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D. Holzman

STEAM GENERATOR EQUIPMENT FOR E/STS 2-3 MASTER

PROPOSAL TO SPACE NUCLEAR PROPULSION OFFICE
OAKLAND, CALIF.

PROPOSAL SRT671754

AUGUST 1967

AEROJET-GENERAL CORPORATION

SACRAMENTO PLANT • SACRAMENTO, CALIFORNIA

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MASTER

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FOR
E/STS 2-3**

**A Proposal to
Space Nuclear Propulsion Office
Oakland, California**

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I. INTRODUCTION AND SUMMARY

This unsolicited proposal presents Aerojet-General's recommendations for a chemical steam generation system for the NERVA altitude test facility E/STS 2-3 at Jackass Flats, Nevada. A unique system, designed to use available Titan I hardware, has been conceived which will provide the required quantities of steam in a reliable, safe, and economical manner.

Aerojet-General is fully aware of the importance of this system in the overall NERVA development program. Aerojet management is keenly interested in supplying this generator and has advanced considerable company effort in support of preliminary design and investigations over the past eight months, which have resulted in a proposal to develop, build, and deliver the steam generator system to a schedule which will assure timely intergration into the construction of the test facility. Furthermore, the supporting facility requirements have been reviewed in this proposal to determine optimum design factors for E/STS 2-3.

The steam generator Aerojet proposes to supply consists of a vertical vessel with integrally mounted steam generator modules. Reactant and water pumps and associated instrumentation and control components, including a control console, will also be supplied. The generator modules will incorporate fully developed and proven Titan I injectors to assure maximum reliability, safety, and economy. Literally millions of dollars of engineering, development, and equipment are made available to this program by utilizing this Titan I hardware. Furthermore, the phaseout of the M-1 LH₂/LO₂ engine makes available to this contract at Aerojet considerable NASA-owned fabrication and test facilities.

I, Introduction and Summary (cont.)

A review of the total E/STS 2-3 facility schedule indicates that the choice of, and definitive information on, the steam generator is a pacing item. Early definition of this steam generating system would provide the timely information to allow the facility procurement to proceed on schedule and, for this reason, the development of this critical system should be started as soon as possible. Aerojet's current preliminary efforts are continuing, but a steam generator contract should be awarded by the end of 1967 to protect the 1971 completion date for E/STS 2-3.

Aerojet's considerable experience in rocket testing includes the design, fabrication, installation, and operation of two large altitude firing facilities that use steam ejectors. Both of these systems have boiler and accumulator systems to supply the steam. This approach was investigated for the proposed contract, but was found to be far too expensive compared to a chemical steam generator. Alternative designs of chemical steam generators have been evaluated and the proposed system is felt to be not only the least costly, but also provides the reliability, flexibility, and growth potential necessary to meet NERVA Program requirements.

Conduct of the program will utilize those management concepts which have contributed in such large measure to the success of the NERVA and Titan Programs, among others. A direct line of responsibility to top management and the use of both projectized and functional groups as required will assure the attainment of program objectives. A technical review board made up of outstanding individuals will provide for review in depth of the disciplines critical to the successful and timely completion of this program.

The unique combination of capable and experienced personnel, familiarity and experience in the operation of the NTO facilities, extensive preliminary design studies, and the utilization of fully developed and proven components provides a firm base upon which Aerojet-General offers to furnish the steam generator system equipment.

II. MANAGEMENT

A. INTRODUCTION

The proposed steam generation system program will be organized on a project basis. Aerojet-General's experience has demonstrated that streamlined project management with a central management, technical, and administration team results in effective control over the technical, financial, and schedule requirements of a program. It also facilitates communication with the customer and the implementation of new technical, financial, or administrative requirements. In addition, the project management technique permits the use of specialized staff personnel from diverse technical and scientific disciplines who may be required and assures that this highly specialized talent is utilized practically and economically.

A basic precept of the Aerojet-General management philosophy is that the assignment of total program responsibility is accompanied by a full delegation of program authority. Not only does this strengthen the project management concept, but it also assures a positive and prompt response to customer direction. The program controls and reporting system, described in Section II,D, were evolved as a result of experience with other programs similar to the proposed steam generator system program. These existing Aerojet systems for monitoring and reporting on program status have proven to be effective project management tools.

The unequivocal delegation of authority and the uncomplicated, direct lines of management control assure firm program control, quick response to changing requirements, and the immediate interest of corporate management, as well as their continuing support. The selective staffing for the steam generation system program and its placement within the Plant organization (see Figure 1) is evidence that Aerojet-General recognizes the significance

Figure 1. Steam Generator Project Organization

II, A, Introduction (cont.)

of the E/STS 2-3 Project. Further, members of the proposed program team have participated in the progressive studies of steam generation systems that have resulted in the preparation of this proposal.

B. PROGRAM MANAGEMENT

Recognizing the importance of the proposed program as part of the development of nuclear rocket propulsion, Aerojet-General has selected Mr. T. D. Dritz of Plant Test Operations as the manager of the Steam Generator System Program. Mr. Dritz has demonstrated outstanding management and technical ability over the years and has established rapport and familiarity with the SNPO/NERVA Organization. He will be the management focal point to assure a continuous and effective liaison with the customer regarding all phases of the engineering, fiscal, and scheduling requirements. He will also serve in this same capacity in keeping Aerojet-General management advised of the program and requirements.

Mr. Dritz will be assigned an organization of trained and experienced people who will have the full responsibility for the steam generator program. This organization will be composed of five principal sections: Steam Generator Module Engineering, Steam Generator Module Manufacturing, Systems Engineering, Assembly and Test, and Administration.

Steam Generator Module Engineering: This organization will be responsible for the development of the chamber, injector, igniter, and generator controls. Technical support will be obtained from experienced personnel who were involved in the development of the Titan hardware.

II, B, Program Management (cont.)

Steam Generator Module Manufacturing: This organization will be responsible for the fabrication, quality control, and procurement of the modular hardware.

Systems Engineering: This group will have the responsibility of technical management and direction of the engineering of the system configuration and controls and providing a close coordination with the E/STS 2-3 facility so that correct interfacing is obtained.

Assembly and Test: To perform the final assembly and conduct the development and acceptance testing will be the responsibility of this group.

Administration: The contract management of the program will be the responsibility of Administration, as well as serving as the central point for all formal contractual communications with SNPO. Also included in the Administration responsibilities will be cost estimating, cost control, material requisitioning, logistics, scheduling, and reports.

The personnel assigned to these key positions will have a depth of experience in the original Titan development.

This organization will be supported by a Technical Review Committee. The Technical Review Committee will periodically review and give technical guidance to the program manager in their areas of specialization.

Upon receipt of the award, Aerojet-General will implement this program under Plant Test Operations, Sacramento, California, which is organized, staffed and equipped to accomplish this specific type of work, both efficiently and economically. All of the facilities required to conduct the program are available without interference with existing programs. In-house fabrication will be centered in the Manufacturing Division shop which has demonstrated

II, B, Program Management (cont.)

capability for efficiently producing parts of high quality. Testing and buildup will be accomplished in Test Zone H where ample capacity for this program will be available.

C. RELATED EXPERIENCE

1. Titan I

Aerojet-General has a vast inventory of data and experience on the Titan I engine upon which it can draw during the performance of the proposed task. During a six and one-half year period, Aerojet conducted 20,940 test firings with YLR-AJ-1 and YLR-AJ-3 hardware.

Six-hundred-million pounds of liquid oxygen and RP-1 were burned during this test program. Approximately 570 tests were conducted using the YLR91-AJ-3 injector configuration which will be used on the steam generator. The reliability record on the last 260 tests was 99.5%.

The extensive experience that was gained during the Titan I design and development program will be invaluable to the modification program for steam generator application. The allowable limits of propellant flows and chamber pressures are well understood, and the stability history of the developed Titan I thrust chamber assembly was outstanding.

Because of Aerojet's extensive background with the Titan I thrust chamber assembly and with cryogenic propellants, the number of tests required to demonstrate the steam generator system will be minimized.

II, C, Related Experience (cont.)

2. Altitude Testing Facilities

Over the years, Aerojet-General has gained a vast amount of experience in design and installation of altitude steam ejector facilities. Present operations at the Sacramento Plant Test Area include two altitude facilities which were designed and installed under the direction of Aerojet-General personnel.

The J-Zone simulated altitude complex (see Figure 2) was conceived and designed under the direct supervision of Mr. T. D. Dritz. This complex, the largest privately owned facility of its kind, consists of six, two-stage, non-condensing steam ejectors manifolded in parallel, and a three-stage condensing steam system. The steam is supplied from five 33,000-gal steam accumulators with a total combined storage capacity of 45,000 lb of steam and a maximum delivery rate of 1800 lb/sec. The accumulators are charged by means of an 8,000 lb/hr steam boiler. In designing this system, chemical steam generator systems were investigated. These investigations have been continued in this E/STS 2-3 steam generator study.

This technology was utilized in development of Minuteman steam augmented altitude facilities subsequently installed in Test Stand P-1 (see Figure 3).

3. Nuclear Engine

The coordination between the steam generator management and NERVA management on this task is very important, and since the NERVA engine is being developed at Aerojet, Sacramento, liaison between the two programs will be simplified. Advance knowledge of impending NERVA engine design changes will aid in incorporating revisions in the steam generator equipment.

Figure 2. J-Zone Simulated Altitude Complex

Figure 3. Minuteman Altitude Facilities

II, C, Related Experience (cont.)

Aerojet's experience with the current steam generator facility on ETS-1 will also be invaluable. Knowledge of the problems that exist with the current facility and their underlying causes will aid in the design of the new facility equipment. During all phases of the program, Aerojet's prime goal will be to make the steam generator equipment 100% reliable, recognizing that it is a critical component in the NERVA engine test facility.

4. Combustion Stability

The most completely developed analytical model of high-frequency combustion stability was developed from the Sensitive Time Lag Theory which was originated at Princeton University.

Dr. Fredrick Reardon of Aerojet participated in the development of the model and applied it to numerous rocket engine programs. The application of this model resulted in the successful conclusion of the Gemini Stability Improvement Program and strong contributions to both the Apollo SPS and the Titan IIIM Engine Development Program. Aerojet is currently under contract to NASA to study the combustion stability problems associated with cryogenic propellants.

It is this background of unprecedented experience and analytical skill that gives assurance that the steam generator modules will perform with no stability problems over the required operating range.

II, Management (cont.)

D. PROGRAM PLAN

1. Program Scope

The program proposed by Aerojet-General is carefully organized to ensure the successful completion of an integrated steam generator system at E/STS 2-3. A detailed analysis of the work to be performed (see Figure 4) leaves every confidence that the system can be completed and successfully tested in the period of time allowed. The steam generator equipment will be designed and built to provide uninterrupted performance under any and all conditions that might be encountered at E/STS 2-3.

Aerojet, in furnishing a steam generating system of minimum complexity, will satisfy the essential criteria of reliability and safety. At the same time, maximum flexibility will be provided to meet the growth requirements of the NERVA engine program.

Aerojet-General recognizes that the E/STS 2-3 task must be accomplished within existing SNPO funding schedule and limitations. It is also recognized that to accomplish this will require a judicious and maximum effort.

Figure 4. E/STS 2-3 Steam Generator System Schedule

Figure 4. E/STS 2-3 Steam Generator System Schedule (cont.)

Figure 4. E/STS 2-3 Steam Generator System Schedule (cont.)

II, D, Program Plan (cont.)

Specific items of work included in this proposal are as follows:

(a) Furnish fully developed steam generator assembly with one spare module.

(b) Furnish the reactant and water pumping equipment complete with drivers and controls.

(c) Furnish a remote control console completely equipped to operate and monitor the steam generator assembly and pumping equipment.

(d) Furnish necessary engineering, management, and liaison to perform above tasks and coordinate activities with SNPO and their subcontractors.

2. Schedule and Manpower

As part of the preliminary engineering study, conducted to date by Aerojet-General, a comprehensive planning and logistic program plan has been developed. Figure 4 defines schedule requirements for each task of the program and is considered to be an acceptable planning document to meet SNPO objectives. Current activities at Aerojet are based upon meeting these schedule milestones. The manpower requirement to accomplish the program has also been estimated and is shown in Figure 5.

Figure 5. Manpower Requirement

II, D, Program Plan (cont.)

3. List of Required Equipment

A summary of typical equipment proposed to be furnished as part of the steam generator system for the Nevada test site is shown in Table 1.

4. Cost Control

The system of cost control and cost reporting in use at Aerojet-General is designed to provide timely and comprehensive budgetary status information to the program, plant, and corporate management. Actual cost control is exercised by the program manager and his staff by work authorizations defining tasks and associated budgets. The functional operations are responsible for performance as defined in the work authorizing documents.

5. NTO Coordination

The steam generator equipment, after acceptance testing at the point of manufacture, will be delivered to E/STS 2-3 at the Nevada Test Facilities. The delivery of the steam generator equipment will be coordinated to coincide with the various operations so as to allow the accomplishment of the total construction of E/STS 2-3 within the required time. Technical direction will be furnished by Aerojet during installation and checkout at the Nevada facilities.

TABLE 1

STEAM GENERATOR COMPONENTS

<u>Component</u>	<u>Quantity</u>	<u>AGC P/N</u>	<u>Candidate Vendor and Model No.</u>	<u>Remarks</u>
Combustor injector	5	1-230247		SNPO-owned
Igniter	5	242999		SNPO-owned
Igniter valve assy	5	1-333991		SNPO-owned
Main oxidizer bypass valve	1		1.Annin 1560 (Similar) 2.Hammel-Dahl 3000	1.With extended stem 2.With extended stem
Main fuel bypass valve	1		1.Annin 1560 (Similar) 2.Hammel-Dahl 3000 3.Continental Bull. 76 4.Worthington 32000	
Diluent bypass valve	1		1.Continental Bull. 76 2.Worthington 32000	
Igniter oxid bypass valve	1		1.Annin 1560 (Similar) 2.Hammel-Dahl 3000	1.With extended stem 2.With extended stem
Igniter fuel bypass valve	1		1.Annin 1560 (Similar) 2.Hammel-Dahl 3000	
Combustor oxidizer valve	5	1-238360		SNPO-owned
Combustor fuel valve	5	1-234500		SNPO-owned
Combustor diluent valve	4		Annin 21860 (Similar)	Y-Globe
Combustor oxid bleed valve	1		Annin 1560	With extended stem
Igniter oxid bleed valve	1		Annin 1560	With extended stem
Combustor oxid purge valve	1		Mason-Neilan 20000	With 2700 controller
Combustor fuel purge valve	1		Mason-Neilan 20000	With 2700 controller
Igniter oxid purge valve	1		Mason-Neilan 20000	With 2700 controller
Combustor oxid isolation valve	4		Annin 21860 (Similar)	Y-Globe with ext. stem
Combustor fuel isolation valve	4		Annin 21860 (Similar)	Y-Globe
Oxidizer pumps (combustor)	3		1.Worthington 10HN27 2.Byron-Jackson 6X10X19 DSM-DB	1.Each pump consists of two identical separate cases 2.Single case
Fuel pumps (combustor)	3		1.Worthington 15M185X10 2.Allis-Chalmers 8X6MH-3 3.Byron-Jackson 6X8X11B 7STG DVMX	3. 7 stage
Diluent pumps	3		1.Worthington 12LN32 2.Byron-Jackson 14X14X20 DVS 3.Allis Chalmers 16X12 SJP 4.Worthington 16LN35	SNPO-owned
Igniter oxidizer pumps	2		1.Worthington 1-1/2HN 122 2.Byron-Jackson 50VLT	1.Each pump consists of two identical separate cases 2.16-stage vertical
Igniter fuel pumps	2		1.Worthington 2WTF89 2.Byron-Jackson 150VLT	2.17-stage vertical
Igniter oxid engine	2		Caterpillar D-330	
Igniter fuel engine	2		Caterpillar D-333	
Combustor oxidizer engine	3		Caterpillar D-399	
Combustor fuel engine	3		Caterpillar D-398	
Combustor diluent engine	3		ALCO 251	

II, D, Program Plan (cont.)

6. Facilities

a. Government Facilities

In this program Aerojet does not envision the acquisition of any new facilities for the development and manufacture of the steam generator equipment. It does contemplate, however, the no-charge use of existing Government facilities. The following is a listing of the Government-owned facilities and special test equipment required on a rent-free, non-interference basis to perform the steam generator program:

Data Processing Center, Building 3308

Data Processing Maintenance and Repair
Equipment, Building 3308

Instrumentation Shop, Building 3308

Oscillograph Processing Shop, Building 3306

Transducer Laboratory, Building 3308

Valve Shop, Building 3409

Dynamic Analog Data Processing Center
(High-Frequency), Building 3308

Hydraulics Laboratory, Building 2009

Test Stand H-8 and Supporting Equipment

Boring Equipment

Milling Equipment

Grinding Equipment

Sheet Metal Equipment

Welding Equipment

Lathe

Heat-Treat Facilities

II, D, Program Plan (cont.)

b. Corporate Investment in Facilities

The Aerojet-General Corporation has invested in excess of 76-million dollars in facilities at the Sacramento Plant. These facilities support all programs--NASA, Air Force, Navy, Army--and would contribute to the proposed program. The administrative, engineering, manufacturing, and test personnel engaged in this project will benefit from the all-encompassing general-type of facilities.

Administrative and engineering personnel are located in the main Administrative Area building complex. Office space of approximately 650,000 sq ft is available for engineers engaged in the development of rocket propulsion systems and for personnel manning the administrative support functions. The general type facilities also include:

- (1) Roads and railroads throughout the Plant.
- (2) Water, electrical, telephone, and sewage disposal systems.
- (3) Facilities for the publication of technical reports, proposals, etc.
- (4) Cafeterias.
- (5) Complete medical facilities, including hospital, X-ray, ambulances, and trained personnel.
- (6) Fire and Plant security protection.
- (7) Plant engineering and maintenance personnel.

An additional capital investment will be required to support the added electrical power requirements for the water pump installation at Test Stand H-8.

II, Management (cont.)

E. RESUMES

D. M. Tenenbaum, Manager, Plant Test Operations

Mr. Tenenbaum is a graduate mechanical engineer (University of California at Berkeley), and a registered professional engineer in the State of California.

Mr. Tenenbaum is Manager of Plant Test Operations providing research, production, and development testing of all Aerojet-General rocket engines and components. His responsibilities include the management of design and procurement of adequate instrumentation and instrumentation operations, plus reduction of all data derived from test programs.

Mr. Tenenbaum commenced employment with Aerojet in 1948, and has served in various management positions which included Sacramento Plant Works Manager and M-1 Test Manager. Under his management, the NERVA and Titan I testing programs were successfully pursued, and the numerous Sacramento Plant altitude simulation testing facilities were designed and activated.

T. D. Dritz, Program Manager

Mr. Dritz is a graduate mechanical engineer (New York University) and holds professional engineering licenses in New York, California, and many other states.

Mr. Dritz has been a practicing engineer for the past 24 years and has been with the Aerojet-General Corporation since January 1961, where he has been Manager of Test Planning Division, and Manager, Planning and Controls, Plant Test Operations. His responsibilities include overall facility planning

II, E, Resumes (cont.)

and utilization, test equipment design and procurement, and fiscal and program controls to support rocket engine test programs. Mr. Dritz directed the design of a company-owned altitude facility, which is the largest of its kind in private ownership. He also introduced unique high pressure test equipment for advanced rocket engines. Employed in the consulting engineering field prior to employment at Aerojet, Mr. Dritz served as project manager and project engineer on various facilities which included Nuclear Test, Steam Power, and Jet Propulsion Test Installations.

G. H. Osborn, Technical Review Committee

Mr. Osborn is a graduate mechanical engineer (California Institute of Technology) and a registered professional engineer in the State of California.

Mr. Osborn is presently acting Manager, Engineering Division, Liquid Rocket Operations. This division is responsible for the engineering effort required to support Titan and all other liquid rocket engine programs at the Sacramento Plant.

For ten years previous to his present assignment, Mr. Osborn was responsible, as assistant manager and manager, for the development of all thrust chamber components required for liquid rocket engines, including Titan I. His experience with the development of rocket combustion devices at Aerojet dates back to 1948 in Azusa, where he developed the first coaxial injector used in the industry.

In addition to his experience at Aerojet, Mr. Osborn has design, development, and industrial engineering experience with major aircraft industrial organizations.

II, E, Resumes (cont.)

J. J. Beereboom, Technical Review Committee

Mr. Beereboom is a graduate chemical engineer (University of Detroit) with three years of advance graduate study at U.C.L.A.

Mr. Beereboom, Manager of Nuclear Rocket Operations System Division, is responsible for systems analysis, test engineering, facility engineering, and controls and support systems for NERVA. Employed at Aerojet since 1955, he has held many responsible positions within its nuclear and liquid propulsion activities. Previous management assignments include Manager, Phoebus Division; Assistant Manager, Component Development Division-REON; Assistant Manager, Engine Department-REON; and program manager for the Kiwi-B Nozzle.

Mr. Beereboom has, in the past, participated as a staff engineer in the design and development of the Aerobee XLR-73 and BOMARC rocket engines.

M. D. Knott, Administration

Mr. Knott is a graduate mechanical engineer (Wyoming University).

His six years of experience with Aerojet-General has been primarily associated with the supervision of preliminary planning, proposal preparation, contract negotiations and cost estimating and cost analysis and control of various programs which include Titan, Apollo, Transtage, M-1, and NERVA.

Mr. Knott has been active in the studies and evaluations of many rocket test and altitude simulation facilities and has been actively participating in the current studies of a steam generation system for E/STS 2-3.

II, E, Resumes (cont.)

Prior to employment at Aerojet, Mr. Knott was a test engineer responsible for testing operations on Ramjet engines.

R. W. Wensch, Assembly and Test

Mr. Wensch is a graduate engineer (Illinois Wesleyan University).

Currently a Test Operations supervisor, he has been primarily associated with the supervision of installation and testing of Titan I and II engines and components. Since his employment at Aerojet in September 1960, he has participated in all major development and acceptance testing of Titan I engines and components, and also was responsible for altitude testing activities on various programs within Plant Test Operations.

Prior to employment at Aerojet, Mr. Wensch was employed as a manufacturing engineer and as a test operations engineer.

L. A. Joy, System Engineering

Mr. Joy is a graduate mechanical engineer (University of Nevada), and a registered professional engineer in the State of California.

During his 11 years with Aerojet, he has been test engineering supervisor on the Titan Programs and a technical supervisor on the NERVA Engine Program.

Mr. Joy conducted the first experimental test on the Titan I second-stage engine. He was supervisor for the Titan I second-stage engine test program responsible for experimental and acceptance testing. His NERVA responsibilities included test stand systems analysis and technical supervision of all NERVA engine component testing activities.

II, E, Resumes (cont.)

H. M. Hudson, System Configuration

Mr. Hudson is a graduate mechanical engineer (University of California at Berkeley).

During his 13 years with Aerojet-General, Mr. Hudson has been primarily associated with system design and analysis of rocket test facilities. Mr. Hudson served as project engineer on the design of the Aerojet altitude steam facility, and performed all of the initial concept studies and evaluations.

Prior to his present assignment, he was a test engineer responsible for testing of Titan I components.

For the past eight months, he has been conducting engineering studies on the E/STS 2-3 steam generator system.

F. C. Thompson, Generator Module Engineering

Mr. Thompson is a graduate aeronautical engineer (Northrop Institute of Technology).

Currently a supervisor of the Titan Programs Thrust Chamber section, he has been employed by Aerojet-General since 1955. One of Mr. Thompson's first assignments was as a project engineer, responsible for design and development of the Titan I thrust chamber assembly. He has also been responsible for design and development on the Titan II engine, the Gemini Stability Improvement Program, and the Titan IIA Program.

Prior to joining Aerojet, Mr. Thompson was employed as a design engineer at North American Aviation Corporation and Whirlajet Corporation.

II, E, Resumes (cont.)

R. G. Ackerman, Chamber Development

Mr. Ackerman is a graduate mathematician (California State Polytechnic College) with extensive courses in engineering and physics.

Mr. Ackerman has been with Aerojet-General since 1960. During this time as a thrust chamber engineer, he has been engaged in all phases of design and development of Titan thrust chamber assemblies, heat exchangers, and gas generators.

He has been engaged in preliminary design studies of the E/STS 2-3 steam generator module for the past eight months.

L. C. Muncy, Titan Steam Generator Manufacturing

Mr. Muncy studied business administration and industrial management at Sacramento State College and American River College.

He has been with Aerojet for 12 years and is presently manufacturing program manager for Titan overhaul and Thor-Delta propulsion system. Responsibilities encompass development of manufacturing plans and schedules, as they apply to fabrication, assembly, quality control and procurement, and coordination of program requirements with Quality Control, Procurement and Material Control.

Mr. Muncy previously served as a Titan system retrofit supervisor and also participated in Titan I testing programs.

III. TECHNICAL

A. INTRODUCTION

The proposed steam generator system is discussed in this section in terms of both the total system and the individual components.

Aerojet recognizes that safe and reliable operation is of utmost importance in this system; therefore, we plan to use the most thoroughly proven, reliable components that are readily available from industry. In addition, four combustion modules, coupled with multiple independent reactant and water pumping systems, afford the Steam Generator System the capability of maintaining full rated steam flow in the event of any single failure. Safe and reliable shutdown can be accomplished upon parallel failures. The entire system is designed to operate in a stable manner with considerable tolerance. As a result of ample design safety factors, system pressures and temperatures are far from being critical, further adding to system reliability and durability.

Aerojet proposes to use the Titan I injectors and gas generators that the SNPO has acquired from the Defense Surplus Sales Office. The use of this fully developed hardware makes available abundant development, engineering, and test data, generating confidence in performance and providing maximum assurance of an optimum system.

The economy of using available, fully developed injectors in the critical module assemblies also results in savings in equipment cost.

The proposed configuration, as illustrated on the proposal cover, consisting of four modules assembled on a generator vessel, allows for optimum accessibility for servicing and inspection. This will contribute significantly to minimizing the cost of operation and limit the required turn-around time.

III, A, Introduction (cont.)

Quality control during the proposed system fabrication and test will be in accordance with Aerojet's high standards established on the NERVA, M-1, Titan, Polaris, Minuteman, and other programs. Maintenance of quality will be assured by in-process inspection and thorough testing of both the components and the assembly.

B. SYSTEMS ENGINEERING

Our studies show that the pump-fed chemical generator system is the most economical system available for the anticipated flow rates and durations. These studies included evaluations of pressure-fed chemical steam systems and boiler-accumulator systems. Neither system can compare to the pump-fed chemical system in terms of economy. Preliminary cost estimates indicated that the installed cost of a pressure-fed chemical system would be about 50% higher, and an accumulator-system about 500% higher than the proposed pump-fed chemical generator system.

The steam generator system will supply steam for operation of the E/STS 2-3 exhaust duct ejector, which in turn will be required to maintain simulated altitudes throughout the NERVA engine duty cycle. The proposed steam generator system will be designed to supply steam with a molecular weight between 18 and 20 at nominal pressures up to 225 psia. It is anticipated that the ejector will require nominal steam flow rates as follows: pumping flow, 3700 lb/sec; safety flow, 1500 lb/sec; standby flow, 600 lb/sec; with a total steam capacity of six million pounds.

The normal Titan I propellants, liquid oxygen and kerosene, will be utilized. A special grade of kerosene, RP-1, was used on the Titan because of its property of reduced fouling of the fuel-cooled nozzle heat-transfer surfaces. However, since the fuel is not used as a coolant in the Steam

III, B, Systems Engineering (cont.)

Generator System, a cheaper and more available grade, JP-5, will be investigated. Water will be a coolant and will be introduced into the 6000°F reacted gas stream to generate steam. Each of the four modules will be equipped with a Titan I second-stage gas generator to serve as a high-energy igniter.

In order to provide the highest possible reliability, the igniters must operate at an elevated chamber pressure so that they will be isolated from pressure fluctuations in the steam generator combustor. Each igniter will therefore discharge into the combustor at sonic flow rates.

The pumping complex will furnish reactants to the steam generator assembly by means of diesel-engine-driven centrifugal pumps. Since no reliable electrical power service is available at the site, diesel engines have been selected as pump drivers because they are self-contained and independent of an external power source. Furthermore, they have proven reliability, are economical to operate and maintain, and are available in standardized designs in a wide range of sizes completely covering the requirements of this system.

The main combustor reactant and water systems will operate at pressures below 500 psig. The combustor reactant delivery pressures will be adjusted in two ways--by a pump discharge bypass system, and by an engine speed-governor control system.

The igniter reactant system will operate at 750 psig nominally. Separate diesel-powered pumping systems will be provided and controls similar to the main combustor reactant system will be used.

Systems to supply oxidizer, fuel, and water to the pumps are envisioned to be arranged as indicated by Figure 6, the water supply being

Figure 6. E/STS 2-3 Steam Generation--Site Arrangement Concept

III, B, Systems Engineering (cont.)

taken directly from the main service to E/STS 2-3, the fuel from a gravity storage tank, and the oxidizer from an elevated low-pressure dewar. Bypass returns for the fuel and oxidizer will be directed to their respective storage tanks, and water bypass will be connected to the main service system.

The combustor assembly and pumping equipment will be monitored and controlled remotely from the control console. The instrumentation and control systems will be automated as much as possible in order to limit the operator requirement to one or two persons.

1. System Operation

After all pumps are operating and reactant and water systems are activated up to the module primary shut-off valves, a typical steam generator system sequence will begin with the opening of all the oxidizer injector purge valves. With these purges, the steam duct will be purged of air. When the duct has been sufficiently purged, the igniters will be started in sequence and their purges simultaneously shut off.

To satisfy the first mode of operation currently designated as "standby," the first combustor will be started and its purge shut off, placing the system on "standby" status. After approximately five minutes, the remaining three combustors will be started in order to pump down the NERVA altitude chamber during start transient and satisfy the "pumping" designation. The duration of this operational mode will be about four minutes; upon completion, the steam generator will be brought to the "Safety" mode of operation by shutting down two modules. Their two igniters, however, will be kept operating in order to be able to restart them after approximately 30 minutes of NERVA engine operation. Upon restarting the two idle units, the steam generator will provide "pumping" steam flow to the

III, B, Systems Engineering (cont.)

ejector for four minutes in order to maintain altitude through the NERVA shutdown. Then the steam generator will be cut back to a single combustor for 10 minutes of "standby" while purging the NERVA exhaust duct of hydrogen, after which the entire steam generator will be shut down in a sequence the reverse of the steam generator startup. The entire operating sequence is shown graphically in Figure 7.

2. Reliability and Safety

The prime considerations in the design and development of this steam generator must be reliability and safety. The NERVA engine must be tested under altitude conditions in an oxygen-free atmosphere. Should air enter the system and mix with 4500°F hydrogen exhaust gas from the NERVA engine, an explosive reaction would occur which could destroy the engine and test facility. Because of the explosion hazard, it is of extreme importance that the steam generation system operate for the entire NERVA engine duty cycle. The Aerojet steam generation system will be designed to operate during the duration of the NERVA engine test, plus the required prefire and postfire purge duration.

The design and development program will ensure that no critical failures of the steam generating system can occur that would result in unprogrammed return to sea level conditions. The steam generator design will include redundant features that will guarantee successful completion of the duty cycle even though one of the generator modules fails.

The critical elements of the system are the module igniters, the module combustion chambers, and the pumps. Each igniter will have redundant spark devices; should one fail, the other spark device will start the igniter. If one of the generator modules fails to operate, three modules are capable of satisfying duty cycle requirements.

Figure 7. Typical Operating Sequence

III, B, Systems Engineering (cont.)

Fuel, oxidizer, and water systems will each have multiple pumps. Upon failure of one pump, the remaining pumps will be capable of delivering the required pressure and flow rates with no interruption in steam delivery.

Redundancy will also be used in the instrumentation and control system to ensure that reliability is not lost due to component malfunctions. Monitoring of the critical parameters will be provided to ensure timely action in case of hardware malfunctions.

3. Test and Checkout

A development and acceptance test program will be conducted on the steam generator assembly at the Aerojet test facility to ensure utmost reliability. Tests are planned to be conducted on the components of the steam generator assembly, including igniter, uncooled module, cooled module, and console. To make maximum utilization of each test a development vessel is planned to be used as the test fixture for the component tests. This will provide information for evaluation of the vessel during the component test program.

The complete steam generator assembly will be tested using the development vessel. After the evaluation of the assembly operation is completed, the modules will be removed and reinstalled on the deliverable generator vessel. A series of acceptance tests will be conducted on the deliverable assembly. At the completion of this test series the steam generator assembly will be cleaned and packaged for shipment.

III, B, Systems Engineering (cont.)

The pumps and the diesel pump driver equipment are off-the-shelf items and will be acceptance-tested prior to delivery to the site. There exists a depth of performance and reliability data on the pumps and diesels, so no further development testing is planned.

The control console will be designed and fabricated at Aerojet and will be completely tested as a component prior to delivery.

Aerojet will provide, as part of the deliverable equipment, an operation manual for the steam generator assembly. Technical support will be provided during the period that the steam equipment is being installed and checked out at E/STS 2-3 facility.

C. STEAM GENERATOR MODULE

1. Use of Proven Components

The injector to be used in the generator module is a standard production unit from the Titan I Stage II engine. During a four-year engine program, this injector design has been subjected to 570 test firings, in addition to 1500 component test firings. This injector has also performed successfully on 53 flights with no failures.

The generator module igniter is a modified Titan I gas generator. During the Titan I Program, the gas generator was also test fired 570 times on the engine in addition to a large number of R&D tests. The electrical igniters are the proven Titan I units that were used to ignite the Titan I Stage II gas generator.

III, C, Steam Generator Module (cont.)

2. Module Design and Fabrication

a. Injector

The only injector modification presently planned is the addition of an igniter passage through the center of the injector. The igniter will be mounted on top of the injector and will provide a hot-gas ignition source for the module combustion zone. The complete proposed module is shown in Figure 8.

The Titan I test program has proven the injector to be statistically stable. It is known, however, that any unbaffled injector can be forced into unstable operation by a perturbation or pulse. The magnitude of the pulse necessary to produce instability can only be determined by testing with a pulse generator.

The steam generator injector will be tested to determine the pulse amplitude required to drive the system into unstable operation. In the unlikely event the margin of safety is not sufficient, a set of baffles will be welded to the injector face. The orifice pattern will have to be modified to plug the orifices near the baffles, but no other orifice modification will be necessary. It must be emphasized that the addition of baffles is a backup program, and will be unnecessary if the injector has sufficient stability under the steam generator operating conditions.

b. Water Jacket

The water jacket will serve a dual purpose. It will contain the hot gas while the fuel and oxidizer are being vaporized and burned, and it will direct water into the mixing tank to be converted to steam.

Figure 8. Steam Generator Module

III, C, Steam Generator Module (cont.)

The water jacket will be nominally 24 in. long. This will provide a total combustion chamber length of approximately 30 in. An analytical analysis indicates that 30 in. is the length required to allow complete combustion of the fuel.

The water jacket will consist of a torus, a tube bundle, and an outer shell. Water velocities in the torus will be approximately 65 ft/sec, and the water in the tubes will reach a maximum velocity of 130 ft/sec. The tubes will be fabricated from type 347 corrosion-resistant steel with 0.050-in. maximum wall thickness. During normal operation the maximum gas side wall temperatures will be approximately 1345°F, well below the tube burn-out temperature. The tubes will be fabricated with an integral flange. In the event of tube damage, the whole tube bundle may be removed and replaced, without changing the torus and outer shell.

c. Igniter

The igniter will consist of a Stage II gas generator mounted on top of the injector. The gas generator produces 1450°F fuel-rich hot gas, which will be directed into the hot gas module combustion zone through the injector face.

The igniter will use the same fuel and oxidizer as the hot gas module. The reactant flow rate to each igniter will be approximately 5 lb/sec, with a mixture ratio of approximately 0.38. The igniter will be started by two sparking devices screwed into the chamber wall. This is the same ignition source used by the Titan I Stage II gas generator.

III, C, Steam Generator Module (cont.)

d. Combustor Module Valves

The fuel and oxidizer flow during start and shutdown of the combustor module will be controlled by the Titan I type thrust chamber valves. These mechanically linked valves will require modification to provide for the proper oxidizer lead. No change will be required in the gas generator control valves.

e. Development Hardware

The following hardware will be required for development testing at Aerojet:

- 5 Titan II injectors
- 1 Water jacket, plus 2 spare tube assemblies
- 5 Igniters
- 2 Uncooled chambers
- 1 Generator vessel
- 2 Water pumps with electric motors
- 5 Sets of thrust chamber valves
- 5 Sets of igniter valves
- 5 Sets of electrical ignitors
- 1 Flow-control valve

Test Stand H-8 will be used for the development test program. This test stand includes pressurized tankage for fuel and oxidizer, a hydraulic actuation system, and all necessary instrumentation and control circuits. Additional reactant and water lines will be added to Test Stand H-8 as required to connect the test stand tanks to the steam generator.

III, C, Steam Generator Module (cont.)

3. Operation

Operation of the generator modules will be similar to that of the Titan I engine in many respects. The valves will be phased with the oxidizer valves opening first to provide an oxidizer lead at the injector face similar to the 0.2-sec oxidizer lead of the Titan I engine.

The igniter system on the Titan I engine consisted of a pyrotechnic device that was ignited inside the combustion chamber. This method of ignition was necessary since liquid oxygen and kerosene do not normally ignite on contact. To provide multiple restart capability for the steam generator, the pyrotechnic starting device has been replaced by the Titan I gas generator, firing coaxially through the injector as shown in Figure 8. The gas generator will in turn be ignited by the same spark devices used on the Titan I system.

Operating pressures in the steam generator module will be a maximum of 300 psi, but pressure differentials and propellant flow rates will be comparable to those in the Titan I system.

Steam generator module instrumentation will cover all necessary operating functions such as steam generator chamber and manifold pressures, igniter chamber pressure and temperature, and valve positions.

D. STEAM GENERATOR ASSEMBLY

1. Concept

The purpose of this steam generator is to deliver reliably a uniform steam product. In the past, chemical steam generators have long been plagued with incomplete combustion, burn outs, incomplete evaporation, and hot cores in the efflux stream. For this reason, Aerojet has developed

III, D, Steam Generator Assembly (cont.)

a steam generator concept incorporating innovations designed to eliminate these problems. In the new concept, completely reacted multiple hot gas and water streams impinge within a sudden flow passage enlargement to promote the turbulent breakup of the hot cores. This turbulence provides the maximum contact area for heat transfer and the subsequent generation of steam. Then the mixture negotiates a baffled turn to remove excess liquid diluent to an integral sump. This turbulent pattern is shown in Figure 9.

2. Design and Fabrication

The steam generator assembly will consist primarily of a pressure vessel and four generator modules. A midsection internal throat, a grating-covered bottom sump, and dual steam outlets on opposite sides of the vessel complete the basic generating assembly. The generator modules will be canted inward so that their centerlines meet in the turbulent mixing section. Combustion gases and injected water issuing from each module will impinge at this point, filling this section with a highly turbulent mixture of cooling combustion gases and evaporating atomized water droplets.

The design of the steam generator allows for injection of excess diluent water. An internal throat accelerates the fluid mixture, and a sharp turn separates the unvaporized water upstream of the outlets, as shown in Figure 9. The centrifugally extracted water will then fall directly into the sump to be drained off. This sump will have anti-slosh baffles to prevent water entering the steam distribution system. The internal throat will also promote turbulence during single-module operation. Dual outlets have been chosen to ensure symmetry of the internal gas flow.

The manhole in the lower portion of the vessel provides for visual access to the four modules between NERVA tests. This allows for reverification of the condition of the injectors and water jackets without disassembly of the units.

Figure 9. Steam Generator Mixing Concept

III, D, Steam Generator Assembly (cont.)

The steam generator assembly package will also include various other items which contribute to its basic function. The combustion modules mounted on the four topside tank openings have already been discussed in Section III,C. Supplying the combustors and igniters with reactants will be five pipe manifolds, one each for the combustor oxidizer, fuel, and diluent; and one each for the igniter oxidizer and fuel. Each of the five manifolds will have a bypass connection and an automatically controlled bypass flow-control valve. These manifolds will present 10 interface connections for the attachment of appropriate service lines. There will also be separate bleed manifolds for oxidizer, fuel, and water.

Other manifolds will be the injector oxidizer and injector fuel purge manifolds. Each of the manifolds on the assembly will be equipped with the necessary remote shutoff valves. An automatic sump drain valve will also be provided.

The mixing tank will be mounted on a skid base supporting the access platform. The access platform structure will support all the manifolds and valves supplied as part of the generator assembly.

The instrumentation and control harnesses will be supplied as a part of the assembly. They will be terminated at an interface located in the local control and lockout box mounted on the access platform structure.

3. Operation

Normal steam generator starting and operating sequence (Figure 7) will be as follows:

III, D, Steam Generator Assembly (cont.)

- a. Open the safety valves; bleed fuel, oxidizer, and water to the generator module valves.
- b. With all pumps operating and fluids being bypassed to their respective sources, start the N_2 purge to the injector oxidizer manifolds.
- c. Start the igniters using the electrical spark devices.
- d. Verify satisfactory igniter operation, then start one generator module.
- e. Verify one module operation, and start additional modules as required.
- f. In the event it is necessary to operate at 100% steam flow with three modules, the valves on the fourth module will be closed and the supply pressure increased to compensate for the additional pressure losses associated with the higher flow rate per injector.

E. SUPPORTING EQUIPMENT

1. Pump Drivers

Since reliable electric power is not available in quantity at the test site, an alternative means of driving the steam generator supply pumps will be necessary.

Diesel engines are suggested in this proposal because of their availability in large sizes, their proven industrial reliability and durability, and their economy of operation and maintenance.

III, E, Supporting Equipment (cont.)

The diesel engines will be sized to meet the maximum horsepower requirements associated with the various pumping operations.

Because diesel engine speeds are characteristically low and design centrifugal pump speeds are usually much higher, each pump will be driven through a speed increaser gearset.

Each engine will be equipped with remote GN_2 start capability, remote governor control, heat exchanger cooling with coolant pumps, mufflers, remote circuits monitoring water temperature, oil pressure and speed, and local gauge panels.

2. Main Supply Pumps

These pumps will be industry standards with proven comparable experience, and they will be arranged for maximum system reliability. The normal four module flow and pressure requirements at the pump discharge are shown in Table 2. However, if one module must be shut down while maintaining full steam production, pump discharge pressures must be increased as indicated in the table. If one pump fails, the remaining capability is designed to satisfy the full requirement. Therefore, a trio of pumps for each service is indicated, each pump capable of satisfying 50% of the flow at the maximum required pressure conditions.

TABLE 2

NOMINAL FLOW AND PRESSURE SCHEDULE

3700 LB/SEC STEAM

	Generator Vessel (psia)		Inj. Face (psia)		Inj. Inlet (psia)		Pump Discharge (psia)		Total Flow Rate		Unit Flow Rate		Minimum NPSH (Feet)	
	4 Module	3 Module	4 M	3 M	4 M	3 M	4 M	3 M	GPM		Lb/Sec	4 M		3 M
<u>Main Supply Pumps</u>														
Fuel	225	225	253	293	305	373	397	465	2,720	305	75	101	15	
Oxidizer	225	225	253	293	331	413	433	515	4,590	728	182	242	15	
Diluent	225	225			248	260	353	365	19,600	2,720	683	907	90	
<u>Igniter Supply Pumps</u>														
Fuel			600	600	675	675	750	750	91.5	14.5	3.62	3.62	15	
Oxidizer			600	600	675	675	750	750	49.5	5.5	1.38	1.38	15	

III, E, Supporting Equipment (cont.)

3. Igniter Supply Pumps

These pumps will also be industry standards with proven service. Inasmuch as the flow is quite small, two pumps have been chosen to fulfill this need with each pump capable of handling the full required flow at the required pressure, as indicated in Table 2.

4. Piping

Piping systems furnished by Aerojet-General will be those on the steam generator assembly package manifolding the bypass systems and the feed lines to the combustor modules, the GN_2 purge manifold, and other bleed, drain, and decontamination piping systems. Interconnecting piping furnished by others, shown by Figure 10, should include pump discharge check valves. These valves will preclude back flow through the idle pump in the event of a pump failure. The pumps in each of the pumping systems should be manifolded into a single feed line terminating at the appropriate steam generator feed manifold.

5. Controls and Instrumentation

The instrumentation and controls system furnished by Aerojet-General consists of the control console and the various remotely controlled components and instrumentation on the steam generator assembly. The control console will be the nerve center of the steam generator system, receiving and dispatching information. It will mount the manual switches, controls, indicators, and recorders. The following parameters will be measured and displayed on this console:

Water pressures

Reactant line pressures

Figure 10. Flow and Control Diagram

III, E, Supporting Equipment (cont.)

- Igniter chamber pressures
- Combustor chamber pressures
- Combustor manifold pressures
- Steam generator pressure
- Diesel engine parameters
- Lox line temperatures
- Steam discharge temperature
- Igniter chamber temperature
- Valve position indicators
- Sump level

The following features will be included in the console: (1) control sequencer for igniters and combustors, (2) critical malfunction detection and compensation units, (3) process control servo amplifiers for maintaining automatic control of propellant and water system pressure, (4) diesel governor remote control, (5) purge, bleed, and decontamination controls, (6) isolation valve controls. There will be a minimum number of small strip chart recorders for trend information.

For each variable measured there will be an electrical interface to provide recording of any or all parameters via the customer's systems.

All the control wiring pertaining to the steam generator will pass through a lock-out panel at the generator which will, during downtime, allow technicians to lock out the console and operate various functions locally.

The console will be designed to harmonize with the decor of the control room.

III, Technical (cont.)

F. TEST AND ACCEPTANCE

The following proposed test program, which will be conducted at Aerojet-General, consists of four phases. The first three phases are component development testing and the last phase is the assembly demonstration and acceptance testing.

<u>Type of Test</u>	<u>Number and Duration of Tests</u>	<u>Test Objective</u>
1. Igniter	4 tests 300 sec each	Evaluate igniter starting and running characteristics
2. Uncooled module	15 tests 3 sec	Evaluate combustor start transient and combustion stability
3. Generator module	20 tests 300 sec each	Check overall module operation. Evaluate limits of operating parameters. Demonstrate module durability.
4. Steam generator assembly tests (acceptance tests)	15 tests 80 sec each	Demonstrate multiple module starting characteristics and operation and run acceptance tests on deliverable hardware.

All module testing will be performed on a development steam generator vessel simulating all inlet and exit conditions that will be encountered at the E/STS 2-3 facility. This test program will be conducted in the NASA-owned Test Stand H-8.

G. NEVADA OPERATIONS

A recommended site arrangement is shown in Figure 6. This arrangement separates as cleanly as possible the liquid oxygen from the fuels and hydrocarbons.

III, G, Nevada Operations (cont.)

To bring the site engineering to a satisfactory completion will require close coordination between the site personnel and the Aerojet Steam Generator project organization.

Coincident with delivery of the steam generator equipment to NTO, Aerojet will assign a steam generator resident design engineer to work as a technical consultant to SNPO and the site contractor through the completion of the generator installation and checkout. This resident will be assisted as required by steam generator system specialists.

H. FACILITIES

1. General

The proposed design, development, and test program will be conducted at Aerojet's Sacramento Plant. The plant is located on Highway 50 approximately 20 miles east of Sacramento. The plant is currently engaged in a wide range of projects, from design of small rocket engines to large engines such as the M-1. Existing facilities to be used in the performance of the contract include engineering laboratories, computers, and test facilities.

2. Engineering Facilities

a. Digital Computing

The IBM 360/65 digital computer is available for the exploration of scientific and engineering problems. This machine is utilized in evaluation, fluid flow, injector design, and heat transfer. The Model 360/65 computer has a 512,000 byte memory system, four 2311 disk drives, a 15 tape drive, and a 0.75-microsec cycle. It is supported by a 2540 card

III, H, Facilities (cont.)

reader punch which punches cards at the rate of 300 per minute and has a reading speed of 1000 cards per minute. Also in support is a 1403 printer which prints at the rate of 1100 lines per minute.

Off-line requirements are handled with an IBM 360/60 driving three 1403 printers, five 2400 tape drives, and a 2540 card reader punch. The Model 30 has an 8000 byte memory and a 2.5-microsec cycle time. A second Model 30 has five 2400 tape drives, two 2311 disk units, one 2671/1012 paper tape punch, one 1403 printer, one 2540 card reader punch, and a 16,000 byte memory.

An 1130 digital computer is also available to be used as an engineering tool to prove concepts and theory before their inclusion into the larger programs that are to be run on the 360/65 computer. The 1130 computer will punch 100 cards per minute, read 400 cards per minute, and print 900 lines per minute. This machine has an 18-microsec access time.

A library has been compiled of over 1,200 operational engineering and scientific programs developed since operations were initiated.

b. Analog Computing

The analog computing facility is composed of two fully expanded Comcor CI 5000's, two EAI 231 R's, two EAI 131 R's, and an EAI 24D consisting of 1700 operational amplifiers with associated nonlinear equipment such as multipliers, function generators, and resolvers. Digital logic is also available for use with the analog computing system. Two automatic digital input-output systems are available to facilitate computer set-up and checkout.

III, H, Facilities (cont.)

This facility is currently being used to simulate real time systems such as liquid rocket engines, nuclear rocket engines, and complete test facilities, including heat-transfer effects, hydrodynamics, and closed loop control system dynamics. The analog facility is also capable of testing actual hardware by electrically or mechanically including it in the simulation.

3. Laboratories

The Sacramento Plant provides the complete laboratory capabilities necessary for development programs. The available laboratories, listed below, house the most modern types of equipment and are staffed by trained personnel.

- Materials and fabrication research and development laboratories
- Propellant chemistry and physics laboratories
- Metals and plastics laboratories
- Analytical chemistry laboratory
- Cryogenics laboratory
- Vibration laboratories
- Environmental laboratory
- Structures laboratory
- Control systems laboratory
- Dynamics laboratory
- Photoelastic laboratory

4. Manufacturing

All hot-gas module fabrication will be done in Aerojet's shops in Buildings 2004 and 2002. These shops are equipped with the necessary machines and heat-treating equipment to complete the task in a minimum of time.

III, H, Facilities (cont.)

The manufacturing machine shop is equipped to fabricate in quantity metal and plastic parts of the high quality and close tolerances required by the aerospace industry. Emphasis has been placed on precision fabrication from the smallest fittings through the most massive thrust chamber.

The materials machined range from conventional steels through Ladish D-6, AMS-6434, 17-4PH and 17-7PH stainless steels, Inconel, Hastelloy, titanium, and molybdenum, as well as various structural plastics. All types of turning, boring, drilling, and grinding are performed.

The equipment varies from conventional machine parts to complex multiple-function rotating machinery.

Aerojet-General has developed the capability of machining steel alloys to precision tolerances in thickness, roundness, and flatness considered impracticable only a few years ago. Specialized applications include the joining of dissimilar metals and the fitting of extremely close tolerances (such as are required for high-pressure and cryogenic fluid valving).

A common operation is the production of nozzles for rocket engines, in which many thin-walled tubes of stainless steel alloys are fabricated into a welded, brazed and machined assembly that is gas-tight and capable of withstanding temperatures up to 6000°F.

The present machine shop is the result of a carefully planned consolidation of three separate machine shop operations and represents an integrated and balanced combination of conventional and numerically controlled machines. In this shop, numerically controlled machining is grouped into a centralized area under single supervision for the efficient use of programming personnel, shop supervision, and associated support functions.

III, H, Facilities (cont.)

Incorporated within the machine shop is a research and advanced technology facility, which is specially tooled and oriented for the fabrication of development hardware. It is operated and supervised specifically for producing engineering designs with a minimum of time lag between development and production facilities.

The machine shop is arranged under the control center concept to minimize the need to transport material and parts and to concentrate appropriate skills for the separate operations of turning, boring, milling, and drilling. When the situation dictates, shop areas can be rearranged so that maximum efficiency is achieved by concentrating all shop functions on a single article.

Integrated within this shop are the other functions that are necessary to achieve cost-effective quantity productions; these include inspection stations, X-ray, and other nondestructive testing operations, blast cleaning, and degreasing.

5. Test

The proposed test program will be conducted on Test Stand H-8. This stand was constructed under the M-1 contract for static testing of TCA's and GGA's. The TCA position is a horizontal firing stand rated at 1,500,000 lb thrust. Located adjacent to the test stand are run vessels. These vessels (7,750-gal, 1800-psig oxidizer and 25,000-gal, 1800-psig fuel) supply propellant to the test hardware through high-pressure piping. The propellant system is basically a conventional pressure-fed flow loop. Brief descriptions of the major components and required modifications for this program are given below, and Figure 11 shows the proposed modifications to Test Stand H-8.

Figure 11. Modified Test Stand H-8

III, H, Facilities (cont.)

a. Propellant-Fed System

The oxidizer and fuel will be supplied to the modules from existing propellant run vessels. The existing 7,750-gal, 1800-psig LO_2 vessel will be used without modification. This vessel is pressurized from a GN_2 cascade consisting of three 360,000-scf, 5000-psig bottles. The LO_2 run vessel is filled from a 30,000-gal, 50-psig storage area. Propellants are transferred from the storage to the run vessel through vacuum-insulated transfer piping.

The fuel will be supplied to the modules from the existing LH_2 run vessel. In view of the weight differences between LH_2 , for which the tank was designed, and the kerosene, 30% of the volume will be used. The existing propellant run lines will be utilized.

The fuel run vessel is presently pressurized with GH_2 from a GH_2 cascade consisting of four 6,400-scf, 3500-psig bottles. To provide pressurization for the kerosene a portion of the existing GH_2 cascades will be converted to GN_2 service.

Reactants will be supplied to the igniters from a separate tank system. Existing government-owned vessels will be relocated from another area and installed in the H-8 Test Stand. These vessels will be pressurized from the same cascade as the main run vessels.

b. Water Supply

To supply the required water to the steam generator system a new, 30,000-gal water storage tank will be installed. Surplus M-1 electric motor driven water pumps, currently owned by SNPO, will be installed to supply water to the steam generator.

III, H, Facilities (cont.)

c. Steam Exhaust

The steam which will be generated will be carried off through parallel ducts up the side of the stand. These ducts will simulate E/STS 2-3 back-pressure.

d. Handling Equipment

The test stand is presently equipped with two overhead traveling test cranes for handling test hardware. There will be no modification to this system. In addition to this crane, each of the large run vessels are equipped with davit cranes for servicing and handling the larger valves and pipe sections.

e. Instrumentation

The existing control room and stand instrumentation capabilities are more than adequate to meet the requirements of this test program. The capabilities which will be available for this program follow.

III, H, Facilities (cont.)

<u>Data Acquisition System</u>	<u>No. Channels</u>
Strain gage pressure	72
Strain gage patch or pressure	18
Thermocouple	48
Cryogenic RTT	24
Flow	12
Valve position	12
Switch trace	48
Accelerometer	24
Photocon (pressure)	6

Control room recording capabilities

<u>Recorder</u>	<u>No. Channels</u>
Analog-to-digital system	96 high-level, 20 low-level 4 digital flow
Oscillograph	4 each with 36 channels
Strip charts	31 each
Direct write	20
Visual meters	46
Analog magnetic tape	32
Liquid level	2
Time interval counter	8

IV. COSTS

A. INTRODUCTION

This unsolicited proposal is submitted to SNPO to aid in the planning of E/STS 2-3 facility. It is a cost plus incentive fee proposal subject to mutual agreement on a definitive work statement. Additional cost detail will be available upon request.

The proposed costs in the cost breakdown summary are based upon accomplishing the program as outlined in this proposal under the following conditions:

(1) All equipment will be delivered FOB Sacramento, California and by Government Bill of Lading to the E/STS 2-3 test site.

(2) Fuel, oxidizer and pressurants for development and testing are assumed to be Government-supplied. The quantities are shown on Table 3.

(3) Government-owned facilities and special test equipment required will be used on a rent-free, noninterference basis to perform the development and acceptance program. (See Section II,D,6.)

(4) The contract performance dates are January 1968 through December 1971.

B. PROPOSED COST ELEMENTS

1. Direct Labor Hours Calculation

The effective manhour-per-month figures used in this proposal are based upon payroll experience.

COST BREAKDOWN SUMMARY

AGCS 0520-13 (REV 11/65) (SPI-K-05-03-1)

PROPOSAL NUMBER

SRT 671754

VOLUME

SECTION

PAGE

OF

TASK/END ITEM/ASSY.

Steam Generator

SUB TASK/COMPONENT

PLANT

POOL

DIVISION NAME

DIVISION NUMBER

FISCAL YEAR

LOWER DETAIL REFERENCE

NEXT SUMMARY REFERENCE

COST ELEMENT		HOURS	RATE	SUB TOTALS	TOTALS
POOL:Engineering O.H. AT 140.0 %	SALARY	82,413	\$ 6.59	\$ 543,102	\$ 2,026,738
	HOURLY	70,579	\$ 4.27	\$ 301,372	
	TOTAL DIRECT			\$ 844,474	
	TOTAL OVERHEAD			\$ 1,182,264	
POOL:Manufacturing O.H. AT 147.5 %	SALARY	12,354	\$ 6.08	\$ 75,112	\$ 516,352
	HOURLY	31,195	\$ 4.28	\$ 133,515	
	TOTAL DIRECT			\$ 208,627	
	TOTAL OVERHEAD			\$ 307,725	
POOL:Out-Plant O.H. AT 48.0 %	SALARY	2,720	\$ 6.98	\$ 18,986	\$ 28,099
	HOURLY	-	\$ -	\$ -	
	TOTAL DIRECT			\$ 18,986	
	TOTAL OVERHEAD			\$ 9,113	
POOL: O.H. AT _____ %	SALARY		\$ -	\$ -	
	HOURLY		\$ -	\$ -	
	TOTAL DIRECT			\$ -	
	TOTAL OVERHEAD			\$ -	
MATERIAL O.H. AT 7.0%	RAW MATERIALS		\$ 747,904		\$ 1,850,462
	PURCHASED PARTS		\$ -		
	SUB-CONTRACTS		\$ 850,000		
			\$ -		
	SPECIAL TOOLING		\$ 1,500		
	SPECIAL TEST EQUIPMENT		\$ 130,000		
	TOTAL DIRECT			\$ 1,729,404	
TOTAL OVERHEAD			\$ 121,058		
OTHER	COMPUTER SERVICES			\$ 11,390	\$ 26,990
	TRAVEL			\$ 15,600	
				\$ -	
	HOURLY LABOR PREMIUM				
	POOL	HOURS	RATES		
			\$ -	\$ -	
			\$ -	\$ -	
	TOTAL DIRECT			\$ 26,990	
TOTAL COST LESS ADMINISTRATIVE EXPENSE					\$ 4,448,641
ADMINISTRATIVE EXPENSE (G&A) AT 12.5%					\$ 556,080
TOTAL ESTIMATED COST (TARGET)					\$ 5,004,721
TARGET FEE 10 %					\$ 500,472
TOTAL ESTIMATED COST					\$ 5,505,193

IV, B, Proposed Cost Elements (cont.)

2. Direct Labor Rates

The Aerojet-General method for estimating direct labor costs is based upon adding the monthly trend line escalation amounts to November 1966 actual pool rates. This method has been reviewed with Defense Contract Audit Agency and approved by the Air Force Plant Representative Office.

The mid-point effort of the proposed program is July 1969. The following rates were used:

	<u>SH</u>	<u>HH</u>
Engineering pool	\$6.59	\$4.27
Manufacturing	\$6.08	\$4.28
Outplant	\$6.98	\$4.38

3. Overhead Rates

Each year, Aerojet-General submits a forecast of direct labor overhead, material burden, and general and administrative expense for the ensuing year. The rates are reviewed by both AFPRO and the resident Defense Contract Audit Agency and are subsequently negotiated. The following overhead rates for Aerojet-General fiscal year 1968, beginning 1 December 1967, have been projected consistent with FY 1967 approved rates and have been used for the total period of performance proposed in their contract:

TABLE 3
REQUIRED FUEL, OXIDIZER, AND PRESSURANTS

<u>Test Series</u>	<u>Requirements, lb</u>		
	<u>Oxidizer</u>	<u>Fuel</u>	<u>Pressurant</u>
Igniter	2,480	4,500	1,800
Uncooled module	12,400	3,730	298,000
Cooled module	1,650,000	496,000	337,000
Steam generator assembly	<u>1,320,000</u>	<u>396,000</u>	<u>298,000</u>
Totals	2,984,880	900,290	934,800

IV, B, Proposed Cost Elements (cont.)

Sacramento Plant

Engineering (DLO)	140.0%
Manufacturing (DLO)	147.5%
Outplant (DLO)	48.0%
Material burden	7.0%
General and Administrative	12.5%

The above rates are applied to estimated costs as follows:

Engineering, Technical Publications, and Test: Direct labor dollars receive the engineering direct labor overhead rate of 140.0%.

Manufacturing and Quality Control: Direct labor dollars receive the manufacturing direct labor overhead rate of 147.5%.

Outplant direct labor dollars receive the outplant direct labor overhead rate of 48.0%.

All direct material and subcontract costs receive the material burden rate of 7.0%.

All direct and overhead costs receive the Sacramento Plant general and administrative expense rate of 12.5%.

IV, B, Proposed Cost Elements (cont.)

4. Computer Costs

The computer time was estimated as follows:

<u>Computer</u>	<u>Time, hr</u>	<u>Rate per Hour</u>	<u>Use</u>
IBM 360-65	9	\$275	Module design
IBM 360-40	5	\$125	System design
IBM 360-40	67	\$125	Data reduction

5. Travel

The travel costs were estimated on the basis of one man at the test site for 17 months. The per diem rate is \$14 per day, plus 8¢ per mile for use of a personal automobile.

C. SUPPLEMENTAL INFORMATION

1. General

Aerojet-General Corporation is incorporated under the laws of the State of Ohio and maintains its corporate headquarters in El Monte, California. The Sacramento Plant currently employs approximately 8500 persons in research, development and production programs for both governmental agencies and commercial organizations.

2. Aerojet-General Systems, Policies, and Procedures

The accounting policies and procedures of Aerojet-General are reviewed and approved periodically by the Defense Contract Audit Agency and the

IV, C, Supplemental Information (cont.)

Air Force Administrative Contracting Officer. It is assumed that this will satisfy the accounting requirements for the proposed contract.

In accordance with the provisions of ASPR 3-903.3, the Aerojet-General purchasing system is reviewed and approved by the resident DCAA auditor and the resident Air Force Administrative Contracting Officer. It is assumed that this system will fulfill all requirements of the contract relative to obtaining prior approval of subcontracts and purchase orders.

3. Royalties

No royalty payments or royalty fees are included in this proposal.

4. Location of Work

It is anticipated that the work involved in this proposed program will be performed at the Aerojet-General Sacramento facility.

5. Initiation of Work

Should it be considered expedient, work can be initiated in the proposed program upon the basis of a teletype notice of award, letter contract, or other interim contractual authority to proceed.

6. Overtime

No overtime is included in or planned for this program.

IV, C, Supplemental Information (cont.)

7. Local Audit and Administrative Agency

Branch offices of the Defense Contract Audit Agency and the Air Force Plant Representative are located at Aerojet-General's Sacramento Plant. They can be reached at the following address:

Air Force Plant Representative
Air Force Contract Management Division (AFSC)
Aerojet-General Corporation
Post Office Box 15846
Sacramento, California 95813
Telephone A/C 916, 355-1000

8. Contractual Procedures

The Aerojet-General Corporation has extensive experience in the administration of Government contracts. In the proposed program, no need is foreseen for any deviation from the established standard procedures.

9. Make or Buy

Aerojet-General has detailed policies and procedures governing make-or-buy policy. Corporate Standard Practice Instruction C-09-03 provides basic guidance and establishes a corporate make-or-buy review committee charged with reviewing and revising corporate policy as well as audited plant make-or-buy programs.

Sacramento Plant Standard Practice Instruction (SPI) K-06-12 establishes the responsibilities and procedures for implementing the corporate policy. In general, the policy provides that available Aerojet-General resources will be employed to the fullest extent practicable for Aerojet-designed parts, assemblies, and processes, but that commercially available

IV, C, Supplemental Information (cont.)

items will not normally be manufactured in-plant. The SPI's also provide that contractual make-or-buy obligations take precedence.

10. Subcontracting

Aerojet-General maintains a comprehensive set of standard practice instructions covering all aspects of procurement. These SPI's are supported and implemented by the Procurement and Materiel Procedures Manual. The purchasing system is reviewed periodically and is currently approved by the Air Force Plant Representative Office.

In addition, Aerojet-General maintains a small business/labor surplus area subcontracting program. The small business specialist of the Naval Ordnance Systems Command reviewed and approved this program in May 1966 and has recommended a plus factor when computing fee or profit based upon the weighted guidelines method.