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ROCKET ENGINE OPERATIONS - NUCLEAR

PROGRAM ACCOMPLISHMENTS - CONTRACT YEAR 1963
VOLUME I

RN-S-0014

30 OCTOBER 1963

SPACE NUCLEAR PROPULSION OFFICE
CONTRACT SNP-1

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CY '63 FINANCIAL PROGRAMS

COMMITTED

REON · ROCKET ENGINE OPERATIONS — NUCLEAR

A. CONTRACTUAL BACKGROUND AND APPROACH

My purpose is to present a little background for this Contract Year 1963 evaluation and put it into context with the contractual responsibilities of both parties. Contract Year 1963 began with Aerojet's Program Plan 2300 submitted in April and August of 1962. During negotiations we were redirected in September 1962 to a hot bleed program and were partially funded on several tasks by month-to-month letter contract authorizations. Report 2322 confirmed the negotiations for the start of the program and was a heated bleed program document. Modification 6, confirming the partially funded heated bleed program, was finally issued by the Government on 30 January 1963. Meanwhile a program was being developed on a hot bleed basis. Aerojet's Report 2434 covering hot bleed effort and continuation of partially funded activities had been submitted in November and negotiations completed at the end of December on the fully funded hot bleed program. This was voided in January by SNPO-C direction to a revised program concentrating on reactor development and de-emphasizing engine development. Change Orders 1 and 2 in February and March of 1963 provided the direction and guidelines. In response to these, Aerojet submitted its Program Plan RN-63002 in March and over the next several months negotiations were pursued. Modification 8 reflecting the revised program for Contract Year 1963 was received on 10 July. Also on 10 July Change Order 1 to Modification 8 was received providing for additional work effort to be initiated in Contract Year 1963.

In addition to the actual contractual twists and turns it should be pointed out that guidelines and direction received for budget and contract program for Contract Year 1964 have also had an impact on 1963 work, resulting in de-emphasis of certain efforts not planned to be pursued in 1964.

In historical summation - Contract Year 1963 was a year of reprogramming. An unusual amount of management time was devoted to changing the program rather than concentrating on detailed performance. There were significant periods of the year wherein the program was not clearly defined and agreed upon. During such periods we could not, prior to negotiations and approval, press forward with vigor on all technical fronts which might have been desirable.

A few words about the incentive arrangement itself should be stated. In 1961, Mr. James Webb of NASA asked our Mr. Bill Zisch if we would consider

some sort of incentive fee contract arrangement on NERVA and would we offer some suggestions for how some such plan could work in the complex NERVA program. Mr. Zisch replied in December 1961 with a general outline of a rating system whereby a joint committee of Government and contractor management would evaluate the past year's performance in several areas as a means of establishing the following year's fee.

In negotiation of 1963 Contract Year SNPO proposed an approach, which Aerojet and the Government agreed upon, on a trial basis only. This unusual arrangement places fully in the hands of the Government a subjective unilateral award decision to make. A provisional or base fee is established for average performance, with a floor and ceiling which would be earned in relationship to the "grade" or evaluation of the contractor. The stated reasoning behind the Government's approach was that technical objectives and milestones in a program such as NERVA are subject to change during development and judgment, not precise yardsticks, would be required to perform the program on a reasonable basis. It was not considered likely that development would truly match the contract periods.

This Contract Year 1963 program was performed within the context of the contractor's interpretation of its contractual obligation under an R&D best efforts, CPFF contract. The contractor's position has been that our obligation was to perform the total job to the best of our ability. This has been done and various decisions have been made by the contractor throughout the year which have traditionally been options within its province. However, it has become apparent within the last few weeks that there has not always been unanimity of interpretation as between Government and contractor. We now recognize that the Government has considered much of our planned program represented by TAD's, milestones and hardware demand schedules as effectively contractual obligations of the contractor contrary to the contractor's position that the work statement represented its obligation. Certain of the decisions mentioned such as rebudgeting within the authorized contract amount and emphasizing some efforts greater than others brings us to a position wherein we may be criticized for less than complete performance of our contractual obligation, whereas in many of these areas Aerojet believes the obligation has been met. In a changing R&D program it is a requirement of sound management that effort be continually redirected as problems

are encountered and new objectives become defined. Day-to-day management redirection provides the emphasis necessary to obtain total program objectives, and recognizes and requires that some minor tasks and interim objectives will become obsolete or deferred. In summary, under a CPFF contract, whether specified in the work statement or not, it is the total task to which program management must address itself, and it is the total task by which fee and incentive evaluation must be measured.

SNPO has requested a presentation on the planned vs actual accomplishments to assist in arriving at our year end report card. Such an evaluation will have a major impact on the contractor and his ability to arrive at and accomplish future mutual objectives on the program. It is our hope that the program environment of 1963 encompassing much change and diversion, plus the contractor's understanding of the contract obligations, will be recognized and objective weighting applied. Aerojet in its turn intends to present objectively its accomplishments, its costs and its effort remaining to be accomplished. Indicative of this intention, I wish to advise you at this time that the current review of the estimate to complete Contract Year 1963 work indicates Aerojet commitments, exclusive of WANL, to be incurred after September 30, 1963 of approximately \$3.7 million. You are already aware of the equivalent WANL figures from last week's presentation in Pittsburgh. We will get into this completion area further later in the agenda but first we wish to advise you of the technical accomplishments performed.

B. CALENDAR YEAR 1963 PROGRAM OBJECTIVES

The presentation of the technical program status of Aerojet's effort during CY 1963 requires a few remarks concerning the overall objectives of the program as seen at the beginning of the year. By discussion with various individuals at SNPO-C during the past few weeks, and, as evidenced by the more formal discussions at Cleveland during the weeks of October 7th and 14th, there is general recognition that the work statements for CY 1963 are not definitive, except where specific end item hardware requirements are delineated, or where certain equipment must be accounted for, as in the case of STE. For the moment, discount the lack of definitive work statements, and permit me to define the overall objectives of the CY 1963 NERVA Development Program. This is necessary in order to review the status of the detail technical program as of September 30, 1963. First of all I shall be quite general, and, subsequently more detailed.

As to the general objectives, in a development program of the nature of NERVA, the first objective is to uncover the development problems. The potential problem areas are in general known both to the Government and the contractor personnel because it is their job to know what problems are to be expected and/or encountered. However, it is the unknown, unanticipated, problem areas that justify the conduct of the program.

The second general objective of this contract year is to provide technical management to maintain the balance between development items competing for the available funding. As Mr. Ryland has pointed out, Aerojet's position has been, since the inception of the SNP-1 contract, that we have had the latitude of re-allocating funds, within the contract dollar limit, from subtask to subtask, to take care of unanticipated problems.

Before going into the detail objectives for the overall program I would like to take a few minutes to point out the various background data which have a definite bearing on the performance of the contractor during the past year in accomplishing the subtask work program.

During the 1963 program plan discussions held in August 1962, Aerojet was informed by SNPO-C of two significant items that affected the conduct of the 1963 Technical Program. The first was in the form of a directive to proceed with the hot bleed engine cycle, instead of investigating both the hot bleed and the heated bleed cycle; and, the second resulted in the elimination of any plans for the use of a thermal-barrier coating on the NERVA nozzle. That these two items had a major impact on the objectives will be demonstrated as you hear the detail technical presentation by subtask. I wish to point out the general areas which were affected as follows. First, the direction to go to the hot bleed cycle resulted in an unscheduled resubmittal of our CY 1963 Program Plan. This was necessitated because of extensive changes in subtasks 1.1, 1.4, to some extent 1.2, and in the support task 2.1 through 2.3, as well as the support test equipment items under tasks 5 and 6 at LRP. The second item, which by the way was mutually agreed upon, contributed to the need for a TPA redesign to provide for the attendant increased pressure drop in the engine system. At the time we were assessing the need for issuing a design change on the increased head requirement of the TPA, because of many small changes. Our evaluation of this included the assessment of whether or not the Mark III could be redesigned to accommodate these changes and an evaluation of the ability to obtain an effective nozzle coating. In our resubmittal for the hot bleed cycle it was our assessment that indeed the Mark III could be redesigned to accommodate the additional head rise required, and a presentation was made to SNPO-C in a technical management meeting on 10 January 1963 and this became the adopted plan. This TPA, designated the Mark III, Mod 2, was capable of meeting FX engine requirements. In subsequent meetings and correspondence, however, the design of the Mark IV was made an immediate goal in order to provide increased turbine efficiency; negotiations that followed stated this position and in essence, the Mark III became a work-horse turbopump, with the specific objective, however, of demonstration of 10-minute duration.

At the beginning of CY 1963 you will recall there was general agreement that a major problem in development of the overall TPA was the development of a liquid hydrogen cooled bearing. A major objective of CY 1963 was to perform a bearing test to demonstrate an endurance of one hour.

The overall engine system area has been de-emphasized during the contract year due to the reactor problems that were made known in November 1962. During the proposal planning and negotiation phase for Mod 8 to the SNP-1 contract the emphasis has shifted from one of obtaining experimental data on the bootstrap phase of the engine startup to one which placed more emphasis on pre-test and post-test analysis. This change in emphasis is one in which the contractor wholeheartedly agrees but, at the same time, we must urge that verifying experimental data on the bootstrap operation be obtained as early as is possible.

During the contract year a decision was made to utilize only "prototype hardware" on the CFDTS. The detail plan by which this was to be accomplished involved utilization of NRX-A1 cold flow hardware, and toward the end of the year a requirement by the customer to utilize Mark IV TPA in the CFDTS was made. These decisions had the result and impact of postponing the obtaining of experimental data on the bootstrap start into the end of CY 1964. You will note throughout the pertinent subtask discussions that items of CY 1963 work supporting the cold flow development test system were adjusted to be compatible with the rescheduling of that system to a later time period. These adjustments were necessitated by unanticipated problems. I wish to emphasize at this time that the replanning and reprogramming to meet these problems was one of the basic objectives of the CY 1963 program.

One of the major objectives of the work in the non-nuclear area during CY 1963 was the nozzle development and nozzle end item deliveries. The major effort in this subtask was devoted to the design incorporating a 347 SS tube bundle cast in an A356 aluminum jacket. This approach had been decided upon in the previous contract year and was based on two significant facts: (1) on the Titan Program successful work had been accomplished utilizing this technique, i.e., the casting of aluminum around a stainless steel bundle was developed to increase the rigidity of the Titan second stage nozzle, and (2) one of the most promising alternative approaches had already encountered difficulty, namely, blind brazing of tubes in a steel forging. Difficulties have been experienced in fabricating this design, however, as it will be pointed out in detailed discussions these problems have been defined and corrective actions have been taken.

There were other major objectives of the non-nuclear hardware development during the contract year in the various component subtasks. These will be identified during the presentations but in general the objectives were to conduct component and subsystem design or analysis and development to define problem areas, or a development approach, and to take the necessary corrective action through the normal development cycle of redesign and retest. In addition, the various support facilities and STE subtask objectives will be delineated during the discussions of these items.

CY 1963 MILESTONE SUMMARY

S/T	TOTAL NUMBER	NUMBER CANCELLED	NUMBER REMAINING	NUMBER COMPLETED	NUMBER CARRIED OVER
1.1	43	6	37	25	12
1.2	20	0	20	11	9
1.4	20	0	20	17	3
1.5	18	1	17	12	2
1.6	30	0	30	19	11
1.7	6	0	6	4	2
1.9	3	0	3	3	0
2.1	15	0	15	14	1
2.2	9	0	9	8	1
2.3	12	0	12	11	1
2.4	31	7	24	22	2
2.6	9	2	7	7	0
2.7	31	0	31	26	5
2.8	14	0	14	12	2
3.1	13	0	13	13	0
3.8	1	0	1	1	0
5.1	14	1	13	9	4
5.2	8	0	8	5	3
5.3	26	1	25	13	12
5.4	7	0	7	5	2
5.5	5	0	5	4	1
5.9	5	0	5	4	1
6.2	3	0	3	2	1
TOTALS	<u>343</u>	<u>18</u>	<u>325</u>	<u>247</u>	<u>75</u>

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C. TASK ACCOMPLISHMENTS

Task accomplishments under Contract SNP-1 for Contract Year 1963 are discussed in this section by subtask.

S/T I.I ENGINE SYSTEM

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.1A (1) ENGINEERING	UPDATE, DISTRIBUTE & MAINTAIN LAYOUT, ASSEMBLY & INSTALLATION DRAWINGS OF THE NERVA BLOCK I ENGINE	COMPLETED	LETTER 737: LOI44
(2)	PREPARE, DISTRIBUTE & MAINTAIN FLOW SCHEMATICS & PARTS LISTS FOR NERVA BLOCK I ENGINE	COMPLETED	LETTER 737: LOI44
(3)	CONDUCT NERVA ENGINE TEST PLANNING EFFORT AS REQUIRED TO SUPPORT ENGINE & STAGE TEST STAND FACILITIES	COMPLETED AS REQUIRED	SIGNIFICANT CONTRIBU- TION TO RPTS 2520, 2316, 2502, 2421, 2506 ISSUE OF DWG. 088958, 737-M3230
(4)	COMPLETE ANALYSIS, DETAIL DESIGN, & FABRICA- TION DRAWINGS FOR THE CFDTs (SEE PG II-A-2, PARA. 1.1A (4))	COMPLETED	732: M0186 AGC IOI3813 DRWG 294130 DRWG 701260 REPORT 2556 REPORT 2710

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S/T 1.1 ENGINE SYSTEM

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
(5)	UPDATE & REVISE AS REQUIRED THE NERVA FX ENGINE PRELIMINARY MODEL SPECIFICATION (SEE PG II-A-2 ; PARA. 1.1A (5))	UPDATED, REVISED, & ISSUED TO SNPO-C	765 : 349 AGC 10095 C
(6)	PREPARE, RELEASE, & MAINTAIN CURRENT THE BLOCK I ENGINE DESIGN SPECIFICATION	REVISED AND RELEASED TO SNPO-C	AGC 10149
(7)	PREPARE, RELEASE, & MAINTAIN CURRENT THE ENGINE SYSTEMS DATA BOOK	RELEASED AND MAINTAINED CURRENT	LTR 765:349 REPORT 2276
(8)	COMPLETE THE DESIGN-MODEL INTERFACE MOCKUPS. MAKE STUDIES, SELECT DESIGNS. (SEE PAGE II-A-2, PARA. 1.1 A (8) PARA. 1.1A (8))	FWD PRESS.VESSEL CLOSURE COMP REMAINING (2) MOCK- UPS DELETED. TEST RPT. STUDIES & SELECTION OF DESIGN DEFERRED TO 1/15/64	MOCKUP ON HAND AT LRP

S/T I.I ENGINE SYSTEM

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
(9)	PERFORM TRANSIENT AND STEADY STATE ANALYSIS (SEE PG II-A-2, PARA. 1.1A (8))	5 MAJOR ANALYSIS COMP.	DRAWING 092017 TM 738:63-201, TM 738:63-204, TM 738:63-207, DWG 732:63 729:R004, 729:R005
(10)	PREPARE, RELEASE, & MAINTAIN ALL NRX INTERFACE CONTROL & ASSEMBLY DRAWINGS & PARTS LISTS	5 DWGS REQ 5 DWGS & P.L. COMPLETED	088096-091882 091390-092346 091256-093523
	COORDINATE, MAINTAIN AND ISSUE NRX TEST PLANS, SPECIFICATIONS, PROCEDURES, AND ASSEMBLY/DISASSEMBLY PROCEDURES	COMPLETED AS REQ.	TNR-097 REVISION O AND I
(11)	PERFORM VEHICLE TO ENGINE TECHNICAL INTERFACE COORDINATION AND APPLICABLE SUPPORT STUDIES	COMPLETED AS REQ.	RPT 2697-RPT 2585 RPT 2671-LMSC A304195; 737:L0052 ; 737:L0142 737:L0031

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S/T I.I ENGINE SYSTEM

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
13-1.1a	PERFORM ANALYSIS IN SUPPORT OF THE LMSC OPERATIONAL SATURN V-N STUDY PROGRAM (SEE PG II-2, PARA. 1.1a)	STUDY 25% COMP BALANCE COMP BY 11/30/63	REPORT 2931
2-1.1 B (1)	FABRICATE TWO (2) SETS OF EACH OF THE FOLLOWING MASTER INTERFACE GAGES: SHIELD TO PRESSURE VESSEL, CORE ASSEMBLY TO NOZZLE, REFLECTOR TO PRESSURE VESSEL, SHIELD- REFLECTOR MATCH PLATE. SHIP (1) SET TO WANL AND RETAIN OTHER AT LRP	CORE ASSY. TO NOZZLE CANCELLED. ALL OTHER GAGES AND MATCH PLATES COMPLETE	PARTS ARE ON HAND AT WANL AND LRP
(2)	INITIATE THE FABRICATION OF UNIQUE TEST HARDWARE ASSOCIATED WITH CFDTs	COMPLETE

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

S/T I.I ENGINE SYSTEM

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.1B (3)	COMPLETE FABRICATION AND DEMONSTRATE THE DESIGN SUITABILITY OF THE FOLLOWING FULL SCALE INTERFACE MOCKUPS FOR NRX-A AND THE BLOCK I ENGINE WHERE APPLICABLE ; NOZZLE TO PRES-SURE VESSEL, FORWARD PRESSURE VESSEL CLOSURE, CONTROL DRUM ACTUATOR TO PRES. VESSEL	FWD PRESSURE VESSEL CLOSURE COMPLETED. FAB. OF OTHER(2) MOCKUPS CANCELLED	PARTS ON HAND AT LRP
(4)	COMPLETE FABRICATION OF NECESSARY FIXTURES FOR THE ATTACHMENT OF THE NRX-A VIB TEST ARTICLE TO THE VIBRATION TABLE	DELETED BY CHANGE ORDER NO. I	DELETED
(5)	FABRICATE UNIQUE HARDWARE, MODIFY EXISTING SHIELD AND REFLECTOR ASSEMBLY UTILIZED IN THE GEN II MOD I PROGRAM, AND ASSEMBLE FOR ACCEPTANCE TEST OF THE NON-NUCLEAR NRX-A1 AND A2	UNIQUE HARD-WARE COMP. ASSY. FOR TEST OF NRX-A1 AND NRX-A2 DEFERRED TO 11/15/63 & 1/15/64	UNIQUE HARDWARE ON HAND AT LRP

S/T I.I ENGINE SYSTEM

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-I.1C (1)	COMPLETE TESTING OF ALL INTERFACE MOCKUP ASSEMBLIES FABRICATED IN PARA. B (3)	TEST OF FWD PRES. VESSEL CLOSURE MOCKUP DEFERRED TO 12/15/63 OTHER (2) TESTS CANCELLED	DEFERRED TO CY 1964
(2)	COMPLETE ACCEPTANCE TEST OF NRX-A1 AND NRX-A2 NON-NUCLEAR ASSEMBLY	NRX-A1 AND A2 DEFERRED UNTIL 11/25/63, 2/20/63. ROUGH DRAFT OF THE ACCEPTANCE TEST PLAN WAS COMPLETED	DEFERRED TO CY 1964

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

SUBTASK 1.1 - ACCOMPLISHMENTS FOR CY 1963

Purpose and Objective

The objective of the work performed under this task item was to provide the engineering, fabrication and testing effort required to:

1. Support the design and integration of the NERVA development engines.
2. Support the mechanical integration and coordination of the NRX-A program including test documentation.
3. Support the technical interface coordination effort and studies required to establish the interface between the NERVA engine and the test facility and the NERVA engine and the RIFT stage.

Specific objectives were as follows:

1. Update and maintain current layout, assembly and installation drawings of the NERVA Block 1 Engine.
2. Conduct engine test planning as required to support test stand facilities planning.
3. Perform test planning, unique hardware design and fabrication, and pre test analysis for CFDTS.
4. Upgrade and maintain current the FX engine preliminary and model specification.
5. Initiate and release the E-Engine design specification and systems data book.
6. Design, fabricate, and test interface mockups as required to support the engine interface design efforts.
7. Provide support to the NERVA program through systems analysis of the NRX-A, CFDTS, and E-Engine systems.
8. Prepare and maintain NRX interface control and assembly drawings.

9. Coordinate, maintain and issue NRX test and assembly/disassembly procedures.

10. Perform vehicle to engine technical interface coordination and applicable support studies.

11. Fabricate master gages and match plates for the inspection and gaging the nuclear and non-nuclear NRX-A hardware.

12. Fabricate unique hardware as required for the acceptance test of the non-nuclear portions of NRX A-1 and A-2.

13. Perform the acceptance test of the NRX A-1 and A-2 non-nuclear assembly.

The accomplishments during this period with respect to the work statements are as follows:

2-1.1A (1)

The updating, distribution, and layout, assembly, and installation drawings of the NERVA Block 1 Engine were completed.

A. Revisions to Block 1 Engine Assembly Dwg. 089507 and Engine Installation Dwg. 088255 were made. These revisions included the following major changes:

1. Relocation of the turbopump discharge line and turbine inlet lines.
2. Addition of a diluent extraction line.
3. Mechanical rearrangement of control drum actuators.

The relocation of the turbopump discharge line and the turbine inlet lines was made to keep axial (or longitudinal) runs of the propellant lines parallel to the geometric centerline of the engine, and to the pitch and yaw planes, and to place them as close as feasible to the pressure vessel.

The addition of the diluent extraction point for the NERVA engine was based on the results of a systems analysis.

4. Rearrangement of the control drum actuators was based on the need to establish the method for interfacing the reactor control drum actuators with the pressure vessel.

2-1.1A (2)

The preparation, and distribution of the flow schematics and parts lists for NERVA Block 1 Engine was completed.

A. Revisions to flow schematics, control and flow diagram, Hot Bleed Block 1 Series No. 089508 were made to reflect the latest engineering systems information. These included the following major items:

1. Addition of diluent line to show location of extraction point at the pressure vessel dome.
2. Relocation of LH_2 purge line to above the top shield for the purpose of reducing shield penetrations.
3. Addition of a LH_2 cooldown bleed line to provide constant bleed off for the emergency cooldown line.
4. Rearrangement of the engine interface remote disconnect actuator supply lines.

B. The Basic Parts List for the NERVA Block 1 Engine was prepared and issued. The Basic Parts List included design configurations completed as of August 1963.

2-1.1A (3)

NERVA engine test planning as required to support engine and stage test stand facilities was performed. The test planning section provided substantial contributions to the following documents.

1. "Basic Criteria Engine Test Stand No. 2 at NRDS" (Report No. 2502). This report was initially released May 1963, revised and released July 1963. The test planning section provided the engine description and the associated peripheral operating and environmental limits of the engine from which, the facility requirements were established. Also, the test program was tentatively defined and a preliminary test schedule established. From this information, a test facility utilization schedule was created.
2. "Mandatory Facility Addition - Engine Test Stand No. 1 at NRDS" (Report No. 2506, released June 1963). This section provided the engine

operating and environmental limits within the constraint of the existing capability of ETS-1. From this information, the working and service fluid tankage requirements were ultimately established.

3. "RIFT Safety Review Program" (Report No. 2421). This report was initially released November 1962, updated and re-released August 1963. Input to this document consisted of providing: FX engine description; a sequence of NERVA engine operations for the RIFT at the launch complex; operating profiles and flight test plans for the scheduled flights. This information was intended to provide data for use by the various subcontractors and Government agencies in their performance of safety evaluations and reviews.

4. "NERVA Post-Operative Requirements & Support System Utilization" (Report Nos. 2325 and 2520). This report was initially released October 1962, updated and re-released May 1963. The test planning section provided the data and test requirements for post-operative examinations. This information was used to establish the E-MAD satellite cells and equipment requirements.

5. "On-Stand Hot Maintenance Study" (Memo No. 737:M3230). This document will be released during CY 1964. A study of irradiated engine components for which on-stand replacement was considered feasible was performed. This information is being used to determine remote handling equipment requirements and ultimate feasibility of the concept.

6. "Test Stand Adapter and Thrust Structure - Interface Control" (Dwg. No. 088958). The basic drawing was revised to the extent of providing the fluid and electrical line penetrations through the 30 in. top shield. This information was transmitted to ETS-1 A & E to allow completion of the top shield detail design. The design study for locating the penetrations involved a radiation analysis of the shielding requirements for the ETS-1. The primary conclusion of this analysis was that the 15 in. water shield in the adapter section could be eliminated without compromising the ETS-1 manned occupancy and material state-of-the-art (above the 30 in. shield) requirements.

2-1.1A (4)

The analysis, detail design, and fabrication drawings for the CFDTS was completed. Early in the contract year, effort was directed toward definition

of objectives for the Cold Flow Development Test System; conducting a design analysis to determine the capabilities of the system; establishing a configuration for the CFDTS; and outlining a test program. This work was reported to SNPO-C and included:

1. Proposed CFDTS configuration
2. CFDTS Flow Schematic
3. CFDTS Basic Parts List
4. Design Analysis, CFDTS (Memo 732:M0186)
5. Test Program, CFDTS

A. The CFDTS Equipment Specification AGC 10138 was completely revised to reflect the change from a heated-bleed to the hot bleed configuration. In addition a requirement for an ejector system to simulate altitude conditions at the nozzle exit and turbine exhaust line outlet was specified. The equipment specification was issued as AGC-10138B.

B. The design effort resulted in a flow schematic and layout drawing for the CFDTS. These were new drawings and formed the basic for subsequent detailed design and fabrication drawings for the components and other hardware in the system. The major drawings are as follows:

1. Dwg. 294129 CFDTS Flow Schematic
2. Dwg. 294130 CFDTS Layout
3. Dwg. 299046 Thrust Structure Assembly
4. Dwg. 702160 Instrumentation Location
5. Dwg. 294063 Pressure Vessel Assembly

C. Test Planning activities were conducted which resulted in the issuance of a Preliminary Test Plan for CFDTS, Report No. 2556. This report covered Test Objectives, Instrumentation Requirements, Design, Operational Flow Plan and an Overall Test Activity Schedule. During the course of the year, as additional information became available and the test program became better defined, the test plan was updated and issued as Report No. 2710. Additional information on System Description, Test Description, and pre-test analysis was included in the revision. The instrumentation requirements list was updated.

2-1.1A (5)

The NERVA FX engine preliminary model specification was revised to reflect new data developed by the design and analyses programs. The revisions included the following major items:

1. Reorientation of the pump discharge and turbine inlet line in accordance with mechanical and facilities handling requirements.
2. , Location of the diluent extraction lines in accordance with systems requirements.
3. Relocation of the LMSC Propellant Isolation Valve.

2-1.1A (6)

The Block 1 Engine Design Specification was released. A preliminary draft was initiated and released to SNPO-C (AGC-10149, 15 September 1963). This document presents the design requirements of the E-Series Block 1 engine and serves as a requirement aid to NERVA engine design.

2-1.1A (7)

The engine systems data book was updated and released. The intent of the Engine Systems Data Book was to present the current performance and design data for the NERVA FX Hot Bleed Engine Model No. AJ30-5. Since the mechanical design and systems analyses for the FX Engine was not a part of the CY 63 program, the Engine Systems Data Book was published early in CY 63 to present the latest E-Engine model specification requirements. Changes included upgraded figures, tables, component test data. An additional revision to this document is now in progress for release early in CY 64.

2-1.1A (8)

Complete the design-model interface mockups. Make studies, select designs.

A. Three full scale interface mockup designs were originally selected as follows:

1. Nozzle to P.V.
2. Forward P.V. Closure
3. Control Drum Actuator

The mockup design for Item 1 was deleted. The mockup design for Item 3 was deleted because lack of design information with respect to the actuators and the manifold prevented completion of this mockup design as scheduled and actual hardware will be used to perform the mockup function.

Design for the mockup for the forward P.V. Closure, Item 2, has been completed and an Interface Mockup Test Plan (No. 1142007 LRP) has been released.

2-1.1A (9)

Perform transient and steady-state analyses

A. This item covers the NERVA systems analysis effort and was completed with all objectives attained during CY 1963. These objectives can be stated as follows:

1. Evaluate and incorporate modifications from analyses and component development into the E-engine and FX engine.

2. Define problem areas in the overall engine development program through test planning and operational studies.

3. Provide analytical support for the NRX-A system, CFDTs and E-engine to anticipate potential problem areas and to guide components development and testing in areas requiring a change in component or facility requirements.

During CY 1963 the NERVA system analysis effort was transferred to sub-subtask 1.1.6 and an overall systems analysis plan was formulated and submitted to SNPO-C for approval. Systems analysis coordinators were established at each plant to implement the plan. Integration of all systems analysis effort is being performed by REON.

The analyses that have been made under sub-subtask 1.1.6 include studies of engine cooldown and restart (Milestone 37), establishment of an analog model of the E-1 Engine and engine programmer for use with remote engine control system model (Milestone 38), studies of the Block 1 engine control loops to develop requirements for these control components (Milestone 39), refinement of the engine operational map and better definition of the component restraints related to steady

state operation of the system (Milestones 41 and 42) and analysis of the CFDTS startup program (Milestone 40) for inclusion in the CFDTS test plan. A large number of other analyses were made during the year covering NRX-A1 run profiles, error analyses of instrumentation for both NRX-A1 and CFDTS, thermal and pressure profile calculations for E-Engine and NRX-A systems over a range of conditions, and establishment of data analysis methods suitable for use with data from both NRX-A and CFDTS test systems. Reports of these analysis are contained in the Bibliography.

2-1.1A (10)

Prepare, release, and maintain all NRX interface control and assembly drawings and parts lists.

A. This item was complied with. The following configuration control drawings for the NRX-A program were prepared and issued during this contract year:

1. 088096 - Interface Control - NRX-A1
2. 091390 - Interface Control - NRX-A2 and A3
3. 091256 - Interface - Propellant Feed Line, Test Car
4. 091882 - Interface - NRX-A1 Nozzle (Rocketdyne RN-6)
5. 092349 - NRX-A1 Final Assy.
6. 093523 - Parts List NRX-A1 Assy.

The first four drawings define interfaces between subcontractor components. The last two drawings present the NRX-A1 final assembly and parts list.

Effort on these drawings was accomplished on a continual basis to reflect the revisions which occurred in the design of the hardware.

B. Coordinate, maintain, and issue NRX test plans, specifications, procedures, and assembly/disassembly procedures.

This item was complied with. The basic documentation requirements and the contents for the test plans and test specs were established.

NRX-A1 - The test plan was initially issued as WANL-TNR-097, Rev. 0. This document was upgraded as a result of AGC and SNPO-C review and reissued as

WANL-TNR-097, Rev. 1. A test specification rough draft for NRX-A1 was prepared, reviewed by AGC, and upgraded. Revised measurement requirements, changes in test parameters and addition of the "Split Flow" tests occurred subsequent to the rough draft issue. A smooth draft was issued as WANL-TNR-121. The final test specification will be published in CY 64. Six (6) NTO prepared NRX-A1 test procedures were received for review. The review was initiated during the contract year.

NRX-A2 - A preliminary test profile was prepared by WANL as a basis for the test plan. A test plan rough draft was prepared by WANL and reviewed by AGC.

Vibration Test Series II - This test series, originally part of the CY 63 effort, involved vibration testing a complete NRX-A assembly. The tests were deleted by Change Order No. 1.

2-1.1A (11)

Perform vehicle to engine technical interface coordination and applicable support studies.

A. This item was complied with. Continual engine technical interface coordination activities were accomplished during the contract year with LMSC, SNPO-C, and MSFC. As a result of this technical coordination, several special studies were undertaken which resulted in the preparation of AGC reports. Major accomplishments were as follows:

1. Meetings were held with LMSC to discuss the mechanical interface between the NERVA Engine and the RIFT Stage, as a part of the effort to reach an interface agreement. A preliminary mechanical interface agreement was published in January 1963 (AGC letter 737:L0052) jointly by the AGC/LMSC mechanical interface task group. This document outlined both the areas of agreement and disagreement and was forwarded to the Interface Working Group for disposition.

2. A special LMSC/AGC task group was organized to establish a preliminary flight test plan for NERVA/RIFT flights. Meetings were held to discuss these plans and special studies were performed by both organizations to optimize thrust-time profiles to meet the established objectives. Results of this effort were published in AGC Report 2421 "RIFT Safety Review Program."

3. Report No. 2585 "Evaluation and Comparison of Attitude Control Systems for Spacecraft with NERVA Engines" was prepared to discuss and compare the LMSC Thrust Vector Trim and the NERVA Thrust Vector Control Attitude Control systems. This report defined the NERVA Engine concept and described the reasons for the design approach chosen. In addition, a technical discussion of the proposed LMSC conceptual design and the implication of this design on the flight vehicle was presented.

4. As a result of the above report, and a meeting held at SNPO-C, it was clear that a common basis had not been used by REON and LMSC in presenting the estimated weight of the two systems. Therefore, a joint LMSC/REON report "RIFT/NERVA Installation TVC/TVT Description and Weights Comparison" LMSC-A304195, was prepared and issued. The report established a firm basis for weight comparison and subsequent design analysis and weight trade off studies.

5. A verbal presentation was made in August 1963 at MSFC on the status of the NERVA Engine program. This presentation was made at MSFC's request and was accomplished in fulfillment of our obligation for liaison with MSFC, as set forth in the contract. A summary of this presentation is given in Report 2671.

6. Report No. 2697, "Comments on LMSC Offset Gimbal" were prepared in response to a request from MSFC/SNPO. The report presents a technical review by REON of the mechanical features of an LMSC configuration with TVC gimbal angle capability.

In addition to the special studies performed, a review of the RIFT Environmental Specification NSPD-650002 was made. The results of this review were published.

13-1.1A

Perform analysis in support of the LMSC Operational Saturn V-N Study Program.

A. This item will be completed by 30 November 1963. At the completion of Contract Year 1963 preliminary operational NERVA class engines were defined in terms of reactor operating temperature and chamber pressure. A mission of national interest utilizing these engines was evaluated together with possible modes of operation. In addition, a preliminary development schedule was prepared. This

data was presented at MSFC 18 July 1963 as part of the Nuclear Lunar Logistics System Study. Report 2931 (AGC 9727) summarizing the presentation material was prepared for distribution.

2-1.1B (1)

Two (2) sets of each of the following master interface gages;

Shield to pressure vessel

Core assembly to nozzle

Reflector to pressure vessel

Shield-reflector match plate

Ship (1) set to WANL and retain other at LRP

were fabricated. The master pressure vessel gages and match plates were designed to provide interchangeability and hole location control for assembly hardware. All of the gage items required for use in the NRX-A gage program were completed and shipped.

The following master gages and match plates were provided for use at WANL:

Description	Usage
T - 603317 - Closure Master	Inspection fixture. Used to control the assembly of the shield inside the closure.
T - 603316 - Pressure Vessel Cylinder Master	Inspection fixture. Used to control reactor assembly with the pressure vessel.
T - 603318 - Nozzle Master	Inspection fixture. Used to control assembly of reflector, core, and related parts.
T - 603093 - Shield to Reflector Match Plate	Inspection fixture for referencing pin and hole locations.

The following master gages and match plates were provided for use at LRP:

T - 603329 - Shield Master	Inspection fixture for assembly of closure and chamber to shield.
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T - 603330 - Reflector Master	Inspection fixture to control length, hole pattern, and perpendicularity of reflector.
T - 603094 - Closure Match Plate	Inspection fixture to hole and port locations in assembly with pressure vessel.
T - 603006 - Cylinder Aft End Match Plate	Inspection fixture for pressure vessel and nozzle interface.
T - 603007 - Nozzle Match Plate	Inspection fixture to control hole location on the nozzle interface.

2-1.1.B (2)

The fabrication and procurement of unique test hardware associated with the CFDTIS was initiated. Raw materials such as stainless steel and aluminum plate, wire and standard AN type bolts, nuts, machine and fitting were ordered. Long lead hardware consisting of various sizes of vee-band couplings, metal seals, pressure vessel high-shear bolts and bellows for suction lines and gimbal were ordered. Fabrication or procurement for all other unique hardware was initiated. This included:

1. Main nozzle and turbine exhaust adapters.
2. Roll control simulating nozzles.
3. Engine to test stand adapter.
4. Turbine exhaust lines.
5. Turbine overspeed control valve.
6. Diluent control valve.
7. Instrumentation transducers.
8. Pneumatic supply system components.

2-1.1B (3)

Complete fabrication and demonstrate the design suitability of the following full scale interface mockups for NRX-A and the Block 1 engine where applicable;

Nozzle to pressure vessel
 Forward pressure vessel closure
 Control drum actuator to pressure vessel

Fabrication of hardware for the forward pressure closure has been completed and design suitability was demonstrated. The fabrication of the nozzle to pressure vessel and control drum actuator to pressure vessel was cancelled.

2-1.1B (5)

Fabricate unique hardware, modify existing shield and reflector assembly utilized in the Gen II MOD I Program, and assemble for acceptance test of the non-nuclear NRX-A1 and A2.

A. Unique hardware has been completed. A pressure vessel inner liner (P/N 298389-19) originally used for the Gen II MOD I Program was modified and an inner liner support (P.N 298431-1) was fabricated. These two parts which comprise the unique hardware are available at LRP for use in the NRX acceptance test program now planned during CY 1964. Assembly for acceptance testing of the NRX-A1 has been deferred to November 15 and NRX-A2 until January 15.

2-1.1C (1)

Complete testing of all interface mockup assemblies fabricated in Paragraph B (3).

A. Tests of the forward pressure closure mockup was deferred to 12-15-63 to be more compatible with the NRX reactor schedule. Test report was deferred to 1-15-64.

2-1.1C (2)

Complete acceptance test of NRX-A1 and NRX-A2 non-nuclear assembly.

A. A rough draft of the test plan for acceptance test of the NRX-A1 non-nuclear hardware at LRP has been completed. This document, when finalized, will serve as the basis for performing the cold flow acceptance tests of the deliverable LRP hardware. The plan provides for acceptance testing at conditions more severe than the test conditions called out in the NRX-A1 test specifications.

Actual acceptance test of NRX-A1 and A-2 non-nuclear hardware, planned during CY 1963, has been deferred to CY 1964 because of delays in the NRX program schedule and fabrication problems encountered with the nozzle.

Conclusions

All objectives, as stated in work statements and summarized under purpose and objectives, except those listed below were met.

A. The interface mockups effort originally planned for the nozzle to P.V., and the control drum actuator to P.V. was deleted.

B. The interface mockup effort planned for the forward P.V. closure was deferred to CY 1964.

C. The acceptance test planned for the non-nuclear portions of NRX A-1 and A-2 was deferred to CY 1964.

Of the 43 milestones established for Subtask 1.1 for CY 1963, 25 milestones were completed, 4 milestones on the Vib II Program were deleted by Change Order No. 1, 3 milestones were deleted by the mutual agreement between REON and SNPO-C that no preliminary test plans or specification would be issued on the NRX-A program, and 5 milestones were deferred to CY 1964.

Additional Effort - Completed but not included in RN 63002 Work Statement.

Sub-Subtask 1.1.1

1. The NERVA design criteria for the Gen II heated-bleed engine simulator was revised to reflect changes in the MOD 1B simulator. Major revisions were the addition of an overhead run tank, a simulated nozzle and an exhaust ejector system. NDC 18C was issued which included the latest configuration.

2. The proposed configuration and program plan for the Gen II MOD 1B simulated were established. The test objectives, analytical program and test program were outlined. A letter, 737:0025 was submitted to SNPO-C, which included the above information.

No further effort was expended on the MOD 1B simulator program since this program was based on a heated-bleed cycle.

3. The final report for the Gen II MOD 1 NERVA engine simulator was written and issued as Report No. 2543. This report included a detailed discussion of the system design, test program, and error analysis. In addition, recommendations for future tests and a comprehensive analysis of the Gen II test results were presented in the report.

Sub-Subtask 1.1.4

A study of the hot flow development test system was made to determine the configuration, the justification, and objectives of a non-nuclear system of

this type. A report, TM 737:63-003, was prepared and submitted to SNPO-C. Analyses were made on the structural dynamics, propellant feed system, thrust chamber assembly, instrumentation, controls system, and validation of the steady state model as part of this study. Flow schematics and control system schematics and a comparison of the HFDTs with the engine system were included.

Sub-Subtask 1.1.5

Effort was accomplished to revise the full scale NERVA FX engine mockup from a heated-bleed engine to a hot-bleed engine. Details with respect to the pneumatic supply system were added during this revision.

Sub-Subtask 1.1.8

Effort was undertaken to prepare interface assembly and installation drawings for the NRX-A1 assembly utilizing the Rocketdyne RN-6 Nozzle Assembly. Five (5) drawings are required as follows:

- One drawing to define the interface between the RN-6 Nozzle and the AGC pressure vessel

- One drawing to show the camera and light installation

- One drawing to show the instrumentation installation, a NRX-A1 assembly drawing, and a NRX-A1 installation drawing.

A NRX-A1 Task Force was organized and put into operation, with the chairmanship and preparation of task force materials funded from this sub-subtask. This task force consisting of members from REON, NTO, WANL, LRP and SNPO-C meets bi-weekly and is responsible for timely identification of intra participant problems providing recommendations to NERVA management for remedial action, and for assessment of the program schedules for participant planning purposes. Biweekly meetings were held where members report on the status of progress for each NRX-A assembly with the objective of identifying pacing problems for remedial action and assuring the best possible schedules for each program.

SUBTASK 1.1 - BIBLIOGRAPHY

SUBJECT AND TITLES OF DOCUMENTS LISTED IN EVIDENCE OF COMPLETION COLUMN

<u>W/S</u>	<u>SUBJECT OR TITLE</u>	<u>DOCUMENT NO.</u>
2-1.1 A (1)	Letter to SNPO-C transmitting drawings	737:L0144
2-1.1 A (2)	Same as above	737:L0144
2-1.1 A (3)	RIFT Safety Review Program Basic Criteria - ETS-2 at NRDS Mandatory Facilities Addition ETS-1 at NRDS NERVA Post Operative Requirements and Support System Utilization On Stand Hot Maintenance Study Test Stand Adapter and Thrust Structure Interface Control	Report 2421 Report 2502 Report 2506 Report 2520 737:M3230 Drawing 088958
2-1.1 A (4)	Design Analysis - CFDTs CFDTs Layout Drawing Instrumentation Location - CFDTs CFDTs Preliminary Test Plan CFDTs Revised Test Plan Equipment Specification for CFDTs NERVA Hot Bleed	737:M0126 Drawing 294130 Drawing 701260 Report 2556 Report 2710 AGC 101388
2-1.1 A (5)	Letter to SNPO-C transmitting AGC 10095C NERVA FX Engine Preliminary Model Spec.	765:349 AGC 10095C
2-1.1 A (6)	NERVA Block I Engine Design Specification	AGC 10149
2-1.1 A (7)	Letter to SNPO-C transmitting Report 2276 Engine Systems Data Book	765:349 Report 2276
2-1.1 A (9)	NERVA Steady-State Operating Map Preliminary Study of Cooldown and Restart Preliminary Study of CFDTs Control Requirements for Block I Engine Analog Model for ETS-1 Controls Estab AGC Program Plan Submittal Overall NERVA Program Plan Submittal	Drawing 092017 TM:738:201 TM:738:204 TM:738:207 Drawing 732:63 729:R004 729:R005
2-1.1 A (10)	Interface Control, NRX-A1 Interface Control, NRX-A2 and A3 Propellant Feed Line, Test Car Interface - NRX-A1 Nozzle NRX-A1 Final Assembly	Drawing 088096 Drawing 091390 Drawing 091256 Drawing 091882 Drawing 092346

SUBJECT AND TITLES OF DOCUMENTS
LISTED IN
EVIDENCE OF COMPLETION COLUMN

<u>W/S</u>	<u>SUBJECT OR TITLE</u>	<u>DOCUMENT NO.</u>
2-1.1 A (11)	Comments on LMSC Offset Gimbal Presentation to MSFC on NERVA Engine Design Evaluation and Comparison of Attitude Control Systems Joint Report - TVC/TVT Description and Weight Comparison LMSC/REON Joint Mechanical Interface Agreement Transmittal of NERVA Performance Steady State and Transient Review of RIFT Environmental Specification 6520002	Report 2697 Report 2671 Report 2585 LMSC/AGC A304195 737:L0052 737:L0031 737:L0142
13-1.1 (a)	Nuclear Lunar Logistics Study	Report 2931

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 11

⬆ SCHEDULED MILESTONE
▲ MILESTONE ACHIEVEMENT

◇ RESCHEDULED MILESTONE
◆ RESCHEDULED MILESTONE ACHIEVEMENT
◇ RESCHEDULED TO CY 64

SCHEDULES AND MILESTONES

CONTRACT YEAR 1963

TASK ITEM 1.1

[illegible]

 SCHEDULED MILESTONE

↑ MILESTONE ACHIEVEMENT

◆ RESCHEDULED MILESTONE

◆ RESCHEDULED MILESTONE ACHIEVEMENT

RESCHEDULED TO CY 64

Sheet 2 of 4

SCHEDULES AND MILESTONES

CONTRACT YEAR 1963

TASK ITEM 1.1

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DATE:

↑ SCHEDULED MILESTONE

↑ MILESTONE ACHIEVEMENT

◆ RESCHEDULED MILESTONE

◆ **RESCHEDULED MILESTONE ACHIEVEMENT**

RESCHEDULED TO CY 64

Sheet 3 of 4

RECON

ROCKET ENGINE
OPERATIONS - NUCLEAR

AERO.
GEN.

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.1

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DATE:

SCHEDULED MILESTONE

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◆ RESCHEDULED MILESTONE

◆ RESCHEDULED MILESTONE ACHIEVEMENT

RESCHEDULED TO CY 64

Sheet 4 of 4

HARDWARE STATUS

9-30-63

TASK ITEM 11
TASK TITLE ENGINE SYSTEM

COMPONENT/SUB-ASSEMBLY	END USE	EST	ACTUAL	REMARKS
MATCH PLATE-NOZZLE	Insp & Tooling Caging LRP	1	1	
MATCH PLATE AFT CYL		1	1	
MATCH PLATE-SHIELD REFL	WANTL	1	1	
MATCH PLATE-CLOSURE CYL	LRP	1	1	
MASTER CLOSURE	WANTL	1	1	
MASTER NOZZLE		1	1	
MASTER CYLINDER		1	0	
MASTER SHIELD	LRP	1	1	
MASTER REFLECTOR		1	1	
MASTER CORE		1	0	Cancelled
DEV TEST SYSTEM ASSY	Simulator CFDTIS	1	0	
MISC CFDTIS COMPONENTS		1	0	
PUMP DISCHARGE LINE ADAPT		1	0	
TURBINE INLET LINE ADAPTER		1	0	
TURBINE EXHAUST ADAPTER		1	0	
CFDTIS NOZZLE ASSY		1	0	
P.V COMP SUPP + BRACKETS		1	0	
P V DUMMY REACTOR ASSEMBLY		1	0	
NOZZLE TO EJECTOR ADAPTER		1	0	
SERVO CONTROL SYSTEM		9	0	
TURBINE OVERSPEED CONTD VALVE		1	0	
SIMULATOR VALVES (SETS)		1	0	
PRESSURE VESSEL AFT FLANGE	Pressure Vessel to Nozzle Interface	1	0	
NOZZLE FLANGE		1	0	

SHEET 1 of 2

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TEST STATUS

9-30-63

TASK ITEM 1.1
TASK TITLE ENGINE SYSTEM

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Interface mockup Pressure Vessel to Nozzle P/N 286934	E-1	Determine amount of distortion due to assembly	Final Assembly Building 2002	1	0	
SAME	E-1	Determine any problems associated with assembly of the components	SRP STRUCTURAL LAB Building 2004	1	0	
Interface Mockup Cylinder to Closure P/N 286935	E-1	Determine amount of distortion due to assembly	Final Assembly Building 2002	1	0	
SAME	E-1	Determine problems associated with assembly of components	SRP Structural Lab Building 2004	1	0	
Interface Mockup Closure to Manifold to Actuators P/N 286936	E-1	Determine amount of distortion due to assembly	Final Assembly Building 2002	1	0	
SAME	E-1	Determine problems associated with assembly of components	SRP STRUCTURAL LAB Building 2004	1	0	

S/T 1.2 WORK STATEMENT SUMMARY

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
<u>1.2.0 ENGINEERING</u>			
2-1.2A (1)	PROVIDE PFS INTERFACE & RE- QMTS TO RIFT CONTRACTOR	COMP - LMSC SUPPLIED W/REQ'D DATA & DWGS	REON MEMOS 734:LO150 737:L0052 734:MO198 734:L0298
<u>1.2.0 FABRICATION</u>			
2-1.2B (1)	FAB SEALS FOR DEVELOPMENT	COMPLETED IN CY 63	REON LTR TO SNPO-C 734:L0331 REPORT: L0560-10-24 L0560-10-25 L0560-10-26
<u>1.2.1 ENGINEERING</u>			
2-1.2A (2)	UPDATE DESIGN OF PUMP SUCTION, DISCHARGE & TURBINE INLET LINES	COMP-LINES DESIGNED & DWGS RELEASED	REPORT : L0560-10-26 L0560-10-27
<u>1.2.1 FABRICATION</u>			
2-1.2B (1)	FAB PFS COMPONENTS, LINES & DISCONNECTS	COMPLETED IN CY 63	REON MEMO 734:MO 380 REPORT: L0560-10-26

S/T I.2 WORK STATEMENT SUMMARY

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
<u>I.2.2 ENGINEERING</u>			
2-I.2A (2)	UPDATE DESIGNS OF TSOV, RCDV, TPCV	COMP-VALVE DWGS RELEASED & REVISED AS REQUIRED	AGC DWGS : 268795 268400 278100
2-I.2A (5)	PREPARE PFS COMPONENT ACCEPT. TEST SPECS	COMP-ACCEPTANCE TEST SPECS FOR TSOV, RCDV, TPCV	REON LTRS TO SNPO-C 734: LO353 734: LO387
<u>I.2.2 FABRICATION</u>			
2-I.2B (1)	FAB FOR DEVELOPMENT TSOV, RCDV, TPCV	FAB COMPLETION DEFERRED TO CY 64	COMP DEFERRED DUE TO FAB PROBLEMS & DELAYS
2-I.2B (2)	COMPLETE FAB OF VALVES	COMPLETED FAB OF INITIAL VALVES	REPORT: LO560-10-24 LO560-10-25 LO560-10-26 LO560-10-27
<u>I.2.2 TESTING</u>			
2-I.2C (1)	CONDUCT PFS DEVELOPMENT TESTING, ENDURANCE & ENVIR- ONMENTAL CAPABILITY-VALVES	TESTS STARTED IN CY 63 AND TO BE CONTINUED IN CY 64	REPORT: LO560-10-24 LO560-10-26 LO560-10-27

S/T I.2 WORK STATEMENT SUMMARY

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
<u>I.2.3 ENGINEERING</u>			
2-I.2A (2)	UPDATE PFS COMPO- NENT DESIGN-TPA	COMP & RELEASED MK III MOD 3 DWG. LAYOUT DWG. MK III MOD 2, MK IV MOD I & MK IV MOD 2	AGC DWGS: 265800, MK III MOD I 278000, MK III MOD 3 297604, MK IV MOD I LAYOUT 284997, MK IV MOD 2 LAYOUT LRP RMR 0072 & 0080
2-I.2A (3)	DEVELOP MK III TPA	COMP -MK III MOD I & MK III MOD 3 TPA DEVELOPMENT ACCOMPLISHED	REPORT: LRP RMR 0072 LRP RMR 0080 LRP LTR & HANDOUT TO SNPO-C 9636:0087, 20 MAY LO560-10-21, 22, 24, 25, 27
2-I.2A (4)	RELEASE MK IV TPA DWGS.	COMP -RELEASE OF MAJOR MK IV DETAIL DWGS. DEFERRED FINAL RELEASE TO OCT 63	REPORT: LRP-27 MO. PROG. FOR 9-63 DEFERRED FINAL REL. DUE TO SNPO-C REDIRECTION OF MK IV TPA: SNPO-C LETTER SCHROEDER TO HOUSE, 8 APR 63
2-I.2A (5)	PREPARE TEST PLANS FOR TPA & BEARINGS	COMP-TEST PLANS ISSUED AND PERIODICALLY REVISED	REON TO SNPO-C LETTERS: 734:LO248 734: LO313 734:LO295 734: LO333 734:LO299 734: LO357

REON ROCKET ENGINE OPERATIONS

S/T 1.2 WORK STATEMENT SUMMARY

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
1.2.3 ENGINEERING (CONT'D)			
2-1.2A(6)	ANALYZE MKIV TPA THRUST BALANCE SYS	COMP - THRUST BAL SYSTEM ANAL- YZED FOR MK IV TPA	MEMO: 9640A:0297, 1 APR 63 9640A:0359, 19 APR 63 OIF: bh: 0108, 11 JUN 63
1.2.3 FABRICATION			
2-1.2B (1)	FAB BEARING SETS, THRUST BAL TEST FIXTURE	COMPLETED BEARING SETS THRUST BALANCE FIXTURE DEFERR- ED TO DEC 63	REPORT: L0560-10-21,22,24,26,27 LRP RMR 0072 & 0080 LRP LTR SNPO-C 9636:0087 THRUST BALANCE FIXTURE DE- FERRED DUE TO MK IV TPA REDIRECTION
2-1.2B (2)	FAB TPA COMPONENTS FROM CY 62	COMP-MKII & MKIII MODI TPA'S	*REPORTS: LRP RMR 0072&0080 LRP MEMO TO SNPO-C 9636:0087 L0560-10-25&27
2-1.2B (3)	FAB MKIII TPA'S & INITI- ATE MK IV FAB	COMP-MKIII MODI & MK III MOD 3 TPA'S MKIV MOD 2 FAB INITIATED	*REPORTS: LRP RMP 0072 & 0080 L0560-10-22,24,27 LRP LTR TO SNPO-C 9636:0087
1.2.3 TESTING			
2-1.2C (2)	BEARING OPER. IN RAD ENVIR. AT LOAD & SPEED	DEFERRED TO CY 64	DEFERRED DUE TO RESCHEDUL- ING OF RET PROGRAM
2-1.2C (3)	10 MIN. TPA ENDURANCE	DEFERRED TO JAN 64	TESTS DEF. DUE TO H-6 ACTIV. SLIP
2-1.2C (4)	THRUST BAL. SYS. COMP. ONENT TESTS	DEFERRED TO JAN 64	DEF. DUE TO MK IV TPA REDIR- ECTION

REON ROCKET ENGINE OPERATIONS - NUCLEAR

NERVA TPA TEST SUMMARY

CY 63 (SST 1.23)

I. NUMBER OF TESTS

MK II		4	COLD GAS DRIVE
MK III	MOD 1	19	COLD GAS DRIVE
MK III	MOD 3	4	COLD GAS DRIVE
MK III	MOD 3	9	HOT GAS DRIVE
MK III	MOD 3	2	POWER TRANSMISSION CHILLDOWN
	TOTAL	38	

2. ACCUMULATED TIME

MK II		313 SEC	COLD GAS DRIVE
MK III	MOD 1	2875 SEC	COLD GAS DRIVE
MK III	MOD 3	253 SEC	COLD GAS DRIVE
MK III	MOD 3	485 SEC	HOT GAS DRIVE (ABOVE 1140° R)

3. LONG DURATION RUNS

MK III	MOD 1	2000 SEC	COLD GAS DRIVE
MK III	MOD 3	274 SEC	HOT GAS DRIVE (ABOVE 1140° R)
MK III	MOD 3	3 MIN.	HOT GAS DRIVE (ABOVE 1140° R AND AT FX SPEED & PRESSURE)

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

NERVA BEARING TEST SUMMARY

(CY 63 (SST 1.2.3.))

I. NUMBER OF TESTS

TURBINE TESTER 44

HIGH SPEED 33

2. ACCOMPLISHMENTS

ACCUMULATED TIME	SPEED	AXIAL LOAD	RADIAL LOAD
75 MIN.	24,000	2000 LB	2000 LB
5 MIN.	24,000	—	2800
3 HRS	16,000	2000	2000
10 MIN.	16,000	3600	—
2.5 MIN.	24,000	—	—

RAD
ENVIRONMENT

ROCKET ENGINE OPERATIONS

SUBTASK 1.2 - ACCOMPLISHMENTS FOR CY 1963

Purpose and Objective

The overall objective of this subtask is to develop a feed system capable of supplying propellant at the required flow rate and pressure to the NERVA engine thrust chamber. Specific objectives for the contract period were to:

1. Demonstrate the Mark III, Mod 3 TPA for 10 minutes duration at FX conditions. This was deferred to CY 1964 primarily due to late activation of the H-6 test stand.
2. To complete the design of the Mark IV, Mod 2 configuration. This was accomplished.
3. To demonstrate prototype bearing operation for 1 hour at FX load and speed. This was accomplished and exceeded.
4. To conduct studies, analysis, and development testing to update the design of propellant feed system components. This is a continuing effort and the work statement was complied with.

During the contract year, the PFS effort was redirected as follows which had significant impact on schedules and cost.

The Mark IV TPA was initially designed to meet the Hot Bleed Engine requirements. In April, SNPO-C directed that a balance piston be included in the designs and shortly thereafter that provision be made to incorporate wet pump capability. This resulted in redesign of the Mark IV to the Mod 2 or present configuration.

2-1.2A (1)

The RIFT contractor has been supplied with the applicable data on the mechanical interface. This material was disseminated in the form of oral presentations and official data submittals as shown in the bibliography.

2-1.2B (1)

190 seals were fabricated for development testing. 205 static seal development tests were conducted during the contract year under ambient, extreme

temperature and vibration conditions. Conoseal joints were subjected to radiation environment test and no leakage was evident. On the basis of these tests, the conoseal was tentatively selected for the PFS static seals. Accomplishments were presented in NERVA Monthly Progress Letter 0560-10-24, 25 and 26. Seal summary report was transmitted to SNPO-C with REON letter 734:L0331.

2-1.2A (2)

This work item was completed. The designs for the pump suction, discharge and turbine inlet lines have been updated and drawings released for fabrication. The major line change was the turbine inlet line which was redesigned late in the contract year to include a cooled jacket and trim orifices to match the TPA requirements. Accomplishments were reported in NERVA Monthly Progress Letters L0560-10-26 and 27.

2-1.2B (1)

Line drawings were released and fabrication initiated. The completion of the PFS lines have been deferred to CY 1964 compatible with the rescheduling of CFDTs from December 1963 to June 1964 and the redesign of the lines late in CY 1963. The line fabrication will be completed by January 1964.

Disconnect development was continued in CY 1963 in conjunction with the static seal development program. PFS line joints were tested with seal and disconnect test cells. Tests included vibration, extreme temperature gaseous pressurization, leak and proof testing. A 5-inch Marman joint test cell was successfully proof tested to 1500 psig. Based on the results of this test program, the Marman disconnect has been selected for further development in the Propellant Feed System.

The progress of the line and disconnect programs are included in the NERVA Monthly Progress Letters L0560-10-24, 25, and 26.

2-1.2A (2)

This work item was completed. The design of the PFS valves were updated during the contract year and the drawings were released for fabrication. Current valve configurations and applicable drawings are:

TSOV Conf. 2A - Drawing 268795

TCDV Conf. 1 - Drawing 268400

TPCV Conf. 2 - Drawing 278100

As a result of seal testing of the TSOV and RCDV a design of the seals for the associated poppet valves was established. At present, the best configuration is a stainless steel on stainless steel seal combination. A change to the TSOV design is required to limit the extension of the valve above the engine interface to 2 inches. In addition, the TPCV interface with the Bendix actuator must be redesigned as a result of interface discussions with Bendix. The redesign of these valves will be started in CY 1964.

2-1.2A (5)

This work item was completed and acceptance test documents for the TSOV, RCDV, and TPCV were issued. These documents were transmitted to SNPO-C.

2-1.2B (1) and 2-1.2B (2)

Fabrication, exclusive of long lead procurement, was initiated in CY 63. One TSOV, one RCDV, and four TPCV's were completed. The balance of components to be completed as follows: TSOV in November 1963, RCDV in January 1964, and TPCV in November 1963.

Fabrication status of valves was reported in NERVA Monthly Progress Letters L0560-10-24, 25, 26 and 27.

2-1.2C (1)

Initial development, operational and environmental testing was conducted with Configuration 1 TSOV. Seal tests, initial assembly, and initial development tests were conducted with Configuration 2 TSOV.

The Reactor Cooldown Valve was subjected to initial assembly and initial development tests. Seal tests were conducted and development tests were conducted on the TCDV actuators.

Tests conducted on the Configuration 2 TPCV included initial assembly, development and operational capabilities. Hot gas testing of the TPCV will be completed in December 1963. The progress of valve testing during CY 1963 was reported in NERVA Progress Letters L0560-10-24, 26, and 27.

2-1.2A (2)

This work item is completed. The Mark III, Mod 1 TPA drawings were released and fabrication initiated in CY 1962. As a result of the increased

performance required for the hot bleed engine the Mark III, Mod 3 turbopump, capable of supplying the new requirements, was designed and drawings released. This turbopump was an interim unit and preceded the Mark IV TPA design. A Mark IV, Mod 1 design was completed which included a balance piston. A later redesign resulted in the Mark IV, Mod 2 TPA included provisions for a shaft seal which was intended to facilitate moving the main shutoff valve downstream of the TPA discharge. This design change was the result of SNPO-C direction. Layout drawings for the various Mark IV configurations were completed. Drawings applicable to the various turbopump configurations are as follows: 265800, Mark III, Mod 1; 278000, Mark III, Mod 3; 297604, Mark IV, Mod 1 layout; and 284997, Mark IV, Mod 2 layout. Design changes of the TPA were also reported in LRP Reports RMR 0072 and 0080.

W/S Ref. 1.2A (3) - Develop Mark III TPA

*The objectives of this work item were completed. During CY 1963, 19 Mark III, Mod 1 cold gas drive tests were completed for an accumulated time of 2,875 seconds which included 200 seconds of operation on a single turbopump. Six Mark III, Mod 3 cold gas drive tests were completed for an accumulated time of 253 seconds. Nine Mark III, Mod 3 hot gas drive tests were completed for an accumulated time of 485 seconds of which 274 seconds were accumulated on a single turbopump unit. Tests at specific values of Q/N and reduced NPSP equivalent to the TPA inlet were run at full and reduced speeds. These data were reported in the form of a pump operating map showing cavitation and instability constraints. The development test program included studies of mechanical life and performance. Tests were performed to determine the effects of TPA inlet conditions on pump pressure rise. Testing of the Mark III, Mod 3 with hot gas drive (above 1140°R) was demonstrated at FX pressure and speed in excess of 3 minutes. Tests of the TPA rotating components was performed to verify critical shaft speed calculation methods. Tests were also conducted to determine the TPA performance when starts during chilldown are attempted. These tests were run using engine configuration suction line and TSOV. The total accumulated TPA run time in CY 1963 with LH_2 cooled power transmission was 3,613 seconds. Progress of the Mark III TPA development has been documented as shown in the bibliography.

2-1.2A (4)

The design of the Mark IV TPA was started in January of CY 1963. In April 1963, the design was redirected so as to include a balance piston. It was also requested that the TPA be designed such that the main propellant shutoff valve could be relocated downstream of the TPA without resulting in a major turbopump redesign. As a result, a proposal was submitted which allowed provisions for a shaft seal in the TPA and included a fabricated pump housing with weld closures for sealing. This design was designated as Mark IV, Mod 2 and resulted in a rescheduling of detail drawings and final release. All major Mark IV, Mod 2 component detail drawings were released at the end of CY 1963. The final release of all detail drawings was rescheduled to October 1963. Progress of the Mark IV, Mod 2 design is presented in NERVA Monthly Progress Letters L0560-10-25 and 26; LRP Monthly Progress No. 27. Design reviews were held with SNPO-C personnel at Cleveland and LRP during the months of July, August and September.

2-1.2A (5)

Test plans for the TPA and bearings were issued during CY 1963 and were periodically revised. These plans and revisions were transmitted to SNPO-C.

2-1.2A (5)

The analysis of the thrust balance system for the Mark IV TPA was completed and the results incorporated in the design of the balance piston assembly for the Mark IV, Mod 2 turbopump. The analysis and design information is documented as indicated in the bibliography.

2-1.2B (1)

Fabrication of bearing sets to support the CY 63 program was completed. 125 roller bearings and 109 sets of thrust bearings were received and used for bearing and TPA development testing. The design of the thrust balance fixture was completed; however, the completion of fabrication of the test fixture will not occur until December 1963; since the design of the test fixture could not be completed until the Mark IV, Mod 2 TPA design was finalized. After the Mark IV, Mod 2 balance piston design was completed, the drawings were prepared for the balance piston test fixture. Reports of the progress on bearings is shown in the bibliography.

2-1.2B (2)

Two Mark II; two Mark III, Mod 1 and 3 Mark III, Mod 3 TPA's were completed utilizing the long lead hardware procured in CY 62. The 3 Mark III, Mod 3's were the result of the redesign of Mark III, Mod 1 turbopumps. (The progress and completion of these TPA's were reported in LRP Reports RMR 0072 and 0080; LRP memo to SNPO-C 9636:0087 and NERVA Monthly Progress Letter L0560-10-25 and 27).

2-1.2B (3)

These work items have been completed. During CY 1963, three Mark III, Mod 3 TPA's were fabricated in addition to the units initiated in the previous contract period. It is currently planned that two additional Mark III, Mod 3 turbopumps will be completed in October 1963. These units will be used for testing in the H-6 facility. Fabrication of Mark IV, Mod 2 long lead time items was initiated. (The progress of these turbopumps was reported in LRP Reports RMR 0072 and 0080, LRP Letter to SNPO-C 9636:0087 and in NERVA Monthly Progress Letters L0560-10-22, 24 and 27).

2-1.2C (2)

The objective of this program was to demonstrate the operation at FX load and speed of the NERVA TPA hydrogen cooled bearings in an equivalent NERVA radiation environment. A 2.5-min test was completed in a radiation environment at speed, however, the tester did not incorporate loading devices for the bearings for the period tested. The bearings showed no obvious effect from the radiation field. A 5-minute demonstration of NERVA TPA bearings at load and speed in a radiation environment was conducted in October 1963 Test No. 902 which resulted in earlier accomplishment of the rescheduled test demonstration.

* During CY 1963, 47 non-radiation bearing tests were conducted utilizing the turbine drive tester which operates at 16,000 rpm. Thirty-three non-radiation tests were conducted using the high speed bearing tester. In September 1963, a successful test was completed which resulted in 75 minutes of operation of NERVA TPA ball and roller bearings at 24,000 rpm with 2,000 lb radial and 2,000 lb axial load and LH₂ cooling. This completed the milepost

requirements for a 1-hour endurance demonstration at load and speed and signifies the accomplishment of a major objective of the NERVA non-nuclear program. In addition, radial and thrust bearings were operated in a non-radiation environment for an accumulated time of 3 hours at 16,000 rpm with 2,000 lb radial and 2,000 lb thrust load. A non-radiation test was completed which resulted in operation for 5 minutes at 24,000 rpm with a roller bearing at 2,800 lb radial load. A thrust bearing was subjected to 3,600 lb load for an accumulated time of 10 minutes at 16,000 rpm.

2-1.2C (3)

This work item was not accomplished during CY 1963 because of rescheduling of the activation of the H-6 test area. Demonstration was rescheduled for completion in January 1964.

2-1.2C (4)

This work item was not accomplished in CY 1963; it has been rescheduled to start in January 1964. The rescheduling of these tests is due to the redesign of the Mark IV necessitating delay in the completion of the thrust balance test fixture. It is currently planned to conduct thrust balance system tests during the months of January and February 1964.

Conclusion

There were 20 major milestones for the year. Thirteen were completed and seven were deferred into CY 1964. Of the seven deferred milestones, three deferrals result from the redirection of the Mark IV, Mod 2 TPA to the Balance Piston Wet Pump configuration.

These are M/S 14: Release Detail Drawing Mark IV TPA

M/S 19 and 20: Fabricate and Test Thrust Balance System

In addition, the following effort over and above that proposed for CY 1963 was accomplished.

1. Redesign of discharge line from 900 to 1100 psi. Added effort.
2. Work associated with TPA for growth potential.
3. Request of SNPO-C for special design review of TPA.
4. Redesign of turbine inlet line - inclusion of cooled jacket around line instead of elbow.

5. Increased liaison with SNPO-C local reps.
6. Additional effort for cost studies not planned.
7. Investigation and completion of drawings, I & C specification requirements, and test planning for NARF.
8. Increased effort of selection of 2 vs 3-stage Mark IV turbine.
9. Preparation of development plan for balance piston.
10. Investigation of wet TPA.
11. Preparation of backup pump development program.
12. Added requirement on test planning and test reporting.
13. Cost of Mark III TPA, TSOV, and TPCV fabrication higher than estimates.
14. More G-7 bearing tests run than anticipated.
15. Cold gas TPA tests - additional.
16. Material investigation of D979.
17. Fab nozzles of D979.
18. ETS-16 studies.
19. New turbine exhaust nozzles for ETS-1 NES.

In conclusion, the development work performed during CY 63 has resulted in major accomplishments in the propellant feed system. Selections were made of candidate prototype static seals and disconnects for the propellant feed system lines and components. The Marman "Conoseals" and disconnects have met the sealing requirements established for the E engine series.

Although the endurance demonstration of the turbopump was not completed, performance was demonstrated for long accumulated periods of time with both cold and hot gas drive fluid. Performance data was obtained and mapped from stall point to flow valves greater than design point. Instability and cavitation data were obtained at full and reduced speeds. The TPA performance was demonstrated in excess of FX pressure and flow at high speed. Turbine data were obtained which provided design information applicable to the Mark IV. This included thrust, hot gas operation and full speed design data.

The turbopump bearings have been developed to the state that long duration operation of these bearings with LH_2 coolant in a radiation environment can be seen as an accomplishment that is possible in the near future. Based

upon the excellent accomplishment achieved in CY 63 which resulted in 75 min operation at load and speed in a non-nuclear environment. 2.5 min operation in a radiation environment at speed and 5 min operation in a radiation environment at load and speed in October 64, it is evident that further development of the bearings will provide the desired life for both E and FX series engines.

SUBTASK 1.2 - BIBLIOGRAPHY

REPORTS

LO560-10- Informal Monthly Progress Letter to AEC-NASA
Space Nuclear Propulsion Office

-21 March 1963

-22 April 1963

-24 June 1963

-25 July 1963

-26 August 1963

-27 September 1963

NERVA LRP-27 Monthly Letter Report, September 1963

LRP RMR 0072, 10 January, TPA and Bearing Progress Report

LRP RMR 0080, 7 March, TPA and Bearing Progress Report

MEMORANDUMS

LO150 Letter to C. T. Donnenworth from D. B. Nickerson, 12 December, 1962, Transmittal of Data on TPA Suction Pressure Requirements.

LO52 Letter to Dr. H. Sweet from R. V. Evloth, 29 January, 1963, Transmittal of "Preliminary Mechanical Interface Agreement."

MO198 Memo to W. D. Stinnett from D. B. Nickerson, 2 February, 1963, "Report on the Ad Hoc Committee for Propellant Feed System and Pressurization System at Huntsville, Alabama, Feb. 14 and 15.

LO248 Letter to J. C. Montgomery from D. B. Nickerson, 17 April 1963, Transmittal of Test Plan for First Series of MK III Mod 3 TPA Tests.

LO295 Letter to J. C. Montgomery from D. B. Nickerson, 5 June 1963, Transmittal of NERVA Test Plans for TPA Endurance Development and TPA Performance Documentation Third and Fourth Quarter CY63.

L0298 Letter to H. Rosenblum from D. B. Nickerson, 10 June 1963, Transmittal of NERVA Engine Performance Curves
 L0299 Letter to J. C. Montgomery from D. B. Nickerson, 12 June 1963, Transmitting memorandum indicating changes to NERVA TPA Test Plan (L0295).
 L0313 Letter to J. C. Montgomery from D. B. Nickerson, 27 June 1963, Transmitting memorandum indicating revision of the TPA Test Plan.
 L0331 Letter to J. C. Montgomery from D. B. Nickerson, 15 July 1963, Transmittal of (1) AGC Static Seal Review, (2) AGC Static Seal Test Experience and Data, and (3) Configuration V Pilot and Cup Flanges (Conoseal) for NERVA Engine Propellant Feed System.
 L0333 Letter to J. C. Montgomery from D. B. Nickerson, 17 July 1963, Transmittal of LRP Bearing Development Test Plan.
 L0353 Letter to J. C. Montgomery from D. B. Nickerson, 20 August 1963, Transmittal of (1) Acceptance Test Requirements for Tank Shutoff Valve (TSOV), (2) Acceptance Test Requirements for Turbine Power Control Valve (TPCV).
 L0357 Letter to J. C. Montgomery from H. H. Borneman, 26 August 1963, Transmittal of Turbopump, LRP Development Test Plans, July thru September 1963, Tentatively thru January 1964.
 M0380 Memo to W. D. Stinnett from H. H. Borneman, 1 October 1963, Deletion of CY63 Deferral Effort from NN-63005.
 L0387 Letter to J. C. Montgomery from H. H. Borneman, 10 October 1963, Transmittal of (1) Bearing Tester Radiation Effects Test Plans, No. 003, Revised 1 October 1963, (2) Acceptance Test Requirements for Reactor Cooldown Valve, dated 11 September 1963, (3) Acceptance Test Requirements for Tank Shutoff Valve Pilot Valve, dated 11 September 1963.
 9640A:0297 Memo to R. Horn from D. E. Glum, 1 April 1963, Subject: "Preliminary Analysis of NERVA Pump Thrust Balancer."
 9640A:0359 Memo to R. Horn from D. E. Glum, 19 April 1963, Subject: "Feasibility Analysis of NERVA Pump Thrust Balancer."
 OIF:bh:0108 Letter to J. C. Montgomery from I. L. Odgers, 11 June 1963, Transmittal of NERVA Thrust Balancer Sketches and Plots.
 9636:0087 Letter to J. C. Montgomery from I. L. Odgers, 20 May 1963, Transmittal of Technical Discussion Handout.

DRAWINGS

265800	TPA Hydrogen Nuclear Rocket Engine
268400	Angle Valve - Reactor Cooldown
268795	Valve Poppet - Tank Shutoff
278000	Turbopump Assembly Mark III Mod 3
284997	Mark IV Mod 1 Turbopump
297604	Mark IV Mod 1 Turbopump

CONTRACT YEAR 1963

TASK ITEM_ 1.2

↑ SCHEDULED MILESTONE

↑ MILESTONE ACHIEVEMENT

◆ RESCHEDULED MILESTONE

◆ RESCHEDULED MILESTONE ACHIEVEMENT

RESCHEDULED TO CY 64

Sheet 1 of 2

CONTRACT YEAR 1963

CONFIDENTIAL

RECON
ROCKET ENGINE
OPERATIONS - NUCLEAR
AERO-
GENS

HARDWARE STATUS

9-30-63

TASK ITEM 1.2
TASK TITLE Propellant Feed System

COMPONENT/SUB-ASSEMBLY	END USE	EST.	ACTUAL	REMARKS
PFS Bellows	Component Development	8	0	Deferral of parts compatible with CFDTS reschedule
PFS Remote Disconnects	" "	38	3	Objectives accomplished with parts received
PFS Seals	" "	272	190	" " " " "
Test Rigs for Seal Tests	" "	8	1	Objectives accomplished with test rigs rec'd & on hand
Prototype Suction Line Assy.	" "	1	1	
Pump Discharge Line Assy.	Component Development, CFDTS, Spare	4	0	Deferral of lines compatible with CFDTS rescheduling
Turbine Inlet Line Assy.	Component Development, CFDTS, Spare, PFNWS	5	0	Deferral of lines compatible with CFDTS rescheduling
				PFNWS delete therefore line deleted
Turbine Exhaust Line Assy.	Component Development, CFDTS, Spare	4	0	Deferral of lines compatible with CFDTS rescheduling
Reactor Cooldown Valve	Component Development, CFDTS, RET	5	1	Valve not required for CFDTS. RET rescheduled to CY 64
RCDV Actuator	Component Development, CFDTS, RET	10	9	RET rescheduled to CY 64. Not required for CFDTS.
RCDV Position Transducers	" " " "	23	11	" " " " " " " "
RCDV Rework	Component Development	3	3	
TSOV and Actuator	Component Development, CFDTS, RET	5	1	RET rescheduled - compatible with CFDTS rescheduling
Remote Disconnect TSOV to Tank	" " " "	6	7	
Purge Check Valves	" " " "	2	3	
TPCV	" " " "	7	4	RET rescheduled to CY 64 - compatible with CFDTS resched.
TPCV Experimental Actuator	Component Development	3	4	
TPCV Rework	" "	4	4	
TSOV Position Transducer	Component Development, CFDTS, RET	17	9	RET rescheduled, component development objectives accomp.
Remote Disconnect Actuator-TSOV to Tank	" " " "	12	6	RET rescheduled - compatible with CFDTS rescheduling
TSOV Assembly Rework	Component Development	2	2	
TSOV Pilot Valves	Component Development, CFDTS, RET	9	6	RET rescheduled - compatible with CFDTS rescheduling.
				Component development objectives accomplished.

TEST STATUS

9-30-63

TASK ITEM 12

TASK TITLE Propellant Feed System

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Pump Suction Line (Partial assy of UTS and LTS) 1.2c(1)	Simulated Line for H ₂ O test Prototype line for LH ₂ test	To determine pressure drop at various flows and gimbal bellows angle.	Component Lab H ₂ O C-8 LH ₂	10 5	4 0	Water tests objectives accomplished LH ₂ tests
TSOV - Suction Line TPA System Tests 1.2c(1)	Prototype hardware if available	To determine minimum MPSP at TSOV inlet and to correlate system and component TPA tests.	C-7	5	6	Objectives accomplished
Seals 1.2c(1)	2, 5, and 12-in. dia.	To determine configuration, leak rate, allowable deflection, surface finish, and effect of LH ₂ environment on various types and sizes of seals	Component & Cryogenic Labs			12 months of testing as scheduled
Remote Disconnect Flange 1.2C(1)	2, 5, and 12-in. dia.	To determine life, ease of operation, proof and burst pressure, allowable loads, and effect of LH ₂ environment	Component & Cryogenic Labs			4 months of testing as scheduled

TEST STATUS

9-30-63

TASK ITEM 1.2

TASK TITLE Propellant Feed System

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
TSOV Assembly	Conf. #1	<u>Initial Dev. Tests</u> - Includes Proof, Leak, and Functional tests to evaluate various part configurations	Component & Cryogenic Labs			8 months planned, 5 months accomplished, test objectives met
TSOV Assembly	Conf. #1	<u>Evaluation of Operational Capabilities</u> - Includes testing of comp. assy. and components life cycle testing, flow testing	Component & Cryogenic Labs			8 months planned, 4 months accomplished, components testing only
TSOV Assembly	Conf. #1	<u>Evaluation of Environmental Capabilities</u> - Includes humidity, icing, and high temp. tests.	Component & Cryogenic Labs			Icing tests run, other tests switched to Conf. 2 valve
TSOV Assembly	Conf. #1	<u>Evaluation of Radiation Resistance</u>	Component & Cryogenic Labs	1	1	See MIT 901 Subtask 1.9.5
TSOV Assembly	Conf. #1	<u>Initial Development Tests</u> - Includes Proof, Leak, and Functional tests to evaluate seals, various part-configurations and effects of tolerances	Component & Cryogenic Labs			10 months planned, 10 months accomplished, objectives met
TSOV Assembly	Conf. #2	<u>Initial Assembly Tests</u> - Determines Assembly Procedures for all components and complete assembly	Component & Cryogenic Labs			1 month planned, 1 month run, objectives met

TEST STATUS

9-30-63

TASK ITEM 1.2

TASK TITLE Propellant Feed System

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
TSOV Assembly	Conf. #2	Component Tests - Includes proof, leak, and functional tests of pilot valve, remote disconnect, and position indicator	Component & Cryogenic Lab			4 months planned, 3 months accomplished, objectives met
TSOV Assembly	Conf. #2	<u>Evaluation of Operational Capabilities</u> - Includes life cycle and flow testing of complete assembly	Component & Cryogenic Lab			1 month planned, tests not run due to late delivery of valve
TSOV Assembly	Conf. #2	<u>Evaluation of Radiation Resistance</u>	Component & Cryogenic Lab			See Subtask 1.9.5, MIT 905 rescheduled
Cooldown Valve Assembly	Conf. #1	<u>Initial Seal Tests</u> - Tests conducted using a seal tester	Component & Cryogenic Lab			6 months planned, 5 months run, objectives accomplished
Cooldown Valve Assembly	Conf. #1	<u>Initial Assembly Tests</u> - Determine assembly procedures for all components and complete assembly	Component & Cryogenic Lab			5 months planned, 2 months run, test objectives met but documentation not complete

TEST STATUS

9-30-63

TASK ITEM 1.2
TASK TITLE Propellant Feed System

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Cooldown Valve Assembly	Conf. #1	<u>Initial Development Tests</u> - Includes proof, leak, and functional tests to evaluate seals, various part configurations and effects of tolerances	Component & Cryogenic Labs			3 months planned, 2 months accomplished, objectives accomplished
Cooldown Valve Assembly	Conf. #1	<u>Component Tests</u> - Includes electrical tests and torque tests of actuator. Also electrical tests of position indicator.	Component & Cryogenic Labs			11 months planned, 9 months accomplished, objectives accomplished
Cooldown Valve Assembly	Conf. #1	<u>Evaluation of Operational Capabilities</u> - Includes life cycle and flow testing of complete assembly	Component & Cryogenic Labs			2 months planned for CY 63, 1 month accomplished
Cooldown Valve Assembly	Conf. #1	<u>Evaluation of Radiation Resistance</u>	Component & Cryogenic Labs			See Subtask 1 9.5, MIT 905 rescheduled
Turbine Power Control Valve Assembly	Conf. #2	<u>Initial Assembly Tests</u> - Determines assembly procedures for all components and complete assembly	Component & Cryogenic Labs			3 months planned, 3 months accomplished, objectives met

TEST STATUS

9-30-63

TASK ITEM 1.2
TASK TITLE Propellant Feed System

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Turbine Power Control Valve Assembly	Conf. #2	Initial Development Tests - Includes proof, leak, functional, and torque tests to evaluate seals, bearings, various part configura- tion changes, and effects of tolerances	Component & Cryogenic Labs			5 months test planned, 1 month accomplished initial results satisfactory
Turbine Power Control Valve Assembly	Conf. #2	Evaluation of Operational Capa- bilities - Includes life cycle, torque and hot flow tests.	Component & Cryogenic Labs			1 month planned in CY 63, 1 month run, initial results satisfactory. Life cycle and hot flow tests deferred.
Turbine Power Control Valve Assembly	Conf. #2	To Develop High Temp. Capa- bilities - Each test consists of flowing GH_2 at 4 lb/sec, 600 psig and 1800°R . Tests will be 5 min. duration. O_2 can be burned with the H_2 to obtain 1800°R .	H-4	4	0	See Subtask 5.3 Hot Gas Facility, rescheduled to allow for TPA and nozzle testing in "H" area.

TEST STATUS

9-30-63

TASK ITEM 1.2
TASK TITLE Propellant Feed System

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Pump Assembly	Long Inducer Series	Performance documentation of development configurations	D-3	13	11	Test objectives accomplished
TPA	Mark II	Pump performance characteristics at low NFSP, various values of flow coefficient and turbine thrust documentation	C-7 Cold-gas drive	4	4	Test objectives met
TPA	Mark III (3-stage turbine)	Performance testing at 22,000 rpm endurance, evaluate LH ₂ cooled power transmission, and recovery from NFSP. Turbine evaluation with hot gas drive.	C-7 Cold-gas drive	19	19	Test objectives met
TPA	Mark III (2-stage turbine)	Performance testing at design speed, endurance, document performance with engine inlet system. Turbine evaluation with hot gas drive.	Hot-gas drive C-7 Cold-gas drive	21	15	Turbine evaluated with hot gas drive. Performance evaluated at design speed.
TPA	Mark III (2-stage turbine, remote removal)	TPA endurance, demonstrate 10 minute duration at required turbine inlet conditions	C-7 Hot-gas drive H-6	6	0	See Subtask 5.3 TPA Facility rescheduled to allow nozzle tests in "H" area.
Bearings	Developmental	Improved bearing endurance at FX speed and load.	G-7 & Cryolab	85	77	Objectives met

S/T I.3.0 PROGRAM PLANNING

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-I.3	CY 1963 PROGRAM PLAN	COMPLETED	RN 63002 RN 63013
	CY 1965 PROGRAM PLAN	COMPLETED	189'S
	NRX-A DESIGN REVIEW & BLOCK-I TEST PLAN	COMPLETED	AGC REPORT 9659 AGC REPORT 9550
	CY 1964 PROGRAM PLAN	COMPLETED	PD 198, 199 LTR TO WANL 8/20/63 770: 2136

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S/T 1.3.0 PROGRAM TECHNICAL GUIDANCE

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.3 TECHNICAL REVIEW OF PROCUREMENT ACTION	-	CONTINUING	277 ACTIONS REVIEWED AND ACTED UPON
• KIWI-B-2A DESIGN REVIEW	-	COMPLETED	AGC REPORT 9502 6-5-63
• KIWI-B-2 A MODULE FRACTURE	-	COMPLETED	AGC REPORT 2719 PUBLISHED OCT. 1963
• KIWI-B-4D DESIGN REVIEW	-	CONTINUING	MEMO 771:RS:057 DTD 9/13/63 MEMO 771:RS:065 DTD 10/18/63 FINAL REPORT TO FOLLOW
• HIGH TEMP. CRITICAL FACILITY EVALUATION	-	COMPLETED	MEMO 771:RS:019 5/17/63 LTR. TO SNPO 770:2031 5/21/63 LTR. TO SNPO 770:2065 6/25/63
• NRX-B DESIGN CRITERIA	-	CONTINUING	AGC REPORT NDC-64 DTD 4/5/63 LTR TO WANL 771:RS:046 8/12/63 LTR TO WANL 771:RS:048 8/14/63 LTR TO WANL 771:RS:050 8/16/63
• NRX-B CEMENTING PROGRAM	-	CONTINUING	AGC LTR TO WANL 771:RS:013 5/20/63

REON ROCKET ENGINE OPERATIONS-NUCLEAR

10-10-63

S/T I.3.0 PROGRAM TECHNICAL GUIDANCE

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.3 AGC NRX-B STUDIES			
a. 6I ELEMENT THERMAL ANALYSIS	—	COMPLETED	AGC MEMO 734:MD:358 8/26/63
b. FABRICATION EVALUATION OF FORGED SUPPORT PLATE	—	COMPLETED	AGC MEMO 746:BIO:422 7/30/63
c. 6I ELEMENT SUPPORT BLOCK DESIGN AND STRESS ANALYSIS	—	COMPLETED	AGC REPORT 10404 JULY 1963 AGC DWG 092645A JULY 1963
d. HEAT TRANSFER STUDIES OF TIE ROD BUTTON	—	COMPLETED	AGC MEMO:729:M:0134 8/16/63
NRX-A MECHANICAL DESIGN REVIEW	—	CONTINUING	430 MECHANICAL DESIGN DRAWINGS REVIEWED AND COMMENTED UPON
NRX-A SPECIFICATION REVIEW AND COORDINATION		CONTINUING	102 SPECIFICATIONS (NTO AND WANL) REVIEWED & COMMENTED UPON

REON ROCKET ENGINE OPERATIONS—NUCLEAR

S/T 1.3.0 PROGRAM TECHNICAL GUIDANCE

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
2-1.3 SPECIAL PROBLEM REVIEW (a) AI BARREL (b) NOZZLE ID SHRINKAGE (c) ALIGNMENT SLEEVE REMOVAL (d) BANDED CORE MODIFICATION (e) INNER REFLECTOR AND NOZZLE INTERFACE	—	CONTINUING	NUMEROUS TWX, MEETINGS AND TELECON REPORT
NRX-A COMPONENT TEST PROGRAM REVIEW AND GUIDANCE.	—	CONTINUING	TNR 095 AND SUBSEQUENT DOCUMENT REVIEW—GUIDANCE MEETING REPORT
PRELIMINARY MODEL SPECIFICATION FOR NERVA NUCLEAR SUBSYSTEM.		COMPLETED	LTR TO WANL 771:RS:043 7/29/63
EXPERIMENTAL AND ENGINEERING PHYSICS PROGRAM REVIEW.		CONTINUING	AGC LTR. TO WANL 770:2095 AND DTD 12 JUL '63 ET SEG

S/T I.3.0 SYSTEM TECHNICAL SUPPORT

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-I.3 • SHIELD DESIGN ANALYSIS FOR MCC (AMF)		COMPLETED	AGC MEMO 744:095: NA 7/22/63
• RADIATION EFFECTS FLUX PROFILE COMPARISON		JULY 63	REON REPORT 2652
• RADIATION ENVIRONMENT OF NERVA ENGINE		COMPLETED	AGC MEMO 744:079 DTD 8/2/63
• INTEGRATED ENGINE OPERATIONAL AND OFF-NORMAL PERFORMANCE ANALYSIS CODE		COMPLETED	OSC AG I AGTRAN
• ENGINE AND FACILITY ACTIVATION ANALYSIS		CONTINUING	11 AGC MEMOS 11/1/62 - 9/30/63
• RADIATION HEATING ANALYSIS		CONTINUING	8 AGC MEMOS, 11/2/62 - 9/23/63
• E-MAD SHIELDING ANALYSIS		COMPLETED	AGC MEMO 774:NA: 021 DTD 4/27/63
• RADIATION FLUX MAP OF NERVA ENGINE		COMPLETED	AGC MEMO 774:NA: 061 DTD 9/27/63
• STANDARD RADIATION MODEL, NERVA ENGINE		COMPLETED	REON REPORT 2492 FEB 63

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REON - ROCKET ENGINE OPERATIONS - NERVA

S/T 1.3.0 SYSTEM TECHNICAL SUPPORT

ACCOMPLISHMENTS

W/S
REFERENCE

PLANNED

ACTUAL

EVIDENCE OF
COMPLETION

- NRX-AI TEST PLAN
COMMENTS
- OTHER S/T SUPPORT

COMPLETED

AGC MEMO 775:NSD:030
DTD 7/23/63

CONTINUING

PARTIAL LIST FOR REP.MO.
AGC MEMO 775:NSD:033
775:NSD:043
775:NSD:045
775:NSD:046
775:NSD:060

- ETS-I COMPOSITE
FLOW DIAGRAM

COMPLETED

AGC MEMO 775:NSD:011

- NRX-AI TEST
SPECIFICATION
COMMENTS

COMPLETED

AGC MEMO 775:NSD:064

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

S/T I.3.0 SYSTEM TECHNICAL SUPPORT

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
ETS -I COOLDOWN REQUIREMENTS		COMPLETED	77I:RS:033 77I:RS:038
NRX-A AND ENGINE NOZZLE ANALYSIS REQUIREMENTS		COMPLETED	77I RI:039
SPENT FUEL COOLING REQUIREMENTS		COMPLETED	77I NSD:088

SUBTASK 1.3 - ACCOMPLISHMENTS FOR CY 1963

Purpose and Objective

The objectives for subtask 1.3 for CY 1963 were:

1. Furnish the necessary management and engineering supervision to provide technical guidance in the design and development of a reactor subassembly that is mechanically and functionally compatible with the NERVA engine development objectives.
2. Conduct a continuing review and analysis, and where necessary perform design on the nuclear and non-nuclear engine components and support equipment to verify or determine the requirements for the reactor integration into the overall NERVA engine system and support equipment items.
3. Review, coordinate and analyze test program plans arising from both the nuclear and non-nuclear engine group to assure the optimum utilization of test facilities and items for the attainment of NERVA design objectives.

In order to accomplish the program objectives, the following general activities were pursued.

1. In conjunction with SNPO and WANL's technical management personnel, a continuous review of the status of the overall nuclear subsystem development program was performed and AGC assisted in determining the course of any necessary redirection of effort.
2. Liaison between WANL and other REON responsible task managers was conducted on a continuous basis to assure adequate exchange of technical information and provision of criteria for maintaining compatibility of nuclear and non-nuclear hardware.
3. A continuous review of designs and specifications generated by WANL was performed to assure adequacy of all parts to meet NERVA requirements.
4. Evaluation of WANL procurement actions was provided on a continuous basis to assure adequate acceptance test and quality control provisions, necessity for hardware being procured and all technical aspects of the procurement actions.

5. Reviewed WANL's efforts in areas of nuclear, heat transfer, fluid flow, and stress analysis to assure that overall system requirements were met and that approaches and methods utilized by Aerojet and WANL were both consistent and adequate.

6. Provided continuing evaluation of component test program to assure careful planning of test program, adequacy of test equipment, optimum utilization of facilities, incorporation of data in reactor hardware design modifications, and evaluation of budgetary, technical and schedular performance.

7. Provided in conjunction with other REON personnel, assistance in the preparation and review of cold flow and hot test plans and specifications.

8. Provided continuing review of LASL designs, tests, and other activities to assure integration in the NRX-A test program of LASL developed technology.

Accomplishment

Integration and technical management functions as performed by REON are not readily identifiable by milestones, and certainly not by hardware demand and test schedules. Rather, they fall into three general classes of work, as follows:

- a) Program planning
- b) Program technical guidance
- c) System technical support

Program planning commenced prior to the beginning of contract year 1963 with preparation of program plans and proposals using information furnished by the various program participants. Once final program acceptance was established with SNPO during CY 1963, revisions were required by changes from expected technical progress, results of LASL tests, and revisions of program guidelines. The revisions, and their implications with respect to the total NERVA program, were analyzed and weighed prior to making recommendations to SNPO. Program and schedule alterations in the non-nuclear area were also reviewed for impact on the nuclear portion of the program. These reviews normally appeared externally as program recommendations and guidance provided in non-nuclear areas.

Chart No. 1 illustrates the overall program planning aspects of this task. Included is the program redirection in the second quarter, preparation of the CY 1964 program plan, and advance planning for the CY 1965 program. In conjunction with each of these, a lengthy process including issuance of project directives detailing the general guidance received from SNPO, meetings with WANL, review of preliminary information submitted by WANL, modification of WANL proposals, and ultimately, preparation of the final documents were accomplished. In May 1963 an extensive review of the NRX-A design was conducted to provide a logical basis for planning CY 1964 and 1965 programs as related to an evaluation of the most likely date on which the NERVA program would have demonstrated a reactor sufficiently to justify proceeding with a full scale engine development program. The results of this design review were incorporated in recommendations related to specific goals for each of the various NRX Block 1 reactor tests.

Program technical guidance in the design and development of the nuclear subsystem could only be intelligently provided by acquiring and maintaining detailed knowledge of the program. This knowledge was acquired through numerous visits to WANL, assignment of two full time technical representatives in large, continual review of all drawings, specifications and reports received, and many technical meetings with WANL and SNPO personnel. Through all of these means, in addition to close attention to routine subcontractor reports (PERT, critical items, regular progress, and topical reports) a detailed knowledge of the program was established and maintained. This knowledge was combined with professional and technical information garnered from related programs, and to a limited extent original design work of a conceptual or preliminary nature performed at REON, into concrete program guidance which was implemented through technical management meetings between REON and WANL, through issuance of project directives, official letters containing guidelines and, as a major activity in program guidance, the review and approval of subcontractor recommendations. Chart No. 2 gives some examples of the effort accomplished in this area.

Technical review of 277 procurement actions was accomplished. In several cases, unnecessary equipment purchase was determined; in at least one case, it was determined that a sole source vendor at higher cost than could be obtained had been selected.

In order to evaluate the optimum direction that the NRX-B effort should take, a careful review of the KIWI-B2A design was undertaken and completed. This review resulted in several potentially troublesome design areas being corrected by LASL and assisted in the determination of the most probable schedule on which any reactor of the KIWI type would have been demonstrated as satisfactory for E-engine development.

An analysis of the module fracture on the B-2A cold flow was conducted with the result that it was determined to be highly likely that this failure resulted from a liquid air-hydrogen explosion. In view of the impact this could have on NRX-A testing, the results of this study have been forwarded to SNPO and WANL for consideration and comment.

An extensive design review of the B-4D design was undertaken at LASL's request to confirm the integrity of that concept. Since this full pressure drop bundling method is an alternative to the WANL solution to the flow induced vibrations which occurred in earlier B4 designs, such an evaluation was imperative. Numerous minor design potential inadequacies were discovered and discussed with LASL.

At the behest of SNPO, Aerojet investigated the potential use of high temperature Pluto critical facilities in the NERVA program and determine that they would be of marginal if any use to the program.

In order to assure that proper regard is given to the requirements for an integrated engine, several documents were prepared for transmittal to WANL to guide them in their NRX-B effort.

In view of the flow induced vibration problems, a study was undertaken to investigate the advantages that might be obtained with clusters cemented together into 7, 19, 37 and 61 element bundles. The results of this study were transmitted to WANL for use in their NRX-B design considerations.

An investigation was also performed to determine the temperature distribution which would occur in an NRX-B core design having a 61 element module. This analysis was utilized in formulating a basis for determining the feasibility of large glued modules.

An evaluation of the NRX-B forged support plate was conducted with specific consideration being given to necessary heat treating, methods of casting, inspection techniques, and machining techniques. Again the results of this study were utilized in evaluation of WANL NRX-B proposed systems.

An analytical method was developed and utilized to determine the structural integrity of support blocks for a 61-element core. Verification of the validity of the analysis was obtained by an experimental investigation using a lucite core base adapter subjected to structural load tests under simulated actual environmental conditions. The strain and deflection stress compared favorably with the theoretical values.

A small test program was performed to evaluate heat transfer to the tie rod support button in the B-4C. A quarter scale model was used and a representative tie rod support button was heated by externally flowed hot gas and internally flowed coolant gas. The support button used in the test program was made of copper and nitrogen was used as the coolant gas.

Technical review of 430 mechanical design drawings was accomplished. Results of these reviews resulted in better capability for review of purchase packages, assistance to WANL on occasion (e.g. doubler strips on the aluminum barrel), and improved coordination of nuclear-non-nuclear hardware mating.

During the course of the year, 102 specifications were reviewed and commented upon and utilized in the course of review of WANL purchase actions.

A number of special problems occurred in CY 63 which required close coordination between REON and WANL. Some of these are listed.

As a result of improper heat treatment, the NRX-A1 Aluminum Barrel required modification. REON participated in the review of the problem and its causes. Discussions were held regarding the implications to the NRX-A1 tests resulting from in-service failure of this component. Suggestions were made regarding procedures for the expeditious evaluation and coordination of the various aspects of the problem. Subsequently REON provided technical support to WANL in regard to methods of repair and the techniques needed to effect this repair.

Nozzle I.D. Shrinkage - Upon receipt of the NRX-A1 nozzle assembly from the brazing operation it was noted that the flange (at the interface of

the nozzle and the inner reflector) had distorted and the I.D. had been decreased from the specified 36.000 inches to 35.900 inches. Acceptability of this discrepancy was worked out with WANL.

Alignment Sleeves - It was learned that WANL had removed the alignment sleeves between the cluster elements and the support blocks for the NRX-A1 reactor. On subsequent investigation it was determined that WANL had removed these sleeves without performing an adequate analysis to determine the effect of element and support block coolant passage mis-alignment. It was requested at this time that the effect of this mis-alignment on the hot channel factor be determined, prior to buildup of NRX-A2. WANL is still evaluating this potential problem.

During the course of the NRX-A1 design, WANL concluded that the installation of a band surrounding the core at the inlet end would be beneficial to the flow stability aspects of the core. The design, the analytical techniques based in determining the design, and the expected performance of the modified design were reviewed and discussed with WANL. REON concurred in this modification in the NRX-A reactor design and so recommended to SNPO.

Detailed cognizance of the NRX-A Component Test Program was maintained with a special view to assuring optimum utilization of facilities, incorporation of test data in design modifications and determination that components as designed would be satisfactory for utilization in system cold flow and hot tests.

A preliminary model specification for the NERVA nuclear subsystem was prepared and transmitted to Westinghouse for utilization in design of the NRX-A systems.

Coordination between the experimental physics effort and the NERVA nuclear engineering effort, to insure that the experimental program and facilities met the engineering requirements, appeared necessary. REON requested that an experimental plan be prepared showing relationship to engineering needs; this plan was subsequently prepared and submitted.

System technical support, as required to properly integrate the nuclear subsystem into the overall NERVA program involved a wide variety of engineering activities. Some examples of this effort are included on the following charts.

A review of shielding for the MCC designed by AMF was requested by the REON group responsible for the MCC, based on casual inspection of the shielding design presented. A detailed review of AMF methods, and a re-analysis of the shielding was performed using current methods available at REON. Substantial advantageous changes in the shield were proposed as a result of this re-analysis.

The radiation flux patterns available from the GTR and ASTR reactors were available only in sketchy form. To insure that NERVA components are tested under conditions at least as severe as those in the eventual engine, a computation of radiation fluxes available was performed expanding the limited information available and compared with expected NERVA fluxes. Test conditions were altered accordingly, to obtain the required fluxes.

It is necessary to identify the radiation environment of the NERVA nozzle, to establish neutron activation hazards on ground test, and potential radiation heating effects in flight. A detailed radiation flux map, by particle and energy level, was constructed to serve this purpose.

To investigate system dynamic behavior under normal and off-normal conditions, including reactor effects from engine-induced transient operation, two IBM 7094 computer codes, OSCAG I and AGTRAN were developed to operational status for system and hazards studies. The latter code is a system analysis code incorporating OSCAG I and yielding reactor effects based on reactor kinetics.

Test operations and hazards analyses require activation analyses of components and facilities, based on the prospective reactor power levels and arrangements of the components of interest during proposed tests. Eleven such analyses were performed during CY 1963.

Test operations, and proposed NERVA operational conditions, require detailed studies of radiation heating in components, which in turn depend on power level and physical location of components, with shielding by other components included. Eight such radiation heating analyses were performed.

Incident to the design criteria for the E-MAD building, an analysis and evaluation of proposed shielding was required by REON to insure adequate and safe operation of spent-engine examination. This analysis was performed and evaluated and radiation criteria measured against predicted shield performance.

To systematize the various radiation studies of the NERVA engine, a radiation flux map of the entire engine, in its reference form, was prepared. This flux map is used for reference, and is kept current as configuration changes are made and additional source information is derived.

To provide a uniform basis for treatment of radiation problems of the engine and its vehicle, a "standard radiation model" of the engine was prepared. This is not a flux map, but rather sets forth a set of characteristics so that calculation uniformity may be achieved. This model is updated periodically at conferences of interested parties.

A vital part of system technical support is the review of proposed reactor test plans to insure that they agree with program objectives and are technically compatible with engine components and systems. The NRX-A1 test plan was reviewed in conjunction with other subtasks, and revised to serve these ends.

WANL external reports such as TME's were reviewed and commented upon for applicability to the system and non-nuclear component design, to insure that the detailed WANL effort is fully integrated into the system design, and that no "mutually exclusive" characteristics are built into the system by the several nuclear and non-nuclear fabricators.

To assure proper operation of the ETS-1, while design was still in a formative stage, it was necessary to describe a composite flow diagram for the test stand with engine installed. This insures that the completed test stand will supply the NERVA engine with all necessary fluids and gases. This study was completed.

Supplementing the reactor test plans, the test specifications must be reviewed to insure compatibility with test stand, non-nuclear hardware, and test objectives. This review was completed for NRX-A1, and specifications modified accordingly.

Supplementing the composite flow diagram for ETS-1, design criteria for post-firing cooldown were required. Requirements for cooldown were derived and published.

Cooling of spent fuel, after removal from the test stand, is required. Criteria for facilities incorporating cooling provisions were prepared.

Conclusions

The preceding represents a sampling of the activities and accomplishments of CY 1963 in subtask 1.3. A more extensive listing of internal memoranda has been prepared also. In summary, during this contract year an extensive effort was undertaken, with SNPO concurrence, to amplify REON's efforts in nuclear subsystem management. The staff was substantially increased over that initially on hand; the majority of the additional personnel having advanced degrees and many years experience in the nuclear field. A markedly improved understanding of WANL's problems and performance has resulted from this amplified effort and with this increased understanding has come better integration of the nuclear and non-nuclear systems, better overall and detailed planning of the WANL effort, improved technical liaison and nuclear subsystem management. Recently, a major effort has gone into the area of improving the WANL procurement activities so that hardware delivery ceases to be the programmatic restriction that it has proven to be in recent months.

SUBTASK 1.3 - BIBLIOGRAPHY

<u>Title or Subject</u>	<u>Document Number</u>	<u>Date</u>
Activation Levels of A1 6061 and T1 A-110-AT Pressure Vessels	774:REIA:007	25 January 1963
Activation of Destruct Test Capsule	774:REIA:011	28 March 1963
Activation of NERVA Turbopump and A1 Nozzle	774:REIA:014	15 April 1963
Report No. 9440-15 (774 Comments On)	774:NA:018	22 April 1963
E-MAD Facility Phase I Nuclear Shielding Report	774:NA:021	27 April 1963
ETS-1 Adapter Heating	774:NA:021	30 April 1963
Activation Analysis of Explosives Irradiation Capsule	774:NA:019 (Revised)	3 May 1963
Fast Neutron Attenuation in LH ₂	774:NA:035	17 May 1963
Radioactivity from ETS Exhaust Duct	774:NA:039	22 May 1963
Activation of NERVA Components	774:NA:042	24 May 1963
Information for Task 3.8	774:NA:045	24 May 1963
Radiation Levels at Throat of NERVA Nozzle	774:NA:047	27 May 1963
Fission Product Plate Out	774:NA:049	31 May 1963
Charts for Attenuation of γ Radiation	774:NA:048	6 June 1963
Activation of NERVA Duct	774:NA:054	25 June 1963
Generation of Decay Heat After Shutdown	774:NA:055	13 June 1963
Radiation Induced Heating in the Exhaust Duct	774:NA:058	27 July 1963
γ and Neutron Heating of Propellant Feed Riser Line	774:NA:062	8 July 1963
γ Heating of NERVA Interface	774:NA:063	9 July 1963
Comments of AMF-ER-7830-"MCC Shielding Analysis of Cab Penetration"	774:NA:064	9 July 1963
Evaluation of γ -Ray Dose Rates in Air from Spent NRX Reactor	774:NA:070	18 July 1963

<u>Title or Subject</u>	<u>Document Number</u>	<u>Date</u>
Activation Analysis of Al Test Capsule	774:NA:072	25 July 1963
γ -Dose from Disposed Duct	774:NA:078	9 August 1963
Radiation Environment of NERVA Exhaust Duct	774:NA:079	2 August 1963
Heating Rates in NERVA Propellant Feed System	774:NA:081	9 August 1963
Activation of Bolt Material	774:NA:087	14 August 1963
Manned Control Car Radiation Level vs Distance from Flat Car Mounted Disassembled Cores	774:NA:092	20 August 1963
γ Environment at Spent Fuel Storage Facility	774:NA:093	16 August 1963
Evaluation of Manned Control Car Shield Design	774:NA:095	22 August 1963
Seating Rates in NERVA Propellant Feed System	774:NA:096	9 August 1963
γ Flux Map of NERVA Engine	774:NA:061	27 September 1963
γ Ray Heating of Dewar to be Used in the GTR Radiation Effects Program	774:NA:102	5 September 1963
Comments on RIFT Environment Specifications	774:NA:107	16 September 1963
Radiation Environment of Bottom of Nozzle	774:NA:108	12 September 1963
New NERVA Nozzle Heating	774:NA:109	12 September 1963
Heating Rates in Test Stand Propellant Line	774:NA:110	19 September 1963
Neutron Activation of the Cylindrical Cryogenic Pressure Vessel and Vacuum Valve to be Used in the GTR Radiation Effects Program	774:NA:111	16 September 1963
Radiation Environment for the Turbine Inlet Line Assembly	774:NA:112	18 September 1963
Evaluation of EFS-1 Radiation Levels Above Adapter	774:NA:113	17 September 1963
γ Heating Values for Pressure Vessel in NDC-6B	774:NA:114	23 September 1963
NERVA Engine Materials Activation	774:REIA:002	1 November 1962
Temperature Rise Due to γ and Fast Neutron Heating in the NERVA Propellant Feed System	774:REIA:003	2 November 1962
Activation of Nozzle and Skirt Coating Material	774:REIA:004	19 November 1962

<u>Title or Subject</u>	<u>Document Number</u>	<u>Date</u>
Procurement of (classified) items	760:4920 (CRD)	16 July 1963
Direction of WANL Fuel Effort	775:139	27 September 1963
Trip Report, LASL Fuel Status	775:037	9 August 1963
Trip Report, Fuel Fabrication Difficulties	775:085	5 September 1963
Trip Report, Fuel Development Status	775:123	27 September 1963
Approval of WANL Fuel Recommendations	TWX	19 August 1963
Approval of WANL Core Recommendations	770:L2155 (CRD)	23 September 1963
Approval of Vibration and Shock Program	770:L2133 (CRD)	17 August 1963
Plugged Core Test Recommendations	775:L092 (CRD)	19 September 1963
G-3 Test; Non-Approval	770:L2091	10 July 1963
LH ₂ Facility Recommendation	TWX 760:4530	16 August 1963
NRX-A Component Test Program Direction	775:111	26 September 1963
Component Test Facilities Review Meeting	TWX 775:1240	30 September 1963
NRX-B CY 1964 Program Recommendations	771:L051 (CRD)	5 September 1963
KIWI B4D Design Comments	771:058	13 September 1963
KIWI B4D Design Comments	771:057	13 September 1963
NRX-B CY 1964 Program Recommendations	771:L062 (CRD)	2 November 1963
NRX-B Design Criteria	771:L048	14 August 1963
NRX-B Forged Plate Design	746:422	10 July 1963
Structural Analysis of Core Base Adapter	Eng Memo (CRD) AGC 10404.5	July 1963
NRX-B Configuration	DWGS 093470 (CRD)	30 September 1963
Fuel Module Thermal Analysis	734:0358 (CRD)	26 August 1963
Fuel Cementing Program	771:L013	20 May 1963
Fuel Cementing Program	771:L011	20 May 1963

S/T I.4 THRUST CHAMBER ASSEMBLY

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
	CONDUCT NRX-A NOZZLE INLET LINE TESTS	DEFERRED	OCT, NOV, '63 NO HARDWARE
	LOWER T.S. STRUCTURAL TEST	PHASE I COMPLETED PHASE II DEFERRED	MONTHLY REPORT FOR AUG '63 FEB - NO HARDWARE
	UPPER T.S. STRUCTURAL TEST	PHASE I COMPLETED PHASE II DEFERRED	MONTHLY REPORT FOR SEPT. '63 FEB-NO HARDWARE
	T.S. RESONANCE SURVEY	COMPLETED	MONTHLY REPORT FOR SEPT. '63

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S/T I.4 THRUST CHAMBER ASSEMBLY

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
2-I.4 A (1)	PERFORM MODIFICATION NOZZLE DESIGN	COMPLETED	NRX-A P/N 284800 (DRAWING) HOT BLEED P/N 294900 (DRAWING)
	DESIGN "U" TUBE NOZZLE	COMPLETED	P/N 285950 (DRWG)
	DESIGN "J" TUBE NOZZLE	COMPLETED	P/N 703560 (DRWG)
	PERFORM NOZZLE EXTENSION DESIGN MODIFICATION	COMPLETED	P/N 294195 (DRWG)
	DESIGN AEROJET NRX-A NOZZLE INLET LINE	COMPLETED	P/N 298065 (DRWG)
13-1.4 (a)	DESIGN & ANALYSIS OF RN-6 NRX-A NOZZLE PROPELLANT INLET LINE	COMPLETED	RN-DR-0001 (REPORT)
2-1.4 A (1)	PERFORM STRUCTURAL ANALYSIS - PRESS. VESSEL FWD CLOSURE BOLTS	COMPLETED	746:B.10-394 (MEMO)

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S/T I.4 THRUST CHAMBER ASSEMBLY

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
2-I.4 A (1)	PERFORM P.V. DESIGN MODIFICATION	COMPLETED	P/N 298252 (CLOSURE DRWG) P/N 2924053 (CYLINDER DRWG)
	PERFORM GIMBAL DESIGN MODIFICATION	COMPLETED	P/N 284843(DRWG)
	PERFORM T.S. DESIGN MODIFICATION	COMPLETED	P/N 296954 (UPPER)(DRWG) P/N 298223 (LOWER)(DRWG)
(2)	PREPARE TCA LAYOUT DRWG FOR BLOCK E-ENGINE	COMPLETED	P/N 101005(DRWG)
(3)	CREATE STRUCTURAL DYNAMICS TEST FIXTURE DRAWINGS	COMPLETED	DRAWING LIST (SEE BIBLIOGRAPHY)

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ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.4 A (4)	PREPARE TEST PLANS AND SPECS FOR TCA AND COMPONENTS	COMPLETED	TEST SPECIFICATIONS & TEST PLAN LIST (SEE BIBLIOGRAPHY)
(5)	DESIGN WATER COOLED ADAPTER	COMPLETED	P/N 296884 (DWG)
(6)	STRUCTURAL ANALYSIS TO DEFINE DYNAMIC RESPONSE OF TCA	COMPLETED	AGC 6000 AGC 10273
2-1.4.B.	EVALUATE NOZZLE JACKET MATERIALS	COMPLETED	SEVERAL FLASH REPORTS - FINAL REPORT IN PREPARATION
2	NOZZLE BRAZE ALLOY DEVELOPMENT	COMPLETED	SEVERAL FLASH REPORTS - FINAL REPORT IN PREPARATION

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ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2 - 1.4. B. 3	TCA MATERIALS EVALUATION	COMPLETED	SEVERAL FLASH REPORTS - FINAL REPORT IN PREPARATION
(4)	LH ₂ HEAT TRANSFER TESTS	COMPLETED	AGC REPORT 2551
	BLEED PORT HEAT TRANSFER TESTS	COMPLETED	SUMMARY REPORT TO BE PUBLISHED 12/1/63
	GENERAL COMPONENTS HEAT TRANSFER ANALYSIS	COMPLETED	SUMMARY REPORT TO BE PUBLISHED 12/1/63
(5)	CMBSP STREAMING TESTS	COMPLETED	SUMMARY REPORT TO BE PUBLISHED 12/1/63
(6)	ANALYSIS OF HOT SIMULATION TESTING CMBSP	COMPLETED	SUMMARY REPORT TO BE PUBLISHED 12/1/63

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ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
13-1.4 (b)	ANALYZE SUITABILITY OF RN-6 NOZZLE AND NRX-A PRESSURE VESSEL	COMPLETED	AGC LRP REPORT NO. SA 63-02037 (0571) DTD 5 AUG 1963
2-1.4 C (1)	FABRICATE HOT BLEED DEVELOPMENT NOZZLES	FABRICATION INITIATED COMPLETION IN CY 64	LONG LEAD ITEMS PROCURED. DEFERRED TO JAN., FEB., MAR., APR., MAY DUE TO FABRICATION PROBLEMS
	FABRICATE ALTERNATE DESIGN NOZZLES	FABRICATION INITIATED. PARTIAL COMPLETION	LONG LEAD ITEMS PROCURED. DEFERRED TO NOV, DEC., DUE TO FAB PROBLEMS WITH STEEL FORGING

REAR ROCKET ENGINE OPERATIONS—NUMBER

S/T I.4 THRUST CHAMBER ASSEMBLY

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
2-I.4C (I)	FABRICATE NOZZLE EXTENSIONS	FABRICATION INITIATED COMPLETION DEFERRED	ITEMS NOT REQUIRED DUE TO DELAY IN NOZZLE FABRICATION DEFERRED TO DEC., JAN., FEB.
	FABRICATE WATER COOLED ADAPTERS (EXTENSION TO DIFFUSER)	FABRICATION INITIATED COMPLETION DEFERRED	ITEMS NOT REQUIRED DUE TO DELAY IN NOZZLE FABRICATION DEFERRED TO OCT, NOV.
	FABRICATE NRX-A DEVELOPMENT PROPELLANT INLET LINES FOR AGC NOZZLE	FABRICATION INITIATED COMPLETION DEFERRED	LONG LEAD ITEMS PURCHASED. DEFERR- ED TO OCT., NOV., DUE TO FABRICATION PROBLEMS

S/T 1.4 THRUST CHAMBER ASSEMBLY

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
13-1.4 C	FABRICATE NRX-A PROPELLANT INLET LINES FOR RN-6 NOZZLES	COMPLETED	
2-1.4 C (2)	FABRICATE (7) NRX-A NOZZLES	FABRICATION INITIATED 1 COMPLETE 4 PARTIAL COMPLETION DEFERRED	LONG LEAD ITEMS PROCURED. TESTED IN SEPT '63 DEFERRED TO CY '64 DUE TO FAB PROBLEMS (OCT., DEC., JAN., FEB.)
13-1.4 d	MODIFY TWO NRX-A NOZZLES TO INCOR- PORATE CAMERAS AND LIGHTS	MODIFICATION INITIATED ON (2) UNITS. COMPLE- TION IN CY '64	DEFERRED TO OCT, NOV. DUE TO FAB PROBLEMS

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S/T 1.4 THRUST CHAMBER ASSEMBLY

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.4 C (3)	COMPLETE 2 HEATED BLEED NOZZLES (RBU)	(1) COMPLETE (2) DEFERRED TO CY '64	TESTED JUNE '63 DEFERRED TO DEC DUE TO FAB PROBLEMS
(4)	FABRICATE ADAPTERS (NOZZLE TO INJECTOR)	FABRICATION INITIATED-2 DEFERRED TO CY '64	ITEM NOT REQUIRED DUE TO DELAY NOZZLE AVAILABILITY (NOY)
	FABRICATE INJECTORS	(1) COMPLETED (2) DEFERRED TO CY '64	ITEM NOT REQUIRED DUE TO DELAY IN NOZZLE AVAILABILITY NOV.
	FABRICATE PLUMBING	COMPLETED	UTILIZED IN TESTING

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S/T I.4 THRUST CHAMBER ASSEMBLY

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.4 C (4)	FAB P.V. FOR STRUCTURAL TESTING	(1) COMPLETED	APRIL (A1)
(5)	MODIFY GEN. II MOD. 1 P.V. FOR CRITICALITY TESTS	COMPLETED	SHIPPED TO WANL JUNE '63 P.V. CYL 294997 P.V. CLOSURE 294052
(6)	FAB FOUR (4) NRX-A P.V.	(2) COMPLETED	APRIL & SEPT 1963 APRIL UNIT CYL 283094. (NRX-A1) CLOS 283095 SEPT UNIT CYL 294053. (NRX-A2) CLOS. 298252
		(2) DEFERRED	DUE TO FORGING REDESIGN OCT '63 (NRX-A3) NOV '63 (NRX-A4)

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S/T I.4 THRUST CHAMBER ASSEMBLY

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
2-I.4C (7)	FAB ONE P.V. OF ALTERNATE MATERIAL (T)	COMPLETE	MARCH 1963 CLOSURE 262223 CYL 262222
(8)	COMPLETE FABRICATION 2 KIWI B NOZZLES	COMPLETE	TEST RESULTS TEST REPORT R-C 6415
	COMPLETE FABRICATION 2 HYBRID NOZZLES	COMPLETE	REPORT NO.8207-63-9
	COMPLETE FABRICATION 1 NERVA HEATED BLEED NOZZLE	CAST & STRIPPED 2 TIMES DEFERRED	DEFERRED TO JAN. DUE TO FABRICATION PROBLEMS
(9)	FAB 4 T.S.	1 COMPLETED 3 DEFERRED	USED IN TCA TEST #NV-DL 025-5V EXPECTED 11/64 AND 12/64

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S/T 1.4 THRUST CHAMBER ASSEMBLY

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.4 C (10)	FAB 3 GIMBALS	1 COMPLETED	USED IN TCA TEST *NV-DL-025-5V
		2 DEFERRED	EXPECTED 11/64
(11)	FAB DUMMY CORE	COMPLETED	USED IN TCA TEST *NV-DL-025-5V
(12)	FAB PRESSURE VESSEL -TO-NOZZLE METALLIC SEALS	(a) COMPLETED	1ST ORDER ON P/N 286766 (P.V-CLOSURE) P/N 286767 (P.V.-NOZZLE) COMPLETED JULY'63 (TESTING WAS INITIATED)
		(b) DEFERRED	2ND ORDER PARTIALLY COMPLETE(ACFI) REMAINDER DUE OCT '63 P/N3-509393 (NOZZLE END) P/N 3-510412 (CLOSURE END DELAY DUE TO FAD PROBLEMS

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S/T 1.4 THRUST CHAMBER ASSEMBLY

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.4 C (13)	FABRICATE TWO NRX-A DELIVERABLE PROPELLANT INLET LINES	FABRICATION INITIATED. COMPLETION DEFERRED	DELAY DUE TO GIMBAL BELLOWS-PROCURE- MENT PROBLEMS DEFERRED TO NOV, DEC.
2-1.4 D (1)	CONDUCT INJECTOR DEVELOPMENT TESTS	COMPLETED	MONTHLY REPORT FOR JUNE 1963
(2)	TEST PV/NOZZLE SEALS	COMPLETED	MONTHLY REPORT FOR SEPT. 1963
	CONDUCT NOZZLE DEVELOPMENT TESTS	(5) TESTS CONDUCTED	MONTHLY REPORTS FOR APRIL, JUNE & SEPT 63
	CONDUCT NOZZLE PFNTS TEST	DEFERRED	MARCH 1964 - NO HARD- WARE ON FACILITY
	CONDUCT NOZZLE EXTENSION TESTS	DEFERRED	MARCH 1964 - NO HARDWARE

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S/T 1.4 THRUST CHAMBER ASSEMBLY

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
	COMPONENT DEVELOPMENT TESTS ON PRESSURE VESSELS (TI & AL)	COMPLETED	TI, STRUCTURAL SERIES #1 7-30-63 AI STRUCTURAL SERIES #2 6-21-63
2-1.4 D (3)	ACCEPTANCE TEST NRX-A NOZZLES	DEFERRED	NOV. 1963 - LACK OF HARDWARE
(4)	CONDUCT HYBRID NERVA NOZZLE, ACFI P.V. STRUCTURAL TEST	COMPLETED	TEST REPORT R-C6415 DTD 22 MAR 1963
(5)	INITIATE TCA DYN TEST	COMPLETED	MONTHLY REPORT FOR SEPT 1963
(6)	CONDUCT TESTS HOT BLEED PORT CON- FIGURATION XLR 87 CHAMBERS	COMPLETED	LRP REPORT FOR 9660-001
	CONDUCT TESTS PROTOTYPE (HOT BLEED PORT) NERVA NOZZLES	DEFERRED	DELAY DUE TO NOZZLE FAB- RESCHEDULE TO JAN '64

S/T 1.4 THRUST CHAMBER ASSEMBLY

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
13-1.4 (e)	TEST RN-6 NOZZLE - NERVA PRESSURE VESSEL	DEFERRED	PENDING EVALUATION OF RN-6 NOZZLE ACFI P.V. TEST BY ACFI

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SUBTASK 1.4 - ACCOMPLISHMENTS FOR CY 1963

Purpose and Objective

The overall purpose of the work to be performed under this task item is to develop the Thrust Chamber Assembly (TCA) for the NERVA engine. The TCA is defined as including the nozzle assembly, pressure vessel, thrust structure, and gimbal assembly. Principal effort in this contract year was directed to develop those components which form a part of the CFDTS, NRX-A, and the Block I E-engine.

An additional objective was to complete the hybrid nozzle - ACFI KIWI-B pressure vessel structural test program.

The specific accomplishments during this period with respect to the work statements for this subtask were as follows:

2-1.4A(1)

The objective of this effort was to design the thrust chamber assembly components for NRX-A tests and component development tests. Designs were completed for the NRX-A nozzle, the hot bleed port nozzle and the "U" tube (alternate design) nozzle, based on the results of analyses and supporting development and material tests. Design of the J-tube nozzle was completed. In addition, the NRX-A nozzle propellant inlet line was designed for both an Aerojet nozzle and the Rocketdyne RN-6 nozzle. Structural analyses were performed on the pressure vessel forward closure bolts which demonstrated that the uncooled bolt design was adequate with the aluminum dummy shield. The NRX-A2, -A3, and -A4 pressure vessel design was completed.

Gimbal and thrust structure designs were completed for fabrication of component development units. The gimbal design provides improved axial and lateral load capabilities to sustain vibration, shock loads, and the inertia and thrust loads to which the gimbal will be subjected during flight operation. The thrust structure design incorporates increases stiffness for the Thrust Vector Control Actuator (TVCA) supports, a one-piece gimbal support housing, and an improved NERVA/RIFT interface flange. A preliminary design was developed for the bolted and/or clamped configuration of the NERVA/RIFT interface joint.

2-1.4A(2)

The thrust chamber assembly layout drawing for the Block I E-engine was updated to reflect the latest component designs.

2-1.4A(3)

Drawings were completed for fixtures to be utilized in support of the thrust structure resonance survey and static testing, and the thrust chamber assembly dynamic test.

2-1.4A(4)

The test plans and specifications were completed for the thrust structure and pressure vessel development tests and thrust chamber assembly dynamic tests.

2-1.4A(5)

A water cooled adapter design was completed to permit the simulated testing of the nozzle and skirt assembly at altitude conditions and NERVA throat heat fluxes.

2-1.4A(6)

Structural analyses were initiated in support of the thrust chamber assembly dynamic test. The portion of the analyses which defines the response characteristics of the thrust vector control actuator and support structures was completed. The required ranges of instrumentation were established for the TCA dynamic test.

2-1.4B(1)

The objective of this effort was to evaluate nozzle tube bundle support jackets fabricated from cast materials and forged materials. In support of the nozzle casting effort, laboratory work was accomplished to identify alloying constituents in the pour having major influence on the properties of the cast jacket. As indicated by improvement in elongation properties in the casting, investigations were conducted on the forged jacket supporting the "U" tube and "J" tube nozzle. Stainless steel was selected on the basis of ease of fabrication.

2-1.4B(2)

The objective of this program was to evaluate by laboratory testing brazing alloys to establish brazing parameters and fabrication techniques for the nozzle tube bundle assembly. As a result of this effort the braze alloy for the cast jacket nozzles was verified and a new braze alloy was selected for the "U" tube nozzles.

2-1.4B(3)

The objective of this effort (see LRP Report 63-4) was to investigate candidate materials (high strength A-286, 18% nickel Maraging steel, and Inconel 718) for the bolts for the primary TCA joints (nozzle/PV, PV/closure, and TS/gimbal). As a result of tests and analyses completed thus far, it appears that A-286 is adequate for the bolts. In addition, titanium was recommended as the preferred material for pressure vessel fabrication based on strength to weight ratio at both ambient and cryogenic conditions. However, lack of radiation effects data at cryogenic temperatures precludes selection of Ti at this time.

2-1.4B(4)

LH₂ heat transfer tests. The objective was to define heat transfer conditions in the tube section near the core under reduced power operation of the engine. The test data obtained was found to correlate with previous data verifying the heat transfer analysis for the nozzle.

Scale model hot-bleed port heat transfer tests. The objective was to define the effects of relocation of the bleed port from the cylindrical section to the convergent section of the nozzle. These tests indicated that relocation could be effected without any effect on heat transfer or fluid flow through the bleed port.

General components heat transfer analysis. Objective to better define thermal design criteria of the nozzle by improving heat transfer correlations. The test data was found to substantiate the heat transfer data previously obtained.

2-1.4B(5)

CMBSP streaming test. The objective was to define the jet impingement effects caused by CMBSP in the converging section of the nozzle. It was demonstrated that the heat transfer was significantly affected by core outlet geometry and distance from the tube handle.

2-1.4B(6)

Analysis of hot simulation testing CMBSP. The objective was to define the effects of H_2O_2 combustion gases on graphite (as a candidate material for simulating the CMBSP exit geometry) by analysis and a scale-model testing program. The tests were performed and it was determined that the reaction rate was found to correlate as a function of graphite surface temperature. The data acquired will permit determination of erosion rate and thus lead to the determination of the feasibility of a chemical propellant test of the CMBSP.

13-1.4(b)

The objective of this effort was to evaluate the adequacy of the Rocketdyne RN-6 nozzle joint and the NRX-A pressure vessel. As a result of this analysis effort, the nozzle was considered to be acceptable for use with the NRX-A pressure vessel.

2-1.4C(1)

The objective of this program was to fabricate thrust chamber assembly components for NRX-A reactor test assemblies and for component development tests in support of E-engine designs. As a result of this effort, fabrication was initiated on hot bleed development nozzles, alternate design nozzles ("U" tube and "J" tube), nozzle extensions, water cooled adapters and nozzle propellant inlet lines for the Aerojet nozzle. Completion of fabrication of the above items was deferred to CY 1964 due to fabrication problems with the nozzle jacket and propellant inlet line gimbal-bellows.

13-1.4C

Fabrication of the NRX-A propellant inlet lines for the RN-6 nozzle was initiated and committed by purchase order as required.

2-1.4C(2) and 13-1.4d

Fabrication was initiated on 7 NRX-A nozzles. Modification of 2 units was initiated to incorporate camera and light ports for NRX-A1 cold flow test. One other unit, Serial No. 004, was completed and subjected to hot fire testing. Completion of the balance of the items will be accomplished in CY 1964.

2-1.4C(3)

The original objective of this effort was to provide 2 KIWI-B reactor backup nozzles for LASL fabricated to the NERVA configuration. Because of nozzle fabrication problems, and subsequent delay in completion of these units, these nozzles were diverted to NERVA component development test. One unit was completed and hot-fire tested. Completion of the second unit will be accomplished in CY 1964.

As indicated in this presentation, because of the nozzle jacket fabrication problems, considerable deferral of work occurred. However, I would like at this time to indicate the large activity in the nozzle fabrication area devoted to investigating and overcoming this problem area. During CY 1963 fabrication of 26 nozzles was funded on Subtask 14. (23 tube bundle and 3 structural). One was deleted when the tubing was lost in a fire (S/N 0000003 Reactor Backup). These nozzles are summarized below.

Nozzle Fabrication Status as of 30 September 1963

1.	Fabrication Authorized (CY 1963)	26
	Deletion of S/N 0000003	<u>1</u>
	Net Funded	25
2.	Nozzles Fabricated	
	Completed	9
	S/N 001K	
	002K	
	001H	
	002H	
	0000002	
	0000004	
	001S	
	002S	
	003S	

In Process Fabrication 13

001H (After Recast)
001N (After Recast)
0000001
0000005
0000006
0000007
0000010
0000011
0000012
0000013
0000008
0000009
"J" Tube

Total Nozzles Completed and/or in Process 22

3. Long Lead Items Procured for 5
Nozzle Fabrication to be Initiated in CY 1964

4. Number of Nozzles Stripped and Recast 5
S/N 001K
002K
001H
001N
006 (Stripped, to be recast in CY 1964)

Thus, the equivalent of at least 27 nozzles have been fabricated and cast. This effort has resulted in substantially improved nozzle properties (elongation in the 6% minimum area) as demonstrated by the last several nozzles cast. In addition, the last nozzle cast (S/N 011 for the NRX-A1 CF test) shows satisfactory X-ray condition.

2-1.4C(4)

The objective of this effort was to fabricate adapters, injectors, and plumbing for nozzle simulation testing in the LRP test area. A portion of this work was not completed due to nozzle fabrication problems. In addition, an aluminum pressure vessel was completed for structural testing (hydrostatic proof test with dummy nozzle).

2-1.4C(5)

The objective of this effort was to modify the aluminum pressure vessel which had been used in the CY 62 Gen II Mod 1 simulation program to the NRX-A1 configuration for reuse at WANL in criticality test. This objective was completed. The pressure vessel was delivered in June 1963.

2-1.4C(6)

The objective of this effort was the fabrication of NRX-A pressure vessels. Two were completed. As a result of a forging redesign which delayed procurement and fabrication, two will be completed early in CY 64.

2-1.4C(7)

The objective of this effort was to complete the fabrication of a titanium pressure vessel which was initiated in CY 62. This effort was completed and the unit was utilized in pressure vessel structural testing series No. 1 and thrust chamber assembly dynamic tests.

2-1.4C(8)

The objective of this effort was to complete the fabrication of two KIWI B nozzles, two hybrid nozzles and one NERVA heated bleed nozzle. The two KIWI B and two hybrid nozzles were completed. One KIWI B nozzle failed in hydrotest. As a result of this test, wire interlocks between the tube bundle and casting were incorporated in the design. The second KIWI B nozzle was expended in hot-fire testing. One hybrid nozzle was utilized in the NERWI nozzle-pressure vessel structural test described below. The second hybrid nozzle was completed and ready for hydrotest at the end of this contract year. The NERVA heated bleed nozzle (S/N 001N) has been cast and stripped twice in the course of the nozzle jacket casting development program. Final casting should occur in January.

2-1.4C(9)

The objective of this effort was to fabricate thrust structures for thrust chamber assembly, TPA, CFDTS, and component development testing. One unit was completed and utilized in thrust chamber assembly dynamic testing and static structural and dynamic testing and three units were deferred to early CY 64 to incorporate the design improvements and modifications which were indicated from the results of the experience with the first unit fabricated.

2-1.4C(10)

The objective of this effort was to fabricate gimbals for TCA, TPA, and CFDTS. One unit was completed and utilized in thrust chamber assembly

dynamic test and thrust structure resonance survey. Two units were deferred to CY 64 due to forging procurement delays.

2-1.4C(11)

The objective of this effort was to fabricate a non-graphite dummy reactor core for the thrust chamber assembly dynamic test. This was completed and will be utilized in Phase II of the thrust chamber assembly dynamic test.

2-1.4C(12)

The objective of this effort was to fabricate metallic seals for the pressure vessel-closure and pressure vessel-nozzle joints. This effort was separated into 2 procurement orders, the first to Marquardt and the second to ACFI, the latter vendor being the supplier to LASL on the KIWI program. The first order was completed and the seals were utilized in development testing with ambient temperature helium. The second order from ACFI was partially completed with the remaining seals deferred to CY 64. This delay was due to fabrication and inspection problems at ACFI.

2-1.4C(13)

The objective of this effort was to fabricate two NRX-A propellant inlet lines. Fabrication was initiated during CY 63 with completion scheduled to occur in November and December due to the long lead times associated with gimbal bellows procurement.

2-1.4D(1)

The objective of this effort was to test injectors to investigate extended firing duration capability required for NERVA nozzle development simulation tests. Tests were conducted utilizing the XLR-87-AJ-1 thrust chamber. Test results indicated that additional development effort will be required to achieve the desired durations.

2-1.4D(2)

The objective of this effort was to evaluate thrust chamber assembly components under various operation conditions. The Marquardt metallic seals were tested to 50% proof pressure under ambient conditions with helium. Leakage was observed in excess of the allowable values. Redesign of the seals has been initiated due to this problem. The ACFI omega metallic seal tests were not

conducted due to vendor inspection problems with the seals and will be performed in CY 64. Three nozzles were subjected to hot-fire testing; one KIWI-B, one NRX-A and one reactor backup nozzle. The jacket mechanical properties were evaluated through prechill of the nozzles and chilldown during the firing. Start transients were evaluated during these tests and heat transfer data was obtained. The nozzle PFNTS tests and extension tests were deferred to CY 64 due to lack of hardware and shifting of the H-area window for the test facilities. The NRX-A nozzle inlet line tests were deferred to CY 64 consistent with the rescheduling of the nozzle tests. The resonance survey and Series I Structural Test of the thrust structure were completed. These tests demonstrated the ability of the thrust structure to withstand limit loads in an ambient environment.

Structural test Series No. 1 (limit load survey) was completed utilizing a simulated nozzle with a titanium pressure vessel. During these tests, the vessel was subjected to pressures of 110% proof. Structural test series No. II was completed utilizing an aluminum pressure vessel and simulated nozzle. This pressure vessel was subjected to 100% proof pressures. Experimental data obtained from these tests verified the prediction of deflections, rotations and strain.

2-1.4D(3)

The objective of this effort was to conduct hot-fire tests on the NRX-A nozzles at NERVA throat heat flux conditions. This effort is deferred to CY 64 due to the nozzle casting problem.

2-1.4D(4)

The objective of this test was to evaluate the hybrid NERVA nozzle and ACFI pressure vessel assembly under NERVA proof pressure conditions in a hydrostatic test for LASL (NERWI test). The nozzle and pressure vessel were instrumented to record strain, deflections, and rotations, for comparison with predicted values. The test resulted in a nozzle shear lip failure at 95% proof pressure. In general, analytical predictions were substantiated. As a result of these tests, redesign of the shear lip was performed.

2-1.4D(5)

The objective of this effort was to initiate thrust chamber assembly dynamic testing using thrust structure, gimbal, pressure vessel and nozzle, and a dummy reactor core. Phase I of this effort was completed using a thrust structure assembly and pressure vessel, without a nozzle or simulated core.

2-1.4D(6)

The objective of this effort was to conduct development tests of hot bleed port configurations using XL-87-AJ-1 (Titan) thrust chamber and also to evaluate the resultant bleed port design on a prototype NERVA nozzle. The Titan chamber bleed port tests were completed. The results contributed toward the refinement of the analysis and design of the bleed port which was incorporated in the NERVA nozzle design. The prototype NERVA bleed port nozzle tests were deferred to CY 64 due to delays associated with the nozzle jacket casting problem. (It should be noted that the first hot bleed port nozzle was diverted to the NRX-A1 ported nozzle configuration.)

13-1.4(e)

The objective of this effort was to initiate testing of the Rocketdyne RN-6 nozzle and NERVA pressure vessel joint similar to the (NERWI) structural tests described above in Paragraph 2-1.4D(4). This test was to be conducted in the event that a similar test at ACFI (with a dummy RN-6 nozzle and ACF pressure vessel) indicated that the test would be necessary with the NRX hardware. This effort was not initiated in CY 63 due to delays in the ACF test and will be conducted in CY 64 if required. In addition, the following effort not proposed for CY 63 was performed:

1. Analyses for Skirt Coolant Presentation in March 1963
2. Nozzle Fabrication Presentation at SNPO-W
3. Incorporation of and test planning for RN-6 nozzle
4. Analyses for Thrust Vector Control Studies for the RIFT mission.

Conclusions

There were 20 separate milestones required for completion during CY 63 on Subtask 1.4. The objectives for seventeen of these milestones were achieved. A brief description of the deferred effort is as follows:

1. Complete Fabrication Reactor Backup
Two (2) NERVA nozzles for LASL	One of the two reactor backup nozzles is deferred to CY 64 due to fabrication problems with the cast jacket.
2. Complete Pressure Vessel and NRX-A Nozzle	Fabrication of two pressure vessels were completed. Fabrication of two nozzles deferred to CY 64 due to fabrication problems with the cast jacket.
3. Complete Fabrication of NRX-A Propellant Feed Line for Rocketdyne RN-6 Nozzle	Fabrication was deferred to CY 1964 due to delays in gimbal-bellows fabrication.

In conclusion, it is evident that considerably more effort was required in this subtask than was proposed. As a result of this increased activity, significant progress has been made toward the solution of the nozzle casting problem. In addition, a second nozzle fabrication vendor is being developed. Concurrently, designs for alternate nozzle configurations have been completed for incorporation in the program if required.

SUBTASK 1.4 - BIBLIOGRAPHY

Work Statement Reference	Item	Number
2-1.4 A (1)	Drawing	284800
	Drawing	294900
	Drawing	294195
	Drawing	298065
13-1.4 (a)	Report	RN-DR-0001
	Report	746:B.10:394
2-1.4 A (1)	Drawing	298252
	Drawing	294053
	Drawing	284843
	Drawing	296954
	Drawing	298223
2-1.4 A (2)	Drawing	701005
2-1.4 A (3) (T.S. resonance survey)	Joint Fixture	T-430619-301
	Drive Ring	T-430619-501
	Tripod Assy	T-430619-401
	Shaker Seismic Mass	T-430619-201
(TCA Dynamics Test)	Drive Quadrant	T-430623-214
	Pneumatic Support Assy	T-430623-201
	Shaker Seismic Mass	T-430623-401
	Longitudinal Drive Cone	T-430623-309
(Pressure Vessel)	Ti P.V. Test Plan	9548-62-6
	Ti P.V. Test Spec	280N-TP
	Al P.V. Test Plan	8207-63-14
	Metallic Seals Test Plan	9443-63-11
	Test Spec Metallic Seals	904N-TP
	Al P.V. Hydrastatic Proof Test Plan	808N-TP
	Test Spec	9443-63-6
	Test Plan for NRX-A	9443-63-10
	Test Plan	9443-63-12
	Transverse Drive Ring	T-430623-403
	Longitudinal Flexures	T-430623-308
2-1.4 A (4) (TCA)	Dynamic Test Plan	9443-63-3
	Dynamic Test Spec	NV-DL-025-SV

Work Statement
Reference

Item

Number

2-1.4 A (4)	(Thrust Structure)	Structural Test Plan	9548-62-7
		L.T.S. Structural	748N-TP
		UTS Test Spec	749N-TP
		Resonance Survey	
		Test Plan	9443-63-8
		Resonance Survey	
		Test Spec	3800-RM-001
		Gimbal Test Plan	9626-63-1
2-1.4 A (5)		Drawing	296884
2-1.4 A (6)		Report	AGC 6000
		Report	AGC 10273
2-1.4 B (1)		Flash Reports	63-123, 63-136, 63-139,
		Nozzle Cast Jacket	63-162, 63-164, 63-171,
			63-180, 63-199, 63-211,
			63-228, 63-252, 63-253,
			63-272, 63-277, 63-281,
			63-282, 63-285, 63-297,
			63-298, 63-302, 63-309,
			63-312, 63-315, 63-322,
			63-334, 63-336, 63-347,
			63-355, 63-361, 63-361,
			63-362, 63-372, 63-378,
			63-387, 63-389, 63-407,
			63-412, 63-414, 63-415,
			63-420, 63-421, 63-424,
			63-443, 63-446, 63-453,
			63-458, 63-480, 63-482,
			63-483, 63-489, 63-522,
			63-531, 63-535
2-1.4 B (2)		Flash Reports	62-579, 63-165, 63-210,
		Nozzle Brazing	63-496
2-1.4 B (3)		Flash Reports	63-245, 63-454, 63-520,
		TCA Materials	63,524, 63-540
		PVA Materials	62-602, 63-183, 63-185,
			63-239, 63-313, 63-321,
			63-321A, 63-419, 63-460,
			63-473
2-1.4 B (4)		Report	AGC 2551
2-1.4 B (5)		Summary Report	To be published 12-1-63
2-1.4 B (6)		Summary Report	To be published 12-1-63
13-1.4 (6)		AGC LRP Report	SA 63-02037 (0571)

Work Statement Reference	Item	Hardware Status
2-1.4 C (1)	Hot Bleed Development Nozzles	Deferred to CY 64
2-1.4 C (1)	Alternate Design Nozzles	Deferred to Nov., Dec.
2-1.4 C (1)	Nozzle Extensions	Deferred to Dec., Jan., Feb.
	Watercooled Adapters	Deferred to Oct., Nov.
	NRX-A Development Propellant Inlet Lines for AGC Nozzle	Deferred to Oct., Nov.
13-1.4 C	NRX-A Propellant Inlet Lines for RN-6 Nozzle	Deferred to Nov.
2-1.4 C (2)	NRX-A Nozzles	(1) Tested in Sept. 1963 (4) Deferred to CY 64
13-1.4 C	NRX-A Nozzles	(2) Deferred to Oct., Nov.
2-1.4 C (3)	Heated Bleed Nozzles	(1) Complete (1) Deferred to CY 64
2-1.4 C (4)	Adapters	Deferred to CY 64
	Injectors	Deferred to CY 64
	Plumbing	Completed
2-1.4 C (4)	P. V. for Structural Testing	Completed
2-1.4 C (5)	Modify Gen. II Mod. I P.V.	Completed
2-1.4 C (6)	NRX-A P. V.	Completed (2)
2-1.4 C (6)	NRX-A P. V.	Deferred (2)
2-1.4 C (7)	P.V., Alternate Material	Complete
2-1.4 C (8)	2 KIWI B Nozzles	Complete
	2 Hybrid Nozzles	Complete
	1 NERVA Heated Bleed Nozzle	Deferred to CY 64
2-1.4 C (9)	Thrust Structure	(1) Completed (3) Deferred to CY 64
2-1.4 C (10)	Gimbals	(1) Completed (2) Deferred

Work Statement
Reference

Item

Hardware Status

2-1.4 C (11)	Dummy Core	Completed
2-1.4 C (12)	Pressure Vessel-to- nozzle metallic seals	286766 - Completed 286767 - Completed 3-509393 - Deferred 3-510412 - Deferred
2-1.4 C (13)	NRX-A Deliverable Propellant Inlet Lines	Deferred

Work Statement Reference	Item	Test Status
2-1.4 D (1)	Injector Development Tests	Completed - June 1963 Monthly Report (LO560-10-24)
2-1.4 D (2)	FV/Nozzle Seals	Completed - Sept. 1963 Monthly Report (LO560-10-27)
2-1.4 D (2)	Nozzle Development Tests	Completed - Monthly Reports April 1963 - LO560-10-22 June 1963 - LO560-10-24 Sept. 1963 - LO560-10-27
	Nozzle PFNTS Tests	Deferred to CY 64
	Nozzle Extension Tests	Deferred to CY 64
	NRX-A Nozzle Inlet Line Tests	Deferred to CY 64
	Lower T.S. Structural Test	Phase I Completed Monthly Report-August 1963 LO560-10-26 Phase II Deferred.
	Upper T.S. Structural Test	Phase I Completed Monthly Report - Sept. 1963 LO560-10-27 Phase II Deferred.
	T. S. Resonance Survey	Completed - Monthly Report Sept. 1963 (LO560-10-27)
	P.V. Component Development Tests	Completed Ti, Structural Series #1 7-30-63 Al, Structural Series #2 6-21-63
2-1.4 D (3)	Acceptance Test NRX-A Nozzles	Deferred
2-1.4 D (4)	Hybrid NERVA Nozzle, ACFI P.V. Structural Test	Completed - Test Report R-06435, 3-22-63
2-1.4 D (5)	TCA Dynamic Test	Completed - Monthly Report Sept. 1963 (LO560-10-27)

Work Statement
Reference

Item

Test Status

2-1.4 D (6)	Hot Bleed Port Configuration XLR 87 Chambers	Completed - LRP Report TCR 9660-001
	Prototype (Hot Bleed Port) NERVA Nozzles	Deferred to CY 64.
13-1.4 (e)	RN-6 Nozzle-NERVA P.V.	Deferred.
13-1.4 (f)	NRX-A Phase II	Deleted - Customer Request, Sept. 1963

CONTRACT YEAR 1963

TASK ITEM 1.4

↑ MILESTONE ACHIEVEMENT

◆ RESCHEDULED MILESTONE ACHIEVEMENT

RESCHEDULED TO CY 64

Sheet 1 of 2

CONFIDENTIAL

CONFIDENTIAL

◆ RESCHEDULED MILESTONE ACHIEVEMENT

RECON

ROCKET ENGINE
OPERATIONS...MIL/YEAR

AEROSPACE
GENERAL

HARDWARE STATUS

9-30-63

TASK ITEM 1.4

TASK TITLE THRUST CHAMBER ASSEMBLY

COMPONENT/SUB-ASSEMBLY	END USE	EST.	ACTUAL	REMARKS
THRUST CHAMBER ASSEMBLY	Component Development	1	1	
THRUST CHAMBER ASSEMBLY	NRX-A Reactor Test	4	1	
SEALS - PRESSURE VESSEL TO NOZZLE	Component Development	40	32	
NON-GRAPHITE DUMMY REACTOR	Component Development (TCA Dynamic Test)	1	1	
SKIRT	Component Development	2	2	
NOZZLE	Component Development	5	0	
NOZZLE	PFNTS	1	0	
NOZZLE ATTACHMENT HARDWARE (SETS)	Component Development	6	4	
NOZZLE ATTACHMENT HARDWARE (SETS)	PFNTS	1	0	
ADVANCE NOZZLE	Component Development	2	0	
IGNITERS	Component Development	42	42	
IGNITERS	PFNTS	4	0	
THRUST CHAMBER THRUST SUPPORT STRUCT.	Component Development	2	2	
THRUST CHAMBER THRUST SUPPORT STRUCT.	PFNTS	1	0	
INJECTOR	Component Development	2	2	
INJECTOR	PFNTS	1	0	
ADAPTER-INJECTOR TO NOZZLE	Component Development	1	0	
ADAPTER-INJECTOR TO NOZZLE	PFNTS	1	0	
FUEL INLET LINE	Component Development	5	3	
THRUST CHAMBER OXIDIZER VALVE	Component Development	4	0	
THRUST CHAMBER OXIDIZER VALVE	PFNTS	1	0	
THRUST CHAMBER FUEL VALVE	Component Development	5	0	
THRUST CHAMBER FUEL VALVE	PFNTS	2	0	
INJECTOR DEVELOPMENT LR-87 - COMB. CHAMBER	Component Development	2	2	

SHEET 1 OF 3

HARDWARE STATUS

9-30-63

TASK ITEM 1.4
TASK TITLE THRUST CHAMBER ASSEMBLY

COMPONENT/SUB-ASSEMBLY	END USE	EST.	ACTUAL	REMARKS
LOWER THRUST STRUCTURE	Component Development & TCA Dynamic Testing	2	1	
LOWER THRUST STRUCTURE	CFDTS	1	0	
LOWER THRUST STRUCTURE	TPA Assembly Test	1	0	
UPPER THRUST STRUCTURE		1	0	
UPPER THRUST STRUCTURE	Component Development and TCA Dynamic Testing	2	1	
UPPER THRUST STRUCTURE	CFDTS	1	0	
REMOTE DISCONNECT	TPA Assembly Test	1	0	
REMOTE DISCONNECT	Component Development	2	0	
REMOTE DISCONNECT	TPA Assembly Test	1	0	
GIMBAL ASSEMBLY	CFDTS	1	0	
GIMBAL ASSEMBLY	TCA Dynamic Tests	1	1	
GIMBAL ASSEMBLY	TPA Assembly Tests	1	0	
THRUST BEARING	CFDTS	1	0	
THRUST BEARING	TCA Dynamic Tests	4	4	
THRUST BEARING	TPA Assembly Tests	2	4	
RADIAL BEARING RACES	CFDTS	2	4	
RADIAL BEARING RACES	TCA Dynamic Tests	8	12	
RADIAL BEARING RACES	TPA Assembly Tests	4	4	
BEARING HOUSING FORGING	CFDTS	4	4	
BEARING HOUSING FORGING	TCA Dynamic Tests	4	3	
BEARING HOUSING FORGING	TCA Assembly Tests	2	1	
PRESSURE VESSEL ASSEMBLY	CFDTS	2	1	
PRESSURE VESSEL ASSEMBLY	Component Development	1	1	
GENERATION II MOD I PRESSURE VESSEL	NRX-A Reactor Tests	4	2

HARDWARE STATUS

9-30-63

TASK ITEM 1.4

TASK TITLE THRUST CHAMBER ASSEMBLY

COMPONENT/SUB-ASSEMBLY	END USE	EST.	ACTUAL	REMARKS
CONTROL ROD ADAPTER (P.V.)	Modified for Criticality Test	1	1	
PRESSURE VESSEL FAST. & SEALS	Component Development	1	1	
PRESSURE VESSEL FAST. & SEALS	NRX-A	8	4	
KIWI-B S/N 1 NOZZLE	Development Tests	1	1	
KIWI-B S/N 2 NOZZLE	Jacket Failure Analysis	1	1	
HYBRID S/N 1 NOZZLE	Development Tests	1	1	
NOZZLE HEATED BLEED, REACTOR BACKUP	KIWI-B Reactor Test (LASL) Backup Units	2	1	
ATTACHMENT HARDWARE & SEAL NOZZLE	KIWI-B Reactor Tests (LASL) Backup Units	2	2	
NRX-A NOZZLE	NRX-A Reactor Tests	7	1	
WATER COOLED ADAPTER-TCA TO DIFFUSER	Component Development	1	0	
NOZZLE PROPELLANT INLET LINE	NRX-A Test Car (Aerojet Line)	2	0	
NOZZLE PROPELLANT INLET LINE	Component Development (Aerojet Line)	2	0	
HYBRID S/N 002H NOZZLE	Component Development	1	1	
NERVA S/N 001N NOZZLE	Component Development	1	0	
PROPELLANT FEED LINE	NRX-A	2	0	
FOR ROCKETDYNE RN-6	Component Development	1	0	
NOZZLE		-	-	
ADAPTER - TCA TO DIFFUSER	Development (FFTS) Tests	-	-	
PRESSURE VESSEL ALTERNATE MAT'L.	Component Devel. - Structural Test Series	1	0

TEST STATUS

9-30-63

TASK ITEM 1.4

TASK TITLE Thrust Chamber Assembly

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Thrust Chamber Assembly	Dynamic Test			10	1	
Pressure Vessel-Nozzle Seals	NERVA-ACFI Seals			12	3	
Nozzle, Hot Bleed and Advanced	NERVA		Sea Level Altitude	11 4	0 0	
Nozzle, Hot Bleed	NERVA			3	0	
Injector Development	Modified LR-87 TCA			3	3	
Hot Bleed Port Development	LR-87			6	6

TEST STATUS

9-30-63

TASK ITEM 14
TASK TITLE Thrust Chamber Assembly

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Upper Thrust Structure Lower Thrust Structure	Structural Tests			12	6	
Thrust Structure Assembly	Resonance Surveys			3	3	
Pressure Vessel Assembly	Structural Tests			6	6	
Nozzle, Heated Bleed	Development			11	2	
Nozzle	NRX-A			8	3	
NERWI Pressure Vessel Nozzle Assembly	Structural Test			1	1

TEST STATUS

9-30-63

TASK ITEM 1.4

TASK TITLE Thrust Chamber Assembly

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Propellant Feed Line for Rocketdyne RN-6 Nozzle	NRX-A			2	0	
RN-6 Nozzle NERVA Pressure Vessel	Structural Test			1	0	

S/T 1.5 ENGINE CONTROLS

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.5 A (1)	DESIGN AND DEVELOP EXP. MODEL OF TPCV	COMPLETE	BENDIX DWG 2775007 #153: A-4-1963; REF. TO LIST #1
(2)	DESIGN AND DEVELOP SYSTEM AMP	COMPLETE	BPAD 863-4-15076R BPAD 863-4-15125R REF. TO LIST #2
(3)	DESIGN AND DEVELOP ENGINE HARNESS	COMPLETE	SKETCH 9710-63-78; DWG. #294180, SCR 141 AND 142
(4)	DESIGN TEST SUPPORT EQUIPMENT	COMPLETE	DWG. 092178; 091586; 091766; 092165; 092492
(5)	COMPLETE DESIGN REQUIREMENTS FOR BLOCK I CONTROL SYSTEM & SYSTEM COMPONENTS	COMPLETE	NDC-24; TM 738:63-201; 738: M2006; NDC-51; NDC-25; NDC-26; NDC-27

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

S/T 1.5 ENGINE CONTROLS

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
(6)	PRELIMINARY FUNCTIONAL DESIGN OF ENGINE PROGRAMMER	COMPLETE	TM 738:63-207; DWG. 089664
2 - 1.5B (7)	FABRICATE BREADBOARD TPCV ACTUATION SUBSYSTEM	COMPLETE	BPAD 863-4-141911; 14930; 15022R; 15091R; 15090R; TM 739:63-103
(8)	FABRICATE EXPERIMENTAL MODEL TPCV ACTUATION SUBSYSTEMS	DELIVERED	2 UNITS FABRICATED BEING TESTED.
(9)	FABRICATE 2 SETS BREADBOARD SYSTEM MAGNETIC AMPLIFIERS	COMPLETE	BPAD 863-4-15096R; 15076R

REON · ROCKET ENGINE OPERATIONS — NUCLEAR

S/T I.5 ENGINE CONTROLS

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
(10)	FABRICATE 3 SETS EXPERIMENTAL SYSTEM MAGNETIC AMPLIFIERS	COMPLETE	BPAB 863-4-15125R
(11)	FABRICATE WOODEN CONSOLE FOR TEST OPERATOR'S CONSOLE	COMPLETE	REQ 270055
(12)	FABRICATE CERAMIC TUBE AMPLIFIERS	COMPLETE	DWG NO. 193720; REF. TO LIST #12
(13)	FABRICATE TEST OPERATOR'S CONSOLE FOR REMOTE ENGINE CONTROL SYSTEM SIMULATION	RESCHEDULED TO DEC '63	REFER TO LIST #13
2-I.5C (14)	PROGRAMMER MODULE FOR RAD TEST	COMPLETE	DWG 191462
(15)	PERFORM DEVELOPMENT TESTING OF TPCV ACTUATOR	COMPLETE	TM 739:63-103; BPAD 8634-15090R, 14917, 14930, 15022R, 15091R

REDON ROCKET ENGINE OPERATIONS - NUCLEAR

S/T 1.5 ENGINE CONTROLS

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
(16)	PERFORM DEVELOPMENT TESTING ON MAGNETIC AND CERAMIC TUBE AMPLIFIERS	COMPLETE	BPAD 863-4-15090R, 15096 R
(17)	CONDUCT EVALUATION TESTS OF TEST OPERATOR'S CONSOLE SIMULATOR	TO BE INITIATED JAN '64	NOT FABRICATED YET

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

SUBTASK 1.5 - ACCOMPLISHMENTS FOR CY 1963

Purpose and Objective

The overall objective of this subtask is to define the control system for the NERVA engine, utilizing analysis and simulation techniques, and to develop those control system components required by the control system criteria. Specifically, during this contract year, the objectives were as follows:

1. Establish, through detailed analog computer simulation studies, the design requirements for the Block I engine control system and system components.
2. Perform design and development work on an experimental Turbine Power Control Valve (TPCV) actuator to define the problem areas and to establish the subsequent development work.
3. Perform design and development work on breadboard and experimental system amplifiers to determine the problem areas and to establish subsequent development work.
4. Support the design of simulator controls and test facilities' controls.
5. Perform design and development of other control system components.

2-1.5a

Several major problem areas occurred during the development of the experimental TPCV actuator during CY 1963. The first of these problems became evident when it was observed that during test the flapper would break away from the main body of the torque motor. Investigations, including analyses of the structure, indicated that the residual noise from the amplifier was exciting the flapper at its natural frequency of vibration, thereby increasing the stress and strain on its welded joints. Three solutions were required to solve this problem: (1) the fundamental frequency of the noise output from the amplifier was reduced by judicious filtering; (2) the mass and spring constant of the flapper were changed to shift the critical frequency; and (3) the welding techniques for flapper fabrication were improved. In addition, a more permanent solution to this problem was the change of the carrier frequency of the actuation system to the vicinity of 1000 cycles (991 cps).

A second major problem in the development of the actuator occurred when an attempt was made to tighten the tolerances of the gear motor to reduce the quiescent flow and increase the efficiency of the motor. It was found that the tolerances could not be met without excessive tooling even when tight quality control procedures were used. Therefore, the old tolerances were retained and the existing hardware was relapped to give satisfactory actuator performance.

A third major problem was uncovered during a thermal analysis of the actuator when attached to the body of an 1800°R valve. This analysis indicated that the actuator and the internal components near the valve flange would be subjected to temperatures of the order of 800 to 1000°R. These temperatures are well over the rated operating environments for the potentiometer, the carbon shaft seal and the material used for the shaft and bearing at this stage of development. To overcome this problem, the following design changes were made.

- a. The output shaft material and bearing material were changed to withstand the increased temperature.
- b. Cooling channels were incorporated to divert the exhaust gas from the gear motor to the pot and the seal bearing area.
- c. An additional linkage was added between the valve and the actuator in order to allow a better alignment procedure to overcome tolerance problems. This design also offered the advantages of additional radiation area and volume to dissipate heat.

In addition to corrections made in the torque motor design, improved quality control was instituted at the torque motor vendor's plant which has resulted in the provision of much better quality hardware. Through continued development, the transmission was brought to a more highly developed stage.

The design of the actuator is shown in Bendix drawing 2775022 and sub-assembly parts are referenced in List No. 1

The design and development of system amplifiers for the temperature and pressure control loops was also pursued during CY 1963. Magnetic amplifiers for these loops were designed and developed, using the requirements set forth by

NERVA Criteria (Letter enclosure 732:10052-1, dated 10 December 1962). Magnetic amplifiers were chosen because of their inherent radiation-resistant properties and temperature stability.

A study was initiated to determine whether auctioneer or averaging was the best approach to the design of temperature signal amplifiers, and the decision was made to design an averaging circuit for signal processing on multiple transducers. The design and development of the breadboard and experimental system amplifiers are reported in referenced Bendix reports (BPAD-863-4-15076R and BPAD-863-4-15121R). Information gained in previous reactor radiation tests of diodes and other components served as a basis for the design. Documentation in the design and development of system amplifiers may be found under List No. 2.

The design and evaluation of engine harness components was conducted at the Sacramento facility. A schematic for the CFDTIS was prepared and coordination of the NRX wiring and cabling was performed. In addition, vendor capability surveys for the procurement of cables and connectors were conducted. Documentation for the harness effort is shown under List No. 3.

Additional test support equipment was required during the year to support the radiation tests and various other tests. The documentation of these items is found under List No. 4.

The design requirements for Block I control system and system components were determined throughout the year, culminating in several referenced documents. This documentation presents the results of detailed analog computer simulation studies of the NERVA engine system with its control components. The gains and compensations of the control amplifiers and signal amplifiers were adjusted to give satisfactory performance during startup and steady state operating conditions. These computer studies resulted in the determination of the dynamic requirements for the control system components.

The coordination of the Block I engine control system with the remote engine controls was conducted and the result of this effort is the design of the remote engine control simulation equipment. Additional documentation can be found under List No. 5.

Preliminary functional design of the engine programmer was performed on the analog computer, and engineering necessary to develop circuit diagrams intended to define the necessary wiring for the harnesses and connectors was performed. Technical memoranda (738:63-207) and drawing (089664) are the results of some of these studies.

2-1.5.b

All planned hardware for the contract year was delivered with the exception of the delivery of two experimental actuators and the completion of the remote engine control system simulator.

Four TPCV breadboard actuation subsystems were delivered and were used in the development test program to be described later.

The fabrication of one experimental TPCV actuator was completed and the unit shipped at the end of the contract year. This unit has undergone preliminary acceptance tests at AGC. One other unit was received on 28 October, and a third one is expected to be shipped within a few weeks.

Two sets of breadboard magnetic system amplifiers were received for development testing. These units were of an open type construction to allow the adjustment of various parameters as indicated by the analyses through their tie-in to the analog computer setup. Minor changes in the gains and compensations of these amplifiers were incorporated in the second generation amplifiers of which three sets were delivered and are slated for computer tie-in to confirm the designs.

The fabrication of the wooden version of the test operator's console was completed as part of the remote engine control system simulation. This wooden console was patterned after the cardboard versions developed by Task Item 2.2.

The fabrication of three versions of ceramic tube amplifiers was completed for environment and radiation tests to determine the feasibility of using this type of amplifier in the NERVA environment and as a possible alternate for the control systems' amplifiers.

The fabrication of the remote engine control system simulator is in process and is expected to be completed in December. At the end of the contract

year almost all of the components had been received, and assembly was in an advanced state of completion.

2-1.5.c

The testing program planned for the contract year was completed with the exception of the performance of the evaluation tests on the remote control system simulator.

The first programmer module which included a breadboard version of a ceramic tube DC amplifier and a ceramic tube logic element was rad-tested in Omega West. During the test it was discovered that a resistor bobbin in one of the circuits was not suitable for radiation and, as a result, was out-gassing radioactive material. As a result, the test was aborted after approximately 10 hours, with the programmer module receiving a total dose of the order of 10^{15} nvt.

The testing of the TPCV actuator has proven to be very successful during this contract year. One actuator has been operated for a period of approximately 80 hours under temperature, vibration and ambient conditions. Approximately 5 hours of this testing were conducted at cryogenic temperatures (liquid nitrogen) and approximately 5 hours under vibration environment. The rest of the time was spent in performance testing and computer tie-in. This actuator is still in operating condition and has shown no degradation in performance.

A second breadboard actuator has been tested at GTR under dynamic conditions where the actuator was under continuous motion for the period of time it was in the reactor. Periodic performance tests were run to determine its dynamic response. This actuator has accumulated 100 hours of radiation tests with no significant degradation in its dynamic or static performance. The dose is about 5×10^{16} nvt. Reports are due in December. This actuator is currently back in the test reactor for an additional 100 hours, or to failure point.

A third actuator has been sent to LRP and is scheduled for use in testing the TPCV under Subtask 1.2.

A fourth breadboard actuator was programmed for high temperature tests but was found by Inspection to have encountered enough damage to require its disassembly and return to the vendor for refurbishing. These temperature

disassembly and return to the vendor for refurbishing. These temperature tests will be conducted with the actuator having some 80 hours of testing on it.

The first set of system amplifiers was utilized for computer tie-in studies. These amplifiers were checked for performance in the laboratory to determine their operating characteristics. The Serial No. 1 amplifiers were found to meet the basic specification. The second set of breadboard amplifiers was tested for 50 hours in the GTR reactor at Fort Worth in August 1963. The preliminary results of this test show that the amplifiers performed satisfactorily and are documented in Bendix report BPAD 863-4-15070R.

The experimental system amplifiers, Serial No. 4, were tested at Azusa to determine their operating characteristics over a wide range of temperatures. The amplifiers were found to operate satisfactorily from +250°F to -350°F.

The control amplifiers at the extreme temperature range had a substantial change in frequency response characteristics. Experimental system amplifiers, Serial No. 5, were shipped to GTR, Fort Worth, for radiation effects testing. This testing has not been completed as of this date.

Experimental system amplifiers, Serial No. 7, are slated for non-radiation environmental testing and for computer tie-in studies.

Ceramic tube amplifiers were tested at the Fort Worth facility in August, but documentation of the results of these tests has not been completed. The ceramic tube amplifiers were environmentally tested for the effects of both temperature and vacuum on their performance. The null of the output was found to shift at the extremes of the temperature test conditions, and this effect was determined to exist from a thermocouple effect in the chopper. Additional design and development effort is needed to solve this problem.

Testing of candidate circuits for the remote engine control system has been conducted during the year to determine the performance of the overall system when completed.

The evaluation tests of the remote engine control system simulator are deferred to an initiation date of January 1964.

Conclusions

Of the 18 milestones scheduled for completion during CY 1963, one was cancelled by May redirection. Of the remaining 17, 2 were carried over to CY 1964 but will be completed within three months of the originally scheduled date for completion.

The objectives of the CY 63 controls subtask were accomplished during this contract period in every respect except for the controls support work required for the test operator's console simulator for the ETS-1 remote engine control system:

a. The TPCV actuators were designed, fabricated and tested under various environmental conditions. Problem areas were defined and corrective actions were taken. That the basic design is sound is demonstrated by the accumulated environmental test time, including radiation testing.

b. The system amplifiers performed well under the environmental test conditions.

c. Under Sub-Subtask 1.1.6, major control systems analyses were completed, allowing component criteria to be further defined and the overall system design improved.

d. Additional definition of the design for programmer circuitry was obtained and various components were tested as a continuation of the evaluation and selection process leading to a reliable controls system.

SUBTASK 1.5 - BIBLIOGRAPHY

List No. 1

<u>BPAD Part No.</u>	<u>Part Name</u>
2775022	Actuator Assembly
2775020	Amplifier Assembly
2775006	Servo Valve Assembly
2775009	Gear Motor Assembly
2775011	Transmission Assembly
2775416	Connector Assembly (Inlet, Outlet, and Electrical Connector)
2151818	Torque Motor
2775117	Seal Assembly
153:A-4-1963	Thermal Analysis

List No. 2

<u>BPAD Part No.</u>	
BPAD 863-4-15076R	Design and Development of Breadboard System Amplifiers
BPAD 863-4-15125R	Design and Development of Experimental System Amplifiers
732:L0052-1	System Amplifier Requirements
2775000	Control Assembly Electronic TSA
2779118	Schematic Diagram TSA
2775002	TCA
2779119	Schematic Diagram TCA
2775001	PSA
2779121	Schematic Diagram PSA
2775003	PCA
2779120	Schematic Diagram PCA

2775017	PSA
2779216	Schematic
2775019	PCA
2779218	Schematic
2775016	TSA
2779215	Schematic
2775018	TCA
2779217	Schematic

List No. 3

9710-63-78	Schematic Controls CFDIS
294180	Schematic Diagram Electrical Instrumentation
SCR-141	Vendor Capability Survey Cables
SCR-142	Vendor Capability Survey Connectors

List No. 4

092178	Valve Simulator Test Assembly
091586	Console Assembly TPCVA Portable Test
091766	Layout - Rad Test Pallet
092165	Schematic TPCVA Rad Test
092492	Actuator Test Stand Schematic

List No. 5

NDC-24	Engine System
TM 738:63-207	Dynamic Requirements E-1 Engine Control
738:M2006	Transducer Requirements
NDC-51	TPCV Actuator
NDC-25	Cables
NDC-26	Connectors
NDC-27	Amplifiers

List No. 6

TM 738:63-207

Dynamic Requirements E-1 Engine Control

089664

Preliminary Engine Programmer
Functional Diagram

096320

Preliminary Engine Programmer
Wiring Diagram

List No. 7

BPAD 863-4-14917

TPCVA S/N 6

BPAD 863-4-14930

TPCVA S/N 8

BPAD 863-4-15022R

TPCVA S/N 9

BPAD 863-4-15091R

TPCVA S/N 10

TM 739:63-103

Response of Breadboard TPCV

List No. 9

BPAD 863-4-15096R

Design and Development of
Breadboard Amplifiers

BPAD 863-4-15076R

Performance Report of
Breadboard Amplifiers

List No. 11

Requisition AGC 270055

List No. 12

193720

Ceramic Tube Amplifier Assembly

091995

Test Assembly Amplifier

091997

Amp. Two-Stage Difference

091998

Schematic Two-Stage Difference Amp.

List No. 13

Dwg. No.

Title

/93436

Indicator Panel

/93437

Main Control Panel

<u>Dwg. No.</u>	<u>Title</u>
/93438	Monitor Panel
/93435	Manual Control Panel
/93439	Relay Chassis
/93441	Ground Test Programmer
	Interconnections, Console
/93433	Main Control Panel
/93434	Monitor Control Panel
/93432	Indicator Panel
/93431	Manual Control Panel
/93442	Ground Test Programmer Panel
/93452	Relay Chassis Panel
/93443	Ground Test Programmer, Bottom Plate
/93451	Relay Chassis, Bottom Plate
/93428 - Sheet 1	Thrust, Programmer-Automatic
/93428 - Sheet 2	Phase Selector
/93428 - Sheet 4	Meters
/93428 - Sheet 3	Manual Controls
/93428 - Sheet 6	Mode Selector and Manual Drum Position
/93428 - Sheet 5	Override, Engine Panel/Reactor Panel Control
/93428 - Sheet 8	Manual Drum Position Pot - Return to Zero CKT
/93428 - Sheet 7	Main Control Panel
/93428 - Sheet 10	Cooldown
/93428 - Sheet 9	Timers
	Front Panels
	Console, Internal

/93446

/93447

/93448

/93449

/93444

/93453

/93454

/93455

/93456

/93445

/93450

/93440

Power Monitor Panel

Drum Position Control Panel

Drum Position Indicator Panel

Main Control Panel

Relay Chassis

Interconnections, Console

Power Monitor, Panel

Drum Position Control Panel

Drum Position Indicator Panel

Main Control Panel

Relay Chassis, Panel

Relay Chassis, Bottom Plate

Front Panels

Console, Internal

Front Panels

Console, Internal

List No. 14

191462

List No. 15

BPAD 863-4-15090R

BPAD 863-4-14917

BPAD 863-4-14930

BPAD 863-4-15022R

BPAD 863-4-15091R

Rad Effects Test in GTR

TPCVA S/N 6

TPCVA S/N 8

TPCVA S/N 9

TPCVA S/N 10

List No. 16

BPAD 863-4-15090R

BPAD 863-4-15096R

Rad Effects Test in GTR

Design & Development of B.B. Amp.

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.5

SCHEDULED MILESTONE

▲ MILESTONE ACHIEVEMENT

◆ RESCHEDULED MILESTONE

◆ RESCHEDULED MILESTONE ACHIEVEMENT

RESCHEDULED TO CY 64

NERVA PROGRAM

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.5 (CONT.)

[illegible]

↑ SCHEDULED MILESTONE

↑ MILESTONE ACHIEVEMENT

◆ **RESCHEDULED MILESTONE**

◆ **RESCHEDULED MILESTONE ACHIEVEMENT**

RESCHEDULED TO CY 64

HARDWARE STATUS

9-30-63

TASK ITEM 1.5

TASK TITLE CONTROL SYSTEMS

COMPONENT/SUB-ASSEMBLY	END USE	NO. PIECES NEW HARDWARE		REMARKS
ACTUATORS				
TPCV B-B	Non-Rad Environment Tests	1	1	
	Thermal Test	1	1	
	Integrated Actuator-Valve no Flow Test and Dec. Rad Test	1	1	
	August Rad Test	1	1	
TPCV EXP	Integrated Actuator-Valve Hot Flow Tests, April 1964	1	1	
	Actuator Rad Test	1	0	S/C Difficulty With Vendor Supplied Parts
	Cold Flow Development Test	1	0	S/C Difficulty With Vendor Supplied Parts
AMPLIFIERS				
PSA B-B	Computer Tie In	1	1	
TSA B-B		1	1	
PCA B-B		1	1	
TCA B-B		1	1	
PSA B-B	Computer Tie In: June Rad. Test	1	1	
TSA B-B		1	1	
PCA B-B		1	1	
TCA B-B		1	1	
PSA EXP	1 Set (1 ea.) Computer Tie In -	2	2	
TSA EXP	and	2	2	
PCA EXP	1 Set (1 ea.) Rad. Test	2	2	
TCA EXP		2	2	
AMPLIFIER SET OF 4 EXP	September Rad. Test	1	1	
ELECTRICAL CONNECTORS	Development Tests	10

TEST STATUS

9-30-63

TASK ITEM 1.5
TASK TITLE ENGINE CONTROLS

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF MONTHS		REMARKS
				EST.	ACTUAL	
Actuator TPCV	B-B	Non-Rad. Environment Radiation Integrated Actuator and Valve Flow	Azusa GTR LRP	3	3	
				1	1	
				2	0	
	EXP	Non-Rad. Environment Radiation	Azusa ASTR	2	0	
				1	0	
Amplifiers	B-B	Computer Tie-in Radiation	Azusa GTR	4	4	
				1	1	
	EXP	Computer Tie-In Non-Rad. Environment Radiation	Azusa Azusa GTR	2	2	
				2	2	
				1	1	
Harness	Conf. #1	Component Testing - Environmental, Vacuum, Salt Spray, Humidity, etc.	LRP	2	2	

S/T 1.6 DESTRUCT SYSTEM

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
2-1.6A (1)	DESIGN EXPLOSIVE FRAGMENTATION EXPERIMENTS	COMPLETED	a. DY 0716-16 (10) MP/JULY 1963
(2)	LIAISON WITH APG AND PICATINNY ARSENAL	COMPLETED (PERFORMED)	a. DY 0716-16 (05) MP/FEB. 1963, p 130 b. TRIP REPORT 8 MAR. 1963 yn:1d c. DY 0716-16 (08) MP/MAY 1963, p104
(3)	DESIGN EXPLOSIVE IRRADIATION EXPERIMENTS AND CAPSULE	COMPLETED	a. DY 0716-16 (12) MP/S SEP. 1963 b. S/S/TASK 1.63 WORK EFFORT TRANSFERRED TO S/S/TASK 1.91 FOR CY '64 c. 733: MO: 413 CCH: AND DTD 7 OCT. 1963

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

S/T I.6 DESTRUCT SYSTEM

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.6A (4)	PERFORM DESIGN OF EJECTABLE AND NON-EJECTABLE ACDS	COMPLETED	a. DY 0716-16 (09) MP/JUNE 1963, p37 b. DY 0716-16 (05) MP/FEB 1963 c. DRAFT RPT #2708 (MILESTONE #19)
(5)	PERFORM ACDS DESIGN AND SYSTEMS INTEGRATION	COMPLETED	a. DRAFT RPT #2708 (MILESTONE #19)
(6)	PERFORM DESIGN FOR PODS CONCEPT CONFIGURATION	COMPLETED	a. REON RPT # 2597
2-1.6 B (1)	FAB VARIOUS EXPLOSIVE CHARGES AND TRAINS	COMPLETED	a. REON RPT #2597 (MILESTONE #30) b. DRAFT RPT #2708 (MILESTONE #19)

REON ROCKET ENGINE OPERATIONS—NUCLEAR

S/T I.6 DESTRUCT SYSTEM

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
2-I.6B (2)	FAB SUB SCALE AND FULL SCALE TARGETS	COMPLETED	(a) REON RPT. #2597 MILESTONE #30 (b) DRAFT RPT. #2708 MILESTONE #19 (c) DY 0717-16 (01) MP/OCT 1962
(3)	FAB FIXTURES AND JIGS AS REQUIRED	COMPLETED	(a) REON RPT. #2597 (MILESTONE #30) (b) DRAFT RPT. #2708 (MILESTONE #19) (c) DY 0716-16 (10) MP/JULY 1963

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

S/T I.6 DESTRUCT SYSTEM

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.6B (4)	FAB EXPLOSIVE IRRADIATION CAPSULES FOR RAD EFFECTS TEST	COMPLETED (a) FAB OF CAPSULES FOR DEVELOPMENT TESTS ONLY DEFERRED FAB. OF CAPSULES FOR RAD EFFECTS TESTS TO CY 64	(a) DYD 716-16 (12) SEP 1963 b. UNABLE TO FINALIZE CRITERIA FOR FINAL CAPSULE DESIGN UNTIL GE VALLECITOS CONTRACT NEGOTIATION COMPLETED

ROCKET ENGINE OPERATION

S/T 1.6 DESTRUCT SYSTEM

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
2-1.6C (1)	CONDUCT FRAGMENTATION TESTS AT VARIOUS TEMPERATURES	COMPLETED	a. REON MONTHLY PROGRESS LTRS b. NEDS-DY MO. PROGRESS RPTS. c. ALT. MECH. & EXPLOSIVE SHOCK SUBSTITUTED FOR PORTION OF TEMP. TESTS REQUIRING B-4 MATERIAL WHICH WAS RE- CEIVED TOO LATE TO CONDUCT TESTS.
2-1.6C (2)	CONDUCT FRACTURE MECHANISM STUDIES	COMPLETED	a. REON MONTHLY PROGRESS LETTERS b. NEDS-DY MONTHLY PROGRESS REPORTS

S/T 1.6 DESTRUCT SYSTEM

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.6C (3)	PERFORM EXPLOSIVE IRRADIATION EXPERIMENTS	DEFERRED TO CY 64 (2-1-64)	UNANTICIPATED DELAY IN NEGOTIATION S/CONTRACT FOR VALLECITOS FACILITY
2-1.6C (4)	PERFORM TESTS OF EJECTABLE AND NON-EJECTABLE ACDS CONCEPTS	COMPLETED	DRAFT RPT #2708 (MILESTONE #19)
2-1.6C (5)	CONDUCT FEASIBILITY DEMON- STRATION OF ACDS CONCEPT	COMPLETED	DRAFT RPT #2708 (MILESTONE #19)
2-1.6D (1)	EVALUATE RESULTS OF FRAG. RES EXPMTS	COMPLETION DEFERRED TO CY 64 (12-5-63)	COMPLETION DELAYED BY LATE RECEIPT OF B-4 FUEL ELEMENTS

REON · ROCKET ENGINE OPERATIONS - NUCLEAR

S/T 1.6 DESTRUCT SYSTEM

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
2-1.6D (2)	EVALUATE IRRADIATION EFFECTS ON VARIOUS EXPLOSIVES	COMPLETION DEFERRED TO CY 64 (2-1-64)	SEE 2-1.6C(3)
2-1.6D (3)	EVALUATE SELECTED ACDS CONCEPT	COMPLETED	DRAFT RPT #2708
2-1.6D (4)	EVALUATE CANDIDATE PODS AND SELECT FOR FURTHER DEVEL.	COMPLETED	REON RPT #2597
2-1.6D (5)	EVALUATES EFFECTS OF TEMP. EXTREMES ON FRAGMENTATION OF CORE MATERIAL	COMPLETED EXCEPT FOR B-4 TESTS	COMPLETION DELAYED BY LATE RECEIPT OF B-4 FUEL ELEMENTS

ROCKET ENGINE OPERATION

S/T 1.6 DESTRUCT SYSTEM

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
2-1. 6E (I) CONT	COMMUNICATIONS INSTALLATION	DEFERRED	A. AWAITING SNPO-C APPROVAL B. TRIP REPORT 10-11-63, 733 : MO 419 : RIV : AMD
	SAFETY AND SECURITY FENCING	DEFERRED	A. AWAITING SNPO-C APPROVAL B. TRIP REPORT 10-11-63, 733 : MO 419 : RIV : AMD
	TEST AREA APPROACHES	COMPLETED	WEEKLY TEST SITE ENG. REPORT 11-30-62

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

S/T 1.6 DESTRUCT SYSTEM

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
2-1.6E (1) CONT	SECURITY LIGHTING	DEFERRED	(a) AWAITING SNPO-C APPROVAL (b) TRIP REPORT 10-11-63, 733:M0419
	WATER SUPPLY	DEFERRED	(a) AWAITING SNPO-C APPROVAL (b) TRIP REPORT 10-11-63, 733:M0419
	ASSEMBLY BUILDING	DEFERRED	(a) AWAITING SNPO-C APPROVAL (b) TRIP REPORT 10-11-63, 733:M0419
2-1 6E(2)	SECURITY GUARD SERVICE AT HAWTHORNE TEST SITE	COMPLETED	P.O. D707095CD

REON · ROCKET ENGINE OPERATIONS — NUCLEAR

SUBTASK 1.6 - ACCOMPLISHMENTS FOR CY 1963

Purpose and Objective

The concept of employing a nuclear reactor as one stage of a flight vehicle requires that adequate countermeasures be provided to insure safety and prevent any possible hazard to any of the earth's population. One type of countermeasure involves the utilization of explosive destruct techniques.

The purpose of an Anticriticality Destruct System (ACDS) is to prevent inadvertent criticality of the reactor in the event of an accident or malfunction of the NERVA engine prior to its operation, by fragmenting and dispersing the core into certain size pieces as established by tentative anticriticality destruct criteria.

The purpose of a Post-operation Destruct System (PODS) is to fragment the reactor core into small enough particles, at any time after engine operation and the accompanying generation of fission products, so that random re-entry of the particles will not create a radioactive contamination hazard.

The objective of the work performed during the CY 63 under sub-task 1.6 was to secure the necessary data and information required for the development of an acceptable, explosive anticriticality (ACDS) and post-operation (PODS) destruct system and for the integration of the destruct system into the NERVA engine.

The specific goals of the CY 1963 Destruct System program were:

1. To determine the feasibility of using an explosive technique as a countermeasure.
2. To screen a number of candidate anticriticality destruct system (ACDS) concepts and post-operation destruct system (PODS) concepts in order to select the most feasible approaches for further development.

The discussion to follow will treat the various tasks undertaken to achieve the program objectives.

2-1.6A(1)

Fundamental explosive fragmentation experiments were formulated as part of the basic research on core material correlation and fracture mechanisms.

This work involved the design of experiments utilizing mechanically or explosively generated energy to fragment single rods or bundles of rods in order to study the fracture mechanisms associated with the fragmentation of graphite materials.

Material correlation experiments were designed to obtain data relating crude graphite simulant materials to the more accurate geometry fuel elements. Experiments were designed to assess the effects of an explosively induced shock on solid round or hexagonal graphite rods, and round B-1 hole pattern or hexagonal B-4 hole pattern rods, as single elements or in a bundle configuration.

The necessary associated test support hardware including various explosive charges and targets was also designed. This hardware included such items as a mechanical drop weight apparatus, a special water aerated recovery tank for collecting fragmented graphite samples, and explosives cast into a variety of geometries and quantities.

2-1.6A(2)

Technical liaison and coordination of the associated work performed by Aberdeen Proving Grounds (APG) and Picatinny Arsenal (PA) was performed.

Aberdeen Proving Grounds (APG) performed tests to determine the dynamic feasibility of projectile penetration and to determine the penetration distances which could be achieved with a minimum disturbance of the simulated NERVA engine target array. Further tests were performed to determine the time and distance of penetration as a function of projectile velocity. Fragmentation tests of simulated engines utilizing three statically positioned charges and dynamically inserting the fourth projectile by means of a tank gun were also performed. This work was performed in support of the Mark D post-operation destruct system concept and was essential for evaluating the feasibility of this PODS concept.

Picatinny Arsenal assisted in the formulation of a program for determining the effects of a radiation environment on explosives. The formulated program gave consideration to the duration and level of irradiation, four types of explosives and one propellant, and the types of tests for ascertaining the

effects of the exposure, and presented a plan for additional phases of work on radiation effects on explosives upon completion of the initial phase. This type of information was needed in order to assess the integrity and reliability of the selected explosive to function upon command for a post operation destruct situation requirement.

2-1.6A(3)

Experiments to determine the effects of radiation on explosives were formulated with the assistance of Picatinny Arsenal as embodied in five phases of work. A tentative radiation facility was identified (GETR at Vallecitos, California) and test reactor modifications indicated. The designs for necessary support hardware, particularly the design for an irradiation capsule capable of containing detonation products in case of accidental detonation during irradiation, were completed. Radiation effects experiments were designed to evaluate the firing time and energy release characteristics of three types of common detonators.

The radiation effects experimental plan was presented in Downey Report RS:24 and the results of the design effort are in various reports listed in the bibliography.

2-1.6A(4)

Design studies to determine the configuration of a candidate ACDS concept of an Ejectable and a Non-ejectable ACDS were performed. The results of this design study indicated the design most suitable for the Ejectable ACDS was the Mk A concept and that for the Non-ejectable was the Mk D concept. These configurations are described as follows:

The MK A Ejectable ACDS consists of one circumferential curvilinear cutting shaped charge mounted at the upper portion and external to the pressure vessel. Four longitudinal cutting shaped charges running the length of the pressure vessel and spaced 90° apart are connected to the circumferential shaped charge. There are two conical shaped charges located diametrically opposite each other at the outer periphery of the nozzle throat and directed toward the center of the engine core. Each of these charges is attached to a longitudinal cutting shaped charge and timed to fire 100 microseconds after the initiation

of the cutting charges. The cutting charges function to open the pressure vessel and other confinement followed by the dispersing action of the conical shaped charges.

The Mk D Non-ejectable ACDS consists of one or more explosive projectiles launched from tubes or guns located forward of the reactor shield. The explosive projectile would function by first penetrating into the reactor core followed by an internal burster type explosive detonation to provide the fragmentation, opening of the pressure vessel and dispersion of the core material.

In addition, the design for the associated test support hardware including various explosive cutting and conical shaped charges, and slab, cylindrical, and full scale targets was performed.

2-1.6A(5)

Design and systems integration studies were performed for the Mk A non-ejectable ACDS concept and for its necessary associated test support hardware, including various explosive charges in order to prepare for a test of this concept against a full scale simulated engine target. This design included the generation of a set of preliminary design drawings presenting the details of component layout and such physical properties as weight, center of gravity, moment of inertia, materials, and stress levels.

2-1.6A(6)

Design studies were performed to determine the configuration for several conceptual post-operation destruct systems including the various explosive charges and trains. Slab and cylindrical geometry subscale targets and full scale simulated engine targets and the associated hardware required for testing the various concepts evolved, were also designed.

Conceptual designs were prepared for the Mk D, E, F, G, H, J, K, and M post operation destruct system concepts against slab, cylindrical and full scale targets. There various concepts involved the use of external cutting or penetrating type shaped charges, implosion type panel charges, projectile inserted internal burster type charges, or various combinations of all of these. Only the most promising of the concepts were tested against full scale simulated engine targets.

The full scale simulated engine targets were designed to present an equal or more difficult target to defeat than the actual NERVA engine core at a fraction of the dollar cost. These target designs initially utilized Polaris salvage casings for the pressure vessel although aluminum pressure vessels were incorporated into the design at a later point. The design simulated the fuel elements with 3/4 inch diameter solid AGSX type graphite rods. The beryllium reflector was simulated with solid curved magnesium sections. The graphite moderator cylinder was simulated with graphite slabs.

2-1.6B(1)

Various explosive charges and explosive trains were fabricated as required for the different portions of ACDS and PODS concepts tested, and for the fragmentation tests required in performance of the fracture mechanism studies and material correlation experiments. The different types of charges expended included linear shaped charges, conical shaped charges, hemispherical and elliptical shaped charges, explosive panels, internal burster explosive projectiles, and explosive timing and firing trains.

2-1.6B(2)

Sub-scale and full scale targets were fabricated. A number of slab and cylindrical geometry targets were fabricated for use in explosive charge development and evaluation. Sub-scale, full diameter half length, and full scale simulated engine targets were fabricated for use in comparative evaluation and design improvement tests of the various candidate ACDS and PODS concepts. Appropriate targets were fabricated also for studying the fracture mechanisms of graphite rods and for material correlation tests.

2-1.6B(3)

Fixtures and jigs were fabricated in support of the target fabrication and as required for support of explosive tests.

Various handling fixtures were required during the fabrication of targets, especially for the full diameter half length and full scale targets. These included such items as dollies which incorporated provisions for turning and devices for holding the various target components in place during assembly.

Fixtures were required also in support of the explosive tests to position the different shaped charges for mounting, and to enhance the obtaining of photographic data and instrumentation.

2-1.6B(4)

Capsules and test modules were fabricated as required for the development of an irradiation capsule for the radiation effects on explosives experiments.

Irradiation testing of explosives required that containers be fabricated which were capable of withstanding the shock and contain the gaseous products which would be generated during accidental detonation of the explosive. Approximately 94 capsules were fabricated during the development of this device.

No additional capsules were fabricated for the radiation effects tests on explosives. This was due primarily to the fact that the design criteria for the capsule could not be firmed until the negotiation of the subcontract to utilize the GETR Facility at Vallecitos, California was completed. The GE subcontract negotiation was completed toward the end of CY 1963.

2-1.6C(1)

Mechanical and/or explosive tests were conducted on round graphite rod core simulants at both elevated (500°F) and cryogenic (LN₂) temperatures to develop material correlation data at the various temperatures. The initial tests indicated that no further temperature effect tests were warranted on crude core simulants. The B-4 fuel elements required for these tests were received too late in the contract year to perform testing at temperature extremes.

2-1.6C(2)

Fragmentation tests were conducted in an attempt to understand the mechanism of fracture of graphite material utilizing such techniques as optical diffraction, X-ray diffraction and acoustical measurements, where applicable. Tests were conducted also to obtain material correlation data to relate crude core simulants to geometrically accurate materials.

Fracture mechanism studies utilizing mechanical and explosive energies were conducted and a photographic and experimental data obtained.

The results of these tests indicate the prime core fragmentation mechanism to be mechanical interaction between neighboring elements and structures, and not explosive shock effects, except at points very near the explosive detonation centers. Additionally, limited testing indicated that the equivalent amount of energy input results in a greater fragmentation of a B-4 type unfueled element than that obtained using the 3/4 inch diameter solid round AGSX type graphite rod.

2-1.6C(3)

The radiation effects experiments to qualify an explosive and assess the resulting variations in its performance characteristics were not performed due to an unanticipated delay in availability of irradiation facilities. This work is deferred to CY 1964 and the irradiation testing will be conducted under sub-subtask 1.9.1.

However, the development and qualification testing of an irradiation capsule was completed during CY 1963.

2-1.6C(4)

Tests of Ejectable and Non-ejectable ACDS concepts were conducted against slab and cylindrical geometry and full-scale targets. ACDS tests were conducted against full scale concrete-filled targets and full-scale simulated engine targets to provide a basis for design changes and to improve the performance of the particular ACDS concept to as great an extent as possible.

These tests indicated the Mk A ACDS to be the most promising of the concepts tested, and a test showed this system to be adequate in satisfying the tentative criteria established for an ACDS.

2-1.6C(5)

Tests were conducted of the Mk A concept which was selected as the most feasible Ejectable ACDS. Tests performed with this system successfully met the tentative anticriticality destruct criteria by providing adequate break-up and dispersion of the simulated reactor core. This tentative criteria

requires that the break-up of the core and the accompanying dispersion be such as to prevent pieces large enough to be close enough to form a critical mass in a moderating environment.

Design changes of this Mk A concept, which were overly optimistic, for a planned demonstration test, resulted in a failure of the concept to satisfy the tentative anticriticality destruct criteria.

2-1.6D(1)

A number of evaluations and comparisons of Fragmentation Research Experiments were performed. However, completion of these evaluations and material correlation analysis was not possible due to late receipt of B-4 fuel elements. Tests using these materials were essential to a meaningful evaluation of fragmentation research experiments.

2-1.6D(2)

The performance characteristics of the various candidate explosive materials in assessing radiation effects was not performed since no irradiation experiments were conducted during CY 1963.

Delays encountered in negotiating an irradiation subcontract with General Electric Corporation were responsible for this delay.

This item will be performed during CY 1963 under sub-subtask 1.9.1.

2-1.6D(3)

The selected Mk A ejectable concept was shown capable of satisfying the tentative anticriticality destruct criteria and appeared feasible for integration into the NERVA engine.

2-1.6D(4)

A comparative evaluation of the various candidate PODS was performed in order to select a single configuration for further parametric development testing.

A total of 49 tests were conducted to develop and evaluate post operation destruct system candidate concepts. The tests included the use of slab targets, and full duration half length and full scale targets. Five concepts were tested actively.

The Mk D internal burster explosive projectile concept was selected as the most promising PODS although it did not completely achieve the tentative post operation destruct criteria. This tentative post operation destruct criteria requires that the total material of the core be pulverized into particles none of which exceeds $1/32$ inch in size.

A test performed at Aberdeen Proving Grounds, utilizing this concept, where one-quarter of the target core utilized depleted B-4 fuel elements, provided extremely encouraging results with this PODS concept in that approximately 52% of the quarter section was under $1/32$ inch in size and only 0.03% was greater than 1 inch. In addition, this Mk D PODS concept appears feasible for incorporation into the NERVA engine design.

2-1.6D(5)

The evaluation of the effects of extremes of temperatures on the fragmentation characteristics of the NERVA engine core material has not been completed.

The completion of this phase of the support research program was delayed by the late receipt of GFE supplied B-4 fuel elements. The fracture mechanism tests are being conducted in CY 1964 using B-4 material at ambient temperature only. (Verbal instructions from SNPO-C.)

2-1.6E(1)

The needs of the Garfield Flats Test Facility (GFTF) at Hawthorne, Nevada for support of the ACDS, PODS and the other portions of the destruct system test program were evaluated.

Work was to be performed and site modifications made as a direct charge to this contract, by fabricating, procuring, and installing, or wherever practicable, renting, the following items as required to facilitate the use of the Garfield Flats Test Facility at Hawthorne, Nevada.

(a) Trailers	(e) Safety & Security fencing
(b) Test pads and necessary support	(f) Test area approaches
(c) Electrical Power Installation	(g) Security lighting
(d) Communications Installation	(h) Water supply
& Equipment	(i) Concrete block assembly building

Not all of these items have been completed.

Two trailers were rented and used continuously throughout CY 1963. Two 300-foot diameter test pads were installed by H-NAD.

The electrical power, communications and fencing were not accomplished and have been deferred until CY 1964. SNPO-C approval is required.

The test area approaches were graded using H-NAD labor and equipment.

The security lighting, water supply and assembly building have been deferred to CY 1964 because of delay in receiving SNPO-C approval.

2-1.6E(2)

Adequate security guard services were furnished at the Garfield Flats Test Facility at Hawthorne, Nevada.

This service was provided by the Pacific Plant Protection company through CY 1963. The service has been extended into CY 1964 to provide continuity in test site security.

CY 1963 Program Milestones

There were a total of 30 milestones established for the sub-task 1.6 destruct system program.

All the milestones have been completed with the following exceptions:

1. Five milestones related to Radiation Effects on explosives as delayed principally by G.E. subcontract prolonged negotiation.

2. Four milestones related to Publishing Reports, although the reports have been completed in rough draft form.

Conclusions

1. A Mark A concept has been selected as the most promising Ejectable ACDS and preliminary designs of the system have been completed. This selection was made by screening a number of candidate anticriticality destruct system concepts, and by comparing and evaluating their performance against simulated engine targets. The feasibility of using an explosive technique as an anti-criticality countermeasure has been demonstrated.

2. A Mark D concept has been selected as the most promising PODS and because of its operational advantages can be considered for possible

bifunctional capability (ACDS application). This selection was made by screening a number of candidate post operation destruct system concepts, and by comparing and evaluating their performance against simulated engine targets. This concept provides sufficiently encouraging results to warrant its selection for further parametric development.

Its utility as an ACDS, giving it a bifunctional capability makes it additionally attractive.

3. The Garfield Flats Test Facility (GFTS) at Hawthorne, Nevada was fully utilized even though all of the support facility items were not completed.

4. Although the capsule for the explosive radiation was developed during the contract year, delays encountered in negotiating a sub-contract with General Electric Corporation for use of their GETR Facility at Vallecitos, California, prevented the completion of the planned "radiation effects on explosive experiments. These are to be deferred to CY 1964.

SUBTASK 1.6 - BIBLIOGRAPHY

DOCUMENT LIST

I. REPORTS

A. DOWNEY - NEDS MONTHLY PROGRESS REPORTS

1. DY 0716-16(01) Oct. 1962
2. DY 0716-16(02) Nov. 1962
3. DY 0716-16(03) Dec. 1962
4. DY 0716-16(04) Jan. 1963
5. DY 0716-16(05) Feb. 1963
6. DY 0716-16(06) Mar. 1963
7. DY 0716-16(07) April 1963
8. DY 0716-16(08) May 1963
9. DY 0716-16(09) June 1963
10. DY 0716-16(10) July 1963
11. DY 0716-16(11) Aug. 1963
12. DY 0716017(12) Sept. 1963

B. REON MONTHLY PROGRESS LETTERS

1. REON Monthly Progress Letter No. 16 Oct. 1962
2. REON Monthly Progress Letter No. 17 Nov. 1962
3. REON Monthly Progress Letter No. 18 Dec. 1962
4. REON Monthly Progress Letter No. 19 Jan. 1963
5. REON Monthly Progress Letter No. 20 Feb. 1963
6. REON Monthly Progress Letter No. 21 Mar. 1963
7. REON Monthly Progress Letter No. 22 April 1963
8. REON Monthly Progress Letter No. 23 May 1963
9. REON Monthly Progress Letter No. 24 June 1963
10. REON Monthly Progress Letter No. 25 July 1963

B. REON MONTHLY PROGRESS LETTERS (Cont'd.)

11. REON Monthly Progress Letter No. 26 Aug. 1963
12. REON Monthly Progress Letter No. 27 Sept. 1963

C. SPECIAL MILESTONE REPORTS

1. Milestone 19 Draft Report No. 2708
2. Milestone 30 REON Report No. 2597

II. MEMORANDA AND TRIP REPORTS

A. MEMORANDA

1. Weekly Test Site Engineering Report 30 Nov. 1962
2. Weekly Test Site Engineering Report 7 Dec. 1962
3. W. D. Stinnert to G. L. Ryland MO404 30 Sept. 1963

B. TRIP REPORTS

1. Trip Report to APG and AEC Headquarters yn:ld 8 Mar. 1963
2. Capsule Evaluation 733:MO:413 sch:amd 7 Oct. 1963
3. Trip Report 733:MO:419 RIU:amd 11 Oct. 1963

III. PHOTOGRAPHS

A. TEST

1. Test A/C - 169A 963-188-14
2. Test IO-91 Fig. B-1 0716-16(10)MP July 1963 (663-82-2)

B. EQUIPMENT

1. Target Showing Dolly Fig. 4 0716-16(09) MP
2. Test Setup Showing Stand Fig. A-1 0716-16(02)MP
3. Test Setup Showing Stand Fig. D-3 0716-16(03)MP
4. Test IO-86 Showing Stand Fig. B-3 0716-16(06)MP
5. Test IO-76 Showing Stand REON Report #2597 pg. 49

IV. DRAWINGS

A. EQUIPMENT

1. Target Dolly (Engine Support Assembly) 511634A
2. Target Dolly (Engine Cradle Assembly) 512610

B. SKETCHES

1. Data Recording Arrangement REON Report # 2597 pg. 107

V. PURCHASE ORDERS AND CONTRACTS

A. PURCHASE ORDERS

1. Trailer Rental P.O. D705 733-CD
2. Security Guard Service P.O. 707095-CD
3. Prepare Testing Areas P.R. 175621 P.O. 706179-CD

B. SUBCONTRACTS

1. G.E. Contract with SNPO 1 Aug. 1963 NP-11

CONTRACT YEAR 1963

AS
OF

DESTRUCT SYSTEM		1962						1963											
		OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER			
	WEEK BEGINNING	6 13 20 27	3 10 17 24	1 8 15 22 29	5 12 19 26	2 9 16 23	2 9 16 23	30 6 13 20 27	4 11 18 25	1 8 15 22 29	6 13 20 27	3 10 17 24	31 7 14 21	28 5 12 19 26	2 9 16 23	30 7 14 21			
1.	COMPLETE PRELIMINARY FRAGMENTATION RESEARCH						↑												
2.	COMPLETE PRELIMINARY MAT'L CORRELATION EXPERIMENTS											↑							
3.	COMPLETE PRELIMINARY STUDIES ON FRACTURE MECHANISMS											↑							
4.	COMPLETE ADDITIONAL FRAGMENTATION RESEARCH EXPERIMENT AND STUDIES												↑		◊				
5.	PUBLISH REPORT ON CY 1963 FRAGMENTATION RESEARCH PROGRAM													↑		◊			
6.	COMPLETE SITE SELECTION AND ESTABLISH CRITERIA FOR SITE PREPARATION	↑																	
7.	PUBLISH PRELIMINARY PROPOSAL FOR TEST SITE PREPARATION						↑												
8.	COMPLETE TEMPORARY PROVISIONS FOR TEST SITE OPERATION							↑											
9.	COMPLETE INITIAL FACILITY CONSTRUCTION											↑		◊		TR 1.9.1			
10.	PUBLISH PROGRAM PLAN FOR EXPLOSIVE AND INITIATOR RAD. EFFECTS EXPERIMENTS		↑																
11.	COMPLETE INITIAL RADIATION EFFECTS ON EXPLOSIVES											↑				TR 1.9.1			
12.	COMPLETE INSTALLATION OF GETR I-BEAM MODIFICATION												↑			TR 1.9.1			
13.	COMPLETE EVALUATION PICATINNY RAD. EFFECTS CAPSULE DESIGN													↑		TR 1.9.1			
14.	COMPLETE INITIAL RADIATION EFFECTS ON INITIATORS												↑			TR 1.9.1			

RESCHEDULED TO CY 64

◆ **RESCHEDULED MILESTONE ACHIEVEMENT**

RECON
ROCKET ENGINE
OPERATIONS NUCLEAR
AEROSPACE

RECON
ROCKET ENGINE
OPERATIONS NUCLEAR
AEROSPACE

~~CONFIDENTIAL~~

RESCHEDULED TO CY 64

◆ RESCHEDULED MILESTONE ACHIEVEMENT

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RECON
ROCKET ENGINE
OPERATIONS NUCLEAR
AEROSPACE
GENERAL

HARDWARE STATUS

9-30-63

TASK ITEM 1.6
TASK TITLE DESTRUCT SYSTEM

COMPONENT/SUB-ASSEMBLY	END USE	EST.	ACTUAL	REMARKS
MK K	Destruct System Concept Screening Tests	21	4	
SLAB TARGET EXPLOSIVE CHARGES "F"	Screening Test Explosive Charges	4	4	
SLAB TARGET EXPLOSIVE CHARGES "G"	Screening Test Explosive Charges	4	4	
SLAB TARGET EXPLOSIVE CHARGES "H"	Screening Test Explosive Charges	4	3	
SLAB TARGET EXPLOSIVE CHARGES "D-J"	Screening Test Explosive Charges	4	1	
SLAB TARGET EXPLOSIVE SHAPE CHARGE	Screening Test Explosive Charges	8	4	
FULL DIAMETER, HALF LENGTH TARGET	Destruct Systems Concept Feasibility Tests	15	19	
FULL DIA. HALF LENGTH EXPLOSIVE CHARGES "F"	Feasibility Test Explosive Charges	2	1	
FULL DIA. HALF LENGTH EXPLOSIVE CHARGES "G"	Feasibility Test Explosive Charges	1	1	
FULL DIA. HALF LENGTH EXPLOSIVE CHARGES "H"	Feasibility Test Explosive Charges	1	1	
FULL DIA. HALF LENGTH EXPLOSIVE CHARGES "D-J"	Feasibility Test Explosive Charges	13	13	
FULL SCALE TARGETS	Destruct System Concept Feasibility Tests	4	4	
FULL SCALE EXPLOSIVE CHARGES "G"	Feasibility Test Explosive Charges	1	1	
FULL SCALE EXPLOSIVE CHARGES "D-J"	Feasibility Test Explosive Charges	1	1	
FULL SCALE EXPLOSIVE CHARGES "F"	Feasibility Test Explosive Charges	1	0	
FULL SCALE EXPLOSIVE CHARGES "E"	Feasibility Test Explosive Charges	1	1	
TEST STANDS - FULL DIA. HALF LENGTH	Mount Full Diameter, Half Length Targets	17	17	
TEST STAND - FULL SCALE	Mount Full Scale Targets	4	4	
AFTER CONF, ALUMINUM	Component for Full Scale Simulated Engine	6	6	
CAVITY SHAPED CHARGE - 5'	Explosive Charges for Feasibility Tests	15	15

HARDWARE STATUS

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TASK ITEM 16
TASK TITLE DESTRUCT SYSTEM

COMPONENT/SUB-ASSEMBLY	END USE	EST.	ACTUAL	REMARKS
CAVITY SHAPED CHARGE - 6'	Explosive Charges for Feasibility Tests	4	4	
CAVITY SHAPED CHARGE - 7"	Explosive Charges for Feasibility Tests	13	13	
CAVITY SHAPED CHARGE - 8'	Explosive Charges for Feasibility Tests	21	21	
CAVITY SHAPED CHARGE - 10"	Explosive Charges for Feasibility Tests	8	8	
LINEAR SHAPED CHARGE - CIRCUMFERENTIAL	Explosive Charges for Feasibility Tests	7	7	
LINEAR SHAPED CHARGE -STRAIGHT LENGTHS	Explosive Charges for Feasibility Tests	46	46	
CYLINDRICAL CHARGES 3" dia x 8'	Explosive Charges for Feasibility Tests	1	1	
CYLINDRICAL CHARGES 4' dia x 26"	Explosive Charges for Feasibility Tests	2	2	
CYLINDRICAL CHARGES 5' dia x 20"	Explosive Charges for Feasibility Tests	5	5	
CYLINDRICAL CHARGES 6" dia x 6'	Explosive Charges for Feasibility Tests	1	1	
CYLINDRICAL CHARGES 4' dia x 32'	Explosive Charges for Feasibility Tests	1	1	
CYLINDRICAL CHARGES 4' dia x 16"	Explosive Charges for Feasibility Tests	2	2	
CYLINDRICAL CHARGES 5' dia x 12'	Explosive Charges for Feasibility Tests	8	8	
STEEL/CONCRETE TARGET	A/C CAVITY SHAPED CHARGE EVALUATION	24	28	
STEEL/SIMULATED CORE MARK C	Mark C Evaluation Test	4	4	
STEEL/SIMULATED CORE MARK D/J	Mark D/J Evaluation Test	4	4	
ALUMINUM/SIMULATED CORE MARK C/A	Mark C/A Evaluation Test	10	10	
ALUMINUM/SIMULATED CORE MARK D/J	Mark D/J Charge and Evaluation Test	2	2	
ALUMINUM/SIMULATED HALF LENGTH	Mark D/J Charge Configuration Evaluation Test	4	4	
STEEL SKIN	Conical Shaped Charge Evaluation Test	6	6	
SIMULATED SKIN	Linear Shaped Charge Evaluation Test	10	10	
FULL SCALE TEST STAND	Full Scale Engine Tests - Target Mount	23	18	
HALF LENGTH TEST STAND	Half Length Engine Tests - Target Mount	4	8	
STEEL FORWARD HEAD	Component for Full Scale Simulated Engine	14	14

HARDWARE STATUS

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TASK ITEM 1.6

TASK TITLE DESTRUCT SYSTEM

COMPONENT/SUB-ASSEMBLY	END USE	EST.	ACTUAL	REMARKS
AFTER CONE, STEEL	Component for Full Scale Simulated Engine	7	7	
GRAPHITE SPECIMENS - LB	Impact Tests	178.5	127.5	
GRAPHITE SPECIMENS - LB	Explosive Tests	1992	1897	
EXPLOSIVE SHEET - LB	Explosive Tests	50	50	
COMP "B" EXPLOSIVE - LB	Explosive Tests	50	50	
EXPLOSIVE BOOSTER - EA.	Explosive Tests	100	100	
EXPLOSIVE DETONATORS - EA.	Explosive Tests	100	100	
EXPLOSIVE PRIMACORD - FT.	Explosive Tests	50	50	
TAPE - ROLLS	Explosive Tests	10	10	
PLYWOOD - SHEETS	Explosive Tests	3	3	
STEEL - LB	Explosive Tests	180	180	
ALUMINUM - LB	Explosive Die	23	23	
SAMPLE - RESIN IMPREGNATION PRESSURE	Evaluation Tests	1	1	
COLD TEMP. EQUIPMENT	Impact Tests	1	0	
HIGH TEMP. EQUIPMENT	Impact Tests	1	0	
PLEXIGLAS ATTENUATOR	Calibration, Development or Fracture Studies, Time of Arrival	500	600	
	Gage and Pressure Gage			
X 98 DETONATORS	Calibration, Development, Fracture Studies and Time of Arrival	637	637	
	Gages			
GRAPHITE DISK	Fracture Studies	115	135	
STEEL PLATE 4" x 4" x 1/4"	Fracture Studies, Flying Plate	80	80	
STEEL PELLET, 10 GRAIN	Fracture Studies, High Velocity Pellet	80	80	
PIEZOELECTRIC CRYSTALS	Design Development and Calibration of Time of Arrival Gages and	100	100	
	Pressure Transducers

HARDWARE STATUS

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TASK ITEM 16
TASK TITLE DESTRUCT SYSTEM

COMPONENT/SUB-ASSEMBLY	END USE	EST.	ACTUAL	REMARKS
PLEXIGLAS PELLETS (0.25" DIA.)	Calibration Fracture Studies	220	220	
PLEXIGLAS RODS	Calibration of Time of Arrival Gages and Pressure Gages	40	40	
GUARD SERVICE - RENTAL	Security Guard	3 Guards	3 Guards	
TRAILER RENTAL	Temporary Office	2 Trailers	2 Trailers	
TEST PADS	Test Firing Locations	2 Pads	2 Pads	
ACCESS ROADS	On-Site Vehicle & Personnel Movement Grade Only			
LINE WAVE GENERATOR	Used with the Flying Plates	80	80	
HIGH GAIN PICKUP TRANSDUCER	Sonic Pick Up 20 CPS to 20,000 CPS Range	1	0	
LOW DISTORTION SOUND TRANSDUCER	To Produce Sonics From 20 CPS to 20,000 CPS	1	0	
GRAPHITE TEST SPECIMENS	Item to be Sonically Tested	10	0	
COMMERCIAL GRAPHITE ROD, LB	Stock for Test Specimens, Structural and Explosive Tests	2046	2046	
COMMERCIAL CARBON ROD, LB	Stock for Test Specimens, Structural and Explosive Tests	1114	1114	
URANIUM LOADED GRAPHITE ROD (GFE)	Stock for Test Specimens, Structural and Explosive Tests	60	0	
MACHINED, LOADED GRAPHITE ROD (GFE)	Test Specimens, Mechanical and Explosive Tests	180	0	
MACHINED, GRAPHITE, B-4 CONFIG.	Test Specimens, Mechanical and Explosive Tests	160	160	
UC ₂ SPHERODIZED BEADS	Microstructural Examination	275	0	
CAPSULE, EXPLOSIVE CONTAINER (3.0 GRAM)	Design Development, Irradiation Experiments	117	94	
CAPSULE, EXPLOSIVE CONTAINER (160 GRAM)	Design Development	12	0	
CAPSULE, EXPLOSIVE CONTAINER (INITIATOR)	Design Development, Irradiation Experiments	25	0	
I BEAM FIXTURE	G F Reactor Handling Fixture to Hold Capsule During Irradiation	1	0	
INITIATOR TEST BLOCKS	Holding Fixture for Initiator During Test Firings	60	0	
INITIATORS	Performance Test Before and After Irradiation	220	0

TEST STATUS

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TASK ITEM 16

TASK TITLE Destruct System

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Slab Targets	MK-F	To determine concept feasibility on simple, crude targets	Chino	4	4	
	MK-G			4	4	
	MK-H			1	1	
	MK-G-H			4	4	
	Shape Charge			8	8	
Full Diameter, Half Length Targets	MK-F	To determine explosives destruct concept feasibility on simulated engine targets	Hawthorne	1	1	
	MK-G			1	1	
	MK-H			1	1	
	MK-D-J			12	12	
Full Scale Targets	MK-G	To determine explosive destruct concept feasibility on full scale targets	Hawthorne	1	1	
	MK-D-J			1	1	
	MK-K			1	1	
	MK-E			1	1	
Radiation Effects Capsules	3 Gram Explosive Capacity	Capsule Design evaluation and qualification	Chino	57	94	Increased because some capsules used to contain initiators
	160 Gram Explosive Cap.			12	0	Delayed because of contract negotiations
	Initiator Capsule			20	0	Delayed because of contract negotiations
Explosive, Confined in Rad. Effects Capsule	Irradiation Tests	Study of Rad. Effects on Explosive Impact Sensitivity. Study of Rad. Effects on Initiator Performance	General Elec. Vallecitos	50	0	Delayed because of contract negotiations
Initiators	Initiator Performance Control Tests	Accumulate performance data for comparison to data obtained from irradiated initiators	Downey	50 60	0 0	Delayed because of contract negotiations Delayed because of contract negotiations
Steel/Concrete Simulated Engine Targets & Charges	Mark A/C Feasibility	Evaluation of cavity shaped charges	Chino	24 1	16 7	Additional tests not necessary Concrete - increased to obtain more data.
Steel/Simulated Core Target & Charges	Mark C Feasibility	Evaluation of Mark C Destruct Concept	Chino Hawthorne	3	3	FSSE

TEST STATUS

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TASK ITEM 1.6

TASK TITLE Destruct System

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Steel/Concrete Simulated Engine Target & Charges	Mark D/J Feasibility	Evaluation of internal burster charges	Chino	5	5	} Eliminated in favor of tests with more accurate simulated engines.
Steel/Simulated Core Target & Charges	Mark D/J Feasibility	Evaluation of Mark D/J destruct concept	Hawthorne	4	0	
Aluminum/Simulator Core Targets & Charges	Mark C/A Fea- sibility	Evaluation of destruct systems on more accurate	Hawthorne	5	4	
Steel Plates & Cavity Shaped Charges	Mark D/J Feasibility	Simulated Engines	Hawthorne	2	3	Increased - more valuable data.
	Parametric Devel. of Shaped Chgs.	Determination of minimum ex- plosive weight required for desired penetration	Chino	6	9	Increased - more valuable design information.
Simulated Pressure Vessel & Linear Shaped Charges	Mark A/B Feasibility	Evaluation of Mark A/B Linear destruct concept charge devel.	Chino	10	18	Modified to obtain more design information on shaped charges
Aluminum/Simulated Core Half Length Target and Charges	Mark D/J Feasibility	Evaluation of charge size for Mark D/J destruct system	Hawthorne	4	2	Reduced after design criteria was met with fewer tests
Graphite & Carbon Test Specimens for Structural Tests	Individual Specimens	To fracture & deform graphite specimens under control condi- tions for study of possible microstructural changes	AGC Azusa Structural Materials Div	700	112	Reduced because these tests established that this method of examination was of no value - no changes observed.
Graphite & Carbon Test Specimens for Explosive Tests	Individual & Multiple Specimens	To fracture & deform graphite specimens at high strain rates for study of possible micro- structural changes	Chino	50	0	Eliminated because no changes observed in above tests.
Graphite & Carbon Specimens for Microscopic and X-Ray Diffraction Examination	Fractured & Unfractured Specimens & Components (UC ₂ , Beads, Binder, Graphite, Flour)	Determination of microstructural changes caused by various frac- ture conditions	AGC Azusa Structural Materials Div	350	0	Eliminated because no changes observed in above tests.

TEST STATUS

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TASK ITEM 1.6

TASK TITLE Destruct System

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Graphite Specimens Explosives Electronic Instruments	Individual Specimens of Graphite and Explosives	Determine Hugoniot Equation of State for graphite	Chino	0	30	Aug. '63 0716-16(11)MP
Shock Propagation Studies with Framing Camera	Explosive Energy Trans- mitted through Plexiglass	Photographically observe shock wave propagation through plexiglass	Chino	0	10	July '63 0716-16(10)MP
High Speed Photography of Multiple Element Breakup		Photographically observe breakup of graphite rod bundle	Chino	0	15	May '63 0716-16(08)MP
Graphite AGS-X or HPC	Single Solid Rods	20 CPS-25 MC Frequency Scan to determine energy attenuation characteristics, transverse only	Downey/Azusa	3	0	Acoustic tests deleted because preliminary tests were unsuccessful
" " " "	Bundle Drilled Rods		Downey/Azusa	3	0	" " " " " " " "
" " " "	Bundle Solid Rods	To determine sonic & ultrasonic attenuation characteristics at various power levels	Downey/Azusa	3	0	" " " " " " " "
" " " "	Bundle Drilled Rods		Downey/Azusa	3	0	" " " " " " " "
" " " "	Single Solid Rod			18	0	" " " " " " " "
" " " "	Single Drilled Rod			18	0	" " " " " " " "
" " " "	Single Solid Rod	20 CPS-25 MC Frequency Scan to determine energy attenuation characteristics at low temp.	Downey/Azusa	18	0	" " " " " " " "
" " " "	Single Drilled Rod			18	0	" " " " " " " "

TEST STATUS

9-30-63

TASK ITEM 1.6

TASK TITLE Destruct System

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Graphite AGS-X or HPC	Bundle Solid Rods	20 CPS-25 MC Frequency Scan to determine energy attenuation characteristics at low temp.	Downey/Azusa	3	0	Acoustic tests deleted because preliminary tests were unsuccessful
" " " "	Bundle Drilled Rods			3	0	" " " " " " " "
" " " "	Bundle Solid Rods	To determine sonic & ultrasonic attenuation characteristics at low temperature with various power levels	Downey/Azusa	3	0	" " " " " " " "
" " " "	Bundle Drilled Rods			3	0	" " " " " " " "
" " " "	Single Solid Rod	" " " "	Downey/Azusa	18	0	" " " " " " " "
" " " "	Single Drilled Rod	" " " "		18	0	" " " " " " " "
Plexiglass Attenuation - X98 Detonator	Explosive Fracture	To determine the explosive energy required to form new surfaces in graphite	Chino	55	8	Reduced - data not reliable
Piezo Electric Crystal - Plexiglass Attenuation	Design, Development & Calibration Tests	To test & calibrate shock wave pressure transducers & time-of-arrival gages	Chino	105	63	Reduced - additional tests not necessary
Plexiglas Attenuator - Plate X-98 Detonator, Linewave Generator	Devel. & Calib. Tests	To develop techniques and determine shock pressure and energy vs. distance for plexiglas attenuator when impacted by a flying plate	Chino	40	0	Acoustic tests deleted because preliminary tests were unsuccessful
Plexiglas Attenuators - Graphite Plate -X-98 Detonator-Line Wave	Fracture Studies Flying Plate	To determine the energy required to form new surfaces in graphite when impacted with a flying plate	Chino	40	0	Acoustic tests deleted because preliminary tests were unsuccessful
Plexiglas Attenuator Pellet X-98 Detonator	Development & Calib. Tests	To determine the attenuation of shock energy by plexiglas when impacted with a high velocity pellet	Chino	40	0	Acoustic tests deleted because preliminary tests were unsuccessful

TEST STATUS

9-30-63

TASK ITEM 1.6
TASK TITLE Destruct System

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Flexiglas Attenuator - Graphite Pellet - X98 Detonator	Fracture Studies High Velocity Pellet	To determine energy required to form new surfaces in graphite when impacted with a high velocity pellet	Chino	40	0	Acoustic tests deleted because preliminary tests were unsuccessful
Graphite AGS-X or HPC Used as Standard for Tests	Single Solid Rod	All samples to be X-rayed to detect flaws which could cause erroneous sonic reflections	Downey	18	0	Acoustic tests deleted because preliminary tests were unsuccessful
	Single Drilled Rod			18	0	Acoustic tests deleted because preliminary tests were unsuccessful
Graphite AGS-X or HPC	Single Solid Rod	20 CPS-25 MC Frequency Scan to determine energy attenuation characteristics, longitudinally and transverse	Downey/Azusa	45	0	Acoustic tests deleted because preliminary tests were unsuccessful
	Single Drilled Rod			45	0	Acoustic tests deleted because preliminary tests were unsuccessful
Single Rods of Various Geometries Comm. Mat'l	Mechanical Im- pact Tests Ambient Temp.	To obtain basic correlation data	Chino	13	28	Increased number of tests to obtain better data
Multiple Rods of Various Geometries Comm. Mat'l	"	To obtain data on fracture characteristics of simulated core configuration targets	Chino	13	13	
Single Rods of One Geometry	Mechanical Im- pact Tests Cryo- genic Temp.	To determine effects of cryogenic temps on fracture characteristics of core mat'l	Chino	3	2	Number of tests reduced because of poor data
	Mech. Impact Tests High Temp	To determine effects of elevated temp on fracture characteristics of core mat'l	Chino	15	4	Number of tests reduced because of poor data
Depleted Core Mat'l	Mech. Impact Tests	To determine fracture character- istics of depleted core mat'l	Chino	10	0	Material not available.
Core Geometry Rods	" "	To determine fracture character- istics of core geometry rods	Chino	10	0	Material not available.

TEST STATUS

9-30-63

TASK ITEM 1.6
TASK TITLE Destruct System

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Core Geometry Rods	Mech. Impact Tests	Verification of previously obtained data	Chino	9	0	Material not available.
Rod Bundle Module	Explosive Frac. Tests	To determine bundle size and configuration required to obtain desired data.	Chino	11	11	
Rod Bundle - Special Rods	Explosive Frac. Tests	To determine fracture characteristics	Chino	10	10	Reduced because of late delivery of material. Material not available Material not available
Rods (Core Config.)	" " "	" " " "	Chino	10	2	
Depleted Core Mat'l.	" " "	" " " "	Hawthorne	2	0	
Fueled Core Rods	" " "	" " " "	Hawthorne	1	0	
Explosive Fragments	Evaluation tests	Microscopic examination of explosive fragments	Downey	6	22	Increased because of valuable results
Plexiglas Attenuator-X98 Detonator (2)	Shock Attenuation & Transmission Expr. Calib. Test	To determine explosive shock press and energy attenuation characteristics of plexiglas	Chino	53	33	Additional tests not necessary

S/T 1.7 PNEUMATIC SYSTEM

ACCOMPLISHMENTS

W/S REFERENCE	ACTIVITY	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.7	ENG.	INITIATE E-1 PNEU- MATIC SYSTEM LAYOUT	LAYOUT OF P.S. FOR E-1 ENGINE COMPLETED SCHEMATICS OF FOLLOWING COMPLETED P.S. FOR E BLOCK I P. S. FOR E BLOCK II P. S. FOR E BLOCK III P.S. FOR FX P. S. FOR CFDTs	AGC 702657 LRP DWG. 296941 LRP DWG. 297725 LRP DWG. 297736 LRP DWG. 296919 LRP DWG. 298463

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

S/T I.7 PNEUMATIC SYSTEM

ACCOMPLISHMENTS

W/S REFERENCE	ACTIVITY	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.7	ENGR.	CONDUCT STUDIES TO SYNTHESIZE P.S.	COMPLETE	AGC RPT. 2697
2-1.7	ENGR.	COMPLETE PRE- LIMINARY DESIGNS, SPECS, AND/OR SELECTIONS FOR ALL P.S. COMP.	COMPLETE	AGC SPEC. NO. 42256 42249 42254 A 42241 42264 42257
2-1.7	ENGR.	COMPLETE, DESIGNS & SPECS, FOR PS. FOR CFDTS	TASK COMPLETED, HOWEVER, RELEASE OF DRWGS. DELAYED TO 11/4/63	23 DRWGS

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

S/T 1.7 PNEUMATIC SYSTEM

ACCOMPLISHMENTS

W/S REFERENCE	ACTIVITY	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.7	FAB.	INITIATE PROCURE- MENT OF CHECK VALVES, PRESSURE REGULATORS, RELIEF VALVES, SHUTOFF VALVES, FILTERS, BELLOWS, LINE & DISCONNECTS	PROCUREMENT INITIATED ON COM- PONENTS BELOW. <u>ITEM</u> a. SHUTOFF VALVES 3 b. CHECK VALVES 6 c. REGULATORS 6 d. RELIEF VALVES 3 e. DISCONNECTS 12 f. TEST STAND PNEUM CONNECTORS * g. SEALS 20 h. FILTERS 4	VENDOR P.O. COMPLETED
2-1.7	ENG.	INITIATE PREPARA- TION OF COMPONENT TEST PLANS	TEST PLANS INITIATED	TEST PLAN PRO- CUREMENT NO. TO BE ASSIGNED

SUBTASK 1.7 - ACCOMPLISHMENTS FOR CY 1963

Purpose and Objective

The overall objective of the work to be performed under this subtask is to develop a pneumatic supply system capable of supplying sufficient gas at the required pressure for NERVA engine actuating devices and the RIFT vehicle propellant tank.

The specific objectives during the CY 63 period are to perform analytical design studies of the pneumatic supply system and to fabricate components for an experimental program to be conducted in the next contract period. Both the analytical effort and the fabrication of prototype experimental hardware were performed as required.

The specific accomplishments during this period with respect to the work statements for this subtask are as follows:

During CY '63 a pneumatic system was synthesized which would serve to supply the engine pneumatic actuators and the main propellant tank with gaseous hydrogen. The system has undergone minor periodic changes throughout the year to reflect changes in the vehicle system and to incorporate added features such as the collection and ducting of leakage gas from the engine through the interface.

While there was uncertainty in the exact sizing of some of the components it was, nevertheless, decided that work would proceed on the components in order to make significant advances in the development of the types they represented. Sizing changes later in the program would not significantly affect the selection of component types. As a result of the decision to proceed, design studies were performed on the pneumatic system components which included relief valve, shutoff valve, regulator, check valve, filter, remote disconnect, and test stand pneumatic connector. Specifications for these components were released.

A layout and 23 detail component drawings of the pneumatic system for the Cold Flow Development Test System were completed in CY '63, however, release

of drawings will be delayed to 11/4/63. The pneumatic system for the CFDTS will provide realistic startup conditions on the filter at the plenum exit as well as the other system components.

Fabrication of all of configuration I components was initiated. The test stand pneumatic connector vendors requested additional time in which to propose, consequently, orders for these components were postponed until the CY '64 period. The milestone would have been completed in CY '63 but for this component.

Test plans were initiated to cover the non-nuclear tests to be performed on the pneumatic system components. Selected components for radiation testing will first be acceptance tested to permit subsequent alterations in their performance.

A layout of the pneumatic system for the E Block I engine was completed during CY '63 and is presented in AGC Drawing 702657. In addition the schematics for Block I, II and III, the CFDTS and FX engine were prepared. The additional schematics were prepared to provide the proper planning information necessary for an orderly development program.

Conclusions

All work statement objectives and the milestones were completed.

Work Not Proposed but Completed

Considerable effort was expended in RIFT interface liason and special reporting activities associated with the Thrust Vector Control System and Tank Pressurization System.

SUBTASK 1.7 - BIBLIOGRAPHY

A. DOCUMENT CONTAINING S/T 1.7 CONTRIBUTION

<u>Report No.</u>	<u>Vol.</u>	<u>Title</u>	<u>Date</u>
2697		REON comments on the Proposed LMSC Offset-Gimbal Engine Suspension System (U)	Oct. 1963
2276		Engine Systems Data Book	Nov. 1962
2320		Instrumentation Data Book	Oct. 1963
2420		Preliminary Survey-Nuclear Rocket Propulsion Systems for Advanced Application	May 9, 1963
		Informal Monthly Progress Letters (Report Nos. L0560-10/16/62 through L0560-10/27/63)	
		Weekly Highlights TWX Reports (No. 1 dtd. 10/24/62 through # 50 dtd 10/2/63)	
		Report No. 2323, Vol I, II, and III, Summary Report for CY '62.	Nov. 1962
2322		All NERVA Program Planning Documents	
2434		" "	
RM63002		" "	
2529		" "	
2544		" "	
2560		" "	
RN3005		" "	
Spec AGC-10095C		NERVA Engine Model Specification	12 July
Spec AGC-10138	Rev. A.	Rest System, Development, Cold Flow, for ST 30-5 Engine	12/31/62

B. S/T 1.7 DOCUMENTS

<u>Document</u>	<u>Title</u>	<u>Date</u>
NDC - 28	Pneumatic System for Hot-Bleed Engine AJ30-5	10/31/62
NDC-29	Valve, Pressure Reducing, Tank, PS, Hot-Bleed Engine AJ30-5	10/31/62
NDC-30	Diaphragm, Burst, PS, for NERVA Hot-Bleed Engine AJ30-5	3/8/63
NDC-31	Coupling Assembly, Quick Disconnect PS, Hot-Bleed Engine AJ30-5	10/31/62
NDC-37	Tank, Storage, Pneumatic, for Hot-Bleed Engine AJ30-5	3/4/63
NDC-39	Valve, Shutoff, PS, Hot-Bleed Engine AJ30-5	10/31/62
NDC-40	Valve, Relief, PS, for NERVA Hot-Bleed Engine AJ30-5	2/27/63
NDC-41	Valve, Check, PS, for Hot-Bleed Engine AJ30-5	12/14/62
NDC-41/1	Valve, check, 1/2" tube size, Pneumatic System Hot-Bleed Engine AJ30-5	3/6/63
NDC-41/2	Valve, Check, 1 1/4" tube size, Pneumatic System Hot-Bleed Engine AJ30-5	3/6/63
NDC-42	Filters, PS, Hot-Bleed Engine AJ30-5	10/31/62
AGC 42256	Relief Valve Specification	
AGC 42249	Shutoff Valve Specification	
AGC 42254A	Regulator Specification	
AGC 42241	Check Valve Specification	
ABC 42264	Filter Specification	
AGC 42257	Test Stand Pneumatic Connector Specification

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.7

↑ SCHEDULED MILESTONE

▲ MILESTONE ACHIEVEMENT

◇ RESCHEDULED MILESTONE

◆ RESCHEDULED MILESTONE ACHIEVEMENT

◇ RESCHEDULED TO CY 64

CONFIDENTIAL

S/T 1.8 NRDS OPERATIONS - CY '63

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.8 (A)	STAFF NERVA/NRDS TEST ORGANIZATION FOR NRX PROGRAM	PERFORMED	SEE MANNING CHART
(B)	ASSIST IN OPERATION & SUPPORT OF NRX TEST FACILITIES	PERFORMED	SEE NRDS PUBLICATIONS
(C)	PROVIDE SUPPORT DURING ETS-I CONSTRUCTION AND CHECKOUT	PERFORMED	LETTER, 10/17/62, L740:0035 CHANGE LIST SUBMITTED TO SNPO
(D)	ETS-I PARTIAL OCCUPANCY, OPERATIONS PERFORMED, AND MAINTENANCE	PERFORMED	LETTER, 7/7/63, CODE L0070 MEETING WITH SNPO-C & SNPO-N AT NRDS 6/11/63 AGC SHIPPER NO. 41528 P.O. NO. 362800

RECON ROCKET ENGINE OPERATIONS-NUCLEAR

AGC MANNING FOR S/T 1.8

NRDS OPERATIONS - CY 1963

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

SUBTASK 1.8 - ACCOMPLISHMENTS FOR CY 1963

Purpose and Objective

The objectives of this task during CY 1963 were to (a) provide an initial NERVA-NRDS test organization for the NRX test program, consisting of an integrated AGC-WANL-LASL team, in which the AGC-WANL members would assist LASL in the KIWI program, obtain valuable training and operating experience and be capable of conducting the NRX program during CY 1964 without further assistance from the LASL organization, and (b) provide technical support and field participation during the construction and checkout of ETS-1, followed by the responsibility for its operation, maintenance, and the correction of minor construction deficiencies. Included in these objectives were the initiation of a Health and Safety program, the establishment of a Quality Control Program, and the provision of necessary administrative services in support of the test organization.

2-1.8

A NERVA-NRDS test organization was established for the NRX program, which participated in the LASL Kiwi program, as well as the preparation of Test Cell "A" for the NRX program. In addition to the engineering staffing, AGC technicians replaced the LASL subcontractor, AP&CI, in test cell operations. During the final quarter of CY 1963, the mixing chamber tests in Test Cell A were conducted almost entirely by NERVA personnel. As part of their training, engineers and technicians were given a Test Cell "A" Indoctrination Course, prepared under Task 2.8. Facility Operating Procedures for Test Cell "A" were prepared and issued, and additional procedures for the Control Point were initiated and will be issued shortly.

Prior to the establishment of this subtask, all work on ETS-1, such as the monitoring of construction contractor's activities and activation planning, was performed as a subtask to Task 3.2, Test Stand ETS-1.

As the work of the construction contractor approached completion, and at the request of SNPO, NTO personnel prepared a list of the facility modifications and changes necessary to make ETS-1 operational in a reliable and safe

manner. This list was presented to SNPO in a meeting held 11 April 1963 at the AEC office in Las Vegas, Nevada.

Subsequent to a review of the listed items by SNPO-N, SNPO-C, and preparation of cost estimates by Catalytic Construction Company, meetings were held between SNPO-C, SNPO-N, and NTO on 13 and 14 May, with the final disposition of the items made on 15 May 1963 in a meeting held at the AEC office in Las Vegas. This final disposition delineated the items necessary to make the various systems operational from a construction standpoint and, as such, the work involved was to be accomplished by construction craft labor. The following items were placed in this category:

- Installation of additional pipe supports.

- Completion of the LN_2 and LO_2 Storage Dewar fill and discharge connections.

- Removal of Tank Flange blinds in all but the high pressure storage vessels.

- Installation of actuation tubing for the water valves in the test stand water pipe system.

- Installation of continuous duty relays in the air compressor cooling water flow control system.

- Providing additional bracing for the Flare Stack, FS 5003.

- Rework of the test stand cross bracing which was removed because of interference with other equipment.

It was further determined that all other items on the list were not absolutely essential to make the system operable, but would be done during or after activation by operating, maintenance, or support services personnel. It was further determined that no operating or maintenance work could be done on the systems involved until they were considered operational.

By the end of the contract year, work on the pipe supports and the actuation tubing of the water valves was initiated; however, none of the systems were declared operational to the point of permitting any operational or maintenance work to be performed.

In anticipation of taking over operational responsibility for the process systems upon assumption of BOD by the government, and in accordance with Contract SNP-1, NERVA Test Operations brought on board five Rocket Test Technicians,

6 May 1963. Upon initial familiarization with the facility, and at the request of SNPO-N, these technicians were utilized in obtaining as-built dimensions of government-furnished cryogenic vessels required for the design of level probes by the I&C contractor. Since the decisions reached at the 15 May meeting precluded any operational, maintenance or modification work, the five technicians were returned to the home plant on 24 May 1963.

The Test Stand and Process Systems, as constructed under Invitation 292-62-14, Contract No. AT(29-2)-1270, were officially accepted by SNPO-N on 24 May 1963 for beneficial occupancy with the following exceptions:

Replacement of the demineralizer.

Testing and validation of the vacuum jacketed piping.

Repair of Vacuum Pump VP-38C1.

Checkout of elevator equipment, which has a tendency to overheat.

Deferment of cold testing of Run Vessel V-5001.

Replacement of Relief Valve 30 PRV 86 due to incorrect operating range.

In a meeting on 11 June 1963, held at NRDS between NTO, SNPO-N and SNPO-C, it was established that operational checks to verify the integrity of contractor-installation systems on ETS-1 would commence on 1 October 1963. A detailed outline of procedures to accomplish the program were prepared, based on a recently imposed constraint on the use of the high-pressure storage vessels, V-3201 through V-3206, at a maximum operating pressure of 1000 psi. This outline was submitted to SNPO-C for review on 17 July 1963, and subsequent to SNPO's review and recommendations, was discussed with SNPO and will serve as a basis for the operational checks to be conducted in Contract Year 1964. These operational checks will include the testing and validation of the vacuum jacketed pipe and the cold testing of the Run Vessel, V-5001.

At the request of SNPO-C, work on the calibration testing of the 42-inch water line was initiated in the final quarter of CY 1963. The test procedures prepared by NTO were approved with minor modifications. The cross-over piping to replace the duct was fabricated in Azusa and shipped to NRDS on AGC shipper No. 41528. However, the fact that the mandatory work by construction craft labor on the valve actuation taking was not completed, precluded any further work in the pipe chase area.

At the request of SNPO-C, work on the testing of the three diesel generators was initiated in the final quarter of CY 1963.

During CY 1963, interface coordination was maintained with Subtasks 3.2 - ETS-1, 3.3 - I&C and Subtasks 3.1 - NES at REON, Azusa.

A NERVA Health and Safety staff was provided during CY 1963 which prepared and issued a Safety Manual to be used by all NERVA personnel. In addition, a Quality Control Program was initiated and a Quality Control Plan for NRDS prepared.

Administrative support was provided in the area of overall management of the NERVA Test Operations organization. A security staff was provided which obtains security clearances, issues security instructions, processed 745 security inspections, and participates on "run days" for area control of personnel. Twelve management directives were issued pertaining to standard practices, travel, communications, etc. A trailer was procured and equipped for document reproduction services, and is now used by all NERVA contractor personnel. A NERVA procurement and material control group was established for the procurement, receipt, storage, and shipment of all materials and equipment. Communications were improved by providing a switchboard in the Las Vegas office, with five trunk lines to the Azusa plant and four to NRDS. In the area of program planning, Report No. 2656 was issued defining the NRDS-NERVA Test Operations Organization, complete with organization charts, manning tables, and position descriptions. Likewise, Report No. 2657, defining the relationship and responsibilities of NTO and the Support Services Contractor was issued. In addition, Report No. 2698 was published as the result of a study made to determine the manpower requirements for the NRX program based on a 90-day test cycle. Assistance was also provided in the preparation and issuance of the Program Requirements Document, and in the coordination of these requirements with SNPO-N. In addition to the Informal Monthly Progress Reports submitted to REON for inclusion in the reports to the customer, monthly reports to the customer were issued on projected manpower at NRDS and personnel staffing by job category and salary bracket.

SUBTASK 1.8 - BIBLIOGRAPHY

1. NRDS publications completed.

<u>Publication Number</u>	<u>Title</u>	<u>Distribution Date</u>
RN-FM-0001	Test Cell "A" Familiarization Manual	6-15-63
RN-HSM-0001	Health and Safety Instructions	9-15-63
RN-FOP-0001	LH ₂ Fill Station, TCA	7-17-63
RN-FOP-0002	GH ₂ Fill Station, TCA	8-30-63
RN-FOP-0003	He Fill Station, TCA	7-9-63
RN-FOP-0004	N ₂ Fill Station, TCA	8-30-63
RN-FOP-0006	Vacuum System, TCA	7-5-63
RN-FOP-0008	Flare System, TCA	8-2-63
RN-FOP-0009	Room Inerting, TCA	7-1-63
RN-FOP-0010	Hydraulic System, TCA	7-17-63
RN-FOP-0011	Compressed Air, TCA	8-9-63
RN-FOP-0012	Reactor Shed, TCA	8-6-63
RN-FOP-0013	LH ₂ Turbopump, TCA	8-6-63
RN-FOP-0014	Water Cooling, TCA	8-26-63
RN-FOP-0015	Dewar Deluge, TCA	7-3-63
2531	Security Instructions	4-1-63
2656	Organization of NERVA Test Operations, Nuclear Rocket Development Station	8-5-63
2657	NERVA Test Operations and Support Services Contractor Responsibilities at NRDS.	8-5-63
2698	NRX Manpower Utilization, Nuclear Rocket Development Station	9-13-63
	Field Testing Diesel Generator Sets	7-16-63
	Checkout Procedure for ETS-1 Stand and Process Systems	7-17-63
	Process Water Calibration Test Procedure	9-24-63

FOP = Facility Operating Procedure

2. NRDS publications in process.

<u>Publication Number</u>	<u>Title</u>	<u>Status</u>
RN-FOP-0007	Gas System, TCA	Procedure approved, multilith masters and illustrations completed; ready for printing.
RN-FOP-0005	Cryogenic System, TCA	Draft submitted to NRDS personnel for review.
RN-IM-0002	CPA Systems Manual	Eight of eleven chapters completed. Approximately 50% of production effort completed.
RN-FOP-0027	Area Coordinator, CPA	Draft at Glendale awaiting final production.
RN-FOP-0025	Power Operator, CPA	Draft at Glendale awaiting final production.
RN-FOP-0018	Program Operator, CPA	Draft approved 10-23-63.
RN-FOP-0028	Forward Area Coordinator	Draft Approved 10-23-63.
RN-FOP-0019	GWLO Operator, CPA	Draft 40% completed. Hold pending completion of CPA Modifications.
RN-FOP-0026	Servives Operator	Started 9-15-63, draft 30% complete.

FOP = Facility Operating Procedure

S/T 1.9 RADIATION EFFECTS

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.9 A (1)	RADIATION EFFECTS PROGRAM SUBMITTAL	COMP	REPORTS 2467 2573
A (2)	TEST PLANS SPECIFICATIONS	COMP PARTIAL	REPORTS TOTAL OF 113, SEE LIST
A (3)	EXPLOSIVES RAD EFFECTS SUPPORT	COMP.	REPORTS 773 : RE : 0134 773 : RE : 0142 773 : RE : 024
A (4)	PROVIDE TECHNICAL DIRECTION TO GTR AND ASTR	COMP.	REPORTS 2467 2573 773 : RE : 0116 773 : RE : 0134

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

S/T 1.9 RADIATION EFFECTS

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
2-1.9 A (5)	PROVIDE NARF OPERATION	COMP	GTR TESTS 4, 7, 8/9 ASTR TEST I
A (6)	FIVE YEAR RAD EFFECTS PLAN	COMP	REPORT 63005 VOL II FIG 1.9-6
B (1)	DESIGN AND FABRICATION FOR GTR AND ASTR TESTS	PARTIAL COMP	GTR TESTS 4, 7, 8/9 ASTR TEST I
B (2)	MATERIALS 12-MONTH PROGRAM	COMP	REPORTS 2743 2512 2275
B (3-6)	WANL TESTS AND EFFORT	—	—

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

S/T 1.9 RADIATION EFFECTS

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-1.9 B (7)	SET UP AND CHECKOUT 90I TEST	COMPLETED	REPORTS 2652 GD-ASTR-I
B (8)	ENGR FOLLOWUP FOR NRDS TEST	DELETED	
B (9)	NARF FACILITIES MODIF CRITERIA	COMPLETED	MODIFIED FACILITIES USED FOR ASTR I TEST
B (10)	TRANSDUCER TEST AT NRDS	DELETED	
13-1.9 B (11)	PBRF SUPPORT (WANL)	—	—
2-1.9 C (1)	ANALYSIS OF TEST DATA	COMPLETED	REPORTS SEE LIST
C (2)	RADIATION EFFECTS DATA BOOK	COMPLETED	REPORTS 2277 2510
C (3)	RADIATION EFFECTS DATA BOOK ANALYSIS	COMPLETED	REPORTS 2277 2652

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

S/T 1.9 RADIATION EFFECTS

MATERIALS IRRADIATION PROGRAM

ORIGINAL SCOPE	AUTHORIZED REVISED SCOPE	STATUS
2 MATERIALS TESTS (TENSILE SHEAR)	1 MATERIAL TEST 1 MATERIAL TEST CHECKED OUT	COMP COMP
1 THERMAL CONDUCTIVITY TEST	1 THER. COND. TEST CHECKED OUT	COMP
	PULLING ASSEMBLY REPAIR AND IMPROVEMENT	COMP
	PROCURE 9 NEW DEWARS	DEFERRED TO CY 64
	PROCURE 10 THER. COND TEST UNITS	DEFERRED TO CY 64

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

S/T 1.9 RADIATION EFFECTS

MILESTONES

<u>MILESTONE ITEM</u>	<u>PLANNED (63002)</u>	<u>NET ADDED</u>	<u>COMPLETED CY 1963</u>	<u>RESCHEDULED CY 1964</u>
TEST PLANS	26	+1	27	0
TEST SPECIFICATIONS	26	+1	23	4
TESTS	26	+1	18	9
TESTS	18	+1	8	11

ROCKET ENGINE OPERATIONS—NUCLEAR

S/T 1.9 RADIATION EFFECTS

CY 1963 CARRYOVER

ITEM	WORK DEFERRED	SCHEDULE	REVISION
# 902	TEST, TEST REPORT	19 OCT	1963
# 903	TEST, TEST REPORT	24 OCT	1963
# 501	TEST	24 OCT	1963
# 502	PART FABR TEST	14 DEC	1963
# 503	TEST PLAN, SPEC, FABRICATION	25 APR	1963
EXPLOSIVES RAD. EFFECTS	(FROM S/T 1.6.3)	—

REON-ROCKET ENGINE OPERATIONS-NUCLEAR

SUBTASK 1.9 - ACCOMPLISHMENTS FOR CY 1963

Purpose and Objectives

The purpose of the Radiation Effects Program is to insure that NERVA engine components and systems will perform their required functions in the environment to be encountered during NERVA engine operation. The combination of cryogenic temperatures and high radiation fields has caused concern that premature failure of components could occur. Specific tests, conducted at cryogenic temperatures in radiation fields produced by test reactors are designed to elucidate the nature of these problems. Changes in component materials, design, fabrication, or location as a result of these irradiations will lead to improved NERVA engine design, operation, and reliability.

General

The obvious function of the Radiation Effects Program is to conduct radiation tests on materials, components, systems, and instrumentation. The production of meaningful engineering data from these tests is the primary goal of the program. To preserve the acquisition of this data, to insure its validity and to promote dissemination of all who are interested, an extensive system of test plans, test specifications, test procedures, and test reports are required for each individual test. Test pallet or test fixture design and fabrication, requires careful engineering and rigorous followup effort for the usefulness of test data acquired relies heavily upon intelligent test fixture design. The main activities of the Radiation Effects Program are planning, scheduling, and coordinating tests, assisting in the selection of components for testing, designing and fabricating test fixtures, incorporating components and instrumentation into test assemblies, performing necessary pre-irradiation and post-irradiation tests, monitoring tests during irradiation, analyzing test results, and documenting the information derived from the tests in the Radiation Effects Data Book.

Program Schedule

The irradiation program of NERVA components, defined in Report No. 63002, is by its own nature a dynamic program. No test program, however well

conceived, can accurately anticipate all test results, in advance, to assure that no changes in scheduled tests will occur during any given contract year's testing. The NERVA irradiation program necessarily changes during the Contract Year for the following reasons: (1) test results from prior irradiation tests may cancel or increase subsequent testing requirements, (2) changes in engine component design and conditions may change test conditions, (3) changes in the schedule of availability of component for testing may require test schedule revision, (4) coordination of tests with other programs may require program shifts because of the fixed amount of space available for irradiation testing in the test reactors, and (5) routine re-evaluation of test requirements during the contract year may require additional tests or allow test deletions. Changes in the CY 1963 irradiation program have occurred and are summarized below.

CY 1963 Radiation Effects Program

(Chart 1) Planning details for the GD/FW test program were completed and submitted in May 1963 as Report No. 2573 ("Program Planning Details for General Dynamics/Fort Worth"). Planning details for the CY 1964 GD/FW program were submitted in preliminary form in August 1963 as Report No. 2666 ("Preliminary Planning Details for GD/FW").

Test plans were submitted for all planned CY 1963 irradiation testing. Test specifications were submitted for all planned tests that were not deferred in CY 1964. All test plans and specifications are listed in the bibliography.

Technical support in the form of consultation and participation in the design of an acceptable irradiation capsule for the irradiation of small high explosives samples was provided for the radiation effects test program for explosives.

Technical direction, coordination, and planning for all radiation testing was completed as evidenced by the previously noted planning details issued to GD/FW (2573 and 2666) and the integration of all testing from WANL and AGC into one combined irradiation program. In addition to this effort, all WANL tests were coordinated in a manner to give maximum results from these irradiation tests.

(Chart 2) Technical direction and planning was conducted for the activation and operation of NARF for the performance of 3 mechanical tests at ASTR, 3 materials tests at GTR, and 4 WANL electrical and instrumentation tests (4,7,7A,8/9) at GTR. Of these planned tests, 1 of the 3 mechanical tests was run, (subsequently completed 2 additional by 24 October 1963), 1 of the 3 materials tests was attempted (others uncompleted because of dewar failures) and all 4 instrumentation tests were completed. Two REON personnel have been stationed at NARF, full time to assist in the accomplishment of this technical direction.

The 5-year Radiation Effects plan was completed, updated and submitted as part of AGC Report No. 63005, Vol. II. The plan presents tentative irradiation target dates for components based on the most realistic estimates of the NERVA program requirements and rate of development. Although useful for planning purposes, it is subject to program change because of the flexibility of the testing program.

Design and fabrication of pallets and supporting hardware for the GTR and ASTR tests were completed as follows:

Completed the design layout of MIT No. 903 (Bearing tester, pallet), MIT No. 905 (TSOV Pallet), and Control Pallet, which will be used with 903 and 905, during the week of 4 March.

Completed fabrication of MIT No. 901 during the week of 4 March, and functional checkout during the week of 11 March.

Shipped MIT 901 to GD/FW on 5 April.

Completed the design of EIT No. 501 and design layout of EIT 502 on 12 April.

Completed design of the modification of pallet No. 901 for use in MIT No. 902 during the week of 29 July.

Completed fabrication of EIT No. 501 and shipped it together with ancillary control equipment to GD/FW on the week of 9 September.

Completed work statement and requisition for use in negotiating with GD/FW for rework of MIT No. 901 Pallet for use in MIT No. 902.

Completed rework at GD/FW of Pallet (MIT No. 901) for use in MIT No. 902, on 20 September.

Initiated fabrication of EIT 502, MIT 903, MIT 905.

Work which was planned but not completed is as follows:

Completion of fabrication and checkout of MIT No. 903 and completion of fabrication of MIT No. 905.

(Chart 3) The Materials 12-month irradiation program described below, as revised and authorized by SNPO-C, was completed:

- a. The modifications for improvement of test assemblies required after performing the first radiation test.
- b. The control tests at room and liquid hydrogen temperatures for all materials scheduled for tensile testing.
- c. The control test at liquid hydrogen temperature of all materials scheduled for shear testing.
- d. Provisions of the prototype of the thermal conductivity apparatus.
- e. The design of the new (cylindrical) dewars.

During the irradiation test 37/A002, conducted near the end of March 1963, failures of the liquid hydrogen dewars occurred, resulting in termination of the radiation part of this program scheduled for CY 1963. Due to this incident, a new dewar design was required. This redesign has been completed. Procurement of the new dewars is awaiting specifications revisions and approval from SNPO-C. Repair and modification of the test fixtures was initiated to minimize the probability of future difficulties and to improve data acquisition equipment. Work originally scheduled but deleted with SNPO-C concurrence consists of the following:

Test 37/A002 - Tensile and Shear Test (irradiation test only).

Test 37/A003 - Tensile Test (irradiation test only).

Test 37/A004 - Thermal Conductivity Test (control and irradiation tests.)

For the test setup of equipment originally scheduled for NRDS tests, the following has been accomplished:

Completed the 750 gal. LH_2 dewar and test setup at Test Zone G-7 (LRP) for the checkout of MIT 901 and completed the checkout. Shipped the 750 gal. LH_2 dewar to GD/FW and completed fabrication, checkout and shipment of MIT No. 901 to GD/FW. Irradiation of MIT 901 was completed on 17 July 1963 in the ASTR at GD/FW.

Engineering followup of the instrumentation pallet scheduled for NRDS was delayed when the irradiation test of instruments at NRDS was cancelled.

Criteria for modifications at NARF for the NERVA irradiation program and STE were provided as follows:

During the week of 28 January an interface coordination meeting was held with GD/FW and REON concerning the gas distribution system to be installed at NARF GD/FW in support of 1.9.5 tests.

Completed design of the gas distribution system for GD/FW during week of 22 April.

Completed fabrication, checkout, and conditional acceptance of the gas distribution system at GD/FW during week of 24 June.

Shipped a 10 channel RTT calibration set to GD/FW for use in mechanical and instrumentation irradiation tests.

(Chart 4) The transducer tests at NRDS were deleted because of KIWI test difficulties and have been incorporated elsewhere in the test program.

Evaluation and analysis of test data generated has been as follows:

Reduction of data from MIT No. 901 was completed during the week of 19 August.

Analysis and report of MIT No. 901 was initiated.

The post mortem inspection of TSOV, TPCV Static Flange and seals, and the bearings tested in MIT No. 901 was completed and data derived for inclusion in final report of MIT No. 901.

The completion of final reports on tests MIT No. 901 and EIT No. 501, and preliminary reports on MIT No. 902 and EIT No. 502 was not accomplished during CY 1963 because of the performance of the test at the end of the contract year.

The Radiation Effects Data Book input was completed and was in the publication process by the end of CY 1963 and was (subsequently published on 15 October 1963).

The analytical studies for the Radiation Effects Data Book were completed and included. In addition, analysis was conducted for the No. 901 bearing tests and documented in Report 2652 ("Analysis of the Fast Neutron and Gamma Ray Spectrum for LRP Mech Test 901").

Chart 5 shows the accomplishments of test plans, test specifications, test, and test reports as planned and as completed. Irradiation tests to be carried over into CY '64 are the 902, 903, 501, 502, and 503 tests. Tests 902, 903, and 501 have been subsequently completed on 24 October 1963 but the post-irradiation analysis and documentation is yet to be performed. Test No. 502 has significant effort remaining for its completion and No. 503 is deferred until 25 April 1964. The major portion of the work for this test remains to be done and it is anticipated that this test will proceed using the new dewars now being procured under the Radiation Effects Material Test Program.

The interruption of the material irradiation program caused by the dewar failure required a redirection of effort in this area. Modifications were made to the tensile test equipment to improve the data acquisition system and to reduce the probability of hydrogen leakage from the system. A liquid hydrogen distribution system was procured to allow use of all three reactor access areas, and an accurate liquid level control was incorporated. A prototype of the thermal conductivity apparatus was completed and new, cylindrical dewars were designed for procurement late in CY 1963. These efforts proceeded in lieu of the originally scheduled irradiation testing outlined in the CY 1963 NTAD.

In summary, the Radiation Effects program has performed the major portion of the effort required for the first series of irradiation tests, both mechanical and electrical. Although the number of tests actually accomplished

in CY 1963 has been 1 out of 6 scheduled (i.e., No. 901 out of 901, 902, 903, 501, 502, and 503) the pretest work accomplished has brought the program to the stage where the testing of 3 of the remaining 5 tests has been accomplished within the first month of CY 1964. Final test data and test reports of all CY 1963 tests will be available during the first months of CY 1964.

The data from these tests has been included in the 15 October 1963 issue of Report 2277 "Radiation Effects Data Book" and final test data has been incorporated in Report 2510 "Radiation Effects Testing".

Conclusion

The results of the limited irradiation tests to date indicates, at the integrated dose levels utilized, that the NERVA components tested will perform adequately within the test environment. Further correlation of test results, test conditions and NERVA engine environmental conditions will establish the degree of confidence that can be placed on these components. Additional irradiation data and evaluation on many components are yet required to establish adequacy of design.

LISTED BELOW ARE THE IRRADIATION TESTS COMPLETED DURING CONTRACT YEAR 1963

Component Test No.	Component Description	Test Reactor	Integrated Fast Neutron Flux E 2.9 Mev.	Integrated Gamma Flux	Test Date
27/A0001	System Amplifiers	OMEGA-WEST			Oct. 1962
23/A502	Pressure Transducer	KIWI-B4A	$1.5 \times 10^{16} \text{ n/cm}^2$		Nov. 1962
24/A001	TCA Temperature Sensor	OMEGA-WEST			Dec. 1962
37/A002	Structural Materials	GTR			Mar. 1963
23/A402	Development Strain Gages	GTR	$1.3-2.3 \times 10^{16} \text{ n/cm}^2$	$6.8 \times 10^{10} - 1 \times 10^{11} \text{ ergs/gm(C)}$	May 1963
22/A002	System Amplifiers (Mag Amps)	GTR	$2.4 \times 10^{16} \text{ n/cm}^2$	$1.4 \times 10^{11} \text{ -ergs/gm(C)}$	May 1963
31/A002-5	Electronic Components	GTR	$1.6 \times 10^{16} \text{ n/cm}^2$	$1.6-2.5 \times 10^{11} \text{ ergs/gm(C)}$	May 1963
1/L001	Tank Shut-Off Valve	ASTR	$1 \times 10^{13} - 9.2 \times 10^{13} \text{ n/cm}^2 *$	$2.1 \times 10^6 - 3.8 \times 10^8 \text{ ergs/gm(C)} *$	July 1963
3/L001	TPA Bearing	ASTR	$1 \times 10^{13} - 9.2 \times 10^{13} \text{ n/cm}^2 *$	$2.1 \times 10^6 - 3.8 \times 10^8 \text{ ergs/gm(C)} *$	July 1963
4/L001	Turbine Power Control Valve	ASTR	$1 \times 10^{13} - 9.2 \times 10^{13} \text{ n/cm}^2 *$	$2.1 \times 10^6 - 3.8 \times 10^8 \text{ ergs/gm(C)} *$	July 1963
8/L001	Static Seals and Flages	ASTR	$1 \times 10^{13} - 9.2 \times 10^{13} \text{ n/cm}^2 *$	$2.1 \times 10^6 - 3.8 \times 10^8 \text{ ergs/gm(C)} *$	July 1963
25/A002	TCA Pressure Transducers	GTR	$1.9 \times 10^{16} \text{ n/cm}^2 *$	$2.2 \times 10^{11} \text{ ergs/gm(C)} *$	Aug. 1963
26/L001	Harness	GTR			Aug. 1963
27/A003	System Amplifiers	GTR	$3.4 \times 10^{15} \text{ n/cm}^2 *$	$6 \times 10^{10} \text{ ergs/gm(C)} *$	Aug. 1963
5/A001	TPCV Actuator	GTR			Sept 1963

* Indicates Preliminary Data.

SUBTASK 1.9 - BIBLIOGRAPHY

<u>Report Number</u>	<u>REPORT TITLE</u>	<u>Date Issued</u>
2277	"Radiation Effects Data Book"	15 February 1963
Not numbered	"Preliminary Program Planning Details for General Dynamics/Fort Worth"	1 April 1963
2554	"Preliminary Test Specifications for ASTR Mechanical Pallet Test of 15 June 1963"	15 April 1963
2514	"Final Test Specifications for Ground Test Reactor (GTR) Tests of 20 April 1963"	20 April 1963
2510	"Radiation Effects Testing"	25 April 1963
2563	"Preliminary Test Specifications for Ground Test Reactor (GTR) Tests of 13 July 1963"	10 May 1963
2569	"Final Test Specifications for ASTR Mechanical Pallet Test of 15 June 1963"	14 May 1963
2573	"Program Planning Details for General Dynamics/Fort Worth"	21 May 1963
2574	"Final Test Plan and Test Specification for Gamma Spectrum Measurement of Modified ASTR"	21 May 1963
2605	"Final Test Specifications for Ground Test Reactor (GTR) Tests of 13 July 1963"	13 June 1963
2622	"Final Test Specifications for Ground Test Reactor (GTR) Tests of 27 July 1963"	5 July 1963
2626	"Preliminary Test Specifications for Ground Test Reactor (GTR) Test of 24 August 1963"	10 July 1963
2641	"Preliminary Test Reports for Ground Test Reactor Tests During 13 through 19 May 1963"	22 July 1963
2660	"Final Test Specifications for Ground Test Reactor (GTR) Tests NO. 's 8 and 9, Tests of 21 September 1963"	23 August 1963
2665	"Final Test Specifications for the Second Mechanical Pallet Test at ASTR, Tests of 3 September 1963"	23 August 1963
2673	"Final Test Specifications for Ground Test Reactor (GTR) Test No. 10, Tests of 21 September 1963"	23 August 1963
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<u>Report Number</u>	<u>REPORT TITLE</u>	<u>DATE ISSUED</u>
2492	"Standard NERVA Analytical Model for Radiation Analysis"	February 1963
AN-924	"NERVA Radiation Environment from Liquid Hydrogen"	April 1963
774:NA:057*	"Secondary Gamma Radiation Around and Above the Pressure Vessel"	6 June 1963
774:NA:0102*	"Gamma Ray Heating of Dewar to be Used in the GTR Radiation Effects Program"	5 September 1963
774:NA:0111*	"Neutron Activation of the Cylindrical Cryogenic Pressure Vessel and Vacuum Valve to be Used in the GTR Radiation Effects Program"	16 September 1963
774:NA:061*	"Gamma Flux Map of NERVA Engine"	27 September 1963
2652	"Analysis of the Fast Neutron and Gamma Ray Spectrum for LRP Mechanical Test 901"	30 September 1963
774:NA:0119*	"Modification of QAD Computer Code"	30 September 1963
2691	"Strain Gage Research and High Output Transducers"	September 1963
BPAD-863-4- 1509OR **	"Final Report, Radiation Effects Test in Ground Test Reactor During Week of 13 May 1963"	September 1963

* Denotes internal memorandum
** Denotes Bendix Report

Report Number	REPORT TITLE	Date Issued
2322	"Program Plan, Contract Year 1963, NERVA Engine Development Program and Associated Tasks"	November 1962
63002	"Revised Program Plan, 1963, NERVA Engine Development Program and Associated Tasks"	June 1963
63005	"Program Plan for Contract Year 1964, NERVA Engine Development Program and Associated Tasks"	August 1963
63013	"Changes to Revised Program Plan, Contract Year 1963, NERVA Engine Development Program and Associated Tasks"	August 1963
L0560-20-16 Through L0560-10-27	"Informal Monthly Progress Letter No. 16 for NERVA Program"	October 1962
	"Informal Monthly Progress Letter No. 27 for NERVA Program"	Through September 1963

In addition to the above, the following test plans, test specifications and test reports were published for insertion in REON Report No. 2510 "Radiation Effects Testing".

FINAL TEST PLANS

3/L002	23/L101	23/W301	27/A001
3/L003	23/L201	23/W302	31/L001
5/A001	23/L302	23/W403	31/L002
8/W001	23/W001	23/W404	31/W001
11/W001	23/W103	23/W503	31/W012
11/W002	23/W104	23/W504	31/W102
21/W003 (Rev)	23/W201	25/A002	39/W201
22/W007 (Rev)	23/W203	27/A003	39/W202

PRELIMINARY TEST SPECIFICATIONS

5/A001	22/W007	23/W203	23/W504
11/W001	23/W004	23/W302	25/A002
11/W002	23/W005	23/W404	27/A003
21/W003	23/W104	23/W503	31/W012
			37/W001

FINAL TEST SPECIFICATIONS

1/L001	11/W002	23/W201	27/A003
3/L001	15/W201	23/W203	27/A004
3/L002	21/W003	23/W302	31/W012
4/L001	22/W007	23/W404	37/W001
5/A001	23/L001	23/L501	39/W001
8/L001	23/W004	23/W503	39/W101
8/W001	23/W005	23/W504	39/W102
14/W001	23/W104	25/A002	39/W201
			39/W202

PRELIMINARY TEST REPORTS

21/W002	27/A002
22/W006	31/A002
23/A402	31/A003
23/W002	31/A004
23/W102	31/A005
23/W201	31/W011
23/W402	36/W001
23/W502	40/W001/2

TASK ITEM 1.9

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RESCHEDULED TO CY 64

Sheet 1 of 10

CONCENTRA

CONTRACT YEAR 1963

TASK ITEM 1.9

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SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.9

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MECHANICAL COMPONENTS (CONT.)																								
6. TPCV CONFIGURATION NO. 2 (LRP)																								
TEST PLANS																								
TEST SPEC. & HARD. DELV.																								
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PRELIM. TEST REPORT																								
7. REMOTE DISCONNECTS (LRP)																								
TEST PLANS																								
TEST SPEC. & HARD. DELV.																								
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PRELIM. TEST REPORT																								
8. STATIC FLANGE & SEALS (LRP)																								
TEST PLANS (8/LOOX)																								
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PRELIM. TEST REPORT																								
9.																								
TEST PLANS																								
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10. THRUST VECTOR CONT. ACTUATOR																								
TEST PLANS																								
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PRELIMINARY TEST REPORT																								

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SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.9

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MECHANICAL COMPONENTS (CONT.)																								
11. CHECK VALVE (LRP)																								
TEST PLANS																								
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TEST DATE																								
PRELIMINARY TEST REPORT																								
12. GIMBAL ASSEMBLY (LRP)																								
TEST PLANS																								
TEST SPEC. & HARD. DELIVERY																								
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PRELIMINARY TEST REPORT																								
13. REACTOR COOLDOWN VALVE (LRP)																								
TEST PLANS (13/L00X)																								
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TEST DATE																								
PRELIMINARY TEST REPORT																								
14. CONTROL DRUM ACTUATOR																								
ASSEMBLY (WANL)																								
TEST PLANS																								
TEST SPEC. & HARD. DELIVERY																								
TEST DATE																								
PRELIMINARY TEST REPORT																								
15. REACTOR COMPONENTS (WANL)																								
TEST PLANS (15/W00X)																								
TEST SPEC. & HARD. DELIVERY																								
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PRELIMINARY TEST REPORT																								

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SCHEDULES AND MILESTONES

CONTRACT YEAR 1963

TASK ITEM 1.9

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FUEL SYSTEM TESTS																									
16. PROPELLANT FEED SYSTEM (LRP)																									
TEST PLANS																									
TEST SPEC. & HARD. DELIVERY																									
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PRELIMINARY TEST REPORT																									
17. ENGINE CONTROL SYSTEM																									
TEST PLANS																									
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PRELIMINARY TEST REPORT																									
18. PNEUMATIC POWER SUPPLY																									
TEST PLANS																									
TEST SPEC. & HARD. DELIVERY																									
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PRELIMINARY TEST REPORT																									
19. PRESSURIZATION SYSTEM																									
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NERVA PROGRAM

SCHEDULES AND MILESTONES

CONTRACT YEAR 1963

TASK ITEM 1.9

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SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
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SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.9

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INSTRUMENTATION & ELECTRONIC COMPS																								
29.																								
TEST PLANS																								
TEST SPEC. & HARD. DELIVERY																								
TEST DATE																								
PRELIMINARY TEST REPORT																								
30. REACTOR LOGIC SYSTEM (AZUSA)																								
TEST PLANS (30/A00X)																								
TEST SPEC. & HARD. DELIVERY																								
TEST DATE																								
PRELIMINARY TEST REPORT																								
31. ELECTRONIC COMPONENTS(WANL) (LRP)																								
TEST PLANS	(X ₁)	(X ₂)							(X ₃)				(X ₅)											
TEST SPEC. & HARD. DELIVERY	(X ₁)	(X ₂)							(X ₃)				(X ₅)											
TEST DATE		(E ₁)							(X ₃)				(X ₅)											
PRELIMINARY TEST REPORT			(X ₁)		(E ₂)				(X ₃)				(X ₅)											
32. ELECT. CIRCUITS (WANL)																								
TEST PLANS (32/W00X)																								
TEST SPEC. & HARD. DELIVERY																								
TEST DATE																								
PRELIMINARY TEST REPORT																								
33. POTS & SOLENOIDS (LINEAR)(LRP)																								
TEST PLANS (33/L00X)																								
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PRELIMINARY TEST REPORT																								

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SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 1.9

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SCHEDULES AND MILESTONES

CONTRACT YEAR 1963

TASK ITEM 1.9

○ = COMPLETE

A - ASTR
C - GTR
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W - OMEGA WEST
P - PBRF
N - NRDS
X - DATE DELV. AT SNPO-C

TEST STATUS

9-30-63

TASK ITEM 1.9

TASK TITLE RADIATION EFFECTS
PROGRAM (LRP)

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
700° F Strain Gage Test Assembly (23/A402)	MK-2	Radiation Effects	GD/FW GTR	1	1	
Cryogenic Strain Gage Test Assembly (23/A403)	MK-1	Radiation Effects	GD/FW GTR	1	0	Deferred to allow results of Test 23/A402 to be incorporated.
Pressure Transducer Test Assembly (TCA) (25/A001)	MK-1	Radiation Effects	GD/FW GTR	1	1	* Combined with 25/A002
Temperature Transducer Test Assembly (TCA) (24/A001)	MK-1	Radiation Effects	LASL	1	1	* Combined with 25/A002
Microphone (23/A901)	MK-1	Radiation Effects	GD/FW GTR	1	0	Transducers not available

TEST STATUS

9-30-63

TASK ITEM 1.9
TASK TITLE RADIATION EFFECTS
PROGRAM (LRP)

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
TPCV Actuator 5/A001	1	Radiation Effects	GTR	1	1	
Bearing Tester 3/L001, 2, 3	1, 2, 3	Radiation Effects	ASTR	3	1	Deferred 002 to October & 003 to November to allow results of 001 to be integrated into design.
Static Flange Seals 8/L001, 2	1, 2	Radiation Effects	GTR	2	1	8/L002 deleted as result of 8/L001 gave necessary info
Pressure Transducer 23/L501, 2	1, 2	Radiation Effects	CTR	2	0	23/L501 deferred to October due to delays in EIT 501 fab & checkout. 23/L502 included with 23/L102 and deferred to April 1964.
Accelerometers 23/L001, 2	1, 2	Radiation Effects	GTR	2	0	23/L001 included with 23/L501 deferred to October 1963. 23/L002 included with 23/L102 deferred to April 1963.
Position Transducer 23/L201	1	Radiation Effects	GTR	1	0	23/L201 included with 23/L101 and deferred to December.

TEST STATUS

9-30-63

TASK ITEM 1.9
 TASK TITLE RADIATION EFFECTS PROGRAM
 (LRP)

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
TSOV Config. 1 1/L001, 2	1 2	Radiation Effects	ASTR	2	1	1/L002 deleted as unnecessary based on results of 1/L001
TSOV Config. 2 2/L001	1	Radiation Effects	ASTR	1	0	Deferred to May 1964 to incorporate results of 1/L001 test in design of 2/L001
Potentiometers & Solenoids 33/L001	1	Radiation Effects	ASTR	1	0	Delay in performing 301 resulted in deferral on all other mechanical tests
Cool Down Valve (CDV) 13/L001	1	Radiation Effects	ASTR	1	0	"
Potentiometers & Motors 34/L001	1	Radiation Effects	ASTR	1	0	"
TPCV 4/L001, 2	1, 2	Radiation Effects	ASTR	2	1	4/L002 deleted as unnecessary based on results of 4/L001

TEST STATUS

9-30-63

TASK ITEM 1.9
TASK TITLE RADIATION EFFECTS PROGRAM
(LRF)

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Resistance Temperature Transducer 23/L101, 2	1, 2	Radiation Effects	GTR	2	0	Delays in first electrical pallet resulted in deferral of all elect. irrad. tests.
Cryogenic Thermocouples 23/L301, 2	1, 2	Radiation Effects	GTR	2	0	"

TEST STATUS

9-30-63

TASK ITEM 2.4

TASK TITLE INSTRUMENTATION

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
TCA Control Temperature Transducers	EXP	Evaluation of Developmental Components	Azusa	7	1

TEST STATUS

9-30-63

TASK ITEM 24
TASK TITLE INSTRUMENTATION

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Pressure Transducer	NRX	Acceptance Test per Procedure AGC-32048	Transducer Lab	92	57	35 in January 1964 to meet new NRX-A Test Schedule
Cryogenic Temperature Resistance Thermometers	NRX	Acceptance Test per AGC-42114 Procedure	Transducer Lab	56	28	8 in December 1963 to meet new NRX-A Test Schedule
Hi Temperature W/W-Re Thermocouples		Hot Flow Qual Test Acceptance Test, per Dept 8770 Procedure	SRP Astrionics Lab	46	3	10 in January 1964 to meet new NRX-A Test Schedule
Accelerometers	NRX	Acceptance Test per Department 8770 Specifications	Transducer Lab	60	24	24 in January 1964 to meet new NRX-A Test Schedule
Pressure Transducers	CFDTS	Acceptance Test and Calibrate	Transducer Lab	90	0	234 in December 1963 to meet new CFDTS Schedule
Cryogenic Temperature Transducers		Acceptance Test and Calibrate	Transducer Lab	60	0	87 in December 1963 to meet new CFDTS Schedule
Electrical Irradiation Test Transducers	501	Acceptance Testing of Candidate Transducers	Transducer Lab MSL	48	48	
24 Pressure Transducers		Nonnuclear Environment Evaluation Testing of Candidate Transducers	EMV Test Lab	9	12	
24 Accelerometers						
18 Resistance Thermometers	502	Acceptance Testing of Candidate Transducers	Transducer Lab	18	12	6 in October 1963 to meet new EIT 502 Test Schedule
6 Position Transducers		Nonnuclear Environ Evaluation Testing of Candidate Transducers	EMV Test Lab	3	3	
7 Limit Switches						
10 Thermocouples						
Cable & Connectors

TEST STATUS

9-30-63

TASK ITEM 2.4
TASK TITLE INSTRUMENTATION

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
8 Pressure Transducers 8 Resistance Thermometers	503	Acceptance Testing of Candidate Transducers	Transducer Lab. MSL	24	0	
8 Accelerometers Cables and Connectors		Nonnuclear Environment Evaluation Testing of Candidate Transducers		6	0	
8 Pressure Transducers 8 Accelerometers 8 Thermocouples 8 Resistance Thermometers Connectors & Cable	504	Acceptance Testing of Candidate Transducers Nonnuclear Environment Evaluation Testing of Candidate Transducers	Transducer Lab MSL	32	0	
Mechanical Component Irradiation Test Instrumentation Kit	902	Acceptance Testing of Instrumentation Components	Transducer Lab MSL	29	25	
"	903	"	"	12	23	
"	904	"	"	12	23	
"	905	"	"	18	13	
"	906	"	"	12	0	23 in November 1963 Rescheduled to meet Pallet Test Schedule
"	907	"	"	15	0	Cancelled
"	908	"	"	12	0	23 in December 1963 Rescheduled to meet Pallet Test Schedule
"	909	"	"	12	0	Cancelled

TEST STATUS

9-30-63

TASK ITEM 24
TASK TITLE INSTRUMENTATION

COMPONENT OR SUBASSEMBLY	CONFIGURATION NO. OR SERIES	TEST OBJECTIVE	FACILITY	NUMBER OF TESTS		REMARKS
				EST.	ACTUAL	
Temperature Sensors· Cryogenic Resistance Thermometers	N.A	To obtain calibration data and determine measurement reproducibility	Measurement Standards Laboratory	32	32	
Cryogenic Temperature Measurement Systems	N.A	To determine overall measure- ment system accuracy	Test Zone "C"	2	1	1 October 1964 (Rescheduled to meet pump test)
Phototype Hydrogen Quality Detector	N.A	To determine technical feasibility of design	Temp Lab.	2	0	
Ceramic Adhesives Rokide Gun	N.A	Evaluate for Hi-TEMP and RAD Environments	Dept. 218 Lab.	10	10	
High Voltage Bonded and/or Unbonded Transducer Elements	N.A	Feasibility of HI-VOLT output Gage	Dept. 218 Lab	3	3	
TCA Control Puressure Transducers	EXP.	Evaluation of Developmental Components	Dept. 218 Lab	4	4

HARDWARE STATUS

9-30-63

TASK ITEM 2.4
TASK TITLE INSTRUMENTATION

COMPONENT/SUB-ASSEMBLY	END USE	EST.	ACTUAL	REMARKS
ACCELEROMETER	NRX-A-1 CF	48	40	
CABLING	NRX-A VIB Series II	1940 ft	6470 ft	
CONNECTORS	NRX-A-2 HF	173	46	
BREAKWIRES, COPPER	NRX-A-3 HF	24	0	
STRAIN GAGE TRANSDUCERS		64	494	
CALORIMETERS		15	6	
CLAMPS, SEALS, TUBING, MISC.		3	3	
PRESSURE TRANSDUCERS (+ 1%)	CFDTS Instrumentation	44	155	
PRESSURE TRANSDUCERS ($\pm 0.4\%$)	" "	30	76	
RESISTANCE THERMOMETERS (+0.6°R)	CFDTS Instrumentation	68	40	
RESISTANCE THERMOMETERS (+1.0°R)	" "	40	45	
THERMOCOUPLES	CFDTS Instrumentation	70	130

HARDWARE STATUS

9-30-63

TASK ITEM 2.4
TASK TITLE INSTRUMENTATION

COMPONENT/SUB-ASSEMBLY	END USE	EST.	ACTUAL	REMARKS
INSTRUMENTATION KIT	Instrumentation for MCIT #902	1	1	
" "	" " " #903	1	1	
" "	" " " #904	1	0	
" "	" " " #905	1	0	
" "	" " " #906	1	0	
" "	" " " #908	1	0	
PRESSURE TRANSDUCERS	For Development Testing & Evaluation Purposes Prior to Radiation Testing	40	54	
RESISTANCE TEMP. TRANSDUCER		32	45	
ACCELEROMETERS		40	55	
THERMOCOUPLES		18	98	
CABLES & CONNECTORS		36	0	
SURFACE TRANSDUCERS	Adhesives Tests	200	200	
STRAIN SENSITIVE WIRE	High Output Transducers	8	8	
PRESSURE TRANSDUCERS	Develop TCA Control Pressure Transducers	16	16	
TEMPERATURE TRANSDUCERS	Develop TCA Control Temperature Transducers	7	2	
PRESSURE TRANSDUCER	NRX-A VIB Series II	48	38	
PRESSURE TRANSDUCER		25	27	
TEMP. TRANSDUCERS (CRYOGENIC)		12	30	
TEMP. TRANSDUCERS (CRYOGENIC)		12	6	
MEDIUM TEMP. THERMOCOUPLE		3100 ft	3040 ft	
HIGH TEMP. THERMOCOUPLE	NRX-A-3 HF	48	12

SCHEDULES AND MILESTONES

CONTRACT YEAR 1963

TASK ITEM 2.4

DATE:

↑ SCHEDULED MILESTONE

▲ MILESTONE ACHIEVEMENT

◆ RESCHEDULED MILESTONE

◆ **RESCHEDULED MILESTONE ACHIEVEMENT**

RESCHEDULED TO CY 64

Sheet 3 of 3

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 2.4

INSTRUMENTATION	1962												1963											
	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER									
	6 13 20 27	3 10 17 24	1 8 15 22 29	5 12 19 26	2 9 16 23	2 9 16 23 30	6 13 20 27	4 11 18 25	1 8 15 22 29	6 13 20 27	3 10 17 24	31 7 14 21 28	5 12 19 26	2 9 16 23	30 7 14 21 28									
11. COMPLETE PERF. ENVIRONMENTAL REQMTS, TEST & DEVELOPMENT PLANS FOR CRYOGENIC TEMP. TRANSDUCERS				↑																				
12. COMPLETE PERF. ENVIRONMENTAL REQMTS, TEST & DEVELOPMENT PLANS FOR TCA TEMPERATURE TRANSDUCERS			↑																					
13. COMPLETE PERF. ENVIRONMENTAL REQMTS, TEST & DEVELOPMENT PLANS FOR TCA PRESS. TRANS.				↑																				
14. REVIEW AND ISSUE 2ND QUARTER INSTRU. DATA BOOK REVISIONS							↑																	
15. REVIEW & ISSUE 4TH QUARTER INSTRU. DATA BOOK REVISIONS													↑											
NRXA - VIB. II																								
16. COMPLETE MEASUREMENT REQUIREMENTS LIST															CANCELLED									
17. COMPLETE DESIGN OF INSTRU- MENTATION SYSTEM INSTALL.															CANCELLED									
18. COMPLETE PROCUREMENT OF INSTRUMENTATION															CANCELLED									
19. COMPLETE PROOF TESTING AND EVALUATION REPORT IN THE INSTRUMENTATION DATA BOOK															CANCELLED									
20. COMPLETE ACCEPTANCE TEST AND CALIBRATION OF INSTRU.															CANCELLED									
21. ISSUE POST-TEST INSTRUMENTA- TION EVALUATION REPORT															CANCELLED									

DATE:

↑ SCHEDULED MILESTONE

▲ MILESTONE ACHIEVEMENT

◇ RESCHEDULED MILESTONE

◆ RESCHEDULED MILESTONE ACHIEVEMENT

RESCHEDULED TO CY 64

Sheet 2 of 3

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 2.4

DATE:

↑ SCHEDULED MILESTONE
↑ MILESTONE ACHIEVEMENT

◇ RESCHEDULED MILESTONE
◆ RESCHEDULED MILESTONE ACHIEVEMENT

◊ RESCHEDULED TO CY 64

Sheet 1 of 3

SUBTASK 2.4 - ACCOMPLISHMENTS FOR CY 1963

Purpose and Objective

There are three major objectives found under Task 2.4. The first objective is to provide accurate instrumentation for measurement and procurement of information from reactor tests and other development testing conducted under the NERVA development program. The second objective is to continuously improve the quality and the reliability of commercial instrumentation procured for use in the over-all development program. The third objective is to develop instrumentation not presently available that is required for the control of the NERVA engine system and for measurement in various subordinate development tasks.

The first objective is achieved through a preliminary selection of commercial instrumentation to meet the requirements of preliminary measurements list evolved during the course of the program year. These instruments are selected through theoretical evaluation of the requirements and an estimation of the available instrumentation that will come the closest to fulfilling the testing information requirements. Acceptance testing, to determine its probable performance during initial NRX and other tests, is performed.

To meet the second objective, continuous preliminary evaluation tests on instrumentation for the first objective is performed. These preliminary evaluation tests are to determine the probability of quality performance by subjecting each selected instrument to a series of probable environmental tests. The requirements for these environmental tests are continuously evolving as information on these tests becomes available. Suppliers are contacted and re-directed to improve their instrumentation on a continuing basis.

There are certain types of instrumentation which are required for control of the NERVA engine and for the acquisition of test data which are not available even in concept from commercial sources. As requirements evolve for such instrumentation an over-all program plan is developed. This program plan details the basic requirements for the instrumentation, studies the various approaches that can be made, evaluates the most probable sources or methods for

the desired instrumentation, analyzes the industrial capability for calibration and testing of the desired instrumentation, determines the necessary backups in case of failure to achieve the necessary goals and eventually estimates the over-all program costs. These program plans furnish the basis for our continued instrumentation development work. The program plan may be extensive or limited depending upon the depth of a problem area. Such program plans are continuously involved as a portion of this task. The way in which we have met these three over-all objectives are shown in the following pages.

This is a continuing work effort encompassing continuous liaison with all facets of the NERVA program. The work was accomplished by means of various project directives, memorandums, technical meetings, etc. The following accomplishments should be mentioned:

1. The various proposals and cost studies were coordinated.
2. The NRX-A test plans and test specifications were checked and/or written.
3. Close liaison was maintained with subcontractors, instrumentation engineers at IASL, and with the appropriate task engineers at SNPO-C.
4. Continuous direction on scheduling and required performance was given by the use of project directives, and follow-up to ensure that project directives were met. Instrumentation for the RN-6 nozzle was coordinated and a special thermocouple for the pass-through was designed. An RN-6 measurement requirements list was prepared and issued to SNPO-C.

The necessary liaison with Task 3.2 personnel is continuous. A preliminary E-1 engine measurements requirements list was generated (I.D.B Vol. I) to give guidance to the Task 3.3 in design of the ETS-1 data acquisition system.

Contacts and discussion with Los Alamos Scientific Laboratory, the National Bureau of Standards at Boulder, Lockheed Missiles and Systems Corporation (RIFT Program), the Douglas Corporation (Acoustic Measurement), Batelle Memorial Institute (Radiation Resistant Components and Radiation Environment), the General Dynamics Corporation (Radiation Testing), Lockheed GELAC, (Radiation Testing) and other organizations including component suppliers were made and

held. Under a sub-contract technical assistance on various instrumentation problems was obtained from Bendix. Eighteen (18) specific reports from Bendix summarized the results of this work. Many additional contacts and discussions followed as a result of this work. A vendor orientation meeting with over 70 vendor representatives was held at LRP.

The Instrumentation Data Book is issued on a quarterly basis. This book, originally a working manual demonstrating transducer requirements and capabilities, has expanded into a complete historical rendition of all instrumentation work including requirements, acceptance test results, other test results, development program plans with their accomplishments regularly detailed. It also includes cable and connector information.

This book, which now consists of five volumes, has been issued in October 1962, January, April, July and October of 1963. All information required is found within its covers. Rough draft portions of the IDB were issued monthly to SNPO-C.

2-2.4C(1)

Instrumentation for this development system was deleted per RN-63012.

2-2.4C(2)

The selection and specification of all instrumentation for this system is complete. All Purchase Orders have been placed and all the instrumentation components are in-house with minor exceptions. The acceptance testing on the transducers is also complete with only a few remaining items to be tested. The wiring schematic is complete. The initial installation drawings were completed in June 1963. However, changes arising out of the placement of windows in the nozzle, changes in pressure ranges to be measured, and changes in pressure transducers to be used have caused several revisions of this drawing. The latest revisions are now being completed.

2-2.4C(3)

The initial instrumentation installation drawing for this system is complete; however changes are continually occurring, in accordance with NRX-A2 requirements, so that this drawing is being revised on a continuing basis.

The measurement requirements list has been prepared. Procurement of the instrumentation has been initiated but not all of the Purchase Orders have been placed. A preliminary wiring schematic has been completed.

Achievements are demonstrated in the I.D.B. Vol. I, Drawings 700276 and 700295, and the procurement status report for CY '63.

Such delays as have occurred in procurement have been occasioned by taking advantage of NRX schedule changes in order to increase efficiency in the selection of more desirable instrumentation to meet the constantly growing needs of the test program for better accuracy, more reliable instrumentation, wider or changed ranges, different installation procedures.

2-2.4C(4)

A preliminary measurements requirements list based upon the NRX-A-2 list has been prepared and is published in the Instrumentation Data Book. Procurement of instrumentation was not initiated in CY 1963.

Judicious engineering judgement entered the picture here. A literal translation of the work statement requirements would have simply entailed the production of installation drawing, instrument specifications, and procurement of instruments which would be, to all practical purposes, identical with NRX-A1. It is obvious that copious changes in this will occur based on previous experience on this and other programs, so, since this item is not racing the NRX-A3 program, this work is deferred until better information is obtained.

2-2.4C(5)

Instrumentation has been specified, selected, designed and Purchase Orders issued for MCIT - 902, 903, -904, -905, -906 and -908. In addition to work in support of these mechanical components irradiation tests, work was performed under subtask 2.4 that has not been originally contemplated when the Contract Year started. The instrumentation for two (2) control pallets was selected, designed and procured. Also, three (3) platinum resistance thermometer calibration systems were designed and fabricated. The work performed is demonstrated in Drawings 248423, -4, -5, -6, -7, -8, -9, -30, -31, -32; the transducer Specification Control Drawings.

2.2-4C(6)

The measurement requirements list for this system is complete. The instrumentation components have been selected, specified, and their procurement has been initiated, as indicated in Vol. I of the I.D.B., and Report 2710, the Revised Test Plan for GFDTs.

2-2.4D(1)

Development of high precision cryogenic temperature transducers is required for turbopump development testing. The major goal of this development program was to develop a transducer that is to be used in a non-radiation environment for the purpose of measuring the inlet temperature of the liquid hydrogen to the turbopump. Analysis had shown that this transducer together with its signal conditioning and data acquisition system would require an accuracy of $\pm 0.05^{\circ}\text{R}$. During the contract year '63 a platinum resistance thermometer was developed, tested, evaluated and calibrated, which, together with a specially designed potentiometric signal conditioning unit has a accuracy of $\pm 0.054^{\circ}\text{R}$. A large quantity of these transducers are now in use at LRP. They are mainly used in NERVA pump tests. Identical units will be used on the NRX-A-1-CF instrumentation system to measure nozzle manifold inlet and nozzle manifold outlet temperatures. Work has been initiated to develop a radiation hardened version of this transducer and will be tested in the radiation environment in EIT-502. Work has also been initiated to develop a backup transducer so that more than one vendor can supply this instrumentation.

The achievements here are shown in Vol. II of the I.D.B., and are detailed in the following Technical Reports:

8771:1944, 8771:1871, 8770:1186, 8771:1542, 8771:1768, and
8771:1718.

Other information is contained in the Transducer Specification Control Drawings No.'s 248635 through 248639.

2-2.4D(2)

Two parallel developmental efforts have been conducted for the development of transducers to measure thrust chamber temperature for control purposes. The development of the tungsten resistance thermometer was initiated, primarily

to overcome the low voltage output which is obtained from the Tungsten/Tungsten - 26% Rhenium thermocouple.

Candidate transducers were ordered from Rosemount Engineering Corporation and Electro-West Corporation. The units obtained from Rosemount failed. Electro-West could not fulfill the purchase order and requested that it be cancelled. While the above mentioned Rosemount units were being fabricated, negotiations were initiated with G.E. in Lynn, Massachusetts for a development subcontract to develop tungsten resistance thermometers. After the experience with the Rosemount units, the negotiations with G.E. were finalized and a specific development subcontract with G.E. was negotiated and is now awaiting SNPO-C approval. At the same time, development work was initiated on a Tungsten/Tungsten-Rhenium thermocouple that would be an improvement over the IASL thermocouple. Initial tests on three candidate thermocouples have been successful.

Achievements under this development program are listed in Vol. II of the I.D.B., in Technical Report MO323, and our definition of part of the problem is shown in the G.E. proposal, No. MP-63-27.

2-2.4D(3)

Initial radiation effects test were conducted on control system thrust chamber pressure transducers in September 1962, in GTR. Various candidate transducers were subsequently tested, side by side, with the KIWI-B4A test in November 1962. Since the control loop requires a high output signal it was decided to initiate the development of a radiation resistant potentiometer pressure transducer. It was the intention to test these transducers in a subsequent hot KIWI test. However, when no such test was forthcoming these units were tested in August 1963 in GTR. Seven out of eight transducers tested showed no degradation in output signal due to radiation. The eighth transducer failed and a post-mortem examination will be performed in the very near future.

Achievements under this development task are reported in Vol. II of the I.D.B.; Report No. 2510, Radiation Effects Testing.

2-2.4E(1)

This program for the development of radiation resistant microphones for measuring acoustic noise generated during NERVA engine tests was initiated upon the request of SNPO-C in February 1963. A development program was submitted

to SNPO-C. A development subcontract is being negotiated with Bolt, Beranek and Newman. It has not yet been approved. Contractual language for this contract is now being negotiated. Coordination with Douglas Aircraft Company in respect to their sound measurement at Test Cell "C" was performed. Other work accomplished is shown in Vol. II of the I.D.B., and a letter to SNPO-C, 733:100:60.

2-2.4E(2)

A development program plan for a vibration transducer was submitted to SNPO-C. Various transducers were procured and they will be evaluation tested in CY '64. This work is reported in Vol. II of the I.D.B., and in the EIT-503 test plan.

2-2.4E(3)

A development program plan for a miniature temperature sensor for measuring nozzle coolant fluid condition was submitted to SNPO-C. Various transducers were procured for evaluation testing that will be conducted in CY '64. Accomplishments are demonstrated in Vol. II of the I.D.B.

2-2.4E(4)

The development program plan for a hydrogen quality detector for measurement of the pump inlet fluid condition was submitted to SNPO-C. A preliminary design for this detector has been completed. Accomplishments are demonstrated in Vol. II of the I.D.B. and in Technical Report No. 8771:1923.

2-2.4F

These requirements are only now evolving and will be submitted as required on programs.

13-2.4B

The test plan was prepared and the tests were then performed by an independent laboratory, the Component Evaluation Laboratory in El Monte, California. Pressure transducers, platinum resistance thermocouples, accelerometers, and cables and connectors were tested.

Accomplishments are demonstrated in Appendix A to Final Acceptance Test Plan for NRX-A1 End Item, and in Vol. II of the I.D.B.

2-2.4 TAD Para 4.1b(10) and 4.1B(11)

In September 1962, preliminary radiation effects tests were performed on several strain gages and surface temperature transducers that were mounted with an aluminum oxide spray method. These tests indicated great promise and during Contract Year 1963, the method of mounting strain gages via this "Rokide" method was developed, process specifications were written, and several hundred gages were mounted and tested. In May 1963, 70 different types of strain gages were tested in GTR at 700⁰F. Very few failures were experienced. The tests indicated, however, that some improvement is necessary in overcoming insulation leakage at the gage terminals. The accomplishments are demonstrated in Vol. II of the I.D.B.; in Report No. 2691, Strain Gage Research and High Output Transducers; and in the Radiation Effects Testing Report No. 2510.

A series of exploratory tests were conducted to ascertain the feasibility of operating Rokided gages at output levels of +1 volt. The tests showed that AGC type Rokided gages can be operated to produce signal outputs of 30 to 40 times as great as those obtained with orthodox gages. Test results are reported in Report No. 2691

Conclusions

Of the 31 milestones originally scheduled for completion during CY 63, 6 (m.s. 16 thru 21) were cancelled by C.O. No. 1 (RN 63013). One was redefined as a task 7.1 responsibility (m.s. No. 27 pre-test evaluation of NRX-A1-CF) and one was deleted (m.s. No. 4 complete preparation of Prel. Spec. of E-1 engine instrumentation) due to de-emphasis of the engine effort. Of the remaining 23 milestones all except one (m.s. 29 complete design of NRX-A2 instrumentation installation) were completed. The deferral of m.s. No. 29 is compatible with the NRX-A2 test schedule and allows the use of additional information developed during the intervening period.

The objectives of this subtask have been met in that

- a) Instrumentation has been provided as requested for the NRX-A1, NRX-A2, the CFDTs, the NCIT as required and on a schedule compatible with these development programs;

- b) Quality and reliability of commercial instrumentation is being upgraded on a continuing basis as evidenced by the design changes and/or redesignation in various transducers listed in the I.D.B.
- c) Development of a high-precision cryogenic temperature transducer has progressed to the point where temperatures can now be measured to $\pm 0.054^{\circ}\text{R}$ whereas a year ago, at the inception of this program the accuracy was no better than $\pm 0.5^{\circ}\text{R}$. This transducer is being utilized in TPA development programs at LRP and will be used to measure nozzle manifold inlet and nozzle tube outlet temperature on the NRX-A1-CF test.

SUBTASK 2.4 - BIBLIOGRAPHY

NERVA Instrumentation Data Book - Report No. 2320

a.	Preliminary Issue	Oct. 1962
b.	Final Issue	Jan. 1963
c.	Final Issue	Apr. 1963
d.	Final Issue	July 1963
e.	Final Issue	Oct. 1963 (4 Volumes, 5 Books)

Bendix Reports

1. Report No. 2239, "Recommended Transducers for the NERVA Environment, Part 1 - - Displacement Transducers," M. C. Johnson, December 1962.
 2. Report No. 2240, "Recommended Transducers for the NERVA Environment, Part 2 - - Temperature," H. R. Farrah, December 17, 1962.
 3. Report No. 2243, "Cooling and Heating Analysis of Pressure and Vibration Transducers Between the NERVA Shield and Gimbal," M. C. Johnson and E. B. Skuta, December 17, 1962.
 4. Report No. 2243, Appendix A, "Derivation of Radiation Heating Rates," January 15, 1963.
 5. Report No. 2254, "Signal Conditioning Amplifiers for NERVA," Somer, January 17, 1963.
 6. Report No. 2256, "Recommended Transducers for the NERVA Environment, Part 3 - - Vibration," Johnson, January 8, 1963.
 7. Report No. 2266, "Error Due to Radiation Heating in the Rosemount Model 134EB Resistance Wire Thermometer," Skuta, January 18, 1963.
 8. Report No. 2281, "Performance Test Procedure for NERVA Pressure Transducers," M. C. Johnson, February 6, 1963.
 9. Report No. 2282, "Borated Insulators in a Radiation Environment," M. C. Johnson, February 8, 1963.
 10. Report No. 2280, "Thermocouple Measurements, Part 1 - - Reference Junctions, Part 2 - - Tungsten Rhenium Thermocouples," H. R. Farrah, February 15, 1963.
 11. Report No. 2243, Appendix C, "Coil Irradiation Test," E. B. Skuta, February 27, 1963.
- Report No. 2243, Appendix D, "Extrapolation of Coil Electrical Heating to Radiation Heating," E. B. Skuta, March 5, 1963.

12. Report No. 2308, "Commutators for the NERVA Environment," T. J. Mohan, April 9, 1963.
13. Report No. 2333, "Noise Considerations in NERVA Diagnostic Instrumentation," T. Somer, April 26, 1963.
14. Report No. 2243, Appendix E, "Temperature of Transducers Fixed by A Metal Strap," May 2, 1963.
15. Report No. 2363, "Evaluation of Beryllia and Thoria as Electrical Insulators for Extreme High Temperature Transducers," Max Frank, July 10, 1963.
16. Report No. 2377, "Evaluation of Piezoelectric Transducers for Nuclear Radiation Environment," F. W. Poblentz, August 2, 1963.
17. "Evaluation of Long Lead Thermocouples"
18. "Evaluation of Electromechanical Choppers for NERVA Environment"

NRX-A Installation Dwg. & Wiring Schematics + Measurement Requirements

- a. NRX-AI-CF Installation Dwg: #700506-9 (3 Sheets)
- b. NRX-AI-CF Wiring Schematic: #294180 (2 Sheets)
- c. NRX-A2 Installation Dwg: #700276
- d. NRX-A2 Wiring Schematic: #700295
- e. NERVA I.D.B. Vol. I

Transducer Specification Control Drawings

- a. Differential Pressure Transducers: #298950 thru 298967
- b. Absolute Pressure Transducers: #298968 thru 298976
- c. Absolute Pressure Transducers: #248812
- d. Absolute Pressure Transducers: #248816
- e. Absolute Pressure Transducers: #298800 thru 298849
- f. Accelerometers: #248491
- g. Accelerometers: #299530 thru 299539
- h. Resistance Temperature Transducers: #248635 thru 248639
- i. Resistance Temperature Transducers: #298870 thru 298886
- j. Pressure Switches: #299740 thru 299749
- k. Pressure Switches: #299750 thru 299759
- l. Turbine Type Flow Transducers: #700259 thru 700268

Element Irradiation Tests Control Panels & Calibration Sets

- a. Drawing No. 248423
- b. Drawing No. 248424
- c. Drawing No. 248425
- d. Drawing No. 248426
- e. Drawing No. 248427
- f. Drawing No. 248428
- g. Drawing No. 248429
- h. Drawing No. 248430
- i. Drawing No. 248431

Cold Flow Development Test System Instrumentation

Report No. 2710: "Revised Test Plan for CFDTTS"
Figures 3, 5, 6, 7, 8, 9, 16, 20
Table No. 5

NERVA I.D.B. Vol. I

Cryogenic Temperature Transducers

- a. NERVA I.D.B. Vol. II: VI-A-7.1.1 thru VI-A-7.4.2
- b. NERVA I.D.B. Vol. II: V-A-6.1.3 thru VI-A-6.3.3
- c. Internal Technical Reports
 - 8771:1944 "Calculation of Temperature Sensor Error Due to Frictional Heating"
 - 8771:1871 "Predicted Radiation Effects Upon Model 134EB Sensor"
 - 8770:1186 "Interim Evaluation Report, Model 134CT250"
 - 8770:1542 "Interim Development Report for Cryogenic Temp. Sensors"
 - 8771:1768 "Establishment of Lode N"
 - 8771:1718 "Calculated Mechanical Resonance Characteristics for Gas Filled Thermometer"

TCA Temperature Transducer Development

- a. I.D.B. Vol. II: VI-A-4.1.3 thru VI-A-4.2.3
- b. Technical Report MO 323
- c. G.E. Proposal No. MP-63-27

TCA Pressure Transducer Development

- a. I.D.B. Vol. II: VI-A-1.1.1 thru VI-A-1.12.3
- b. Radiation Effects Testing Report 2510; Vol. V: Tests 25/A001 and 25/A002

Microphone Development

- a. I.D.B. Vol II: VI-A-12.1
- b. Bolts, Beranek & Newman Proposal P 64-LA-6
- c. Letter to SNPO-C 733:LO060

Accelerometer Development

- a. I.D.B. Vol. II: VI-A-10.1.5 thru VI-A-10.1.7
- b. EIT-503 Test Plan

Miniature Cryogenic Temperature Transducer Development

I.D.B. Vol. II: VI-A-13.1.1 thru VI-A-13.1.4

H₂ Quality Detector Development

- a. I.D.B. Vol. II: VI-A-14.1.1 thru VI-A-14.1.2
- b. Internal Technical Report No. 8771:1923

Evaluation Testing of Transducer

- a. Appendix A to Final Acceptance Test Plan for NRX-A1 End Item
- b. I.D.B. Vol II: VI-A-2.2.6 thru VI-A-2.2.12
- c. I.D.B. Vol II: VI-A-6.2.4 thru VI-A-6.2.8
- d. I.D.B. Vol II: VI-A-10.5.3 thru VI-A-10.5.5

Strain Gage Development

- a. I.D.B. Vol II: VI-A-9.1.3 thru VI-A.12.3
- b. Report No. 2691: Strain Gage Research & High-Output Transducers
- c. Radiation Effects Testing Report 2510, Vol. II:
Test 23/A402, Section No. 1.7.2.4.0, pp 1-21
Test 23/A402, Section No. 1.7.1.4.0, pp 1-3

S/T 2.4 INSTRUMENTATION

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>										
13-2.4(b)	PREPARE A TEST PLAN FOR NRX-A TRANSDUCERS FOR SUBMITTAL TO SNPO-C PROCURE ADDITIONAL TRANSDUCERS & PERFORM EVALUATION TESTS TO DETERMINE ACCEPTABILITY FOR NRX-AI DEVELOPMENT OF RADIATION RESISTANT MOUNTING METHODS FOR STRAIN GAGES & SURFACE MOUNTED TEMP TRANSDUCERS. THE FEASIBILITY OF DEVELOPING HIGH-OUTPUT, HIGH-TEMP, STRAIN-SENSITIVE TRANSDUCERS WILL BE INVESTIGATED	(1) TEST PLAN PREPARED (2) TEST PERFORMED BY COMPONENTS EVALUATION LABORATORY FOR NRX-AI END ITEM <table><tr><th><u>COMPONENTS TESTED</u></th><th><u>TEST CONDITIONS</u></th></tr><tr><td>6 PRESSURE TRANSDUCERS</td><td>VIBRATION</td></tr><tr><td>5 RESISTANCE THERMOMETERS</td><td>a. SINE 5-2 KC, 50 G b. RANDOM KC-1</td></tr><tr><td>3 ACCELEROMETERS</td><td>TEMPERATURE</td></tr><tr><td>14 CABLES & CONNECTORS</td><td>a. +150°F (4 HRS) b. -300°F (4 HRS) c. +150°F TO -300°F (SHOCK) MACHINE SHOCK: 30G, 6.5MS HUMIDITY: 95 ± 5% (96 HRS)</td></tr></table> (1) 70 TRANSDUCERS WERE TESTED IN G.T.R IN MAY'63 @ 700°F SPECIFICATIONS WRITTEN (2) A STRAIN GAGE HAVING ±1 VOLT OUTPUT SIGNAL WAS BUILT & TESTED IN NON-RADIATION ENVIRONMENT	<u>COMPONENTS TESTED</u>	<u>TEST CONDITIONS</u>	6 PRESSURE TRANSDUCERS	VIBRATION	5 RESISTANCE THERMOMETERS	a. SINE 5-2 KC, 50 G b. RANDOM KC-1	3 ACCELEROMETERS	TEMPERATURE	14 CABLES & CONNECTORS	a. +150°F (4 HRS) b. -300°F (4 HRS) c. +150°F TO -300°F (SHOCK) MACHINE SHOCK: 30G, 6.5MS HUMIDITY: 95 ± 5% (96 HRS)	(1) APPEND. A TO FINAL ACCEPT TEST PLAN (2) I.D.B. VOL II: VI-A-2.2.6 THRU 2.2.12 I.D.B. VOL II: VI-A-6.2.4 THRU 6.2.8 I.D.B. VOL II: VI-A-10.5.3 THRU 10.5.5 I.D.B. VOL II: VI-A-9.1.3 THRU 9.12.3 REPORT NO. 2691: STRAIN GAGE RES & HIGH-OUTPUT TRANSDUCERS. RADIATION EFFECTS TESTING RPT. #2510, VOL II: TEST 23/A402; SECT. NO. I.7.2.4.0 PPI-21, SECT. NO. I.7.1.4.0 PPI-3.
<u>COMPONENTS TESTED</u>	<u>TEST CONDITIONS</u>												
6 PRESSURE TRANSDUCERS	VIBRATION												
5 RESISTANCE THERMOMETERS	a. SINE 5-2 KC, 50 G b. RANDOM KC-1												
3 ACCELEROMETERS	TEMPERATURE												
14 CABLES & CONNECTORS	a. +150°F (4 HRS) b. -300°F (4 HRS) c. +150°F TO -300°F (SHOCK) MACHINE SHOCK: 30G, 6.5MS HUMIDITY: 95 ± 5% (96 HRS)

S/T 2.4 INSTRUMENTATION

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
	(2) VIBRATION TRANSDUCER FOR NERVA ENGINE	DEV. PROGRAM PLAN SUBMITTED TO SNPO-C TRANSDUCERS PROCURED FOR EVALUATION TESTING TO BE CONDUCTED IN CY '64	I.D.B. VOL II: VI-A-10.1.5 THRU-10.1.7 EIT-503 TEST PLAN
	(3) MINIATURE CRYOGENIC TEMP. TRANSDUCER FOR NOZZLE COOLANT TEMP. MEASUREMENT	DEV. PROGRAM PLAN SUBMITTED TO SNPO-C TRANSDUCERS PROCURED FOR EVALUATION TESTING TO BE CONDUCTED IN CY '64	I.D.B. VOL II: VI-A-13.1.1 THRU -13.1.4
	(4) HYDROGEN QUALITY DETECTOR FOR MEASUREMENT OF PUMP INLET FLUID CONDITIONS	DEV. PROGRAM PLAN SUBMITTED TO SNPO-C - PRELIMINARY DESIGN COMPLETE	I.D.B. VOL II: VI-A-14.1.1 THRU-14.1.2 - TECHNICAL REPORT NO. 8771:1923

S/T 2.4 INSTRUMENTATION

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
	(3) THRUST CHAMBER PRESSURE TRANSDUCER FOR CONTROLS	CANDIDATE TRANSDUCERS TESTED, NOV. '62, IN KIWI - B4 A; AUG '63; IN GTR - POST MORTEMES CONTINUING	I.D.B. VOL. II VI-A-1.1.1. THRU VI-A-1-12.3 RADIATION EFFECTS TESTING REPORT #2510, VOL V; TEST 25/A001 & 25/A002
2-2.4 E	PREPARE DEVELOPMENT PROGRAM PLANS & INITIATE DEVELOPMENT OF: (SUBJECT TO SNPO-L APPROVAL)		
	(1) RADIATION RESISTANT MICRO- PHONES FOR MEASURING ACOUSTIC NOISE	DEVELOPMENT PROGRAM PLAN SUB- MITTED TO SNPO-L DEV. PROGRAM NEGOTIATED WITH BOLT, BARENEK & NEWMAN. COORDINATION WITH DOUGLAS PERFORMED	I.D.B VOL. II-A 12.1.1 THRU 12.1.6 -B, B & N PROPOSAL P64-LA-6 LTR TO SNPO-C: 733: L0060

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REON · ROCKET ENGINE OPERATIONS — NUCLEAR

S/T 2.4 INSTRUMENTATION

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
2-2.4 D	DEVELOPMENT PROGRAMS: CONTINUING-		
(1) HIGH PRECISION CRYOGENIC TEMP TRANSDUCER FOR TURBO- PUMP DEVELOPMENT TESTING	(1) RTT #134 CT PROBE - $\pm 0.05^{\circ}\text{R}$ ACCURACY - (2) RTT #134 EB PROBE - RADIATION RESISTANT- (3) BACKUP TRANSDUCER WORK CONTINUING		I.D.B VOL II-VI-A-7 1.1 THRU VI-A-7-4-2, VI-A-6.1.3 THRU VI-A-6.3.3, TECHNICAL REPORTS: 8771:1944, 8771:1871, 8770:1186, 8771:1542, 8771:1768, 8771:1718. TRANSDUCER SPEC. CONTROL DWGS. #248635 THRU 248639
(2) THRUST CHAMBER TEMP. TRANSDUCER FOR CONTROLS	1st CANDIDATE TUNGSTEN RTT-TESTED & FAILED NEGOTIATED DEV. PROGRAM WITH G.E. FOR W/RTT (AWAITING SNPO APPROVAL) - 1st CANDIDATE W/W 26% R.L.Tc - SUCCESSFULLY TESTED		I.D.B. VOL II: VI-A-4.1.3 THRU 4.2.3. TECHNICAL REPORT M0323-G.E. REPORT #MP-63-27

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

S/T 2.4 INSTRUMENTATION

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
(3)	NRX-A2	INITIATED: INSTALLATION DWGS; TRANS- DUCER PROCUREMENT INITIATED, MEASUREMENT REQUIREMENT LISTS COMPLETED	DWG. 700276 & 700295 PROCUREMENT STATUS RPT. I.D.B. VOL. I
(4)	NRX-A3	DEFERRED PROCUREMENT TO CY '64 MEASUREMENT REQUIREMENTS LIST PREPARED	NRX-A3 TEST DELAY I. D. B. VOL I
(5)	MCITS	INSTR. DESIGNED, FAB., PROCURED FOR MCIT-902-3, 904, 905, 906, 908, CONTROL PALLETS NO.1 & NO.2 - 3 CALIBRATION SETS DESIGN & FAB.	DWGS 2484-23-4-5-6-7-8-9- 30-31-32 - TRANSDUCER SPEC. CONTROL DWGS.
(6)	CFDTS	MEASUREMENT REQUIREMENTS LIST COMPLETE COMPONENTS SELECTED - PROCUREMENT INITIATED	I.D.B. VOL I V-A.1.1 THRU V-A.1.6 - RPT. #2710 REV. TEST PLAN-CFDTS - FIGS. 3,5,6,7,8,9,16,20. TABLE 5 P.S.R.

BEON · ROCKET ENGINE OPERATIONS — NUCLEAR

S/T 2.4 INSTRUMENTATION

ACCOMPLISHMENT

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-2.4 A	PROVIDE TECHNICAL DIRECTION	COORDINATION & DIRECTION WERE PROVIDED - TECHNICAL REPORTS & STUDIES WERE GENERATED	I.D.B. MEASUREMENT REQ'T LISTS-NRX-A TEST PLANS & SPECS - 18 BENDIX RPTS-
2-2.4 B	ISSUE I.D.B. QUARTERLY	I.D.B'S WERE ISSUED OCT '62 (PRELIM)-JAN '63, APRIL '63 JULY '63, OCT '63	RPT 2320 (4 VOLS, 5 BOOKS)
2-2.4 C	SELECT & PROCURE INSTRUMEN- TATION FOR:		
(1)	NRX-A VIB. II	DELETED PER CHANGE ORDER TO MOD 8 (RN 63013)	
(2)	NRX-AI CF	COMPLETED : PROCUREMENT DWGS, SCHEMATICS, COM- PONENT EVALUATION & TESTING	DWGS 700506→3 ; DWG 294180 ; I.D.B. TRANSDUCER DATA SHTS ; TRANSDUCER SPEC CONTROL DWGS; PRO- CUREMENT STATUS REPORT

REON ROCKET ENGINE OPERATIONS—NUCLEAR

S/T 2.2 GSE CHECKOUT & TEST SYSTEMS

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-2.2A	INITIATE CRITERIA: ENGINE EQUIPMENT	COMP	SEE DOC LIST #29
	: CHECKOUT TRAILER	COMP	NDC 76
	: REM ENG CONT. SYSTEM	COMP	TASK 1.5 DOC
	COMP DES: BLOCK I EQUIPMENT - WANL	3 ITEMS	WANL 63 REPORT
	-LRP	COMP (2)	SEE COLD FLOW
	: NRX COLD FLOW - WANL	2 ITEMS	WANL 63 REPORT
	-LRP	COMP (2)	SEE DOC LIST #45
	: VIBRATION TEST SYSTEM	DELETE	COI, MOD 8
	: CFDTS	1/1/64	SEE DOC LIST #46
	MAINTAIN & UPDATE EQUIPMENT LISTS: NRX	COMP	TME 416; 394
	: E-ENGINE	COMP	RN 2477
	PREPARE & MAINTAIN OSP-NRX-A1	COMP	AGC 2516; TNR-13
	-NRX-A2	DEC 63	AGC 2516; A2 RESCHED
	PREPARE & MAINTAIN INFO FOR PRD	COMP	REPORT 2578
	CONDUCT NECESSARY E-ENGINE OSP SUPPORT	COMP	SEE DOC LIST #29

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

S/T 2.2 GSE CHECKOUT & TEST SYSTEMS

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-2.2 B	COMP FAB: NRX COLD FLOW EQUIP - WANL - LRP : VIBRATION TEST EQUIPMENT : NRX BLOCK I - WANL -LRP	4 ITEMS 11/1/63 (2) DELETE 6 ITEMS 11/1/63 (2)	WANL 63 REPORT A-I RESCHED COI, MOD 8 WANL 63 REPORT SEE COLD FLOW
13-2.2 a	INITIATE FAB CFDTs EQUIPMENT INITIATE PROCUREMENT CAMERA EQUIPMENT FAB LIGHT & CAMERA MOCKUP TEST CAMERA POSITIONING	COMPLETE COMPLETE COMPLETE 2/10/64	SEE DOC LIST #46 SEE DOC LIST #48 SEE DOC LIST #49 SNPO TWX 003
2-2.2 C	COMP ACCEPT TEST: NRX COLD FLOW - WANL - LRP COMP ACCEPT TEST: VIBRATION TEST	4 ITEMS 11/8/63 DELETE	WANL 63 REPORT AI RESCHED COI, MOD 8
ADDITIONAL WORK			
LTR 741:0221	NRX E-MAD FEASIBILITY STUDY	COMPLETE	LTR 741:0264
SNPO LTR 11/20/62	TEST CELL "B" EQUIPMENT REQUIREMENTS STUDY	COMPLETE	REPORT 2433

ROCKET ENGINE OPERATIONS—NUCLEAR

SUBTASK 2.2 - ACCOMPLISHMENTS FOR CY 1963

See page 2.1-1 for a discussion of the accomplishments under subtask 2.2 during CY 1963.

SUBTASK 2.2 - BIBLIOGRAPHY

See page 2.1-1a for the bibliography for subtask 2.2.

CONFIDENTIAL

DATE:

SCHEDULED MILESTONE

↑ MILESTONE ACHIEVEMENT

◆ RESCHEDULED MILESTONE

◆ RESCHEDULED MILESTONE ACHIEVEMENT

 RESCHEDULED TO CY 64

S/T 2.3 GSE HANDLING & MAINTENANCE

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-2.3 A	COMP DES: BLOCK I EQUIPT-WANL -LRP : COLD FLOW EQUIPT-WANL -LRP : VIBRATION TEST EQUIPT : CFDTs INITIATE ANALYSIS OF E-ENGINE DES CRIT MAINTAIN & UPDATE EQUIPT LISTS: NRX : E-ENGINE PREPARE & MAINTAIN OSP: NRX-AI : NRX-A2 CONDUCT NECESSARY E-ENGINE OSP EFFORT PROVIDE SUPPORT FOR SHIPPING DEMO MANAGE SHIPPING DEMO	12 ITEMS COMP (12) 49 ITEMS COMP (12) DELETE 1/1/64 COMP COMP COMP COMP DEC 63 COMP COMP COMP	WANL '63 REPORT SEE COLD FLOW WANL '63 REPORT SEE DEC LIST # 51 CO 1, MOD 8 SEE DOC LIST #46 SEE DOC LIST #29 TME 416 ; 394 RN 2477 AGC 2516 ; TNR 113 AGC 2516 ; A2 RESCHED SEE DOC LIST #29 WANL '63 REPORT WANL '63 REPORT
13 -2.3 a			
13-2.3 b	COMP FAB : BLOCK I EQUIPT-WANL -LRP	23 ITEMS COMP (10) 11/1/63 (20)	WANL '63 REPORT SEE COLD FLOW SEE COLD FLOW

S/T 2.3 GSE HANDLING & MAINTENANCE

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-2.3 b (CONT)	:COLD FLOW EQUIPT.-WANL -LRP	56 ITEMS COMP (10) 11/1/63 (20)	WANL '63 } SEE DOC LIST #52
	:VIBRATION TEST EQUIPT. INITIATE FAB CFDTS EQUIPT.	DELETE COMP	COI, MOD 8 SEE DOC LIST #46
2-2.3 C	COMP ACCEPT TEST: NRX COLD FLOW-WANL -LRP : VIBRATION TEST	56 ITEMS 11/8/63 DELETE	WANL '63 REPORT AI RESCHED COI, MOD 8
ADDITIONAL WORK			
LTR 741:0221	NRX E-MAD FEASIBILITY STUDY	COMP	LTR 741: 0264
SNPO LTR 11/20/62	TEST CELL "B" EQUIPT. REQTS STUDY	COMP	REPORT 2433

SUBTASK 2.3 - ACCOMPLISHMENTS FOR CY 1963

See page 2.1-1 for a discussion of the accomplishments under subtask 2.3 during CY 1963.

SUBTASK 2.3 - BIBLIOGRAPHY

See page 2.1-1a for the bibliography for subtask 2.3.

SCHEDULES AND MILESTONES
CONTRACT YEAR 1963
TASK ITEM 2.3

AS
OF

[illegible]

DATE:

 SCHEDULED MILESTONE

↑ MILESTONE ACHIEVEMENT

◆ RESCHEDULED MILESTONE

◆ RESCHEDULED MILESTONE ACHIEVEMENT

RESCHEDULED TO CY 64

S/T 2.1 REMOTE HANDLING EQUIPMENT

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-2.1A	COMP. DES: BLOCK I EQUIPMENT - WANL	53 ITEMS	WANL 63 REPORT (SEE DOC. LIST #1)
	: BLOCK I EQUIPMENT - LRP	COMPLETE (2) DELETE (1)	SEE DOC. LIST #2
	: OPS	COMPLETE	SEE DOC. LIST #3
	: EIV	COMPLETE	SEE DOC. LIST #4
	: MCC	COMPLETE	SEE DOC. LIST #5
	: BLOCK I TEST CAR MODS		WANL '63 REPORT
	INITIATE DES: BLOCK I POST MORTEM EQUIPMENT		WANL '63 REPORT
	: FMHS	COMPLETE	DES DATA BOOK
	COMP DES STUDY: FMHS	COMPLETE	DES DATA BOOK
	: BUSRAIL EXTENSION	COMPLETE	AGC LTR 745:0754
	: EIV DUST COVERS	COMPLETE	NDC 74
	COMP DES STUDY: ENGINE COOLANT SYSTEM	COMPLETE	NDC 73
	: INTERCELL RAIL ROAD	COMPLETE	NDC 80
	: ENGINE STORAGE STAND	COMPLETE	NDC 75

REON · ROCKET ENGINE OPERATIONS — NUCLEAR

S/T 2.1 REMOTE HANDLING EQUIPMENT

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
2-2.1A (CONT)	: MALFUNCTION EQUIPMENT	COMP	NDC 83
	: NES PRIME MOVER	COMP	NDC 79
	: NES INSPECT SYSTEM	COMP	NDC 81
	: NES DECON SYSTEM	COMP	NDC 84
	: LOCOMOTIVE	COMP	AGC 10126
	: MATERIAL TRANS SYSTEM	COMP	NDC 82
	: WASTE DISPOS EQUIPMENT	COMP	NDC 78
	: TEST & TOOLING METHODS		WANL 63 REPORT
	INITIATE PRELIMINARY DES DUCT TRAILER	COMP	SEE DOC LIST #20
	COMP ACCEPT TEST SPEC BLOCK I : WANL	53 ITEMS	WANL 63 REPORT
	: LRP	COMP	TWX 745 0140
	COMP EQUIPT SPEC BLOCK I : WANL	53 ITEMS	WANL 63 REPORT
	: LRP	COMP (1)	GSE-N-211
		DELETE (2)	SEE DOC LIST #23
	: OPS	COMP	AGC 10136A
	: FMHS	COMP	AGC 10137A

RECON ROCKET ENGINE OPERATIONS—NUCLEAR

S/T 2.1 REMOTE HANDLING EQUIPMENT

ACCOMPLISHMENTS

W/S REFERENCE	PLANNED	ACTUAL	EVIDENCE OF COMPLETION
2-2.1 A	: EIV	COMPLETE	AGC 10125 B
	: MCC	COMPLETE	AGC 10134 A
	: LOCOMOTIVE	COMPLETE	AGC 10126 A
	INITIATE ANALYSIS E-ENGINE DES. CRITERIA	COMPLETE	SEE DOC LIST #29
	MAINTAIN & UPDATE EQUIPT LISTS: NRX	COMPLETE	TME 416; 394
	: E-ENGINE	COMPLETE	REPORT 2477
	PREPARE & MAINTAIN NRX OSP: NRX-A1	COMPLETE	AGC 2516 ; TNR 113
	: NRX-A2	DEC 63	AGC 2516; A2 RESCHED
	CONDUCT NECESSARY E-ENGINE OSP EFFORT	COMPLETE	SEE DOC LIST #29
	PROVIDE TECH COORD OF ACFI ACTIVITIES		WANL 63 REPORT
13-2.1 A	COMP ON-STAND HOT MAINTENANCE STUDY	11/1/63	LTR 740: M0300
2-2.1 B	COMP FAB BLOCK I EQUIPT : WANL	101 ITEMS	WANL 63 REPORT
	: LRP	2/1/64 (1)	A2 RESCHED
		DELETE (2)	SEE DOC LIST #23
	INITIATE FAB : OPS	COMPLETE	P.O. 8533
	: MCC	COMPLETE	P.O. 8530
	: EIV	COMPLETE	P.O. 8531

REON · ROCKET ENGINE OPERATIONS—NUCLEAR

S/T 2.1 REMOTE HANDLING EQUIPMENT

ACCOMPLISHMENTS

<u>W/S REFERENCE</u>	<u>PLANNED</u>	<u>ACTUAL</u>	<u>EVIDENCE OF COMPLETION</u>
2-2.1B(CONT)	INITIATE PROCURE BLOCK I POST MORTEM COMP FAB TEST FIXTURES FOR TOOL METHODS		WANL 63 REPORT WANL 63 REPORT
2-2.1C	COMP ACCEPT TEST BLOCK I-LRP -WANL PARTICIPATE IN ACCEPT TEST ACFI EQUIPT	2/15/64 (I) IOI ITEMS	A2 RESCHED WANL 63 REPORT WANL 63 REPORT
ADDITIONAL WORK			
LTR 741:0221	NRX E-MAD FEASIBILITY STUDY	COMP	LTR 741:0264
SNPO LTR 11/20/62	TEST CELL "B" EQUIPT REQUIREMENTS STUDY E-MAD & ETS-I COMPLEX MODELS	COMP 10/31/63	REPORT 2433 SEE DOC LIST #43

RECON ROCKET ENGINE OPERATIONS—NUCLEAR

SUBTASK 2.1, 2.2, AND 2.3 - ACCOMPLISHMENTS FOR CY 1963

This part of the presentation covers Subtask 2.1 - Remote Handling Equipment, Subtask 2.2 - Checkout and Test Equipment, and Subtask 2.3 - Logistics, Transport and Maintenance Equipment. The Remote Handling Equipment is required to properly assemble, disassemble, transport, maintain and operate the NRX System, subsystems, and components in the various operating areas. Subtask 2.2 - Checkout and Test Equipment, is required to properly verify the operational integrity of the NRX System throughout the developmental phase in the contractors' plant and at NRDS. The Logistics, Transport and Maintenance Equipment, Subtask 2.3, in turn, is required to handle and transport the NRX System at the same facilities.

The support equipment effort is accomplished in four locations. The nuclear systems support equipment is being developed by WANL and ACFI; the non-nuclear systems equipment is being developed by the Aerojet Liquid Rocket Plant in Sacramento; the major remote handling equipment items for the E-MAD are being developed by AMF Atomics; and the overall integration and management of the support equipment program is being directed by REON from Azusa.

The following is a detailed review of the accomplishments for Subtasks 2.1, 2.2, and 2.3, and a review of 63002 Milestones.

The first chart of Subtask 2.1, Remote Handling Equipment, covers all work required by the Work Statement as modified by Change Order No. 1, Mod 8.

The first requirement was to complete the design of the NRX Block I Equipment, which is divided into two major areas; WANL and LRP.

In the case of WANL, we refer you to 53 provisioned WANL items, which were covered in their 63 Report. LRP has completed the design of all three originally provisioned equipments; the requirements for one of which was subsequently deleted because the pressure vessel and forward closure design was changed eliminating captive bolts, substituting standard hex head bolts. This is detailed in document list No. 2.

The design of the Overhead Positioning System (OPS), Engine Installation Vehicle (EIV), and Manned Control Car (MCC), were completed during CY 63. The details of these accomplishments are listed in document list Nos. 3, 4, and

5 respectively. The OPS, EIV, MCC, and Floor Mounted Handling System (FMHS) development programs, conducted by AMF Atomics, has been a major portion of the support equipment program.

The design of the Block I Test Car Modification was completed and design initiated for the Block I Post-Mortem Equipment. The status of this work has been reported in the WANL 63 Report.

The initiation of design of the FMHS and the design study for this subsystem has been completed and reported in the Design Data Book.

Design studies have been completed and NERVA Design Criteria prepared for the FMHS Busrail Extension, EIV Dust Covers, Engine Coolant System, Inter-cell Railroad, Engine Storage Stand, Malfunction Equipment, NES Prime Mover, NES Inspection System, NES Decontamination System, Locomotive, Material Transport System, and Waste Disposal Equipment. The design study of Test and Tooling Methods accomplishment was reported in the WANL 63 Report.

The initial preliminary design of the NES Duct Trailer has been completed. The acceptance test specification for the NRX Block I has been completed and the 53 provisioned WANL items were covered in their 63 Report. LRP has completed the acceptance test specifications for their Block I Remote Handling Equipment. The status of the completion of the specifications for this equipment is the same as for acceptance test specification. It will be noted here that a second item of LRP equipment (Item 21⁴) was deleted. After LRP completed the preliminary design of this item, the fabrication cognizance was transferred to ACFI (document list No. 23).

The equipment specifications for the OPS, FMHS, EIV, MCC, and Locomotive have been completed and specifications issued.

The analysis of the E-Engine Support Equipment Design Criteria has been initiated, as documented in document list No. 29. The support equipment lists for the NRX and E-Engine Remote Handling Equipment have been maintained and updated as required. The preparation and maintenance of the NRX-A1 Operational Support Plan has been completed and issued in July 1963 as TNR-113. The issuance of the Operational Support Plan for NRX-A2 has been rescheduled for December 1963, since the plan is basically dependent on information derived from the NRX-A2 test plan. The Operational Support Plan for the E-Engine has been completed and reported in document list No. 29.

The provision for technical coordination of the ACFI activities has been properly implemented as reported in the WANL 63 Report.

In Change Order No. 1, it was required that On-Stand Hot-Maintenance Study be completed during this contract year. This completion has been rescheduled to be completed during November, because the study, as it evolved, was more complex and detailed than originally anticipated.

The next area of the Work Statement involves fabrication, and it was required that fabrication be completed for Block I equipment fundamentally by WANL and LRP. WANL fabrication accomplishments (101 units) were reported in their 63 Report. The LRP Item N-211, Forward Closure Lifting Fixture, has been rescheduled to February of 1964 because this item is a remote unit and it is being provisioned consistent with the NRX-A2 test.

The fabrication of the OPS, MCC, and EIV has been initiated.

The initiation of procurement of NRX Block I Post-Mortem Equipment and the completion of fabrication of test fixtures for tooling methods was reported in the WANL 63 Report.

The acceptance testing of WANL Remote Handling Equipment for the NRX Block I Reactor System and participation in acceptance of the ACFI equipment was reported by WANL in their 63 Report. Acceptance test of the LRP item of equipment has been rescheduled for February of next year, consistent with equipment delivery.

Additional work, not contemplated in the 63 work program, that has been accomplished under Subtask 2.1 has been the NRX E-MAD Feasibility Study and the Test Cell "B" Equipment Requirement Study. The latter was reported in Report No. 2433. In addition, a series of models have been constructed for the E-MAD and ETS-1 Complex (document list No. 43).

This concludes the review of accomplishments for Subtask 2.1.

The initial requirement for Subtask 2.2, Checkout and Test Systems, is the initiation of criteria for the E-Engine checkout and test equipment, checkout trailer, and the remote engine control systems. This has been accomplished as evidenced in document list No. 29 and NERVA Design Criteria 76, and within Subtask 1.5, NERVA Controls Systems Documentation.

It was originally planned that the design of the checkout equipment for the NRX Block I Systems, the NRX Cold Flow and Vibration Test Systems, and Cold Flow Development Test System (CFDTS) would be completed in CY 63. The actual progress was: the five provisioned WANL items were completed and covered in the WANL 63 Report; LRP completed design of the two provisioned items as shown in Cold Flow Documentation, document list No. 45 (these items also to be used with NRX Block I); the vibration and test system design was eliminated by Change Order No. 1, Mod 8; and CFDTS equipment design has been completed where common usage exists for NRX and CFDTS equipment. Three new items have been scheduled for design completion in January of 1964, as stated in document list No. 46.

The completion of requirements for the support equipment lists for NRX and E-Engine checkout and for the NRX Operations Support Program is identical to that reported for Subtask 2.1; that is, the equipment lists for the NRX and E-Engine have been completed, the Operational Support Plan for NRX-A1 has been completed, the Operational Support Plan for NRX-A2 has been rescheduled for December of this year to be compatible with the NRX-A2 schedule.

The required information for the Program Requirements Document has been submitted and is incorporated in Report No. 2578.

The effort necessary to support the E-Engine Operational Support Plan for E-MAD activation has been completed (document list No. 29).

Fabrication effort under Work Statement Subtask 2.2 requires completion of fabrication for the NRX Cold Flow and Vibration Test Checkout Equipment. The NRX Cold Flow Equipment for WANL, which consists of four items, was reported in their 63 Report. The two equipments required to be furnished by LRP for NRX-A1 (cold flow) have been rescheduled to November of this year. Both units have been fabricated. One unit is being modified to accommodate an additionally identified requirement; the second is being held at LRP for testing with a suitable nozzle. The vibration test equipment has been deleted as required in Change Order No. 1, Mod 8.

The fabrication of NRX Block I Checkout and Test Equipment includes six items for WANL, as reported in the 63 Report, and the same two cold flow items just noted for LRP which have been rescheduled to November of this year.

The initiation of fabrication of the CFDTS Checkout and Test Equipment has been completed.

Under Change Order No. 1, Mod 8, for Subtask 2.2, it was required to initiate the procurement of camera equipment and fabricate a mockup to test camera positioning and lighting intensities within the NFX nozzle. This has been accomplished (document list Nos. 48 and 49). The completion of the test to extend the camera coverage time, using a larger reel, has been scheduled for February of next year.

It was planned that the acceptance test of checkout equipment for the NRX Reactor Cold Flow and Vibration Test Systems would be completed in CY 63. The completion of acceptance tests of the WANL Cold Flow Equipment consists of four items as reported in the WANL 63 Report. The LRP Cold Flow Equipment acceptance has been rescheduled to November of this year to be compatible with equipment deliveries. The acceptance test of the vibration test equipment has been deleted, as required in Change Order No. 1, Mod 8.

The additional work, not anticipated in CY 63, that has been accomplished under Subtask 2.2 includes the NFX E-MAD Feasibility Study, and the Test Cell "B" Equipment Requirement Study, as discussed under Subtask 2.1.

This concludes the review of the accomplishments in Subtask 2.2.

The first objective for Subtask 2.3 was to complete the detailed design of: the NRX Block I and Cold Flow Maintenance and Handling Equipment; the Vibration Test Equipment; and the CFDTIS Maintenance and Handling Equipment. WANL has reported on the design of 61 provisioned NRX Block I and Cold Flow items in their 63 Report. LRP has completed their 12 provisioned NRX Cold Flow items; the same items to be used for NRX Block I (document list No. 51). The vibration test equipment was deleted according to Change Order No. 1, Mod 8. The design of all CFDTIS equipments has been completed where NRX/CFDTIS equipment common usage exists; with the design of three new CFDTIS equipment requirements being scheduled to the first of 1964 (document list No. 46).

As shown in document list No. 29, the analysis of the E-Engine Support Equipment Design Criteria was initiated. Again, the support equipment lists for NRX and E-Engine handling and maintenance equipment and the preparation and maintenance of the required NRX Operational Support Plan are the same as reported under Subtasks 2.1 and 2.2. That is: the current equipment lists for NRX and E-Engine are completed; the Operational Support Plan for NRX-A1 is complete; and the NRX-A2 Operational Support Plan will be issued in December of this year.

The requirement to conduct E-Engine Operational Support Plan effort, as necessary to support the E-MAD activation date, has been completed.

In Change Order No. 1, Mod 8, a requirement to provide support and management of reactor shipping demonstrations was listed. This has been completed and documented in the WANL 63 Report.

The CY 63 Program called for the completion of the fabrication of NRX Reactor Block I Cold Flow and Vibration Test Handling and Maintenance Equipment. The 79 units of provisioned WANL NRX Block I (23 items) and Cold Flow Equipment (56 items) were reported on in the WANL 63 Report. LRP has provisioned 12 items and fabricated 10 of their 30 units, with the remainder being rescheduled for November of this year. Of the 12 provisioned LRP items, a first unit of each is required for NRX-A1 shipping, handling and maintenance. Of these 12, eight were fabricated as of 30 September 1963. Of the remaining items (N-704 - Nozzle Shipping and Storage Container, and N-916 - Maintenance Platform, Rocket Engine) are scheduled for completion in November. Item 704 will meet required nozzle shipping schedules and is late because of shop fabrication priorities on more critical test article hardware. Item 916 is required only in-plant at LRP for NRX-A1 and is actually in operation at present, awaiting delivery of some permanent aluminum tubing to be shipped from vendor (document list No. 52).

The fabrication of vibration test equipment was deleted in accordance with Change Order No. 1, Mod 8.

The fabrication of CFDTS has been initiated as required (document list No. 46).

The 56 units of WANL NRX Cold Flow and Vibration Test Systems equipment were covered in the WANL 63 Report. LRP has rescheduled completion of NRX-A1 acceptance testing to November 1963 to be compatible with equipment deliveries. The vibration test equipment acceptance tests have been deleted in accordance with Change Order No. 1, Mod 8.

Additional work that has been accomplished is the NRX E-MAD Feasibility Study and the Test Cell "B" Equipment Requirement Study, as shown in Report No. 2433, and discussed under Subtasks 2.1 and 2.2.

This completes the discussion of Subtask 2.3 accomplishments.

A summary of the remaining accomplishments in the Support Equipment Program are as follows: Under Subtask 2.1 we have completed the Study of NRX E-MAD Operations; initiated preliminary design of FMHS Busrail Extension; initiated preliminary design of Intercell Railroad; completed Design Criteria Specifications for Remote Crane, Prime Mover System, Remote Bulldozer, and Dump Car. Analysis and study of E-MAD Wall Mounted Handling System, Radioactive Materials Complex, and Test Stand Complex were completed.

Under Subtask 2.2, equipment specifications were released for NRX (WANL and LRP) and CFDTS (LRP). The Checkout Plan and Operating Procedure were developed and upgraded, and a study of NRX E-MAD Operations was conducted.

Under Subtask 2.3, we released Design Criteria for NRX and CFDTS Equipment, developed and upgraded GSE Operating Procedures, and initiated GSE Operational Documents for E-Engine in E-MAD.

A significant remaining accomplishment that has not been specifically discussed is the REON Support Equipment Department's management of the subcontractors.

Among the continuing functions of this group is the review, analysis and approval of bid packages and all top assembly drawings involving support equipment developed by WANL. We have instituted a bi-weekly technical liaison meeting with WANL to review design progress and to maintain a current reporting status for all SNP-1 provisioned equipment.

The management of the AMF subcontract has included the review and approval of all released drawings and procurement packages for the OPS, EIV, MCC, and FMHS. To date, we have approved 875 released drawings for these systems and overall, we have reviewed approximately 1,800 drawings. Analysis and approval of special reports, such as equipments stress analysis, shielding studies, viewing studies and operating procedures have been provided.

The non-nuclear support equipment development efforts were monitored and documentation, such as equipment drawings, specifications and operating procedures, have been reviewed and approved.

Another continuing effort has been the integration of the 253 separately provisioned items of support equipment into a functional and economical support equipment system. This integration has involved 66 technical direction, design review and liaison meetings with the NERVA subcontractors during CY 63.

The following is a review of the Milestones for Subtask 2.1. There were 14 2.1 Milestones scheduled for CY 63. Thirteen were completed and one has been deferred to December of 1963. This deferred item is the Operational Support Plan for the NRX-A2 Reactor Series. The December date was chosen to utilize NRX-A2 test plan information.

The following is a review of the Milestones for Subtask 2.2. There were eight 2.2 Milestones scheduled for CY 63; six were completed and two have been deferred to CY 64. These two deferred items are: complete acceptance testing of checkout equipment for the MAD Building and Test Cell "A," and issue a revised Block I Operational Support Plan, which is the Operational Support Plan for NRX-A2. The Operational Support Plan will be issued in December 1963 and the acceptance testing of checkout equipment will be completed consistent with NRX-A1 and NRX-A2 use dates.

Subtask 2.3 has 12 Milestones scheduled during CY 1963. Six Milestones have been completed and six deferred to CY 1964.

1. The design release of NRX-A2 support equipment is scheduled for the first quarter of 1964, consistent with the new NRX-A2 test date.

2. In the Milestone, design release of NRX-A2 storage containers and casks, the casks are now to be furnished as GFE. The containers, in turn, are being designed for NRX-A1 and NRX-A2 use. Consequently, the NRX-A2 requirement is adequately being accomplished.

3. Completion of fabrication of NRX-A1 GSE is being deferred to CY 64. The required equipment will be available for the NRX-A1 test, as the only outstanding items are WANL containers and two LRP items.

4. The delivery of the NRX-A1 GSE to NRDS depends upon the previous fabrication Milestone.

5. The system integration and checkout of NRX-A1 GSE is rescheduled to CY 64. The integration and checkout of NRX-A1 equipment will be compatible with equipment deliveries and with the NRX-A1 test date.

6. The issuance of the revised Block I Operational Support Plan is rescheduled to December 1963.

As a summary, all major equipments required for the NRX-A1 test have been completed except for the test car. The actual completion of the test car will not be accomplished until immediately prior to the NRX-A1 test to allow the necessary and continuing changes to the test system. Equipments required for NRX-A2 reactor test are on schedule, considering that the delivery date for this equipment is consistent with the current NRX-A2 test date. All equipments being developed by AMF are on schedule.

The specific accomplishments for each item of equipment, including design, fabrication, or delivery, are individually detailed in Report RN-S-0005. Report RN-S-0005 is a complete status of all NERVA support equipment as of 30 September 1963.

In conclusion, the total NERVA support equipment program accomplishments have been both timely and efficient and have satisfied the support equipment requirements of the NRX and E-Engine Programs during CY 1963.

SUBTASKS 2.1, 2.2, AND 2.3 - BIBLIOGRAPHY

The following reference documents are listed in their order of appearance on the Work Statement and Change Order 1 flip charts used to illustrate accomplishments in CY 63 for Subtasks 2.1, 2.2, and 2.3.

1. WANL and WANL/ACFI Management by REON (2.1, 2.2, 2.3)

This package contains evidence of REON management of WANL and ACFI under Subtasks 2.1, 2.2, and 2.3 during CY 1963; and WANL and ACFI support equipment status lists and technical descriptions for Subtasks 2.1, 2.2, and 2.3 as compiled by REON. Contents are as follows:

	<u>Originator</u>	<u>Type Document</u>	<u>Ident. Number</u>	<u>Title or Subject</u>	<u>Issue Date</u>
a.	REON	Memo	744:MO195	Reply to Memo 760:4857, dated 3 October 1963, Subject: REON Significant Directions to WANL During Contract Year 1963, Miller to REON Division and Dept Managers (all referenced enclosures attached - TWX, letters, reports, etc.)	10-8-63
b.	REON	Manual		WANL Support Equipment Status and Technical Descriptions Manual (transmitted to Mr. E. Burciaga of NASA-WOO During Monthly Status Review Meetings at Azusa)	

2. LRP Block I Equipment Design (2.1)

This package contains evidence of design completion of three LRP Subtask 2.1 items (N-25, N-11 and N-214) and the eventual deletion of Item N-25, as follows:

	<u>Originator</u>	<u>Type Document</u>	<u>Ident. Number</u>	<u>Title or Subject</u>	<u>Issue Date</u>
a.	REON	TWX	745:0031	Deletion of Requirements for NRY Captive Bolt Removal Tool. Item N-25 deleted from Program Requirement, W. D. Stinnett to J. J. Peterson, LRP	7-8-63
b.	LRP	Drawing	293750	Tool Kit, Rocket Engine, Disassembly, Remote (Dwg of deleted item N-25)	4-17-63
c.	LRP	Drawing	276300	Fixture, Lifting, Rocket Engine, Forward Closure - Remote, Item No. N-211	5-13-63

d.	LRP	Drawing	276320	Fixture, Lifting, Rocket Engine Nozzle - Remote, Item No. N-214	4-19-63
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3. OPS Design (2.1)

This package contains evidence of completion of OPS design as follows:

	<u>Originator</u>	<u>Type Document</u>	<u>Ident. Number</u>	<u>Title or Subject</u>	<u>Issue Date</u>
a.	AMF	Drawing	89-80-R- 1000	OPS General Assembly	9-26-63
b.	AMF	Drawing	89-80-R- 3000	OPS Mast Assembly	9-26-63
c.	AMF	Drawing	89-80-E- 9001	OPS Elec. Diagram	9-25-63
d.	AMF	Drawing	89-80-R- 4550	OPS Floating Head	9-26-63
e.	REON	Letter	REON to AMF	Technical Approval (Provides technical approval for all of the above top assembly drawings)	9-26-63

4. EIV Design (2.1)

This package contains evidence of completion of EIV design as follows:

	<u>Originator</u>	<u>Type Document</u>	<u>Ident. Number</u>	<u>Title or Subject</u>	<u>Issue Date</u>
a.	AMF	Drawing	89-71-R- 1004	EIV General Arrangement	9-27-63
b.	AMF	Drawing	89-71-E- 2500	EIV Elec. Dist. Diagram	9-27-63
c.	REON	Letter	REON to AMF	Technical Approval (Provides technical approval for each of the above top assembly drawings)	9-27-63

5. MCC Design (2.1)

This package contains evidence of completion of MCC design as follows:

	<u>Originator</u>	<u>Type Document</u>	<u>Ident. Number</u>	<u>Title or Subject</u>	<u>Issue Date</u>
a.	AMF	Drawing	89-73-E- 1000	MCC General Arrangement	9-25-63

b.	AMF	Drawing	89-73-E-1301	MCC Engine Compartment	9-25-63
c.	AMF	Drawing	89-73-E-1404	MCC Control Cab Arrangement	9-25-63
d.	AMF	Drawing	89-73-E-3000	MCC Elec. Equip. Arrangement	9-17-63
e.	AMF	Drawing	89-73-E-3018	MCC Power and Lighting Diagram	9-25-63
f.	REON	Letter	REON to AMF	Technical Approval (Provides technical approval for all of the above top assembly drawings)	9-26-63
6.	AMF	Design Data Book		FMHS Design Data Book (Complete set of preliminary designs for the FMHS)	11-62
7.	REON	Letter	745:0754	Stinnett to Schroeder, Subject: E-MAD Phase II, Minutes of Design Review Meeting, Vitro Engineering, NY, 12 and 13 March 1963 (Confirms Bucrail operational requirements)	6-7-63
8.	REON	NDC	74	Covers, Dust, for E-Series Engines	Draft 9-30-63
9.	REON	NDC	73	Aftercooling System for NERVA Engine	Draft 9-30-63
10.	REON	NDC	80	Intercell Transfer System, E-MAD Building, NRDS	Draft 9-30-63
11.	REON	NDC	75	Stand, Hold, Hot Engine, Remote	Draft 9-30-63
12.	REON	NDC	77	Containers, for Transport and Storage of Radioactive Materials	Draft 9-30-63
13.	REON	NDC	83	Test Stand Malfunction and Equipment Requirements at EIS-1	Draft 9-30-63
14.	REON	NDC	79	Prime Mover, for Handling NES Duct Trailer in Nuclear Environment	10-15-63
15.	REON	NDC	81	Inspection System, NERVA Exhaust Duct, EIS-1	Draft 9-30-63

16.	REON	NDC	84	Decontamination System, NES Duct at ETS-1	Draft 9-30-63
17.	REON	Spec	10126	Locomotive Specification (Specific modifications to GFE Locomotive)	5-62
18.	REON	NDC	82	Hot Cell Material Transfer System, Post-Operative Cells, E-MAD Bldg NRDS	Draft 9-30-63
19.	REON	NDC	78	Waste Disposal, Radioactive Materials, Equipment for	Draft 9-30-63

20. NES Duct Trailer Preliminary Design (2.1)

This package contains evidence of completion of initiation of NES Duct Trailer preliminary design as follows:

	<u>Originator</u>	<u>Type Document</u>	<u>Ident. Number</u>	<u>Title or Subject</u>	<u>Issue Date</u>
a.	REON	Drawing	CD-81363	NES Trailer Preliminary Design Configuration (Hard Rubber Tire)	9-63
b.	REON	Drawing	093699	NES Trailer Preliminary Design Configuration (Railway)	10-63
c.	REON	Drawing	093700	NES Trailer Preliminary Design Configuration (Pneumatic Tires)	10-63
21.	REON	TWX	745:0140	LRP/GSE Acceptance Testing. TWX confirms telecon of avail- ability of LRP inspection and test procedures for all LRP/ GSE. TWX requests that LRP provide REON with copies, W. D. Stinnett to J. J. Peterson, LRP	10-22-63
22.	REON	Performance (Equipment) Spec	GSE-N-211	N-211 Fixture, Lifting, Rocket Engine Forward Closure - Remote (Preliminary)	6-63

23. LRP Block I Equipment Specifications (2.1)

This package provides evidence of deletion of Item N-25 and transfer of Item N-214 to WANL/ACFI cognizance as follows:

	<u>Originator</u>	<u>Type Document</u>	<u>Ident. Number</u>	<u>Title or Subject</u>	<u>Issue Date</u>
a.	REON	TWX	745:0031	Deletion of Requirement for NFX Captive Bolt Removal Tool. Item N-25 Deleted from Program Requirement, Stinnett to Peterson (LRP)	7-8-63

b.	REON	Letter	L745:0003	Transmittal of LRP Item N-214 Preliminary Design and Design Criteria of NRX-A2, Item 1133, "Nozzle Handling Fixture," for WANL/ACFI Use (Cognizance for N-214 was transferred to WANL/ACFI. Item was renumbered to No. 1133.) From Stinnett to Faught (WANL)	6-19-63
24.	REON	Spec	10136A	OPS Specification	10-62
25.	REON	Spec	10137A	FMHS Specification	10-62
26.	REON	Spec	10125B	EIV Specification	10-62
27.	REON	Spec	10134A	MCC Specification	10-62
28.	REON	Spec	10126A	Locomotive Specification	7-63
29.	<u>E-Engine Design Criteria and Operational Support Plan (2.1, 2.2, 2.3)</u>				

This package contains documents developed during the analysis of engine design criteria and in the preparation of a portion of the E-Engine Operational Support Plan, as follows:

	<u>Originator</u>	<u>Type Document</u>	<u>Ident. Number</u>	<u>Title or Subject</u>	<u>Issue Date</u>
a.	LRP	Report	LRP-62-1697	NERVA Engine Assembly Procedure (Step-by-step procedures with sketches from component stage through loading on highway transport trailer)	12-7-62
b.	AMF	Report		Sequence of Assembly/Dis-assembly Operations of the E-Engine in E-MAD Hot Bay	1963
c.	LRP	Report		NERVA Engine Support Equipment Sequential Flow and Functional Requirements (flow diagrams, systems engineering approach, handling equipment sketches from factory to test stand)	1963
d.	REON	Report		E-Engine Operational Support Plan Preliminary Operations Outline	9-12-63
e.	Bendix	Report	Letter, Tamm to Allen, 2.1, 2.2, 2.3	E-Engine Operational Support Plan and Provisioning List	9-12-63

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f.	REON	Report	AGC 2477	E-Engine Provisioning List	2-63
30.	WANL	Report	TME-416	Revision 3, NERVA Support Equipment Provisioning List and Schedule for NRX-A1	10-16-63
31.	WANL	Report	TME-394	Revision 1, NERVA Support Equipment Provisioning List and Schedule for NRX-A2	10-16-63
32.	WANL	Report	2477	NERVA Support Equipment Provisioning Lists and Schedules (NRX and CFDS Portions)	2-63
33.	REL	Report	2516	NRX Operational Support Plans	4-63
34.	WANL	Report	TMR-113	NRX-A1 Cold Flow Operational Support Plan	6-6-63
35.	REON	Memo	740:MO300 (Verbal presentation at SNFO-C/REON Mtg 8-28-63)	On-Stand Hot-Maintenance Study, Stinnett to Ryland	9-13-63
36.	AMF	Purchase Order	8533	To PAR for the OPS Manipulator (one of many OPS PO's)	6-63
37.	AMF	Purchase Order	8530	To Plymouth Locomotive for MCC Engine Compartment and Under-carriage (one of many MCC PO's)	7-63
38.	AMF	Purchase Order	8531	To Thrall Mfg Co for EIV Flat Car Assembly (one of many EIV PO's)	7-63
39.	REON	Letter	741:0221	House to Schroeder (References SNFO authorization to REON to perform feasibility study of E-MAD Complex to accommodate NRX/E-Engine Program	9-13-63
40.	REON	Letter	741:0264	House to Schroeder, Subject: Transmittal of Feasibility Study of E-MAD Complex to Accommodate NRX/E-Engine Program	9-13-63
41.	SNFO-C	Letter		Schroeder to House (authorizes REON to conduct a Feasibility Study of an Interim NERVA Engine Test Facility Arrangement, "Upward Firing Engine" - REON Rept 2433 (SRD) contains results of study and references the SNFO-C authority letter)	11-20-62

42. REON Report 2433 Nuclear Rocket Engine 12-28-62
(SRD) Auxiliary Static Test
Facility Study (Upward Firing
Engine)

43. E-MAD and ETS-1 Complex Models (2.1)

This package contains evidence of work performed by REON to build E-MAD and ETS-1 Complex Models, by reference to REON General Work Release Numbers as follows:

	<u>Originator</u>	<u>Type Document</u>	<u>Ident. Number</u>	<u>Title or Subject</u>	<u>Issue Date</u>
a.	REON	GWR 7	0716-21-5000	E-MAD Facility and Support	6-25-63
b.	REON	GWR 13	0716-21-5000	Equipment Models and ETS-1	7-19-63
c.	REON	GWR 11	0716-21-5000	(The development of functional and study models of the E-MAD Hot Bay and Disassembly Cells,	7-19-63
d.	REON	GWR 12	0716-21-5000	ETS-1 Test Stand, Vault Ditch, NES Duct, Duct Trailer, ETV, MCC, Locomotive, Beetle, and	7-24-63
e.	REON	GWR 4	0716-21-5000	some FMBS Equipment to evaluate operations and viewing.)	7-22-63
f.	REON	GWR 14	0716-21-5000		7-22-63
g.	REON	CWR 23	0716-21-5000		8-21-63
h.	REON	GWR 25	0716-21-5000		8-21-63
i.	REON	GWR 22	0716-21-5000		8-21-63
j.	REON	GWR 24	0716-21-5000		8-21-63
k.	REON	GWR 21	0716-21-5000		8-21-63
44.	REON	NDC	76	Trailer, Checkout, E-Engine	Draft 9-30-63

45. LRP NRX Cold Flow Design (2.2)

This package contains evidence of design completion of two LRP Subtask 2.2 items (N-450 and N-451) as follows:

	<u>Originator</u>	<u>Type Document</u>	<u>Ident. Number</u>	<u>Title or Subject</u>	<u>Issue Date</u>
a.	LRP	Drawing	293235	Closure Kit, Pressure Testing, Rocket Engine (N-450)	4-4-63
b.	LRP	Drawing	293700	Closure Kit, Pressure Testing, Nozzle Throat, Rocket Engine (N-451)	7-5-63

46. CFDTS Equipment (2.2 and 2.3)

This package contains documents generated for NRX support equipment and analyzed for CFDTS usage. The analysis indicated common usage during in-plant operations, which resulted in the completion of design of all LRP and WANL CFDTS equipment programmed in CY 63. Three additional items (Turbopump Sling, Thrust Structure Sling and Thrust Structure Stand) are programmed in CY 64. These items were deleted during CY 63 negotiations due to lack of funding. Other items of equipment originally planned and deleted during CY 63 negotiations have been substituted for by using manufacturing tools and equipment in an effort to reduce costs. Document listings are as follows:

	<u>Originator</u>	<u>Type Document</u>	<u>Ident. Number</u>	<u>Title or Subject</u>	<u>Issue Date</u>
a.	LRP	Report	GSE-9652-N-1010	NRX System Preliminary Support Equipment Plan Operating Ground Equipment (An analysis of support events in NRX assembly from component assembly through testing. Recommends support equipment systems.)	1-21-63
b.	LRP	Report	LRP-NRX-A1	Non-Nuclear Engine Assembly (Provides instructions and information necessary to assemble the NRX-A1 Non-Nuclear Engine for test at LRP)	10-1-63

47. REON Report 2578 Program Requirements Document 6-63

48. Camera Equipment Procurement (2.2)

This package contains copies of stores and purchase requisitions, purchase orders, General Work Releases, Interplant Work Authorizations and Test Order for Documenting Camera Equipment Procurement for NRX-A1 Nozzle Photography, as follows:

	<u>Originator</u>	<u>Type Document</u>	<u>Ident. Number</u>	<u>Title or Subject</u>	<u>Issue Date</u>
a.	REON	Req	270043	Stores and Purchase Requisition for TV Monitor and Case	8-5-63
b.	REON	Req	286459	Stores and Purchase Requisition for Instrumentation Connectors	9-5-63

c.	REON	Req	270078	Stores and Purchase Requisition for Instrumentation Connectors	8-30-63
d.	REON	Req	270080	Stores and Purchase Requisition for Lights	8-30-63
e.	REON	Req	270159	Stores and Purchase Requisition for C-Mounts	7-11-63
f.	REON	Req	270157	Stores and Purchase Requisition for Camera, Cable, Control Unit and Synch. Generator	6-25-63
g.	REON	Purchase Order	364544	AGC Purchase Order for Power Supply, Cable, etc.	8-23-63
h.	REON	Purchase Order	364505	AGC Purchase Order for Camera, Camera Mount, etc.	8-1-63
i.	REON	Purchase Order	361060	AGC Purchase Order for Quartz	8-8-63
j.	REON	Work Release	0716-22-8000	General Work Release for TV, Camera, and Lighting System	7-3-63
k.	REON	Work Release	0716-22-8000	General Work Release for Fabrication, Material and Technical Coordination	8-20-63
l.	REON	Work Auth	062703	Interplant Work Authorization to LRP	7-26-63
m.	REON	Test Order	98-4045	AGC Test Order for Quartz Window Test	8-8-63

49. Camera and Lighting Mockup (2.2)

This package contains four photographs verifying completion of fabrication of the mockup of cameras and lighting for MRX-A1 nozzle photograph, as follows:

	<u>Originator</u>	<u>Type Document</u>	<u>Ident. Number</u>	<u>Title or Subject</u>	<u>Issue Date</u>
a.	REON	Photo	863-54	Camera and Lighting Mockup	N/A
b.	REON	Photo	863-55	Camera and Lighting Mockup	N/A
c.	REON	Photo	863-56	Camera and Lighting Mockup	N/A
d.	REON	Photo	863-57	Test Photograph Made with Camera and Lighting Mockup	N/A
50.	SNPO-C	TWX	003	External Reel, Camera (SNPO-C direction to proceed with larger reel for extension of the camera coverage time)	10-3-63

51. LRP NRK Cold Flow Design (2.3)

This package contains evidence of design completion of all twelve (12) LRP Subtask 2.3 items as follows:

	<u>Originator</u>	<u>Type Document</u>	<u>Ident. Number</u>	<u>Title or Subject</u>	<u>Issue Date</u>
a.	LRP	Drawing	278500	Shipping and Storage Container, Rocket Engine Nozzle (N-704)	6-1-63
b.	LRP	Drawing	278960	Semitrailer, Rocket Engine (N-724)	6-21-63
c.	LRP	Drawing	278580	Sling, Multiple Leg - Multiple Purpose, 3000 lb Capacity (N-801)	4-11-63
d.	LRP	Drawing	279150	Fixture, Lifting, Rocket Engine Forward Closure (N-803)	4-24-63
e.	LRP	Drawing	278570	Sling, Beam Type (N-809)	4-13-63
f.	LRP	Drawing	278660	Beam, Hoisting, Nozzle - Rocket Engine (N-813)	7-17-63
g.	LRP	Drawing	278670	Sling, Multiple Leg - 12,000 lb Capacity (N-817A)	6-19-63
h.	LRP	Drawing	279025	Adapter, Handling, Rocket Engine (N-914)	4-23-63
i.	LRP	Drawing	279050	Stand, Rocket Engine (N-915)	6-19-63
j.	LRP	Drawing	279110	Maintenance Platform, Rocket Engine (N-916)	4-19-63
k.	LRP	Drawing	279160	Stand, Forward Closure, Rocket Engine (N-917)	4-24-63
l.	LRP	Drawing	279180	Stand, Nozzle, Rocket Engine (N-918)	4-24-63

52. LRP NRK Cold Flow Fabrication (2.3)

This package provides evidence of completion of fabrication of ten (10) units of LRP Subtask 2.3 equipment, and provides completion schedule data for the balance of the provisioned items (20 units to complete) compatible with the NRK-A1 and A2 test schedules, as follows:

- a. Completed Hardware

<u>Originator</u>	<u>Type Document</u>	<u>Ident. Number</u>	<u>Title or Subject</u>	<u>Status</u>
(1) LRP	Photo	10-63SP-2449	Item N-801, Sling, Multiple Leg - Multiple Purpose, 3000 lb Capacity	5 units completed
(2) LRP	Photo	10-63SP-2448	Item N-803, Fixture, Lifting, Rocket Engine, Forward Closure	1 unit completed
(3) LRP	Photo	10-63SP-2444	Item N-809, Sling, Beam Type	1 unit completed
(4) LRP	Photo	10-63SP-2175	Item N-817A, Sling, Multiple Leg - 12,000 lb Capacity	1 unit completed
(5) LRP	Pending		Item N-917, Stand, Forward Closure, Rocket Engine	1 unit completed
(6) LRP	Pending		Item N-918, Stand, Nozzle, Rocket Engine	1 unit completed

b. Uncompleted Hardware (scheduled for completion compatible with NRX-A1 and A2 Test Schedules)

(1) REON	Status Sheet	S/T 2.3 NRX-A1 and A2	Item N-704, Shipping and Storage Container, Rocket Engine Nozzle	2 units not complete
(2) REON	Status Sheet	S/T 2.3 NRX-A1 and A2	Item N-724, Semitrailer, Rocket Engine	2 units not complete
(3) REON	Status Sheet	S/T 2.3 NRX-A1 and A2	Item N-809, Sling, Beam Type	1 unit not complete
(4) REON	Status Sheet	S/T 2.3 NRX-A1 and A2	Item N-813, Beam, Hoisting, Nozzle, Rocket Engine	1 unit not complete
(5) REON	Status Sheet	S/T 2.3 NRX-A1 and A2	Item N-817A, Sling, Multiple Leg, 12,000 lb Capacity	1 unit not complete
(6) REON	Status Sheet	S/T 2.3 NRX-A1 and A2	Item N-914, Adapter, Handling, Rocket Engine	5 units not complete
(7) REON	Status Sheet	S/T 2.3 NRX-A1 and A2	Item N-915, Stand, Rocket Engine	2 units not complete

(8) REON	Status Sheet	S/T 2.3 NRX-A1 and A2	Item N-916, Maintenance Platform, Rocket Engine	2 units not complete
(9) REON	Status Sheet	S/T 2.3 NRX-A1 and A2	Item N-917, Stand, Forward Closure, Rocket Engine	2 units not complete
(10) REON	Status Sheet	S/T 2.3 NRX-A1 and A2	Item N-918, Stand, Nozzle, Rocket Engine	2 units not complete

SCHEDULES AND MILESTONES

CONTRACT YEAR 1963

TASK ITEM 2.1

DATE:

↑ SCHEDULED MILESTONE

◇ RESCHEDULED MILESTONE

↑ MILESTONE ACHIEVEMENT

◆ RESCHEDULED MILESTONE ACHIEVEMENT

◇ RESCHEDULED TO CY 64

Sheet 1 of 2

CONTRACT YEAR 1963

TASK ITEM 2.1

[illegible]

DATE:

↑ SCHEDULED MILESTONE

↑ MILESTONE ACHIEVEMENT

◆ RESCHEDULED MILESTONE

◆ **RESCHEDULED MILESTONE ACHIEVEMENT**

RESCHEDULED TO CY 64

Sheet 2 of 2