over a large number of thermal gradients. Analyze load distributions, conditions of wear, reliability, and design adequacy. Issue a final report.
 - (3) Complete tests to establish the structural integrity of Block I W-7 components at low, ambient, and high temperatures under static, alternating and vibratory loads. Obtain stress-strain data and fatigue strength from which the W-7 component performance can be equated to operating conditions. Issue a final report.
 - (4) Complete tests to demonstrate that the Block I W-11 component will tolerate the maximum environmental vibratory and shock loadings and determine maximum radial loadings, dimensional tolerance limits, and lateral shift of these assemblies relative to the Y-1 component. Use vibration characteristics to determine internal damping. Issue a final report.
 - (5) Complete tests of Block I lateral support system X-2 components under static and vibratory conditions with X-4 and X-1 components in place to determine deterioration of mechanical properties under vibratory and alternating loads and to determine wear and interaction mechanisms between lateral support components. Issue a final report.
 - (6) Complete tests on Block I lateral support components and W-6 components under design operating conditions of temperature, pressure, mechanical load, and hydrogen flow. Evaluate the effects of the environmental exposures and thermal shock to determine the adequacy and feasibility of the design. Issue a final report.
 - (7) Complete tests on the Block I Z-4 component by subjecting it to pressure loading. Check permeability and tendency to buckle. Statistically evaluate the strength of the internal threads after numerous static and dynamic tests. Use a prototype Z-4 component for the test. Issue a final report.
 - (8) Complete vibration, shock and static loading tests on a partial length core assembly. Investigate motions, frictional damping forces, static friction and hysteresis, and geometrical gap considerations. Study the effects of

Sub-Subtask 8.0.4 (continued)

increased lateral support pressures. Issue a final report.

- (9) Complete tests on the Block I support system of the NRX-A reactor under static loading conditions with simulated differential pressure conditions to determine stresses and deflections. Compare these with design values. Apply thermal gradients simultaneously with load to assess combined effects. Issue a final report.
- (10) Complete tests under various conditions of operating environment to determine whether flat metal surfaces or threaded engagements may seize and prevent the orderly disassembly of the NRX-A reactor. Issue a final report.
- (11) Complete shock, vibration and flow tests under cryogenic conditions on a Z-3 assembly to determine its ability to function in design environments. Assess mechanical difficulties that may arise due to vibration and shock and the associated fretting or brinelling of parts, and determine whether gas flow will introduce objectionable vibration. Issue a final report.
- (12) Complete the laboratory vibration and shock tests on the Block I NRX-A reactor design. Obtain complete structural dynamics information from four series of tests. Complete a series of developmental and environmental tests consisting of core assembly tests, reactor assembly tests, shock tests and environmental tests. Measure responsiveness of components to sinusoidal vibration inputs of various levels and at various frequencies with sweep and dwell tests. Obtain stress levels in the core and relative displacements of components. Upgrade the reactor with new graphite parts and a Y-4 part during disassembly preceding the environmental tests. Correlate response, stress and damping forces obtained experimentally with computer studies to provide significant information necessary for the NRX-A1 cold flow and NRX-A2 hot test.
- (13) Complete a study and evaluation, from test program experience, of the modes of deformation and fracture of Block I components. Provide input based on this information for a program on techniques for post-operative inspection of reactor parts. Correlate component test failure experience with possible damage of parts in cold flow and power tests. Submit a final report.
- (14) Complete tests and issue a report on material components at each interface in the reactor for the purpose of determining static and dynamic friction coefficients in the operating temperature ranges and hydrogen environment.

Sub-Subtask 8.0.4 (Continued)

- (15) Perform general service tests and associated analysis in support of the various design and other testing groups. Obtain timely input of experimental data to certify design analysis in development areas. Issue a final report.
- (16) Complete preliminary tests on Block I components with known deviations and flaws. The goal of these tests is the determination of the effect of various deficiencies on the integrity of the component. Use this information to develop inspection limits.
- (17) Submit prerequisite testing report one month prior to full scale reactor tests NRX-A1, A2, and A3.
- (18) Submit a report on full scale tests, post-mechanical analysis, for NRX-A1, A2, and A3.

Sub-Subtask 8.0.5 - Open

Sub-Subtask 8.0.6 - Open

Sub-Subtask 8.0.7 Component Flow Tests

A. Engineering

- (1) Accomplish necessary analytic effort to define the flow maldistributions and instabilities observed in various reactor components to be tested.
- (2) Prepare required reports.

B. Fabrication

- (1) Provide test fixtures and equipment as required to accomplish project objectives.

C. Testing

- (1) Complete the flow testing and issue a final report on Block I W-7 components such as hanger, centering bushing, and support cup.
- (2) Complete the calibration of the W-10 components for various types of operating conditions. Issue a final report.

Sub-Subtask 8.0.7 (Continued)

- (3) Complete flow tests and issue a final report on the seven W-11 assembly with a simulated reactor lateral support system to determine core stability region and amplitude of vibrations in unstable domains.
- (4) Complete the tests and issue a final report on the lateral support X-1 system under conditions of high temperature and pressure.
- (5) Complete the tests and issue a final report on segments of the impedance rings between the Z-4 and Z-1 components and the Z-1 component and pressure vessel to determine the pressure drop for various flow rates.
- (6) Complete the tests and issue a final report on segments simulating the Z-4 component and X-1 components to determine flow characteristics.
- (7) Complete tests and issue a final report on the Z-3 drive shaft models to evaluate possible flow paths and maldistributions.
- (8) Complete the tests and issue a final report on simulated Z-3 components to determine flow distribution in the various flow channels.
- (9) Complete flow tests and issue a final report on simplified and reduced scale models of the entire reactor to evaluate the effect of flow maldistributions as well as suitable methods to minimize the maldistributions of flow.
- (10) Complete tests and issue a final report on a full scale reactor with a plugged core to evaluate the pressure distribution of the Block I reactor lateral support system and map the region of flow-induced instabilities.
- (11) Complete air tests and issue a final report on a model of the replacement shield segment to investigate and measure the flow distribution.
- (12) Evaluate multivalued flow instability through parallel tubes at constant pressure drop with heat addition. Issue a final report.
- (13) Issue summary report on prerequisite testing for NRX-A1, A2, and A3.

D. Tooling - As required

Sub-subtask 8.0.8 - Corrosion Tests

A. Engineering

- (1) Evaluate thermal gradients and the corrosion resistance capabilities of the Block I reactor components.
- (2) Prepare and issue required reports.

B. Fabrication

- (1) Provide test facility equipment as required to accomplish project objectives.

C. Testing

- (1) Complete the corrosion, heat transfer, and thermal gradient testing of fuel elements and unfueled center pieces representative of production material for NRX-A2, NRX-A3 and A4 reactors. Elements will be resistance heated to reactor simulated operating temperature and pressure. Issue statistical testing reports for NRX-A2, A3, and A4.
- (2) Complete hydrogen flow tests to evaluate support block and tie-rod hardware interaction at elevated temperatures for the Block I design. Issue a final report.
- (3) Complete tests to investigate the behavior, on an integrated basis, of a suspended single cluster, resistance heated to operating temperature, at operating pressure, and issue a final report for the Block I design.

D. Tooling - Not applicable

Sub-subtask 8.0.9 - Reactor Pre-Assembly and Proof Critical Tests

A. Engineering - As required

B. Fabrication

- (1) Supply incidental equipment necessary to the accomplishment of all the NRX-A Block I critical experiments.

C. Testing

- (1) Operate the critical facility as required to conduct pre-assembly and proof testing of NRX-A2, A3 and A4 reactors in accordance with the test plan.

Sub-subtask 8.0.9 (Continued)

- (2) Measure the core reactivity, calibrate the control drums, shim the core as required, and measure the power distribution of the NRX-A2, A3 and A4 reactors.
- (3) Determine, specify and evaluate the expected reactivity differences between pre-assembled and final assembled NRX-A2, A3 and A4 reactors.

D. Tooling - As required

Subtask 8.1 Nuclear Sub-System Procurement Management and Control

Support and control the delivered nuclear subsystem components and subassembly to the configuration and schedule required for the NRX-A Block I ground test program. Based on overall project direction, analyze and prepare detailed ordering requirements for procurement. Provide all hardware, tooling and services. Establish and maintain priority scheduling and inventory control on all work in progress. Receive, store, dispatch and maintain records of finished parts, raw materials and other government property. Assemble and ship all reactors and major components or subassemblies.

Sub-Subtask 8.1.0 Procurement Management and Control-NRX-A Block I Reactors

A. Engineering - Not applicable

B. Fabrication

(1) Provide all NRX-A Block I raw material, tooling and fabricated components as required for the following:

- a. Modification of NRX-A1 to the CFDTs reactor assembly.
- b. The NRX-A3 reactor.
- c. The NRX-A4 reactor.
- d. The Phase I vibration test assembly rebuild(s).
- e. The Component Test Program.

(2) Maintain overall procurement schedule information and monitor program.

(3) Provide manufacturing engineering support to design engineering on manufacturing techniques, processes and process capabilities; investigate, define and develop improved fabrication methods and techniques.

(4) Prepare, develop and monitor manufacturing process development programs.

C. Testing - As required

D. Tooling - As required

Sub-Subtask 8.1.1 Procurement Management and Control - Outer Reflector

Provide delivered outer reflector components and subassemblies to the configuration of the NRX-A Block I reactor program, as follows:

Sub-Subtask 8.1.1 (contd)

A. Engineering - Not applicable

B. Fabrication

- (1) Provide outer reflector parts for NRX-A Block I reactor program, as follows:
 - a. Modification of the NRX-A1 to the CFDTS assembly.
 - b. The NRX-A3 reactor.
 - c. The NRX-A4 reactor.
- (2) Provide required hardware for the Phase I vibration reactor assembly rebuild(s).
- (3) Provide specification grade hardware as required for the Component Test Program.

C. Testing - Not applicable

D. Tooling

- (1) Provide tooling required to accomplish the project objective as applicable.

Sub-Subtask 8.1.2 Procurement Management and Control - Inner Reflector

Provide inner reflector and lateral support components to the configuration and schedule of the NRX-A Block I test program, as follows:

A. Engineering - Not applicable

B. Fabrication

- (1) Provide inner reflector parts for NRX-A Block I reactor program, as follows:
 - a. Modification of the NRX-A1 reactor to the CFDTS assembly.
 - b. The NRX-A3 reactor.
 - c. The NRX-A4 reactor.
- (2) Provide inner reflector parts for the Phase I vibration reactor assembly rebuild(s).
- (3) Provide specification grade hardware as required for the Component Test Program.

C. Testing - Not applicable

Sub-Subtask 8.1.2 (cont.)

D. Tooling

- (1) Provide tooling required to accomplish the project objectives as applicable.

Sub-Subtask 8.1.3 Procurement Management and Control - Core (non-fuel)

Provide the delivered core components and subassemblies to the configuration of the NRX-A Block I test program, as follows:

A. Engineering - Not applicable

B. Fabrication

- (1) Provide core parts, as required, for the Block I reactor program as follows:
 - a. Modification of the NRX-A1 reactor to the CFDTS assembly.
 - b. The NRX-A3 reactor.
 - c. The NRX-A4 reactor.
- (2) Provide core parts, as required, for the Phase I vibration reactor rebuild.
- (3) Provide specification grade hardware as required for the Component Test Program.

C. Testing - Not applicable

D. Tooling

- (1) Provide tooling required to accomplish the project objective as applicable.

Sub-Subtask 8.1.4 Procurement Management and Control - Poison and Misc. Parts

Provide the miscellaneous components and subassemblies to the configuration of the NRX-A Block I test program as follows:

A. Engineering - Not applicable

B. Fabrication

- (1) Provide poison and miscellaneous parts, as required, for the following:
 - a. Modification of the NRX-A1 reactor to the CFDTS assembly.

Sub-Subtask 8.1.4 (cont.)

- b. The NRX-A3 reactor.
- c. The NRX-A4 reactor.
- (2) Provide appropriate miscellaneous parts as required for the Phase I vibration reactor rebuild.
- (3) Provide specification grade miscellaneous parts as required for the Component Test Program.
- C. Testing - Not applicable
- D. Tooling
 - (1) Provide tooling required to accomplish the project objective as applicable.

Sub-Subtask 8.1.5 Procurement Management and Control - Shield

Provide the delivered shield assembly and related components to the configuration of the NRX-A Block I reactor test program as follows:

- A. Engineering - Not applicable
- B. Fabrication
 - (1) Provide simulated shield replacement unit, seals and flow screen hardware as required for the following:
 - a. The NRX-A3 reactor.
 - b. The NRX-A4 reactor.
 - c. The Component Test Program.
- C. Testing - Not applicable
- D. Tooling
 - (1) Provide tooling required to accomplish the project objective as applicable.

Sub-Subtask 8.1.6 Procurement Management and Control - Controls & Actuators

Provide control equipment for modification of the Test Cell "A" Control System to monitor and control NRX-A Block I reactor tests as follows:

- A. Engineering - Not applicable
- B. Fabrication
 - (1) Provide up-dated material, components and subassemblies for

Sub-Subtask 8.1.6 (Cont.)

the NRX-A Block I control systems as required for the following:

- a. The NRX-A2 reactor.
- b. The NRX-A3 reactor.
- c. The NRX-A4 reactor.

(2) Deliver the above control items to NRDS for incorporation into the Test Cell "A" control system.

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-Subtask 8.1.7 Procurement Management and Control - Instrumentation

(Instrumentation for the NRX-A Block I reactors is provided under Sub-Subtask 2.4.2)

Sub-Subtask 8.1.8 Procurement Management and Control - Fuel Elements

Provide reactor fuel elements and related graphite core parts required for the NRX-A Block I test reactors as follows:

A. Engineering - Not applicable

B. Fabrication

(1) Provide fuel elements for NRX-A Block I test reactors as follows:

- a. The NRX-A2 reactor.
- b. The NRX-A3 reactor.
- c. The NRX-A4 reactor.

(2) Provide fuel elements and graphite test pieces for detailed engineering tests as required.

(3) Provide protective processing of graphite and pyrographite for components and other graphite parts as required.

C. Testing - Not applicable

D. Tooling

(1) Provide tooling required to accomplish project objectives as applicable.

Sub-Subtask 8.1.9 Reactor Assembly, Packaging and Shipping

Assemble reactors and components thereof to the specified configuration; prepare these assemblies for shipment; transport assemblies to required test site.

A. Engineering - Not applicable

B. Fabrication

- (1) Assemble parts and components into subassemblies and complete reactor assemblies in accordance with design requirements and safety conditions approved by SNPO-C for NRX-A Block I reactors: the NRX-A2, A3 and A4 PAX components, the G-3 plugged core and the CFDTS reactors. Disassemble and reassemble the vibration test reactor, the NRX-A1 reactor and the NRX-A2, A3 and A4 PAX components as required.
- (2) Prepare and package reactors, assemblies and/or components for shipping and ship according to specification the NRX-A Block I reactors, G-3 plugged core, Phase I vibration reactor and rebuild, the CFDTS reactor and NRX-A2, A3 and A4 PAX components.
- (3) Document by logs, reports, motion pictures, etc. all major assembly operations and all hardware used in the above assemblies.

C. Testing - Not applicable

D. Tooling

- (1) Provide tooling required for assembly of above reactors and associated components including tools and fixtures, safety equipment and checkout and handling equipment.

Subtask 8.2 NRX-A Block II Nuclear Subsystem Engineering

The Nuclear Subsystem designation NRX-A Block II reactors shall denote the following reactors: NRX-A5, A6, A7 and A8.

Provide layouts, detailed designs and design support and evaluate the mechanical design and performance of the NRX-A Block II reactors and their modifications and replacement shields. The Block II reactors are to be based on a complete redesign of the lateral support area and associated core components, are to be based on flight environment requirements, and are to serve as a basis for development of the reactor to a qualified flight status.

Perform the thermal and fluid flow design of the NRX-A Block II reactors, replacement shields and their modifications; develop analytical techniques required to carry out the thermal and fluid flow design; specify and analyze component tests required to verify or support the thermal and fluid flow design; specify the thermal and fluid flow requirements, capabilities, and performance of the as-manufactured reactors; specify the requirements for thermal and fluid flow testing of integral reactors.

Perform the nuclear design and analysis of the NRX-A Block II reactors, develop design methods as needed to predict nuclear characteristics of the reactor, and prepare nuclear specifications of reactor components.

Perform the radiation and shielding analysis for the NRX-A Block II reactor to determine heating rates and activation of all reactor components and to evaluate radiation analysis methods.

Complete an initial series of mechanical tests of Block II reactor components and assemblies under various static, vibration and shock conditions simulating the combined loads of flight, shipping and operating environment to verify, to the extent possible, the design parameters and to demonstrate design margins. Furnish data and analysis of component physical properties to the design groups and provide qualification tests of final designs. These tests shall, to the extent feasible, demonstrate prior to committing to hot test the capability of the reactor components to operate under at least as severe conditions as those anticipated during hot testing of the Block II reactors.

Complete a selective component flow test program aimed at developing, testing, and selecting NRX-A Block II components. These components will be based on a limited redesign of Block I reactors and the component tests will be a continuation and extension of the Block I tests.

Provide statistical and developmental testing of NRX-A Block II fuel elements, evaluate the parameters affecting inter-element corrosion in integrated fuel clusters, and evaluate support blocks.

Perform low power nuclear tests of pre-assembled NRX-A Block II reactors to determine core reactivity, required shim content, calibration of control drums and power distribution.

Sub-Subtask 8.2.0 Reactor Mechanical Design

A. Engineering

- (1) Complete and issue NRX-A Block II reactor and replacement shield layouts and release long lead time material requirements for all NRX-A Block II reactors.
- (2) Complete and release the detailed designs of all NRX-A Block II reactors incorporating lateral support and core sealing changes indicated as a result of stress and dynamic analysis, component testing and analysis, KIWI testing, Block I vibration, G-3 plugged core and NRX-A1 cold flow testing, and such hot testing of NRX-A2 and A3 as may be available.
- (3) Investigate required and selected design improvements, such as: improved W-8 components, elimination of tapped holes in Z-4 component for lateral support X-2 retention, improved sealing at nozzle interface, improved coolant of W-7 components, reduced W-1 interspace gaps, and improved core lateral support.
- (4) Analyze steady state and transient component stresses; define allowable temperatures and temperature gradients; achieve increased margins of safety, particularly in brittle components, issue stress reports for each reactor on a continuing basis; and develop improved analytical techniques.
- (5) Determine, update and issue the shipping and reactor test environments to be used for Block II design; define response of components to established environment; improve component damping and minimize fluid-induced vibrations; and investigate fluid flow paths, such as W-1 interspace gaps, which may influence core dynamic behavior; establish and issue vibration test objectives.
- (6) Provide design support as required for procurement, inspection and acceptance of reactor hardware including the following:
 - a. Evaluate processes submitted by vendors for compliance with drawing requirements, such as welding, fabrication, cleaning and forging processes.
 - b. Establish non-destructive standards for inspection of graphite and beryllium parts.
 - c. Assist in the development of new materials and processes and fabrication techniques, by exploring and evaluating changes which will fulfill design and procurement objectives.
- (7) Define and specify objectives of component test programs required to substantiate the adequacy of the NRX-A Block II reactor and replacement shield mechanical design on a continuing basis; evaluate, analyze and report the effects of component test results and analyses on designs; determine and specify all tests required to verify reactor designs, design concepts and assumptions.

Sub-subtask 8.2.0 (continued)

- (8) Evaluate and coordinate design changes requested by other groups such as Reactor Analysis or Manufacturing Engineering; define engineering parts requirements for each NRX-A Block II reactor, the G-3 rebuild, and the vibration test rebuild by means of lists of parts.
- (9) Maintain and periodically issue updated master design layouts for each NRX-A Block II reactor, the G-3 rebuilding and vibration test rebuild to evaluate changes requested by vendors and other groups such as Manufacturing Engineering.
- (10) Determine and specify NRX-A5 reactor test and data requirements and accuracies for mechanical design development purposes.
- (11) Incorporate ground handling and flight environment data into NRX-A Block I design specifications on a continuing basis.
- (12) Study, define and release instrumentation requirements for Block II reactors and shields and establish and issue detailed design drawing modifications required for instrumentation of the NRX-A5 and A6 reactors.
- (13) Maintain liaison with Los Alamos Scientific Laboratory on all aspects of reactor mechanical design.
- (14) Coordinate reactor and shield pressure vessel interfaces and mechanical requirements on a continuing basis to ensure compatibility with the engine.
- (15) Modify and issue detailed design and instrumentation drawings to update the G-3 plugged core and Phase I vibration reactor to test and verify NRX-A Block II reactor design concepts and assumptions.
- (16) Specify instrumentation and data requirements for the G-3 plugged core and Phase I vibration reactor rebuilds to support NRX-A Block II reactor design requirements.
- (17) Conduct an NRX-A Block II design review prior to release of detailed design drawings.

B. Fabrication - as required

C. Testing - as required

D. Tooling - as required

Sub-subtask 8.2.1 Reactor Thermal and Fluid Flow Design

A. Engineering

- (1) Complete design studies sufficient to define, and release for manufacture, the NRX-A Block II reactor and replacement shields incorporating knowledge gained from NRX-A Block I Component and reactor assembly tests and analysis and issue NRX-A Block II Design Report.
- (2) Complete analytical predictions of the thermal and fluid flow performance in the NRX-A Block II reactor over the full operating range and for both steady-state and transient conditions.
- (3) Determine the cooling requirements and temperature patterns of mechanical structures and investigate the effects of mechanical modifications.
- (4) Specify the component and reactor assembly experiments required to verify or determine the thermal and fluid flow characteristic and capabilities of the NRX-A Block II reactors.
- (5) Complete analysis of the available heat transfer and fluid flow data from component, reactor, and basic experiments and incorporate selected data into the NRX-A Block II reactor design calculations to be used in analysis design reports.
- (6) Ensure the adequacy of the fuel element specifications for NRX-A Block II core thermal and fluid flow performance.
- (7) Complete the analysis of the NRX-A Block II reactor hot channel factors on the basis of inspection data from the fuel manufacturing operating and laboratory test and determine statistically the effect of these data on NRX-A Block II reactor performance.
- (8) Develop design methods as required to carry out the design and analysis of NRX-A Block II reactors.
- (9) Study, define and prepare the necessary instrumentation lists required for proper execution and acquisition of data of the NRX-A5, reactor test and specify the instrumentation range and accuracy required.
- (10) Complete the NRX-A5, reactor test request.
- (11) Issue Standard System Design Model.
- (12) Issue Component Test Design Significance Status Report.

Sub-subtask 8.2.1 (Continued)

- (13) Prepare for design review on NRX-A Block II.
- B. Fabrication - Not applicable
- C. Testing - Not applicable
- D. Tooling - Not applicable

Sub-subtask 8.2.2 Reactor Nuclear Design

A. Engineering

- (1) Complete and issue nuclear design studies sufficient to define and release to manufacturing the NRX-A Block II reactor incorporating knowledge gained on NRX-A Block I test and analysis.
- (2) Initiate prediction of nuclear parameters required in design of NRX-A Block II reactors.
- (3) Determine and specify the NRX-A6, A7 and A8 fuel element loading distribution and resulting power distribution in the reactor core.
- (4) Prepare reactor fuel element nuclear specification requirements for NRX-A6, A7 and A8.
- (5) Predict and specify reactivity parameters and their respective uncertainties for the NRX-A6 and monitor fuel element fabrication to assess material reactivity effects.
- (6) Compute and specify reactivity coefficients and other kinetic parameters necessary for control system design and accident analysis of NRX-A Block II reactors.
- (7) Prepare and issue detailed test plans and provide theoretical support for the NRX-A6 reactor nuclear tests to be performed at WANEF.
- (8) Prepare detailed test plans for the NRX-A6 reactor nuclear tests to be performed at NRDS.
- (9) Develop and issue standard design methods of computation for nuclear design, of the NRX-A Block II reactors.
- (10) Evaluate and update design methods by comparing test results with predictions.

Sub-subtask 8.2.2 (Continued)

- (11) Design and issue specification requirements of poison systems for criticality control of assembled reactors.
- (12) Review, analyze and report on design changes and variations for their effects on the reactor nuclear characteristics.
- (13) Review applicable reactor test procedures for compatibility with reactor nuclear characteristics.
- (14) Coordinate and review nuclear calculations performed for criticality control during assembly, shipping handling, and storage.
- (15) Specify the Block II data requirements for the flexible critical experiments and analyze and report the results of the experiments on a continuing basis, as applicable to the Block II design.
- (16) Complete and issue NRX-A Block II Nuclear Design Report.
- (17) Conduct an NRX-A Block II Reactor Nuclear Design review prior to completion of detailed design release.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 8.2.3 Shielding and Radiation Analysis

A. Engineering:

- (1) Complete computation of detailed radiation heating patterns, fast neutron flux, gamma dose rate and activation in all components of the reactor sub-assembly. Heating distributions are to be developed for both reactor startup and shutdown as well as steady state conditions. Issue a design release report.
- (2) Review facility shielding and provide radiation information required for studies of reactor sub-assembly handling during test site operation.
- (3) Perform analysis to evaluate required design changes for the Block II shield replacement unit.
- (4) Issue the Block II Design Report.
- (5) Issue Standard Design Model for the Block II reactor.

Sub-Subtask 8.2.3 (Continued)

- B. Fabrication - Not applicable
- C. Testing - Not applicable
- D. Tooling - Not applicable

Sub-Subtask 8.2.4 Mechanical Analysis and Testing

A. Engineering

- (1) Prepare a test program document defining the Block II component tests and submit for approval two months prior to initiation of testing.
- (2) Evaluate the results of the tests conducted in accordance with this test program document.
- (3) Provide required reports and data summaries.

B. Fabrication

- (1) Provide test facility equipment as required to accomplish project objectives.

C. Testing

- (1) Complete the tests and issue test reports on W-1 and W-2 components including center elements to establish any changes in physical properties. Study fuel element loading changes and material development to support reactor Block II design changes. Evaluate statistical distribution of these properties.
- (2) Complete the W-8 component tests to demonstrate that these parts and the associated W-5 parts for the Block II reactors meet design requirements. Investigate the physical effects and keying of the W-1 components to the W-8 parts. Perform experimental studies on peripheral W-8 components and W-7 components. Issue a test report.
- (3) Complete the W-7 component tests required by design changes. Determine tensile and fatigue strength and permanent set in a series of tests under combined and independently applied vibration and static tensile loads. Perform tests under simulated reactor axial thermal gradients. Study the effects of material changes, upset ratio, thread form and manufacturing variables on reliability. Issue a test report.

Sub-Subtask 8.2.4 (Continued)

- (4) Complete the vibration tests of seven W-11 components of full-length Block II reactor unfueled elements with simulated lateral support pressures to determine the effects of vibration on W-1 components and to investigate fretting on W-10 plates fabricated of various materials. Study the suitability of W-8 component keying on the W-1 components, as well as other W-8 changes evolved with the Block II reactor series. Perform vibration tests using input simulating the results of full scale tests in order to develop more satisfactory designs. Issue a test report.
- (5) Complete the tests of various designs of X-2 components and lateral support components for the Block II reactors to obtain data on fretting and wear of the lateral support components under simulated environmental conditions. Perform tests on alternate materials and configurations, and perform tests using various X-2 component rates.
- (6) Complete the tests and issue a report on lateral support X-1, W-3, and W-6 component modifications for Block II design at operating temperature, temperature gradient, and pressure. Investigate the effects of bowing of W-6 and X-1 components under thermal shock and operating conditions. Investigate the corrosion of the parts under hydrogen flow at operating temperatures.
- (7) Plan and specify the buckling and permeability tests on prototype NRX-A Block II Z-4 components. Complete photoelastic model studies of stress distributions due to radial thermal gradient conditions.
- (8) Complete the vibration, shock, and static loading tests on a partial length core assembly. Develop lateral support design information necessary for Block II reactors. Complete tests on various configurations of dome end-seal, Y-4 designs, and W-3 component bonding methods. Obtain developmental information on new lateral support X-2 and X-1 component designs. Investigate motions, frictional damping forces, static friction and hysteresis. Issue a test report.
- (9) Complete the test of the support system of Block II NRX-A reactor designs under static loading conditions. Perform tests under simulated differential pressure while thermal gradients are applied. Investigate the effects of differential expansion of various combinations of materials in Y-1 and Y-3 assemblies. Complete the thermal gradient tests. Issue a test report.

Sub-subtask 8.2.4 (Continued)

- (10) Complete the tests and issue a report on seizing and galling between various metal combination interfaces in the Block II reactor design under different operating environments. Test interface behavior of adjacent flat, as well as thread profile surfaces, under low and high temperature and high pressure environments. Study possible malfunction and the effect of debris generated at interfaces.
- (11) Issue a test plan and specification for the series of laborator vibration, shock, and static loading tests on a Block II NRX-A reactor design consisting of the Block I reactor modified with a Block II core and inner reflector, and other possible minor changes. Complete a series of developmental and environmental tests based on the results obtained for Block I tests. Perform sinusoidal vibration input and random motion environmental tests and provide analog and digital computations of vibration and shock models of the reactor as a means of analysis of, and correlation with, the test results.
- (12) Evaluate the component test program with regard to modes of deformation and fracture of materials related to the NRX-A1 and A2 tests. Develop a program on techniques for utilizing post-operative reactor test results which will help establish better defined design objectives for the Block II reactor series.
- (13) Complete the friction tests of various combinations of critical interface materials found in Block II reactors under simulated reactor operating conditions. Simulate the reheat and restart environmental conditions in combination with high surface loadings and a large number of cycles.
- (14) Perform general service tests and associated analysis in support of the design and testing groups resulting in a direct timely input of experimental data to certify design analysis in development areas. Issue a test report.
- (15) Conduct tests on selected defective components to establish suitable criteria for acceptance.

D. Tooling - As required

Sub-subtask 8.2.5 - Open

Sub-subtask 8.2.6 - Open

Sub-subtask 8.2.7 Component Flow Tests

A. Engineering

- (1) Define a component test program compatible with the Block II modifications resulting from the Block I reactor and component test programs.
- (2) Prepare and submit for approval a test program two months prior to initiation of the Block II component flow tests. Upon receiving approval, conduct the component flow test program.
- (3) Prepare required reports and data summaries for tests conducted.

B. Fabrication

- (1) Provide test facilities and equipment as required to accomplish project objectives.

C. Testing

- (1) Complete tests and issue a report on redesigned W-7 components affected by modified core and operating conditions.
- (2) Complete the flow tests and issue a report on fuel element W-10 component for the NRX-A5 and A6 reactors.
- (3) Evaluate alternate designs and issue a report on the lateral support and X-1 systems.
- (4) Complete tests on the lateral support and X-1 systems under high temperature and pressure conditions.
- (5) Complete the flow tests on a modified scale model of the Block II reactor and evaluate the flow distributions.
- (6) Conduct and evaluate flow instability tests through parallel tube at constant pressure drop with heat addition. Issue a test report.
- (7) Complete flow tests and issue a report on selected Block II reactor support and reflector components including impedance rings, outer reflector and Y-2 component, and Z-3 component drive shaft and drive shaft orifices.
- (8) Issue a test plan for G-3 reactor flow tests with Block II modifications.

D. Tooling - as required

Sub-Subtask 8.2.8 Corrosion Tests

A. Engineering

- (1) Prepare a test program for the Block II component corrosion tests and obtain approval prior to implementation.
- (2) Evaluate the parameters affecting W-1 and W-11 component corrosion.
- (3) Prepare required reports and data summaries.

B. Fabrication - As required

C. Testing

- (1) Perform high temperature corrosion tests of fuel elements to obtain information on statistical behavior, changes in protective processing, evaluation of new protective processing materials, and measurement of heat transfer and friction. Issue statistical testing reports.
- (2) Evaluate modifications to the W-8 components and issue a test report.
- (3) Investigate the corrosion of W-1 components grouped and suspended as a W-11 assembly at operating temperature and pressure. Issue a test report.

D. Tooling - as required

Sub-Subtask 8.2.9 Reactor Pre-Assembly and Proof Critical Tests

A. Engineering

- (1) Modify the critical facility as required to prepare for pre-assembly and proof testing of the NRX-A Block II reactors.

B. Fabrication

- (1) Supply incidental equipment necessary to accomplish facility modification and pre-assembly testing on the NRX-A6 reactor.

C. Testing

- (1) Operate the critical facility, as required, for pre-assembly and proof testing of the NRX-A6 reactor.

Sub-subtask 8.2.9 (Continued)

- (2) Initiate measurement of core reactivity and calibration of the Z-3 parts for the NRX-A6 reactor.

D. Tooling - As required

Subtask 8.3 Nuclear Subsystem Procurement Management and Control

Support and control the delivered nuclear subsystem components and subassemblies to the configuration and schedule required for the NRX-A Block II ground test program. Based on overall project direction, analyze and prepare detailed ordering requirements for procurement. Provide all hardware, tooling and services. Establish and maintain priority scheduling and inventory control on all work in progress. Receive, store, dispatch and maintain records of finished parts, raw materials and other government property. Assemble and ship all reactors and major components or subassemblies.

Sub-Subtask 8.3.0 Procurement Management and Control - NRX-A Block II Reactor

Provide delivered reactor components and subassemblies to the configuration of the NRX-A Block II reactor program, as follows:

A. Engineering - Not applicable

B. Fabrication

- (1) Provide all NRX-A Block II raw material, tooling and fabricated components, as required, for the following:
 - a. The NRX-A5 cold flow reactor.
 - b. The NRX-A6 reactor.
 - c. The NRX-A7 reactor.
 - d. The NRX-A8 reactor.
 - e. The Component Test Program.
- (2) Maintain overall procurement schedule information and monitor program.
- (3) Provide manufacturing engineering support to design engineering on manufacturing techniques, processes and process capabilities; investigate, define and develop improved fabrication methods and techniques.
- (4) Prepare, pursue and monitor manufacturing process development programs.

C. Testing - As required

D. Tooling - As required

Sub-Subtask 8.3.1 Procurement Management and Control - Outer Reflector

Provide delivered outer reflector components and subassemblies to the configuration of the NRX-A Block II reactor program, as follows:

A. Engineering - Not applicable

B. Fabrication

(1) Provide outer reflector parts for NRX-A Block II reactors as follows:

a. The NRX-A5 reactor.

b. The NRX-A6 reactor.

(2) Provide, as required by program schedule, outer reflector parts for the following:

a. The NRX-A7 reactor.

b. The NRX-A8 reactor.

(3) Provide specification grade hardware as required for the Component Test Program.

C. Testing - Not applicable

D. Tooling

(1) Provide tooling required to accomplish the project objective as applicable.

Sub-Subtask 8.3.2 Procurement Management and Control - Inner Reflector

Provide inner reflector and lateral support components to the configuration and schedule of the NRX-A Block II test program as follows:

A. Engineering - Not applicable

B. Fabrication

(1) Provide all inner reflector parts for NRX-A Block II reactor program as follows:

a. The NRX-A5 reactor.

b. The NRX-A6 reactor.

Sub-Subtask 8.3.2 (continued)

- (2) Provide, as required by program schedule, inner reflector parts for the following:
 - a. The NRX-A7 reactor.
 - b.. The NRX-A8 reactor.
- (3) Provide specification grade hardware as required for the Component Test Program.
- C. Testing - not applicable
- D. Tooling
 - (1) Provide tooling required to accomplish the project objective as applicable.

Sub-Subtask 8.3.3 Procurement Management and Control - Core (Non-Fueled)

Provide the delivered core components and subassemblies to the configuration of the NRX-A Block II test program as follows:

- A. Engineering - not applicable
- B. Fabrication
 - (1) Provide core parts, as required, for the Block II reactor program as follows:
 - a. The NRX-A5 reactor.
 - b. The NRX-A6 reactor.
 - (2) Provide, as required by program schedule, core parts for the following:
 - a. The NRX-A7 reactor..
 - b. The NRX-A8 reactor
 - (3) Provide specification grade hardware, as required, for the Component Test Program.
- C. Testing - Not applicable
- D. Tooling
 - (1) Provide tooling required to accomplish the project objective as applicable.

Sub-Subtask 8.3.4 Procurement Management and Control - Poison and Misc. Parts

Provide the miscellaneous components and subassemblies to the configuration of the NRX-A Block II test program, as follows:

A. Engineering - Not applicable

B. Fabrication

(1) Provide poison and miscellaneous parts, as required, for the following:

a. The NRX-A5 reactor.

b. The NRX-A6 reactor.

(2) Provide, as required by program schedule, poison and miscellaneous parts for the following:

a. The NRX-A7 reactor.

b. The NRX-A8 reactor.

(3) Provide specification grade miscellaneous parts, as required, for the Component Test Program.

C. Testing - not applicable

D. Tooling

(1) Provide tooling required to accomplish the project objective as applicable.

Sub-Subtask 8.3.5 Procurement Management and Control - Shield

Provide the delivered shield assembly and related components to the configuration of the NRX-A Block II reactor test program as follows:

A. Engineering - Not applicable

B. Fabrication

(1) Provide simulated shield replacement unit, seals and flow screen hardware, as required, for the following:

a. The NRX-A5 reactor.

b. The NRX-A6 reactor.

Sub-Subtask 8.3.5 (continued)

- (2) Provide, as required by program schedule, shield assembly and related components for the following:
 - a. The NRX-A7 reactor.
 - b. The NRX-A8 reactor.
- (3) Provide specification grade shield assembly components, as required, for the Component Test Program.
- C. Testing - Not applicable
- D. Tooling
 - (1) Provide tooling required to accomplish the project objective as applicable.

Sub-Subtask 8.3.6 Procurement Management and Control - Controls & Actuators

Provide control equipment for modification of the Test Cell "A" control system to monitor and control NRX-A Block II reactor tests, as follows:

- A. Engineering - Not applicable
- B. Fabrication
 - (1) Provide updated material, components and subassemblies for the NRX-A Block II control systems, as required, for the following:
 - a. The NRX-A5 reactor.
 - b. The NRX-A6 reactor.
 - (2) Deliver the above control items to NRDS for incorporation into the Test Cell "A" control system.
- C. Testing - Not applicable
- D. Tooling - Not applicable

Sub-Subtask 8.3.7 Procurement Management and Control - Instrumentation

(Instrumentation for the NRX-A Block II reactors is provided under Sub-Subtask 2.4.2)

Sub-Subtask 8.3.8 Procurement Management and Control - Fuel Elements

Provide reactor fuel elements and related graphite core parts required for the NRX-A Block II test reactors, as follows:

A. Engineering - Not applicable

B. Fabrication

(1) Provide fuel elements for NRX-A Block II test reactors, as follows:

a. The NRX-A6 reactor.

b. The NRX-A7 reactor.

(2) Provide fuel elements and graphite test pieces for detailed engineering tests as required.

(3) Provide protective processing of graphite and pyro-graphite for components and other graphite parts as required.

C. Testing - Not applicable

D. Tooling

(1) Provide tooling required to accomplish project objective as applicable.

Sub-Subtask 8.3.9 Reactor Assembly, Packaging and Shipping

Assemble reactors and components thereof to the specified configuration; prepare these assemblies for shipment; transport assemblies to the required test site.

A. Engineering - Not applicable

B. Fabrication

(1) Assemble parts and components into subassemblies and complete the NRX-A5 reactor, the NRX-A6 PAX assembly, the G-3 plugged core rebuild and vibration test reactor rebuild assemblies in accordance with design requirements and under appropriate environmental and safety conditions, as approved by SNPO-C.

(2) Prepare reactor assemblies and/or components thereof for shipping and ship according to specifications the G-3 plugged core rebuild and vibration test reactor rebuild.

Sub-Subtask 8.3.9 (continued)

- (3) Document by logs, reports, motion pictures, etc. all major assembly operations and all hardware used in the G-3 plugged core rebuild and vibration test reactor rebuild.

C. Testing - Not applicable

D. Tooling

- (1) Provide equipment required for assembly of NRX-A5, A6 (PAX), G-3 plugged core rebuild and vibration test reactor rebuild.

Subtask 8.4 NRX-A Block III Nuclear Subsystem Engineering

The Nuclear Subsystem designation NRX-A Block III reactors shall denote the following reactors: NRX-A9, A10, A11, ~~A12~~ and A13.

Establish layouts and detailed designs of a flight type reactor and shield based on results of NRX-A Block I and NRX-A Block II designs, analysis and component test programs, the Block I reactor test results and the shield design criteria for the NERVA engine. The Block III reactor design is to be based on a major redesign of prior reactors, incorporating all flight considerations including increased control span, flight after-cooling requirements, restart capability, bottom-loaded design and long-life fuel elements. The NRX-A Block III design will serve as the basis for development of the reactor for flight qualification.

Perform the thermal and fluid flow design necessary for release to manufacturing of the NRX-A Block III reactor and shield; develop analytical techniques required to carry out the thermal and fluid flow design; and specify component tests required to verify or support the thermal and fluid flow design.

Perform the nuclear design and analysis necessary to support the development studies for the NRX-A Block III reactor in the area of power flattening, shim rod design and other areas as required from previous NRX-A design and analysis effort. Develop analytical methods required for predicting NRX-A Block III reactor nuclear characteristics.

Perform the nuclear shield design required for the NRX-A Block III reactors.

Sub-subtask 8.4.0 Reactor Mechanical Design

A. Engineering

- (1) Initiate Block III reactor and shield layouts
- (2) Initiate the detail design of Block III reactors for flight qualification by incorporating changes indicated as a result of stress and dynamic analysis, component testing and analysis, KIWI testing, vibration testing, and Block I and II cold flow and hot testing. Initiate detailed design layouts of a shield suitable for use in the NRX-A Block III reactors, based on reliability, design simplicity and using proven materials.
- (3) Complete the detail design layouts of a shield suitable for use in Block III reactors based on the revised shield design criteria for the NERVA engine.

Sub-subtask 8.4.0 (Continued)

- (4) Study Block III instrumentation requirements to initiate design modifications required for instrumentation.
- (5) Maintain liaison with Los Alamos Scientific Laboratory on all aspects of reactor mechanical design.
- (6) Coordinate reactor and shield pressure vessel interfaces and mechanical requirements on a continuing basis to ensure compatibility with the engine.
- (7) Define, specify and analyze a limited shield component test Program required to verify the shield design concepts and design assumptions.
- (8) Plan and issue a component test program to complete the verification of shield design.
- (9) Define objectives of component test programs required to substantiate the adequacy of the reactor and shield mechanical design on a continuing basis; determine and specify all tests required to verify the reactor designs, design concepts and design assumptions.
- (10) Incorporate ground handling and flight environment data into design specifications on a continuing basis.

B. Fabrication - As required

C. Testing - As required

D. Tooling - As required

Sub-subtask 8.4.1 Reactor Thermal and Fluid Flow Design

A. Engineering

- (1) Initiate an evaluation of methods for improving the reflector, lateral support, shield, and core thermal and fluid flow designs for a Block III reactor based on the design and on the test experience gained in the Block I and II reactors.
- (2) Determine the cooling requirements, flow, and temperature patterns of mechanical and nuclear designs being investigated for Block III.

Sub-subtask 8.4.1 (Continued)

- (3) Analyze the available heat transfer and fluid flow data from component, reactor, and basic experiments and incorporate selected data into the NRX-A Block III reactor design calculations.
- (4) Develop design methods as required to carry out the design and analysis of NRX-A Block III reactors.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-subtask 8.4.2 Reactor Nuclear Design

A. Engineering:

- (1) Initiate an evaluation of methods for improved power flattening, shim rod design, and additional reactivity control for a Block III reactor based on Block I and Block II design and test experience.
- (2) Support the Mechanical Design and Thermal Design efforts by determining the effect of proposed design upon fuel element loading requirements and resulting power distributions.
- (3) Initiate preparation of fuel elements specifications for Block III reactors.

B. Fabrication - not applicable

C. Testing - not applicable

D. Tooling - not applicable

Sub-subtask 8.4.3 Shielding and Radiation Analysis

A. Engineering

- (1) Initiate computation of radiation heating patterns, fast neutron flux, gamma dose rates and activation for development studies leading to a Block III design. This information will be developed for reactor startup, shutdown, and steadystate conditions as required to evaluate the merit of the proposed designs.

Sub-subtask 8.4.3 (Continued)

- (2) Perform analyses and support to Aerojet-General as required for the development of NERVA shield design criteria.
- (3) Complete the required nuclear design of the shield selected for the NRX-A Block III reactors.
- (4) Develop improved methods of computation as required for NRX-A Block III radiation analysis.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Subtask 8.5 - Open

Subtask 8.6 NRX-A Block IV

No work this contract period.

Subtask 8.7 - Open

Subtask 8.8 - Open

Subtask 8.9 Nuclear Subsystem Basic Technical Support

Provide technical support to the design and development effort on NRX-A reactors, including fuel, fuel process development and non-fuel materials evaluation. Provide basic data for solution of reactor design and control problems under various conditions of flow during transient and steady-state operation. Develop analytical techniques required for calculation of nuclear properties under steady-state and transient conditions.

Sub-Subtask 8.9.0 Basic Technical Support - Fuel Element Process Development and Control

Perform manufacturing process and development required to support the fuel element fabrication activity. The scope includes the development of specifications required for effective process control and provides consultation and training services to candidate fuel suppliers; a program for qualification of candidate fuel suppliers is included.

A. Engineering

- (1) Complete the required manufacturing process and inspection development to support fuel element fabrication activity and issue relevant fabrication reports for the following NRX-A Block I reactors: NRX-A2, A3 and A4.
- (2) Develop and issue specifications to achieve effective materials and process control on Block I reactors as follows: NRX-A3 and A4.
- (3) Develop and issue specifications to achieve effective materials and process control on Block II reactors as follows: NRX-A6, A7 and A8.
- (4) Consult with and train candidate fuel suppliers as required; establish detailed plans for qualification of selected fuel suppliers; initiate timely fuel element sample procurement; monitor fuel supplier's process operations on a continuing basis.

B. Fabrication - Not applicable

C. Testing - As required to accomplish project objectives.

D. Tooling

- (1) Provide tooling required to accomplish project objectives as applicable.

Sub-Subtask 8.9.1 Basic Technical Support - Non-fuel Materials

Develop and provide data and specifications on a continuing basis for reactor structural, shield, control and instrumentation materials with regard to mechanical and physical properties, fabrication and irradiation behavior. Establish operational limits for selected materials under reactor conditions and develop new materials if required. Support and analyze reactor and shield component tests to verify adequacy of material application.

A. Engineering

- (1) Evaluate for design purposes the mechanical and physical properties of all non-fuel reactor materials including shield, reflector, control, core structural materials and instrumentation materials, and submit relevant reports.
- (2) Issue and revise specifications for reactor non-fuel material.
- (3) Evaluate fabrication processes for shield materials, control materials, structural materials and support materials and submit relevant reports.
- (4) Issue and revise process specifications as required; submit list of specifications reviewed with vendors.
- (5) Define component tests required to verify adequacy of material for intended applications.
- (6) Analyze materials test results from the component test program and reactor hot tests and submit relevant reports.
- (7) Conduct materials analysis in support of the Component Test Program.
- (8) Evaluate the effect of cryogenic conditions and limited pyrogenic conditions upon some materials of interest including critical graphite components and lateral support hardware.
- (9) Evaluate the effects of irradiation upon materials intended for instrumentation applications.
- (10) Participate in planning, design and analysis of irradiation tests on non-fuel materials of interest for reactor components, and submit relevant reports.
- (11) Submit a proposal for Contract Year 1965 on reactor, non-fuel materials.

Sub-Subtask 8.9.1 (continued)

B. Fabrication

- (1) Manufacture test specimens required for the test programs.
- (2) Manufacture and assemble irradiation capsules required for the irradiation program.

C. Testing

- (1) Participate in the observation of irradiation tests of non-fuel materials.
- (2) Conduct materials tests in support of reactor non-fuel components test program.
- (3) Conduct materials irradiation of candidate reactor structural control and support materials.
- (4) Determine the engineering and mechanical properties and the flow and fracture behavior of structural and insulating graphites.

D. Tooling - Not applicable

Sub-Subtask 8.9.2 Basic Technical Support - Fuel Material Development and Evaluation

Determine and evaluate the quality and capability of the reference fuel used in NERVA reactors and perform studies of processes, materials and phenomena which will lead to the development of fuel elements with the operational capability required in the NERVA program.

A. Engineering

- (1) Provide assistance in preparing specifications on raw materials and in setting up standard quality control procedures.
- (2) Perform studies on raw materials to permit characterization and identification of quality control requirements.
- (3) Perform laboratory parametric studies on fuel protective processing to assist process development.
- (4) Provide assistance on problems which may arise in production of reference fuel elements.

Sub-Subtask 8.9.2 (continued)

- (5) Continue collection and analysis of data to establish proper quality control and operational capability of reference fuel material.
- (6) Continue studies of the mechanical behavior of the reference fuel material as a function of thermal and corrosion history, temperature, strain rate and micro-structure.
- (7) Continue evaluation of the behavior of the reference fuel with respect to thermal stability, thermal cycling, thermal stress resistance and thermal gradient diffusion.
- (8) Continue studies to evaluate results of hydrogen corrosion testing of reference fuel as a function of temperature, time, number of cycles, transverse thermal gradients and start up transients.
- (9) Continue evaluation of development quantities of modified fuel material produced under sub-subtask 8.9.0.
- (10) Assist in evaluation of irradiated fuel material generated in steady-state and transient irradiation program.
- (11) Continue assistance in evaluation of fuel materials tested in the Component Test Program and coordinate test results.
- (12) Submit a preliminary report on the results of short-term development studies.
- (13) Define and issue specifications for raw materials and processing parameters to be used in production of fuel elements for NRX-A Block II reactors.
- (14) Submit topical report on evaluation of raw materials used in NRX-A reactors.
- (15) Submit topical reports on raw material evaluation, basic fuel elements property data and comparison of reactor and environmental testing of fuel elements.

B. Fabrication

- (1) Provide test facilities and equipment as required to accomplish project objectives.

Sub-Subtask 8.9.2 (Continued)

C. Testing

- (1) Conduct development studies with the objective of short-range improvement in fuel element properties, capabilities, reliability and processing for application in NRX-A reactors.
- (2) Conduct development of fuel material stable to higher temperatures than reference fuel material.
- (3) Perform studies of graphite raw materials and processes with regard to improvement in mechanical properties and dimensional stability of fuel elements.
- (4) Conduct studies of improved protective processing to increase fuel element lifetime and operating temperature capability.
- (5) Conduct quality control destructive testing of reference fuel material. Submit reports on destructive test evaluation of reference fuel for NRX-A Block I reactors.
- (6) Continue measurement of thermal expansion and thermal conductivity of reference fuel as a function of temperature, thermal and corrosion history, fuel loading, atmosphere and manufacturing variables.
- (7) Continue studies of the resistance of the reference fuel to hydrolysis as a function of fuel element processing variables and thermal and corrosion history.

D. Tooling - Not applicable

**Sub-Subtask 8.9.3 Basic Technical Support - Reactor Flexible
Critical Experiment**

Perform the clean, critical experiments to develop basic data needed for evaluation of theoretical methods for reactor design. Measurements will be performed on clean assemblies to determine critical mass, core reactivity, local and gross power distribution and material reactivity coefficients.

A. Engineering

- (1) Establish the objectives of the flexible critical experiment program.
- (2) Complete the design, procurement, and assembly of a clean, critical experiment having the flexibility required to accomplish the desired objectives of the flexible critical experiment program.
- (3) Contribute the required critical experiment characteristics of the planned experimental program and the operating procedures to the hazards report for this experimental program.
- (4) Plan and submit for approval an experimental program to determine the characteristics of the flexible critical facility and to produce the data required by the program objective.
- (5) Prepare and issue an operating manual covering utilization of this flexible critical assembly.
- (6) Report results and pre- and post-analysis of each flexible critical experiment.

B. Fabrication

- (1) Supply all equipment and hardware necessary to the operation of the facility and to accomplish the flexible critical experiments.

C. Testing

- (1) Perform an initial critical experiment to verify the predicted safety characteristics of the assembly.
- (2) Perform measurements specified in the experimental plan.

D. Tooling - As required

Sub-Subtask 8.9.4 Basic Technical Support - Reactor Transient
Flow Analysis and Test

Generate basic data required for the solution of reactor design and control problems under conditions of mixed (two phase) and liquid propellant flow and in support of analytical models which describe the flow during transient operation of the reactor.

A. Engineering

- (1) Investigate need for a facility to measure transient characteristics under zero gravity conditions and issue report.
- (2) Continue development of mathematical models for transient heat transfer and fluid flow and compare with experimental results.
- (3) Investigate techniques that may be suitable to measure the composition of two phase hydrogen systems and issue status report.

B. Fabrication

- (1) Supply all jigs, fixtures, instrumentation and test hardware required to accomplish project objectives.
- (2) Complete installation of high pressure cryogenic loop test rig.

C. Testing

- (1) Conduct transient flow experiments in aluminum tubes with single and multiple passages, utilizing a vertical geometry and various time-dependent power inputs and compare results with those of horizontal tests.
- (2) Complete beryllium flow tests and compare with aluminum test data and issue report.
- (3) Determine the effect of turbulence generators to eliminate slug flow.
- (4) Investigate the effect of high pressure in transient heat transfer and fluid flow and issue report.

D. Tooling - Not applicable

Sub-Subtask 8.9.5 Basic Technical Support - Reactor Physics
and Mathematics

Provide specialized support for design of the NERVA nuclear subsystem by developing new analytical techniques, by modifying existing analytical techniques and by providing basic nuclear data required for reactor analysis.

A. Engineering

- (1) Provide guidance and support to nuclear design activities and evaluate requirements for improved calculational method.
- (2) Provide improved multi-dimensional transport methods for calculating reactivity and power densities in the reactor, reflector, control vanes and shield.
- (3) Provide methods and techniques for calculation of the neutron spectrum distribution in the thermal and epithermal range to improve reactivity and power distribution calculations at interfaces and discontinuities between fuel zones.
- (4) Complete and issue report on the integration of the space-time dependent reactor kinetics program for determination of the spatial power distribution in the reactor during transient conditions, such as startup, with heat transfer and fluid flow program.
- (5) Collect, evaluate and issue status report on nuclear cross-section data for nuclear design. Apply nuclear models to provide information in areas where experimental data are not available. Prepare appropriately averaged cross-section data for use in nuclear design calculations.
- (6) Assist in the development of analytical techniques and computer programs in support of technical effort including analysis of vibration, thermal stress, fluid flow, heat transfer and the re-entry of reactor particles.
- (7) Develop and issue status report on digital computer code to study flow-induced vibration.
- (8) Complete and issue report on the application of the variational method.

B. Fabrication - Not applicable

Sub-Subtask 8.9.5 (continued)

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-Subtask 8.9.6 - open

Sub-Subtask 8.9.7 Basic Technical Support - Reactor Models & Mockups

Provide partial models and mockups of reactor structural and core parts, full scale models and mockups and scale model mockups of reactor design to assist in engineering analysis and for appraising mechanical arrangements.

A. Engineering

- (1) Design Block II instrumentation mockups to prove instrumentation design concepts from the standpoint of design integrity, instrument location, methods of securing, routing and bundling leads, and to isolate design discrepancies, deficiencies and omissions.
- (2) Design Block II assembly mockups to permit checkout of WANL and R-MAD assembly/disassembly equipment.
- (3) Verify interface dimensions and evaluate design changes.

B. Fabrication

- (1) Provide models and partial mockups of reactor components and assemblies to assist in design evaluation.
- (2) Provide and assemble modified components to update the Block I instrumentation mockup and to meet Block II requirements.
- (3) Provide training aids for assembly personnel.
- (4) Procure and assemble Block II assembly mockups to permit checkout of WANL and R-MAD assembly/disassembly equipment.
- (5) Procure mockups as required to assist in the installation of instrumentation components for individual reactors in NRX-A Block I and Block II.

Sub-Subtask 8.9.7 (continued)

- (6) Provide, assemble and ship half-scale models of the KIWI B4A, KIWI B4D and two (2) NRX-A reactors.

C. Testing

- (1) Employ the mockup assembly to verify compatibility of design with assembly procedures and to isolate design discrepancies, deficiencies and omissions in assembly and disassembly equipment.

D. Tooling - As required

Sub-Subtask 8.9.8 - open

Sub-Subtask 8.9.9 - open

Task 9. NRX-B NUCLEAR SUBSYSTEM DEVELOPMENT

Subtask 9.0 NRX-B Block I Nuclear Subsystem Engineering

Perform the conceptual and preliminary designs of one or more flight reactor configurations, designated NRX-B, or portions of reactors intended to serve as a backup for the NRX-A program. Conduct design reviews of candidate designs leading to selection of the final NRX-B design configuration.

Perform the required reactor thermal, fluid flow, shielding, radiation and nuclear design work and analysis required to support the preliminary designs.

Specify, plan and conduct a mechanical test program on several advanced reactor components or assemblies and analyze test results to assess the capability of the component or assembly and to verify adequate basic performance of the selected configuration.

Perform flow and thermal tests to assess flow and thermal capabilities and structural integrity of critical components of conceptual and preliminary reactor designs.

Sub-Subtask 9.0.0 NRX-B Block I Reactor Mechanical Design

A. Engineering

- (1) Create two reactor designs to the complete layout stage and in sufficient detail necessary for selection as NRX-B Block I reactor and issue report.
- (2) Select one of these designs as the NRX-B reactor by September 1964.
- (3) Submit for approval a test program document outlining the plans and specifications for the mechanical testing of NRX-B components.
- (4) Design test hardware for the purpose of experimentally evaluating the design concepts of interest.
- (5) Release Y-5 component tube orificing test hardware.
- (6) Release articulated Y-5 component test hardware.
- (7) Perform selective component tests aimed at verifying design principles of the candidate designs and thus provide experimental information to assist in the selection of preferred designs.

Sub-Subtask 9.0.0 (continued)

- (8) Conduct the related stress and vibration analysis concerned with the design and component tests.
- (9) Prepare a W-12 reactor layout and perform mechanical stress analyses for incorporation into the design report to be reviewed in December, 1963. No further effort shall be expended on the W-12 reactor concept subsequent to December, 1963, unless specifically authorized.
- (10) Incorporate ground handling and flight environmental data into NRX-B design specifications on a continuing basis.

B. Fabrication - As required

C. Testing - Not applicable

D. Tooling - As required

Sub-Subtask 9.0.1 NRX-B Block I Reactor Thermal & Fluid Flow Design

A. Engineering

- (1) Provide mechanical design with thermal and fluid flow analysis leading towards the establishment of appropriate component coolant passages, orificing and flow metering devices and sealing systems for concepts selected for preliminary design and development.
- (2) Prepare and submit for approval a test program document outlining the plans and specifications for component flow testing of NRX-B components.
- (3) Release orifice test hardware for Y-5 flow tubes.
- (4) Establish by analysis and test the temperature, pressure and flow relationships throughout the reactors selected for preliminary design.
- (5) Confirm design through analysis of results obtained from a component flow testing program.
- (6) Confirm a W-12 design through analysis of temperature, pressure and flow relationships in the structure.

Sub-Subtask 9.0.1 (continued)

- (7) Participate in the technical evaluation leading to the selection of NRX-B reactor design in September, 1964.
- (8) Prepare for review of W-12 design in December, 1963. No further effort shall be expended on the W-12 reactor concept subsequent to December, 1963, unless specifically authorized.

B. Fabrication - Not applicable

C. Testing - As required

D. Tooling - Not applicable

Sub-Subtask 9.0.2 NRX-B Block I Reactor Nuclear Design

A. Engineering

- (1) Provide sufficient nuclear analysis for and participate in the development of preliminary layouts to assure adequate control capability, fuel density requirements and acceptable propellant reactivity worths.
- (2) Define the poison wire configurations necessary for adequate shutdown in the flooded condition.
- (3) Develop the analytical tools required by novel features in the NRX-B design.
- (4) Participate in the technical evaluation leading to the selection of NRX-B reactor design by September, 1964.
- (5) Prepare for review of W-12 design in December, 1963. No further effort shall be expended on the core cage reactor concept subsequent to December, 1963, unless specifically authorized.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-Subtask 9.0.3 NRX-B Block I Shielding and Radiation Analysis

A. Engineering

- (1) Prepare estimates of heating rates in structures and components of the layouts selected for preliminary design.
- (2) Complete evaluation of changes in the shield design necessary to accommodate NRX-B geometries.
- (3) Participate in the technical evaluation leading to the selection of NRX-B reactor design by September, 1964.
- (4) Prepare for review of W-12 design in December, 1963. No further effort shall be expended on the W-12 reactor concept subsequent to December, 1963 unless specifically authorized.

B. Fabrication - Not applicable

C. Testing - Not applicable

D. Tooling - Not applicable

Sub-Subtask 9.0.4 Mechanical Tests

A. Engineering

- (1) Evaluate the results of tests conducted.
- (2) Prepare required reports and data summaries.

B. Fabrication

- (1) Provide test facilities and equipment as required to accomplish project objectives.

C. Testing

- (1) Complete the series of mechanical load and thermal shock tests on both the fabricated and forged metal Y-5 components. Issue an evaluation report on the ability of these parts to withstand mechanical loads and thermal shock.

Sub-Subtask 9.0.4 (continued)

- (2) Complete the initial series of W-13 component tests and issue the the test report.
- (3) Complete the initial series of tests on the Y-6 component and issue the test report.

D. Tooling - As required

Sub-Subtask 9.0.5 - open

Sub-Subtask 9.0.6 - open

Sub-Subtask 9.0.7 Component Flow Tests

A. Engineering

- (1) Evaluate the results of the tests conducted.
- (2) Prepare required reports and data summaries.

B. Fabrication

- (1) Provide test facilities and equipment as required to accomplish project objectives.

C. Testing

- (1) Complete the air tests on the 60° plastic model of the forged Y-5 component . Issue a test report on the radial pressure drop and flow distribution.
- (2) Complete the hydrogen flow tests on the seven hole fabricated Y-5 component model. Issue a test report on the evaluation of the pressure and flow distribution.
- (3) Complete the cryogenic hydrogen quench tests on the fabricated and forged full scale prototype Y-5 component. Issue a test report.
- (4) Complete the flow tests on the W-14 component and issue a test report on flow and pressure drop characteristics.
- (5) Complete the air and hydrogen testing on the Y-5 component flow tube orifices. Issue a report on the flow and pressure drop characteristics.

Sub-Subtask 9.0.7 (continued)

- (6) Evaluate through hot flow tests the corrosion, fretting, vibration tendencies and adequacy of the insulation for the Y-5 component. Issue a test report.

D. Tooling - As required

Sub-Subtask 9.0.8 - open

Sub-Subtask 9.0.9 - open

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Subtask 9.1 Nuclear Subsystem - Procurement Management and Control - NRX-B Block I

Provide the planning and procurement for maintaining efficient and orderly progress toward the earliest realization of a NRX-B flight reactor system.

Sub-subtask 9.1.0 - Procurement Management and Control - NRX-B Block I Reactors

Support and control the delivered nuclear subsystem components and/or subassemblies to the configuration and schedule required for the NRX-B Block I development program. Based on overall project direction, analyze and prepare detailed ordering requirements for procurement.

Provide necessary hardware, tooling and services. Establish and maintain scheduling and inventory control on all work in process. Receive, store, dispatch and maintain records of finished parts, raw materials and other Government property.

A. Engineering - Not applicable

B. Fabrication

- (1) Provide NRX-B Block I raw material, fabricated components and facility, as required.
- (2) Maintain overall procurement schedule information and monitor program.
- (3) Provide manufacturing engineering support to design engineering on manufacturing techniques, processes and process capabilities; investigate, define and develop improved fabrication methods and techniques.
- (4) Prepare, pursue and monitor manufacturing process development programs.

C. Testing - Not applicable

D. Tooling

- (1) Provide tooling required to accomplish project objective, as applicable.

Subtasks 9.2 through 9.8 - Oper

Subtask 9.9 - Basic Technical Support - NRX-B Block I Reactors

Develop and provide preliminary data and specifications for potential NRX-B Block I Reactor Components.

Sub-subtask 9.9.1 Basic Technical Support - NRX-B Reactors - Non-Fuel Materials

Provide non-fuel materials information in accordance with the special needs of the NRX-B program.

A. Engineering

- (1) Develop and provide preliminary data and specifications for potential NRX-B reactor structural and shield materials in the fields of mechanical properties, fabrication and irradiation behavior.
- (2) Support and analyze NRX-B reactor component tests to assure adequacy of material application.

B. Fabrication - Not applicable

C. Testing

- (1) Perform testing under conditions simulating as closely as possible the operating environments in reactor service.

D. Tooling - Not applicable