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AEROJET NUCLEAR SYSTEMS COMPANY
Sacramento, California

MEMORANDUM

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TID/SNA -- 1697

To: Distribution
From: R. V. Evleth
Subject: MCDAC Report A3-130-2421
Distribution: AD Cornell, JR DaVolio, JJ Stewart, WA Fiala
Enclosure: (1) MCDAC Report A3-130-2421

December 17, 1971
RVE:es:5-6903

The subject report is forwarded for your information.

R. V. Evleth, Manager
Configuration Control
NERVA Rocket Operations

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MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

5301 Bolsa Avenue, Huntington Beach, CA 92647 (714) 896-3311

15 December 1971
A3-130-2421

Subject: CONTRACT NAS8-27951, SUBMITTAL OF FIRST MONTHLY PROGRESS AND STATUS REPORT

To: National Aeronautics & Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

Attention: Mr. W. F. Crawford, A&TS-PR-RS

1. Pursuant to Data Requirement Document Number 265 of subject contract, the Contractor is submitting herewith one (1) copy of the First Monthly Progress and Status Report as required by DR Number MA-02. Additional distribution has been made to the below addressees.

2. In order that we may have a record of compliance with contractual requirements, we will appreciate your acknowledging receipt by signing and returning the attached copy of this letter.

William E. Schweickert
Contract Administrator
Advance Systems & Technology

WES/hm

Enclosure: First Monthly Progress and Status Report (1 copy)

cc: NASA/MSFC
A&TS-PR-M (1 copy)
A&TS-MS-IL (1 copy)
J. W. Russell, PD-SA-P (10 copies)

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FIRST MONTH'S LETTER PROGRESS REPORT
REUSABLE NUCLEAR STAGE SYSTEM DEFINITION

STUDY - PHASE IV

CONTRACT NAS8-27951

REPORT PERIOD: SEPTEMBER 13 - NOVEMBER 30, 1971

SUMMARY

This document represents the first progress letter under Contract NAS8-27951. Brief technical summaries of Parts A and B are given below. A more complete technical summary is given in the following sections according to tasks.

Part A -- Alternate RNS Concepts Definition

Part A Task 1, Concept Synthesis and Evaluation, was initiated with a review of the proposed candidate RNS system concepts with the COR at the orientation meeting. An important aspect of these discussions was to define the range of space shuttle concepts which would be evaluated during the course of the study. Baseline second stages for the space shuttle booster have been selected as follows: (1) current hardware derivative -- S-IVB/J-2/8 Poseidon SRM, and (2) new stage -- common LH₂ tank. NERVA suborbit start has also been investigated as an alternate second stage concept. A variety of external launch configurations has been investigated and launch of two modules at a time with the modules mounted over the wings and parallel to the fuselage appears most favorable. Preliminary design optimization and logistics analyses have been initiated. The investigation of assisted mission modes has also been initiated and preliminary performance data are reported. The task will culminate with selection of the RNS concepts to be evaluated during the balance of the study. These activities will be initiated and reported during the next period.

Part B -- Interface Definition and Trade Studies

The initial engine/stage interface review produced a number of areas in which either a NERVA modification is recommended or further analysis will be required. These will be further discussed with MSFC, ANSC and SNSO at MSFC on December 16.

Four trade studies were active: Engine/Stage Astrionics System Optimization, Safety Criteria Analyses, Development Test Propulsion Module Feasibility and Program Support. The specific requirement across the engine/stage interface have been defined. This task is awaiting completion of an Aerojet evaluation of their requirements. The safety task is to be completed in December. Facility modifications to ETS-1 have been defined to handle the propulsion module. Engine and propulsion module ground and flight test objectives will be defined in the next month. Several interface meetings were conducted between ANSC and MDAC with action items delineated in the body of this monthly report.

Study Status

The study activities performed during the first reporting period were in accordance with the program schedule shown on the following figure. No deviations were taken from the major milestones. The engineering hours expended on the contract are indicated on the second chart, with the total hours being within budget.

The planned activities for the next two months of the study include initiation and continuation of trade studies and interface tasks in Part B, Task 2, as well as initiation of Tasks A2 and A3. Top level trade studies within these tasks will be reviewed by the COR at the Milestone 2 meeting, and first level definitions of these efforts will be transmitted at the technical working meetings accompanying the Milestone 3 briefing.

TASK PROGRESS REPORT

Part A

ALTERNATE RNS CONCEPTS DEFINITION

TASK 1 -- CONCEPT SYNTHESIS AND EVALUATION

The activities under Task 1 are largely reported in a data package which has been prepared for the Task 1 technical review at MSFC on December 2. Therefore, the ongoing activities will be summarized only briefly in the present report. The task was initiated with a review of the proposed candidate RNS system concepts with the COR at the orientation meeting. An important aspect of these discussions was to define the range of space shuttle concepts which would be used as a basis for the RNS assessment during the study. The high staging velocity -20B booster is being deemphasized accordingly and primary attention is being given to the parallel burn booster and the new LO_2 /RP/F-1 booster which are low staging velocity concepts.

Task 1.1 -- RNS Launch Assessment

This task is subdivided into evaluation of SSB/alternate second stage concepts, external launch concepts, and definition of initial deployment concepts.

Task 1.1.1 -- SSB/Alternate Second Stage Concepts

Baseline SSB second stages have been selected within the categories of current hardware derivative and new stage concepts on the basis of feasibility, cost effectiveness, and payload compatibility. Alternate second stages derived from S-IVB and S-II configurations have been evaluated for a range of space shuttle booster concepts. Reference performance as a function of staging velocity is shown in Figure 1. The associated reference cost and performance values are shown in Table 1. An S-IVB with a J-2 engine and 8 Poseidon solid rocket motors (SRM) is selected as a baseline for RNS design optimization for this class of launch vehicles in Task 1 of the RNS Phase IV study based on the following considerations: (1) adequate launch

PREPARED BY: _____
CHECKED BY: _____

DIVISION _____

MODEL: _____

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CURRENT HARDWARE - DERIVATIVE PERFORMANCE

Figure 1

Table 1 -- CURRENT-HARDWARE-DERIVATIVE SECOND STAGE PERFORMANCE AND COST

		Payload Delivered (k-lb)			Cost (\$10 ⁶)	
Alternate Second Stage	Booster	-20B (V _s = 11,000 fps)	Parallel Burn Heat Sink (V _s = 6,000 fps)	LOX/RP-1 (V _s = 7,900 fps)	Operational	DDT&E
Expendable:						
	S-IVB/J-2/8SRM	156	64	88	30.1	114
	S-II(-1 ring)/2SSE	229	112	146	48.5	162
Partially Reusable						
	S-IVB/SSE/8SRM	178	88	114	28.0	149
	S-II(-1 ring)/2SSE	229	112	146	35.0 (32.3)*	280 (183)*

*Alternate value -- NAR estimate

vehicle performance to deliver the RNS hardware to orbit for all candidate boosters considered, (2) superior (or at least equal) operating cost effectiveness compared to S-II derivative systems, (3) availability of fifteen J-2 engines (or at least 7 if 2 Mark I orbiters are produced), (4) minimum development cost compared to S-II derivative systems, and (5) minimum loading impact on the space shuttle booster. However, an S-II derivative stage is acceptable for the RNS program if the potentially larger payload capability of that stage were required to deliver other space program elements to orbit.

Two types of SSB/new stage concepts have been considered: (1) a discrete stage, and (2) a common LH₂ tank concept, consisting of reusable LO₂ tanks/space shuttle engine module that uses LH₂ from the RNS LH₂ payload. Both feature reusability and space shuttle equipment retrieval to offset higher development costs. The reference performance for these systems is shown in Figure 2. The reference values of performance and launch costs are shown in Table 2. The alternate new second stages are assumed to use the same engines as the corresponding orbiter. This can pose problems with respect to retrieval of multiple engine configurations. A common LH₂ tank concept was recommended as a baseline for RNS design optimization for this class of launch vehicles in Task 1. based on the following considerations: (1) comparable performance and launch costs, with the consideration that launch of small single module RNS configurations could favor use of a discrete stage to overcome the volume limited condition, (2) lower development cost, (3) minimal mission performance penalty from increased RNS design requirements (these essentially amount to providing additional feed system legs to accommodate higher space shuttle engine flow rates on the second stage), (4) reduced overall payload/second stage length. However, it is considered that a discrete stage is acceptable for the RNS if an optimum new stage is required for other space program elements.

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LAUNCH VEHICLE PERFORMANCE - NEW SECOND STAGES
FIGURE 2

Table 2. NEW SECOND STAGE SIZING, PERFORMANCE AND COST SUMMARY

Item	Booster	-20B		Parallel Burn, Heat Sink		LOX/RP-1	
	2nd Stage	Discrete	Common LH ₂	Discrete	Common LH ₂	Discrete	Common LH ₂
Engine(s)		1 SSE		2 SSE		4 J-2	
Thrust per Engine (K-16)		632		632		230	
LO ₂ Capacity (K-16)		480		692		602	
LH ₂ Consumption (K-16)		80		115		109	
Module Inert Weight* (K-16)		51,532	38,852	73,143	56,202	65,740	49,516
Payload to Orbit (K-16)		248,000	260,680	187,000	203,941	173,000	189,224
LH ₂ Residual ⁺ (K-16)		204,000	216,680	143,000	159,941	129,000	145,224
Operational Cost** (\$M)							
o Retrieve full CPM		15.4	12.6	17.3	13.9	17.4	14.1
o Jettison LO ₂ tank		17.2	14.4	19.7	16.3	19.4	16.1

*Inert weight of full discrete stage or CPM for common LH₂ tank.

**Based on 3 units over 20 missions.

⁺Single, 300K-lb capacity RNS propellant module (44,000-lb inert).

Trajectory simulations have been performed for alternate second stage launch of RNS propellant modules by a range of space shuttle boosters to establish booster controllability and determine the dynamic pressure and angle-of-attack for critical loading conditions. Launch configurations consisting of two 150 K-lb LH_2 modules at 22 and 33 ft. diameter were investigated together with configurations consisting of two 100 K-lb LH_2 modules also at 22 and 33 ft. diameter. Dynamic response simulations were performed for both -20B and parallel burn boosters to establish the response to head winds, tail winds, and side winds. In addition, still air simulations were performed for the LO_2/RP booster. Dynamic response simulations were computed utilizing drift minimum gains which result in zero drift in the case of a steady state wind. This constraint is in general incompatible with achieving minimal loads. However, it provides a common basis for comparing the various boosters and second stage payload combinations. It was found that the still air angle-of-attack fell in a narrow range based on each of the boosters and second stage/payload configurations evaluated. The shifts in angle-of-attack due to head wind, tail wind, or side wind is also found to fall into the narrow ranges. The consistency of the dynamic response simulation behavior provided a basis for interpolation and a more complete parametric analysis for the range of configurations. Parametric loading analyses have been initiated based on these data.

The suborbit start mode has been investigated as an alternate second stage concept. The approach is based on utilizing thrust augmentation with solid rocket motors as is done in the case of the S-IVB second stage concept. These serve the purposes of thrust augmentation, providing ballast and introducing a mode for separating the booster from the RNS prior to NERVA startup thereby minimizing the radiation impact on the booster. The mission profile utilizes NERVA idle mode operation during the African overfly to reduce the likelihood of failure during this period.

The injection profile envisioned includes injection by the NERVA at full thrust into an 80 n.mi. by 260 n.mi. phasing orbit followed by idle mode circularization at 260 n.mi. The performance of the NERVA in suborbit start has been demonstrated as approximately 100,000 lbs of LH_2 residual in the operational earth orbit when employed with the -20B shuttle booster. However, the feasibility of the concept when employed with a low staging velocity booster has yet to be demonstrated. The implications of these systems are still being investigated.

Task 1.1.2 -- External Launch Concepts

A variety of external launch configurations have been investigated including mounting a module on top of the cargo bay door or launching two modules at a time on the side of the orbiter over the wings and adjacent to the fuselage. In the case of the tip tank orbiter the modules can be located parallel to the tip tanks or above the tip tanks. Configurations with the propellant modules located after the tip tanks were also investigated. However, these are subject to constrained geometry to avoid protruding aft into the plume of the orbiter engines. Another configuration investigated for a belly tank orbiter consisted of mounting RNS modules external to the belly tank and parallel to it. Consideration was given to the controllability of the shuttle booster with externally mounted modules on the orbiter and to controllability of the orbiter during separation and during orbiter flight. The latter was the dominant consideration and most amenable to analyses, since mass data was available so that thrust vector deflections could be analyzed and control margins could be determined. Determination of booster controllability would require wind tunnel data which is not available at this time. Top mounting was considered severe for each of the configurations and would be excluded on the basis of orbiter controllability. In the case of the orbiters with a clean fuselage the mounting over the wings and parallel to the fuselage appears most favorable. Two modules would be launched at a time in this configuration.

In the case of the tip tank orbiter similar mounting parallel to the tip tanks is presently considered most favorable.

Task 1.1.3 -- Initial Deployment

The initial deployment concept selected for the external launch concept is launch of two modules per launch. Selection of the configuration for the alternate second stage launch concepts is deferred pending completion of loading analyses, which will be reported in the next period.

Task 1.2 -- Preliminary Design Optimization

This task is concerned with defining and optimizing design features to a sufficient level to establish significant differences and implications of the candidate RNS concepts -- 1, 2, 3, 4, and 8 propellant modules. Subsystem weights have been determined based on Phase III data and the utilizing of the no single failure criteria. Meteoroid thermal protection requirements and NERVA external shield requirements have also been determined. In addition the fiberglass intermodule struts have been defined as a function of RNS diameter. The structural weights will be completed during the next period and optimum RNS configurations will be derived based on these results.

Task 1.3 -- Logistics and Support

This task is concerned with evaluating logistics and support systems compatible with the launch concepts selected in Task 1.1. This effort has been initiated and the results will be reported during the next period. Sensitivity to program models ranging from 2 to 8 RNS flights per year over a ten year period is being investigated. In addition, sensitivity to space shuttle cost effectiveness is also being investigated.

Task 1.4 -- Mission Analysis

Mission concepts and their associated operational and support requirements have been defined. A four-burn lunar shuttle mission profile with 20,000 lb payload return to earth is being used as a baseline for mission analyses. Utilizing preliminary RNS design data the performance shown in Table 3 was obtained. Propellant utilization was determined corresponding to these mission profiles. In addition, investigation of assisted mission modes has been initiated. Preliminary performance data are shown in Table 4.

Task 1.5 -- Concept Evaluation and Selection

This task will select the RNS system concepts to be evaluated during the balance of the study using the mission performance and cost data generated for the optimum launch concepts, designs, and operations defined in preceding tasks. This task represents the culmination of the first phase of the study and will be initiated and reported during the next period.

Table 3

RNS CONCEPT PERFORMANCE COMPARISON
JETTISON VS. NON-JETTISON

Module Configuration No. @ Capacity (Klb)	PL* D	No. Modules Jettisoned After TLI	No. Modules Jettisoned In Lunar Orbit
1 @ 300	149.6	-0-	-0-
2 @ 150	163.3 189.0 193.5	-0- 1	-0- 1
3 @ 100	155.1 189.6 196.5	-0- 2	-0- 2
4 @ 75 (Alt. 2nd Stage)	150.1	-0-	-0-
4 @ 75 (External Launch)	162.5 199.6 206.6	-0- 2	-0- 3 1
8 @ 37.5	139.0 180.6 194.2 195.9	-0- 4 4 5	-0- 2 1

*PL_D = Payload delivered to lunar orbit; return payload, PL_R, = 20 Klb.

Table 4
ASSISTED MISSION MODE PERFORMANCE COMPARISON

Mode	Optimum Tug Capacity (K-lb)	LH ₂ Required for Trans- fer (K-lb)	PL [*] D (K-lb)	Trans- porta- tion Cost (K-lb)
Baseline; Non-assisted (3 @ 100K)	--	--	155.1	193.5
Jettison 2 in lunar orbit (3 @ 100K)	--	--	189.6	158.4
Tug-assist via propellant transfer				
No jettison	20	24.5	225	155.3
Jettison	20	20.7	256	135
Propellant transfer in lunar orbit	--	74	309.8	143
Tug-assist via retrieval				
No jettison	50	--	212	167.4
Jettison	40	--	240	143.7
Aerobraking (8 @ 37.5, jettison 6 modules	--	(see Figure 4)		

* PL_D = payload delivered to lunar orbit; Return payload = 20 K-lb

TASK B-1

REFERENCE INTERFACE DEFINITION

The 400E version of NERVA has been reviewed to establish interface requirements. Additionally, coordination meetings with Aerojet concerning the physical and functional interface with NERVA have been held and are summarized under Task B-2.

A primary objective of this task is to seek an interface between NERVA and the stage which would be applicable to all of the flight configurations for the RNS identified in both Phases III and IV. Accordingly, the interface review identified those characteristics which would be common to all concepts, but also noted those which could be improved with the propulsion module interface applicable to all Phase III and Phase IV MDAC concepts.

This initial interface review produced a number of areas in which either a NERVA modification is recommended or further analysis will be required. These are:

- o Launch vehicle -- space shuttle
- o Length and weight -- reduce
- o Maintenance level -- full module (MDAC concepts only)
- o Structural interface -- at gimbal bearing
- o Electronics location -- forward of run tank (MDAC concepts only)
- o Electrical connection -- external to thrust structure
- o Malfunction mode -- consider reduction to 60% of rated flow
- o Main feed lines -- incorporate thermal analysis
- o Auxiliary propellant supply to engine -- integrate equipment as much as possible and perform further analyses
  - o Engine chilldown
  - o Startup and shutdown
  - o Pulsed cooldown

During the next month these interface recommendations will be reviewed during the first technical review at MSFC on December 2 and further discussed at an interface meeting planned at MSFC for December 16. A first version of the interface working document will be prepared. Following these reviews the interface features selected will be incorporated into an interface control drawing.

TASK B2

RNS TRADE STUDIES

Four trade studies were active during the first reporting period, namely, I-002 - Engine/Stage Astrionics System Optimization, S-001 - Safety Criteria Analyses, P-002 - Development Test Propulsion Module Feasibility, and P-005 - Program Support. Summary Status Statements for each of these activities are presented in the following paragraphs.

TS-I-002-Engine/Stage Astrionics System Optimization

This trade study is comprised of three discrete efforts, namely, engine/stage processor integration, engine/stage communication and data bus trade study, and electrical distribution. All of these efforts have been active, with the primary emphasis on the engine/stage processor integration trade study. The processing and storage requirements for the NERVA and stage subsystems have been established based on the NERVA/Aerojet "Controls and Simulation Computer Study to support engine and reactor testing - 23 December 1970." Although these were originally established for the ground test problem, the requirements were reviewed for applicability to the airborne problem in conjunction with Aerojet. A subsequent Aerojet refinement is in process. The stage requirements were derived from the MDAC Phase III RNS Study. The requirements have been characterized by mission phase and requirement for real time processing. Engine and stage requirements are combined to eliminate areas of overlap, particularly in data processing and malfunction detection approaches. For each candidate class of processing (e.g., TMR, Standby Module Sparing, Multiprocessor and Standby Computer), representative subcandidates have been identified consistent with ongoing development activities, and block diagrams have been prepared for some of the candidates. Similar block diagrams will be prepared for each of the subcandidates as part of the future effort on this trade study. A survey of the capability of state-of-the-art processor development has been completed. Generic module reliability data are being gathered, and the relative cost and development risk will be included as evaluation criteria. The remaining activities on the engine/stage processor integration trade study will consist of completing selection of the candidates within each class, evaluation of the selected candidates and recommendation of the most attractive system architecture. The selected configuration will

then be detailed and the consistency with ongoing development activities will be considered.

The engine/stage communication and data bus trade study activities included estimation of the engine command rates. Aerojet places this requirement at 10,000 bits per second. Data bus requirements will be based upon a summation of the Aerojet estimates and the Phase III RNS Stage estimates. The balance of this trade study will be conducted after the engine/stage processor architecture has been selected.

The MDAC preferred harnesses for stage electrical distribution have been presented to Aerojet, and they are presently considering the implications of these approaches on their design. The specific requirements across the engine/stage interface have been defined, with the remaining trade study tasks to be conducted following the completion of the Aerojet evaluation.

TS-S-001-Safety Criteria Analyses

This trade study is currently investigating the benefits versus the cost of several safety design criteria. The analyses to date have included an evaluation of the status of a representative partially redundant RNS design relative to the no single failure criteria and the fail operational-fail safe criteria. In addition, a simplified multiple failure analysis was conducted to determine the reliability value for a multiple failure safety criteria. These data were used to determine the modifications required to achieve a no single failure and a fail operational-fail safe criteria status, and the installed weight increment was estimated for each component involved in the modification. From these data, a weight penalty was obtained for each of the candidate design criteria on a component by component basis. Both class 1 hybrid and class 3 RNS concepts were treated.

Reliability increases have been calculated as a function of the additional components required to meet each of the safety criteria, and component failure data were also factored in to determine maintenance requirements and module failure probabilities. Various sensitivity data, including estimates of the cost per trip, cost of a discarded module, cost of external rescue capability, cost of an aborted mission, program cost per lb of added module weight, etc. are being developed, including considerations such as the effects of varying external

leakage. These data will form the basis for making recommendations on the reliability philosophy to use during the remainder of the study, and will also be used as inputs to maintainability trade study efforts. This trade study effort will be finished during December with the completion of the sensitivity data generation and formulation of recommendations.

TS-P-002-Development Test Propulsion Module Feasibility

The activity on the propulsion module trade study included analysis of the feasibility of propulsion module installation and testing in ETS-1 at NRDS, preliminary identification of propulsion module ground test objectives at NRDS, and identification of the NRDS facility modifications required to accommodate the propulsion module configuration. The effort concentrated on the possible utilization of ETS-1 for propulsion module testing. An analysis of the facility capabilities, in conjunction with Aerojet, established the feasibility of installing and testing the propulsion module as it is currently defined, with the only questions being the finalization of the specific modifications and the associated cost estimates. Additional work on the feasibility question will be performed only as required to resolve specific points of concern that may arise during a more detailed definition of the program as the trade study progresses.

Initial discussions have taken place between ANSC and MDAC personnel on the identification of propulsion module ground test objectives at NRDS, with the ANSC verification test plan and MDAC Phase III RNS studies serving as the basis for this discussion. It is currently anticipated that these joint test program objectives will be defined for use during the next month. The gross NRDS facility modification requirements have been identified. The current ANSC estimate for these modifications is approximately \$3.5 million over basic facility upgrading, whereas the MDAC estimate is less than \$1 million. Selected specific modifications are discussed below.

It has been determined that the propulsion module could fit into ETS-1 by removing the existing top shield and test stand adapter and moving the existing top shield support beams up to the bottom of the LH₂ run tank. However, the existing LH₂ run tank could be raised by about 6 feet for a reasonable cost (less than \$200,000) to allow more flexibility in operations. Other modifications include the incorporation of the top shield into the support beam and the addition of a test

compartment closure extending down from the top shield to the existing movable side shields. Additional height on the existing side shields is unnecessary.

ANSC currently favors having the propulsion module run tank as part of the test stand facility in order to provide greater flexibility for performing maintenance on the engine. MDAC opposes this position on the grounds that providing this capability early in the program means it will most likely be retained for the entire program, with the net result that the proper engine/stage interface will not be developed to reflect the flight configuration during the ground test program. MDAC prefers to move the entire propulsion module in and out of the test stand for performing engine maintenance, since that would represent minimum disturbance to the engine/stage interface. It was suggested to ANSC that they examine the feasibility of doing maintenance on engine components with the run tank attached. If that configuration doesn't pose a problem, there is no strong motivation for having a remote assembly/disassembly capability between the engine and run tank.

There are several solutions to the problem of removing the complete propulsion module from the facility and transporting it to the E-MAD building, considering that the door to the E-MAD is not high enough to permit a vertical entry. These include: (1) using a modified Engine Installation Vehicle (EIV) to transport the module to the E-MAD door and then using a crane to install the module on a horizontal transporter, (2) a scheme whereby the transition from vertical to horizontal occurs at ETS-1, and (3) a method whereby a Simulated Engine Test Stand (SETS) is used to hold the module while a "cut" is made to separate the NERVA and the run tank.

The next month's activities will include finishing the identification of preliminary propulsion module requirements for ground test and flight test for each candidate program and option combination, reflecting both engine and propulsion module test objectives. The engine test objectives will be Aerojet input data, and the joint test program will be defined with Aerojet participation.

TS-P-004-Program Support

The activities in the area of program support during the first reporting period consisted of five technical meetings with Aerojet. They are identified and

briefly described below. Details of the meetings have already been treated in appropriate Part B tasks and/or trade studies.

MDAC/ANSC Electrical Interface Meeting -- The functional aspects of the electrical interface between the engine and stage were discussed by Gil Abrams in Sacramento on September 23rd with special emphasis on design criteria, astrionic sensitivity to possible changes in engine configuration, data management, instrumentation and interfaces (both internal and external). The engine processing and storage requirements were obtained from Aerojet allowing for initiation of the astrionics optimization trade study (TS-I-002) and the physical interface requirements for the 400E engine configuration were updated.

Trip to NRDS -- A trip was made to the Nuclear Rocket Development Station by Cliff Boehmer on September 29 to discuss the proposed modification to ETS-1 for propulsion module testing with Aerojet personnel. The specific items discussed were documented in memorandum A3-830-BSEO-M-24, and the significant results of the trip are treated under the discussion of the propulsion module trade study (TS-P-002).

MDAC/ANSC Interface Meeting -- An informal meeting between MDAC and Aerojet personnel was held in Huntington Beach on October 6th to discuss a number of engine/stage interface items, as indicated below.

1. Review of ANSC work on engine with propulsion module design concept.
2. Review of MDAC work on propulsion module.
3. Specific areas where ANSC would like comments.
  - Structural definition (spring rates) of run tank and tandem tank for use in engine dynamic analyses.
  - Requirement for engine thrust angular alignment at stage interface.
  - Engine electronics location.
  - Remote assembly/disassembly joint between engine and run tank.
  - Gimbal plane relocation to joint between tandem tank and propulsion module to allow closer integration of engine and run tank.

- Minimum natural frequency requirement for engine as supported by run tank.
  - Engine gimbal control system maximum frequency requirement.
4. Part B discussion.
  5. ETS-1 modifications for accommodating propulsion module testing.

Detailed comments pertinent to each of the items, as well as action items resulting from the meeting, have been documented in memorandum A3-830-BSEO-M-27.

Trip to ANSC on Propulsion Interface -- Yale Oster spent October 20th and 21st at ANSC covering NERVA/Stage propulsion interface.

References: Record of Discussion, dated October 12, 1971.

Trip Memorandum, dated November 1, 1971.

Subjects Discussed:

- Physical Interfaces
  1. Structural Attachment
  2. Fluid and Electrical Connect Panel
  3. Pump Inlet Duct Loads and Deflection Requirements
- NERVA Valving
  1. Motor Driver Stage Potential Applicability
  2. Valve Main Gate Seals
  3. Valve Lubrication Philosophy
- Functional Interface
  1. Chillover Conditioning

Semi-Annual NERVA Program Status Review -- Yale Oster attended the Semi-Annual NERVA Program Status Review Meeting at ANSC on November 9 and 10, during which a Program Summary, Engineering Summary, Quality Assurance, and Test Facilities/Operations Summary were presented. Specific subjects treated were: engine system/ design analysis, controls, reliability/safety, structural/thermal/nuclear analysis, materials, nozzle/extension/pressure vessel, turbopump valves/ actuators, and test operations. Detailed comments are being documented.