GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station

**PROJECT INITIATION**

Date: August 24, 1970

Project Title: Foreign Technology Study

Project No.: A-1280

Project Director: Mr. R. M. Goodman

Sponsor: U. S. Army Missile Command

Effective August 19, 1970 Estimated to run until: October 19, 1970*

Type Agreement: Contract No. DAAH01-71-C-0042 Amount: $ 9,984.00

*Two additional weeks allowed for Final Technical Reporting.

Reports Required: Monthly Progress Letter, Cost & Performance Report, Final Technical Memorandum

Sponsor Contact Persons:

Technical Matters
Mr. Joseph W. Holmes
U. S. Army Missile Command
Missile Intelligence Directorate
ATTN: AMSMI-YPM
Redstone Arsenal, Ala. 35809

Administrative Matters
(Individual not named)
U. S. Army Missile Command
ATTN: AMSMI-RKC
Redstone Arsenal, Ala. 35809

Defense Priority Rating: DO-A2 under DMS Reg. 1

Assigned to Electronics (Sensor Systems) Division

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# GEORGIA INSTITUTE OF TECHNOLOGY
## Engineering Experiment Station

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### PROJECT TERMINATION

Date 4/23/71

PROJECT TITLE: Foreign Technology Study

PROJECT NO: A-1280

PROJECT DIRECTOR: Mr. R. M. Goodman, Jr.

SPONSOR: U. S. Army Missile Command, Redstone Arsenal

TERMINATION EFFECTIVE: 2/12/71*

CHARGES SHOULD CLEAR ACCOUNTING BY: 2/28/71 (or have been encumbered by that

*Date Final Technical Report submitted.

Contract Closeout Items Remaining: Final Invoice & Closing Documents
Final Report of Inventions
Government Property Inventory and related Certificate of Disposition if applicable (no Government Property Clause in this contract)
Classified Material Certificate.

Electronics (Sensor Systems) Division

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A - 1280

GEORGIA INSTITUTE OF TECHNOLOGY
EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

19 October 1970

U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

Attention: AMSMI - IYC

Reference: Contract No. DAAH01-71-C-0042

Subject: Cost and Performance Report
24 August to 29 September 1970



Gentlemen:

The subject Cost and Performance Report covers the period 24 August through 29 September 1970. On 10 September 1970, a trip was made to MID for project planning and to view hardware. MID agreed to send certain reports and drawings to Georgia Tech for project use. In order to best utilize the project resources, all work was suspended at that time until receipt of the material. No further work was done during the period.

It is estimated that 20% of the work has been completed.

Respectfully submitted:

R. M. Goodman, Jr.
Head, Sensor Systems Branch

RMGjr:lb

A-1280

GEORGIA INSTITUTE OF TECHNOLOGY
EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

19 October 1970

U. S. Army Missile Command
Redstone Arsenal, Alabama 35809


Attention: AMSMI - IYC

Reference: Contract No. DAAH01-71-C-0042

Subject: Monthly Letter Progress Report
19 August - 31 August 1970

Gentlemen:

This is the first Monthly Letter Progress Report under the reference contract and covers the bi-weekly period of 19 August to 31 August 1970.

Part I:

1. Task Title: Foreign Material Exploitation
2. Indicated Action for MID: none
3. Visitors to project: none
4. Trips and Visits to other installations in connection with the project: none

Part II:

The contract was received 24 August 1970. A project planning meeting was held on 31 August 1970 with project personnel from Georgia Tech and the Lockheed Georgia Co. A visit to MID was planned to view hardware and discuss plans with the sponsor.

Respectfully submitted:

R. M. Goodman, Jr.
Head, Sensor Systems Branch

RMGjr:lb

ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY
EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

19 October 1970



U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

Attention: AMSMI - IYC

Reference: Contract No. DAAH01-71-C-0042

Subject: Monthly Letter Progress Report
1 September to 14 September 1970

Gentlemen:

This is the second Monthly Letter Progress Report under the reference contract and covers the bi-weekly period of 1 September to 14 September 1970.

Part I:

1. Task Title: Foreign Material Exploitation
2. Indicated Action for MID: none
3. Visitors to project: none
4. Trips and visits to other installations in connection with the project: A visit was made 10 September 1970 to MID by the following Georgia Tech and Lockheed Georgia Co. project personnel:

| Georgia Tech | Lockheed Georgia Co. |
|---|---|
| R. M. Goodman, Jr. | E. E. Underwood |
| J. E. Rhodes, Jr. | W. H. Lewis |
| S. Spooner | H. H. Kranzlein |
| L. G. Klinker | |

Part II:

The hardware located at MID was examined by the seven project personnel during the 10 September 1970 visit. In addition, project plans were discussed.

MID agreed to send certain reports and drawings to Georgia Tech for project use. In order to best utilize the project resources, all work was suspended until receipt of this material.

Respectfully submitted,

R. M. Goodman, Jr.
Head, Sensor Systems Branch

RMGjr:lb

ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY
EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

19 October 1970

U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

Attention: AMSMI - IYC

Reference: Contract No. DAAH01-71-C-0042

Subject: Monthly Letter Progress Report
15 September to 28 September 1970



Gentlemen:

This is the third Monthly Letter Progress Report under the reference contract and covers the bi-weekly period of 15 September to 28 September 1970.

Part I:

1. Task Title: Foreign Material Exploitation
2. Indicated Action for MID: none
3. Visitors to project: none
4. Trips and visits to other installations in connection with the project: none

Part II:

No work has been done. Work remains suspended pending receipt of material expected from MID.

Respectfully submitted:

R. M. Goodman, Jr.
Head, Sensor Systems Branch

RMGjr:lb

ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY
EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

19 October 1970

U. S. Army Missile Command
Redstone Arsenal, Alabama 35809



Attention: AMSMI - IYC

Reference: Contract No. DAAH01-71-C-0042

Subject: Monthly Letter Progress Report
29 September to 12 October 1970

Gentlemen:

This is the fourth Monthly Letter Progress Report under the reference contract and covers the bi-weekly period of 29 September to 12 October 1970.

Part I:

1. Task Title: Foreign Material Exploitation
2. Indicated action from MID: none
3. Visitors to project: none
4. Trips and visits to other installations in connection with the project: none

Part II:

The reports expected were received from MID. The project personnel familarized themselves with the material and general recommendations were formulated. A format for presentation of the recommendations was selected and an outline thereof was drawn up. Sample portions of the actual recommendation were set down and plans were made to take the foregoing to MID for discussion. It is hoped that by obtaining the sponsor's opinion of the format and other work, the final report will meet the sponsor's requirements.

Respectfully submitted:

R. M. Goodman, Jr.
Head, Sensor Systems Branch

RMGjr:lb

ENGINEERING EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

27 January 1971



U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

Attention: AMSMI - IYC

Reference: Contract No. DAAHOI-71-C-0042

Subject: Monthly Letter Progress Report
13 October to 26 October 1970

Gentlemen:

This is the fifth Monthly Letter Progress Report under the reference contract and covers the bi-weekly period of 13 October to 26 October 1970.

Part I:

1. Task Title: Foreign Material Exploitation

2. Indicated action from MID: none

3. Visitors to Project: none

4. Trips and visits to other installations in connection with the project: A visit was made 14 October 1970 to MID by J. E. Rhodes, Jr. of Georgia Tech and W. H. Lewis of Lockheed Georgia Co., both project personnel.

Part II:

During the 14 October 1970 visit, specific examples of recommendations along with an outline of the proposed final result were presented by Mr. Lewis and Mr. Rhodes to Mr. Holmes and Mr. Howard of MID. After discussion and agreement on certain adjustments, the proposed format and content of the examples were declared satisfactory for MID's purposes. During the visit, MID agreed that certain additional documents would be sent to Georgia Tech and that pending receipt of these documents Tech would suspend work to conserve contract funds. More efficient use of project personnel can be obtained with the documents in hand.

Respectfully submitted:

[redacted]
Head, Sensor Systems Branch

RMGjr/bbw

ENGINEERING EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

27 January 1971


U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

Attention: AMSMI - IYC

Reference: Contract No. DAAHOI-71-C-0042

Subject: Monthly Letter Progress Report
27 October to 9 November 1970

Gentlemen:

This is the sixth Monthly Letter Progress Report under the reference contract and covers the bi-weekly period of 27 October to 9 November 1970.

Part I:

1. Task Title: Foreign Material Exploitation
2. Indicated Action from MID: none
3. Visitors to Project: none
4. Trips and Visits to other installations in connection with the project: none

Part II:

Negotiations to extend the contract period at no additional cost for two months were initiated. No work was done pending receipt of certain documents requested during the 14 October visit to MID.

Respectfully submitted:

R. M. Goodman, Jr.
Head, Sensor Systems Branch

RMGjr:bbw

ENGINEERING EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

27 January 1971



U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

Attention: AMSMI - IYC

Reference: Contract No. DAAHOI-71-C-0042

Subject: Monthly Letter Progress Report
10 November to 23 November 1970.

Gentlemen:

This is the seventh Monthly Letter Progress Report under the reference contract and covers the bi-weekly period of 10 November to 23 November 1970.

Part I:

1. Task Title: Foreign Material Exploitation

2. Indicated action from MID: none

3. Visitors to project: none

4. Trips and visits to other installations in connection with the project: none

Part II:

No work was done pending receipt of certain documents from MID.

Respectfully submitted:

R. M. Goodman, Jr.
Head, Sensor Systems Branch

bbw

ENGINEERING EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

27 January 1971



U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

Attention: AMSMI - IYC

Reference: Contract No. DAAHOI-71-C-0042

Subject: Monthly Letter Progress Report
24 November to 7 December 1970

Gentlemen:

This is the eighth Monthly Letter Progress Report under the reference contract and covers the bi-weekly period of 24 November to 7 December 1970.

Part I:

1. Task Title: Foreign Material Exploitation

2. Indicated action from MID: none

3. Visitors to project: none

4. Trips and visits to other installations in connection with the project: none

Part II:

No work was done pending receipt of certain documents from MID.

Respectfully submitted:

R. M. Goodman, Jr.
Head, Sensor Systems Branch

bbw

ENGINEERING EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

27 January 1971


U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

Attention: AMSMI - IYC

Reference: Contract No. DAAHOI-71-C-0042

Subject: Monthly Letter Progress Report
8 December to 21 December 1970

Gentlemen:

This is the ninth Monthly Letter Progress Report under the reference contract and covers the bi-weekly period of 8 December to 21 December 1970.

Part I:

1. Task Title: Foreign Material Exploitation

2. Indicated action from M. I. D.: none

3. Visitors to project: none

4. Trips and visits to other installations in connection with the project: none

Part II:

Documents necessary to going forward with the work per discussions at M.I.D. 14 October 1970 were received at Tech. Detailed assembly of material for the recommendations to be incorporated into the final report was begun.

Negotiations for a second no-cost contract extension were started.

Respectfully submitted:

R. M. Goodman, Jr.
Head, Sensor Systems Branch

bbw

ENGINEERING EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

27 January 1971



U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

Attention: AMSMI - IYC

Reference: Contract No. DAAHOI-71-C-0042

Subject: Monthly Letter Progress Report
22 December 1970 to 4 January 1971

Gentlemen:

This is the tenth Monthly Letter Progress Report under the reference contract and covers the bi-weekly period of 22 December 1970 to 4 January 1971.

Part I:

1. Task Title: Foreign Material Exploitation

2. Indicated action from M.I.D.: none

3. Visitors to project: none

4. Trips and visits to other installations in connection with the project: none

Part II:

Assembly of material begun during the last reporting period was continued.

Respectfully submitted:

R. M. Goodman, Jr.
Head, Sensor Systems Branch

bbw

ENGINEERING EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

27 January 1971



U. S. Army Missile Command
Redstone Arsenal, Alabama 35809

Attention: AMSMI - IYC

Reference: Contract No. DAAHOI-71-C-0042

Subject: Monthly Letter Progress Report
5 January to 18 January 1971

Gentlemen:

This is the eleventh Monthly Letter Progress Report under the reference contract and covers the bi-weekly period of 5 January 1971 to 18 January 1971.

Part I:

1. Task Title: Foreign Material Exploitation

2. Indicated action from M.I.D.: none

3. Visitors to project: none

4. Trips and visits to other installations in connection with the project: none

Part II:

Recommendations for the final report were formulated on the basis of material assembled during previous periods. Arrangements were made for Mr. J. W. Holmes of M. I. D. to visit Georgia Tech to review a draft of the recommendations and final report.

Respectfully submitted:

R. M. Goodman, Jr.
Head, Sensor System Branch

bbw

A-1280

ENGINEERING EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

11 February 1971



U.S. Army Missile Command
Redstone Arsenal,
Alabama 35809

Attention: AMSMI - IYC

Reference: Contract No. DAAH01-71-C-0042

Subject: Monthly Letter Progress Report
19 January to 31 January 1971

Gentlemen:

This is the twelfth Monthly Letter Progress Report under the reference contract and covers the bi-weekly period of 19 January to 31 January 1971. The Final Report will follow this report.

Part I:

1. Task title: Foreign Material Exploitation
2. Indicated action from M.I.D.: none
3. Visitors to project: Mr. J. W. Holmes of M.I.D., 22 January 1971
4. Trips and visits to other installations in connection with the project: none

Part II:

Mr. J. W. Holmes of M.I.D. visited Georgia Tech during the report period and reviewed a draft of the recommendations and final report. Discussions were on the format and emphasis that would make the material most useful to M.I.D.

Funding Estimate

An estimate of man-month requirements to carry out the program described in the Final Report will be given in that document. For the benefit of the sponsor, we set forth here an estimate of the funding requirements to carry out the program, provided it is initiated before significant cost changes may have occurred.

| | | |
|---|---|---|
| 1. | Observation and test phase | $78,000 |
| 2. | Evaluation, conclusion, assessment phase | 51,000 |
| 3. | Program management and coordination | 28,000 |
| 4. | Clerical and administrative support | 41,600 |
| 5. | Travel | 2,200 |
| 6. | Reports, documentation | 9,800 |
| | TOTAL | $210,600 |

The total funding suggested to completely attain the objectives of the program is as follows.

| | |
|---|---|
| Basic program, as set forth above | $210,600 |
| Contingency for anticipated additional requirements | 25,000 |
| TOTAL | $235,600 |

The above total does not include contractor's fee or profit. The type of contractual arrangement recommended as most suitable for this program is cost plus fixed fee (CPFF).

This estimate was arrived at by assuming the "rule of thumb" cost of a technical R&D man-year of effort to be $35,000. This figure is commonly used by such agencies as the Air Force Materials Laboratory to estimate funding requirements of contractual efforts and includes fixed overhead, and clerical and administrative support.

Respectfully submitted:

R. M. Goodman, Jr.
Head, Sensor Systems Branch

bbw

FINAL REPORT

Project A-1280

# FOREIGN MATERIAL EXPLOITATION

Prepared for

HEADQUARTERS
US ARMY MISSILE COMMAND
REDSTONE ARSENAL, ALABAMA 35809

Under

Contract DAAH01-71-C-0042



J. Elmer Rhodes, Jr., William H. Lewis, Harvard H. Kranzlein, and Robert M. Goodman, Jr.

1971

16 February 1971

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station
Atlanta, Georgia 30332

FINAL REPORT

Project A-1280

# FOREIGN MATERIAL EXPLOITATION

by
J. ELMER RHODES, JR.
WILLIAM H. LEWIS
HARVARD H. KRANZLEIN
and
ROBERT M. GOODMAN, JR.

16 February 1971

Prepared for
Headquarters
US Army Missile Command
Redstone Arsenal, Alabama 35809
Under
Contract DAAH01-71-C-0042

## FOREWORD

This Unclassified report was prepared for the Missile Intelligence Agency, US Army Missile Command, Redstone Arsenal, Alabama, under Contract DAAH01-71-C-0042. Mr. J. W. Holmes (AMSMI-YPP) was program monitor. The program under this contract was directed by personnel of the Sensor Systems Branch of the Electronics Division, Engineering Experiment Station, Georgia Institute of Technology. The detailed technical effort was performed by a team comprised of Georgia Tech personnel and members of the technical staff of Lockheed-Georgia Co. on loan to Georgia Tech under Lockheed's LEND (Lending Employees for National Development) program. The latter service was arranged under subcontract from Georgia Tech.

Contract DAAH01-71-C-0042 was dated 19 August 1970 and provided for a two-month work period. The work to be done under the contract included examination of certain equipment at Redstone Arsenal and study of certain collateral documents to be supplied by the sponsor; the remainder of the work was to be based on information acquired in these activities. The equipment was examined in September and again in October. The sponsor encountered difficulties in gathering the requisite collateral documents and the resulting delay in acquisition of the documents by Georgia Tech for study made necessary two two-month, no-cost extensions of the work period. These extensions were arranged under Contract Amendments P00001 and P00002. The latter modification extended the performance period through 16 February 1971, with two additional weeks thereafter for preparation, submission, approval, and distribution of this Final Technical Report.

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# I. INTRODUCTION

## A. Purpose of Study

This program was intended to generate a detailed plan for examination and testing of a specific item of non-US-made hardware. The plan has been developed in format such that it can serve as a Scope of Work for an anticipated future program in which that hardware item is to be intensively studied with the aim of deriving information concerning the materials technology of the economy which fabricated it. In developing the plan of attack, consideration has been given to the implications of materials composition, quality, fabrication methods and rates, the research and development required, and cost and maintenance factors for the system as a whole.

## B. Report Organization

The text of this report is entirely Unclassified. A separately bound classified Supplement contains a short description of the specific item of hardware to be examined, a statement of the broad goals to be sought in the anticipated study of that item of hardware, and references to the collateral documents studied under this present contract.

## II. ITEMS TO BE EXPLOITED

### A. Priority of Exploitation

The order of priority for exploitation of the various items, as listed in Section II-B below, is based primarily upon the recommendations of the sponsor. It reflects the sponsor's major interest in engine components and the use of magnesium alloys in structural applications. The materials and methods used in the manufacture of tankage are also judged important areas for exploitation.

The order of priority is established only to provide a basis for selecting the more critical items to be investigated, should it be necessary to modify the program due to time or cost limitations. The priorities are not meant to imply a lesser degree of thoroughness in the investigation of lower priority items.

A classified Supplement to this report contains identification and description of the item of hardware to be studied, a discussion of the broad goals of the program, and a short list of references.

Review of previous exploitation studies of similar items indicates that heretofore only fragmentary investigation was possible, due to the limited number of components available. Also, the earlier studies related to items of a different manufacturing period. It is recommended, therefore, that all components of interest from the currently available hardware be included in this proposed investigation, including those similar to previously studied items. The few overlapping evaluations which occur will be beneficial in detecting possible changes in materials or manufacturing methods.

B. List of Components to be Tested

| Priority/Item No. | Component Description | Photograph No. * |
|---|---|---|
| 1. | Sustainer engine | 1 |
| | a. Combustion chamber and nozzle | |
| | b. Injectors and injector plate | |
| | c. Turbo pump turbine wheel and exhaust pipe | |
| | d. Propellant valves | |
| | e. Gas generator | |
| | f. Propellant lines | |
| | g. Fuel sump | |
| | h. Engine mount brackets and frame | |
| | i. IPN tank | |
| | j. Air bottle and line | |
| | k. Propellant pump impellers | |
| 2. | Magnesium alloy section | 2,6,7 |
| | a. Body | |
| | b. Hatch | |
| 3. | Tanks | 2,3,4,5 |
| | a. Oxidizer | |
| | b. Fuel | |
| 4. | Bolted junctures | 4 |
| 5. | Tank pickups | none |
| | a. Fuel tank | |
| | b. Oxidizer tank | |

* Photograph numbers here are the same as in Reference 1; see Supplement.

B. List of Components to be Tested (Continued)

| Priority/Item No. | Component Description | Photograph No. |
|---|---|---|
| 6. | Tank filler ports | none |
| | a. Fuel tank | |
| | b. Oxidizer tank | |
| 7. | Tank bulkhead | 3,4,5 |
| | a. Fuel tank | |
| | b. Oxidizer tank | |
| 8. | Outside paint | none |
| 9. | Tank baffles | none |
| | a. Fuel tank | |
| | b. Oxidizer tank | |
| 10. | Wings | 2 |
| | a. Panel | |
| | b. Support frame | |
| 11. | Nose ogive | 2 |
| 12. | Bearings | none |
| 13. | Control surfaces | 2 |
| 14. | Aft fairing | 2 |
| 15. | Boattail | none |

## III. GENERAL SCOPE OF TESTS AND EQUIPMENT REQUIRED

The specific test requirements for each item will vary according to size, geometry, function, composition, and the nature of the conclusions which are required. The accuracy, depth, or thoroughness of the tests will also depend somewhat on the desired results, but should be commensurate with sound, generally accepted engineering practice. Wherever possible, American Society for Testing Materials (ASTM) Standard Practices should be followed. As a further guideline, the specific tests and detailed procedures outlined below shall be followed whenever specified by the Detailed Test Plan (Section IV).

Equipment used, including calibration standards, and procedures followed shall be of such quality that resulting data will always be consistent with requirements of ASTM, or, alternatively, of the National Bureau of Standards.

All test specimens, photographs, photomicrographs, test data, and records of observations will be permanently maintained and surrendered to the sponsor at the conclusion of the contract. Test specimens will be identified by number, and a record describing the specimens, their origin, and their purpose will be maintained and also surrendered to the sponsor.

### A. Description - Observations

Each item specified will be inspected in sufficient depth to furnish a description for each item tested, including, but not necessarily limited to the following.

1. General configuration, function, location, and method of attachment to vehicle or related components
2. General dimensions
3. Weight

4. Method of removal from vehicle

5. Method of disassembly of component

6. Photographs of item, assembled and disassembled

7. Markings, identification numbers

8. Handling damage

9. Corrosion damage

10. Surface coatings and protective finishes

11. Surface finish

12. Method of fabrication (where apparent)

13. Special functions, i.e. sliding surfaces, bearing surfaces, etc.

The following equipment is required for performing the above observations.

1. Photographic equipment

2. Photographic laboratory (approved for processing classified material)

3. Scales and balances

4. Mensuration equipment

B. Nondestructive Testing

Nondestructive tests will be conducted as required on the items specified in the test plan to assist in the evaluation of material quality and fabrication techniques. Personnel conducting and evaluating the tests shall meet or exceed the requirements of SNT-TC-1A, "Recommended Practice for the Qualification and Certification of Nondestructive Testing Personnel," Level II.

The tests to be conducted should not necessarily be limited to, but shall include the following, when specified by the Detailed Test Plan.

1. X-Ray (Radiographic)

All radiographic testing shall be accomplished in accordance with ASTM, E 94-68, "Recommended Practice for Radiographic Testing." Where X-ray results are inconclusive, ultrasonic inspection of the questionable area will be accomplished in accordance with Item 3 below.

2. Liquid Penetrant

All liquid penetrant inspection specified shall be conducted in accordance with ASTM E 165-65, "Liquid Penetrant Inspection, Method A, Fluorescent Penetrant," and shall be accomplished following Procedures A-1 or A-2.

3. Ultrasonic

Ultrasonic inspection of the welds shall be accomplished in a manner similar to ASTM E 164-65 except that the requirements for a Reference Weldment (Para. 4) may be waived and the actual test piece used as the reference. Where applicable or desirable, the procedure described in ASTM Recommended Practice E 214-63T, "Immersed Ultrasonic Testing," may be substituted for E 164-65 at the discretion of the inspector.

4. Eddy Current (Conductivity)

Conductivity testing when specified will be conducted as specified in Aerospace Recommended Practice (ARP)891 issued by the Society of Automotive Engineers. This applies to any material or alloy when specified by the Detailed Test Plan (Section IV), and is not limited to determination of aluminum alloy tempers.

The following equipment is required for performing the above tests.

1. Radiographic facility - 200 kilovolt minimum
2. Fluorescent penetrant inspection facility
3. Ultrasonic pulse-echo flaw detection equipment
4. Eddy-current conductivity measurement equipment

C. Chemical Analysis

Qualitative and quantitative chemical analyses will be conducted on each item specified to determine the concentration of a sufficient number of elements present so that positive material identification can be made.

1. Metallic Materials (4 samples normally required)

a. Optical emission spectrographic analysis to determine major elements and relative concentrations.

b. X-ray fluorescence analysis for specific concentration of chromium, nickel, iron, manganese, molybdenum, zinc, copper, etc.

c. Atomic absorption spectrophotometer analysis for specific concentrations of magnesium, aluminum, silicon, titanium and other trace elements which potentially influence the properties of alloys of the type being analyzed.

d. Combustion carbon analysis of sufficient accuracy to determine carbon content to $\pm$ 0.01%.

e. Flame emission spectrographic analysis for alkaline earth metals when the concentration requires the use of this technique.

f. Wet chemistry analytical methods for elements not suitable to instrumentation methods.

2. Non-Metallic Materials (2 samples normally required)

a. Infrared spectrophotometric analysis for identifying elastomeric materials, including thin-film spectrum analysis, potassium bromide pellet techniques, and pyrolyzate analysis after pyrolysis of specimen in an inert atmosphere. Infrared attenuated total reflectance analysis will also be conducted on pliable materials where applicable.

b. Gas chromatographic analysis with pyrolyzer accessory for identification of unknown plastics, rubbers, and adhesives. This method will supplement infrared analysis.

c. Near-infrared, visible, and ultraviolet spectrophotometric analysis for analysis of specific materials, including adhesives and lubricants. Ultraviolet analysis will be used if needed for trace stabilizers in plastics.

Note: Electron probe microanalysis should be considered as an applicable method of chemical analysis in such cases as identification of metallic and nonmetallic constituents in alloys, identification of the composition of brazing alloys, and/or when more conventional methods of analysis are inadequate.

The following equipment is required for performing the above tests.

1. Optical emission spectrograph
2. X-ray spectrograph
3. Atomic absorption spectrophotometer
4. Flame emission spectrophotometer
5. Carbon analyzer
6. Wet chemistry analytical facility
7. Infrared spectrophotometer
8. Gas chromatograph
9. Electron probe microanalyzer

D. Metallographic and Microscopic Analyses

Metallographic and microscopic analyses will be conducted on each specified item of sufficient extent to characterize the constituents and structure of the metal and alloys, to determine the nature of defects in base metals and/or welded or brazed joints, and to determine the physical characteristics of joints and surfaces.

Written records of macroscopic and microscopic analysis will be made, and supplemented by sufficient macrographs and micrographs to substantiate

and illustrate conclusions of the metallographic study. The record will include the exact location from which metallographic specimens were taken, and will designate the orientation of the surface examined relative to an identifiable reference frame on the component or system.

1. Metallographic Analysis, Macroscopic

a. Specimens for macroscopic analysis will be taken from base metal, welded joints, brazed joints, and mechanically fastened joints in accordance with the specified test plans.

b. Cutting, machining, and all other sample preparation methods shall not alter the basic properties and structure of the metal or alloy.

c. Macroscopic examination of sufficient depth will be made to determine macroscopic characteristics including but not necessarily limited to the following.

1) Evidence of defects produced by casting, primary or secondary metal-forming operations and machining.

2) Weld joint configuration, weld method (manual or automatic), number of passes, and weld quality, e.g., porosity, cracks, inclusions, oxides.

3) Brazed joint configuration, fitup, and defects, e.g., insufficient wetting.

2. Metallographic Analysis, Microscopic

a. Metallographic specimens will be taken as specified in the test plans.

b. Cutting, machining, and all other sample preparation methods shall not alter the basic properties and structure of the metal or alloy.

c. Where feasible, specimens used for macroscopic study may be repolished and etched for microscopic examination.

d. Metallographic preparation, examination, and photomicroscopy will be made in conformance with standard metallographic practice at least equivalent to ASTM Standards.

e. Microscopic examination will be made in sufficient detail to determine microstructural characteristics, including but not necessarily limited to the following.

1) Type of structure, cast or wrought

2) Grain size and shape and/or distortion indicative of forming or shaping

3) Identification and distribution of phases present

4) Distribution of non-metallic impurities and other imperfections

5) Heat treat condition

6) Weld joint structure (weld deposit and heat-affected zone)

7) Evidence of segregation or microstructural nonuniformity

Also, where applicable:

8) Surface imperfections

9) Thickness, structure, and continuity of protective coating

10) Evidence of corrosion and/or wear

11) Degree of plastic deformation

f. Optical microscopy will be used at magnifications up to 1000 diameters.

g. Applicable ASTM Standards

1) E2-62

2) E3-62

3) E112-63

4) E157-63

5) E340-68

3. Electron Microscopy

Electron microscopy will be used only to supplement optical microscopy where specified in the test plan, and/or where necessary to adequately describe the constituents or structure of materials.

a. Replica and/or transmission electron microscopy methods may be used. Details of specimen preparation must be recorded.

b. Sampling must be sufficient to ensure observations are truly representative of microstructure.

Note: Scanning electron microscopy will be used only where specified in the test plan and/or if necessary to adequately describe surfaces or surface-related phenomena when more conventional methods of analysis are inadequate.

The following equipment is required for performing the above tests.

a. Machine shop

b. Metallographic specimen-preparation facility, including grinding and polishing equipment, chemical and electrochemical etching apparatus

c. Metallographs and microscopes suitable for observations up to 1000 diameters

d. Photographic equipment and darkroom facilities

e. Electron microscope and associated specimen-preparation apparatus

f. Scanning electron microscope

E. Physical and Mechanical Properties

Physical and mechanical properties will be tested for each item specified in sufficient detail to determine the average values of each required physical or mecahnical property. All tests will be conducted on equipment calibrated in conformance with appropriate ASTM standards or equivalent.

Tests to be conducted include but are not necessarily limited to the following.

1. Tensile Tests

a. Where tensile testing is specified, determine yield strength, tensile strength, elongation, and reduction in area in conformance with accepted standard procedures (ASTM) where possible. In all cases, details of test procedure must be reported, e.g., sample geometry, gage length, strain rates, type and calibration of test equipment used.

b. If possible, a minimum of three specimens will be tested to obtain the average value for each property determination required.

c. Samples will be removed from test items in conformance with the specified test plan, and each sample will be identified to completely describe the exact location and orientation from which it was taken.

d. All tests are to be conducted at ambient temperature.

e. Tensile tests of welded joints will be made both with weld bead intact and with weld bead ground flush.

f. Applicable ASTM Standards

1) E4-64

2) E8-69

3) E74-64

4) E83-67

5) A370-68

2. Hardness Tests

a. Hardness tests will be made where specified in the test plan.

b. Details of type test used will be reported as well as specimen preparation procedures. All tests will be in conformance with applicable ASTM standards or equivalent.

c. A minimum of five hardness readings will be made to determine the average hardness number.

d. Samples will be removed from test items in conformance with the test plan and each specimen will be identified to completely describe the location and orientation from which it was taken.

e. Applicable ASTM Standards

1) E10-66

2) E18-67

3) E92-67

4) E140-67

The following equipment is required for performing the above tests.

a. Tensile testing machine (calibrated)

b. Extensometer (calibrated)

c. Hardness testing machines (Brinell and Rockwell)

d. Microhardness testing machine

3. Properties of Paints and Coatings

a. Properties of paints and coatings will be determined where specified in the test plan or where detailed observations warrant such determinations.

b. Details of test procedures, including specimen preparation, will be reported. All tests will be conducted in conformance with standard practice as specified in ASTM Standards or equivalent.

c. Properties to be evaluated shall include but not necessarily be limited to the following.

1) Corrosion protection and service life

2) Abrasion resistance

3) Adhesion

4) Temperature resistance (Tests similar to those specified in ASTM D2485-68, Procedure Method 2)

d. Applicable ASTM Standards

1) B117-64

2) D658-44

3) D968-51

4) D1654-61

5) D1197-68

The following equipment is required for performing the above tests.

a. Salt spray cabinets

b. Abrasion test apparatus

c. Adhesion test apparatus

d. Weatherometer

4. Melting-Point Determination

a. The melting point (range) for brazing alloys will be determined where specified in the test plan.

b. Details of the test method will be reported. All tests will be conducted in conformance with standard practice as specified in ASTM standards or equivalent.

c. A minimum of three melting-point (range) determinations will be made for each brazing alloy.

d. Applicable ASTM Standard

E14-63

The following equipment is required for performing the above tests.

a. Furnace

b. Temperature measuring devices (calibrated)

c. Time measuring devices (calibrated)

5. Vibration Damping Capacity

a. The damping constants of alloys will be determined where specified in the test plan.

b. The damping constant shall be determined for torsional, shear, and longitudinal modes of strain.

c. Details of test procedures will be recorded. Three determinations of damping constant for each of five samples from each alloy shall be used to determine the average damping constant.

The following equipment is required for performing the above tests.

a. Machine shop

b. Elastomat or equivalent apparatus for determining elastic constants

6. Determination of Galvanic Potential

Areas of dissimilar metal contact will be located and the galvanic potential of each material will be measured with respect to a standard-reference electrode.

a. Applicable Method

The galvanic potential will be measured by means of a potentiometer in series with an electrometer connected to a reference calomel electrode. The exact procedure will be as delineated in Experimental Electrode Kinetics by N. D. Greene of Rensselaer Polytechnic Institute, or in accordance with approved NBS procedures.

The following equipment is required for performing the above tests.

a. Electrometer

b. Potentiometer

c. Reference calomel electrode

d. Standard polarization cell

7. Bearings

Determine the type of bearings used in all high-rpm applications, (i.e., turbines, pumps), their method of construction, and the materials used. Bearing materials will be analyzed to determine the composition. Lubricating characteristics will be evaluated to determine type of lubricant used, such as liquid, solid-film, plastic, impregnated materials, or soft babbitt-like materials. Hardness readings of bearing surfaces will be made. The temperature resistance of the material will be determined. Bearings will be examined by experts in bearing technology to determine the construction and assembly techniques.

## IV. DETAILED COMPONENT TEST PLANS

This section specifies minimum test requirements for each component listed in Section II-B. All tests will be conducted in conformance with requirements set forth in Section III. As a guide to the sequence and general scope of testing required, a flow chart for component testing is presented in Fig. 1 (see page 74).

The test plans specified here are best estimates based on study of available information and photographs, and on visual inspection of the hardware without detailed observation or disassembly. Additional test requirements may of course become obvious in later work.

The requirement to determine the method of manufacture is of particular importance to the sponsor. The test program outlined in this section should be sufficient for this determination in most cases. Should difficulty in assessing the manufacturing method be encountered, the sponsor will be notified immediately and provided with a recommendation for further evaluation procedures. Such procedures, when beyond the scope of the detailed test plan, will be considered under the contingency provisions outlined in Section VI-C.

TEST PLAN

A-1 Sustainer Engine: Combustion Chamber and Nozzle (Item 1a*)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing

a. X-ray all welds and brazed joints

b. Penetrant inspect welds

c. X-ray through chamber walls at injector end, throat, nozzle end flange, and oxidizer manifold

3. Chemical Analysis

a. Identify alloy composition and type used in chamber walls (4 samples required - random sampling)

b. Identify composition of weld alloys (4 samples required - random sampling)

c. Identify braze alloy composition - base and exit positions (8 samples required - random sampling - 4 each position)

4. Metallographic and Microscopic Analysis

a. Metallographic evaluation and micrographs of alloy(s) used in combustion chamber walls and nozzle (4 specimens required - random sampling)

b. Macrographs of sections through combustion chamber and nozzle walls, through oxidizer manifold, flange, throat, and propellant manifold (12 specimens required - random sampling - 2 each at positions specified)

*Item numbers of components are as listed in Section II-B.

5. Physical and Mechanical Property Analysis

a. Hardness tests - combustion chamber and nozzle walls (4 specimens required)

b. Hardness tests - oxidizer manifold, flange, and throat areas (6 specimens required, 2 each area)

c. Microhardness traverse of welded and brazed joints (8 specimens - 2 each from oxidizer manifold, flange, throat, and propellant manifold)

d. Melting temperature range for brazing alloys (3 specimens required each brazing alloy - multiple alloys possible if stepbrazing techniques are employed - total number of specimens undetermined)

TEST PLAN

A-2 Sustainer Engine: Injectors and Injector Plate (Item 1b)

1. General Description and Observations

   a. Include all items applicable in Section III-A

   b. Check concentricity, tolerance control (6 samples required)

2. Nondestructive Testing - X-ray injector-plate assembly

3. Chemical Analysis

   a. Identify injector-plate alloy composition and type (4 samples required - random sampling)

   b. Identify injector alloy composition and type (4 samples required-random sampling)

   c. Identify brazing alloy composition (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis

   a. Macrographs of injector-plate assembly cross-section (2 specimens required)

   b. Metallographic evaluation and micrographs of injector-plate alloy (2 specimens required)

   c. Metallographic evaluation and micrographs of injector alloy (2 specimens required)

   d. Metallographic evaluation and micrographs of brazed joints (6 specimens required)

5. Physical and Mechanical Property Analysis

   a. Hardness test, injector plate (2 specimens required)

   b. Hardness test, injector nozzle (2 specimens required)

c. Microhardness traverse of brazed joint (3 specimens required)

d. Determine brazing temperature range (3 specimens required)

TEST PLAN

A-3 Sustainer Engine: Turbopump Turbine Wheel and Exhaust Pipe (Item 1c)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing

a. 100% inspection of all welds in turbine wheel and exhaust pipe

b. X-ray all welds

c. Penetrant inspect welds, mark all significant defects for metallographic evaluation and document location

3. Chemical Analysis

a. Identify alloy composition and type used in turbine wheel (8 samples required - 4 samples each from wheel and blades)

b. Identify exhaust-pipe alloy and type (4 samples required - random sampling)

c. Identify weld alloy composition (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis

a. Metallographic evaluation and micrographs of turbine-wheel alloy (4 specimens required - 2 specimens each from wheel and blades)

b. Metallographic analysis and micrographs of exhaust-pipe alloy (2 samples required - random sampling)

c. Metallographic analysis, macrographs, and micrographs of turbine-wheel welds (2 samples required)

d. Metallographic evaluation and micrographs or macrographs of all significant weld defects found by nondestructive testing

5. Physical and Mechanical Property Analysis - Hardness test of turbine wheel, blades, and exhaust pipe (6 specimens required)

TEST PLAN

A-4 Sustainer Engine: Propellant Valves (Item 1d)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing - X-ray valve housing (oxidizer valve and fuel valve)

3. Chemical Analysis

a. Identify alloy composition and type used in each valve component (approximately 32 samples required - 2 each from each component of oxidizer valve and fuel valve)

b. Identify gasket and sealant materials

4. Metallographic and Microscopic Analysis - Metallographic evaluation and micrographs of each valve component (approximately 32 samples required - 2 each from each component of oxidizer valve and fuel valve)

5. Physical and Mechanical Property Analysis - Hardness tests of each component (test may be made directly on component where feasible)

TEST PLAN

A-5 Sustainer Engine: Gas Generator (Item 1e)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing

   a. X-ray all welds

   b. Penetrant inspect welds

3. Chemical Analysis

   a. Identify gas-generator alloy composition and type (4 samples required - random sampling)

   b. Identify weld alloy composition (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis

   a. Metallographic evaluation and micrographs of generator alloy (2 specimens required - random sampling)

   b. Metallographic evaluation, macrographs, and micrographs of welds (2 specimens required - 1 from longitudinal weld - 1 from circumferential weld)

5. Physical and Mechanical Property Analysis

   a. Hardness test of gas-generator alloy (2 specimens required - 1 from wall, 1 from end closure)

   b. Microhardness traverse of welds (2 specimens required - 1 from longitudinal wall, 1 from circumferential weld)

TEST PLAN

A-6 Sustainer Engine: Propellant Lines (Item 1f)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing

   a. X-ray all welded junctions

   b. Penetrant inspect all welded junctions

3. Chemical Analysis

   a. Identify tubing alloy composition and type (4 samples required - random sampling)

   b. Identify weld-metal alloy composition (4 samples required - random sampling)

4, Metallographic and Microscopic Analysis

   a. Metallographic evaluation and micrographs of tubing alloys (2 specimens required - random sampling)

   b. Metallographic evaluation, macrographs, and micrographs of welds (4 specimens required)

5. Physical and Mechanical Property Analysis

   a. Hardness tests (2 specimens required - random sampling)

   b. Microhardness traverse of welds (2 specimens required - random sampling)

TEST PLAN

A-7 Sustainer Engine: Fuel Sump (Item 1g)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing

   a. X-ray welds

   b. Penetrant inspect welds

3. Chemical Analysis

   a. Identify fuel-sump alloy composition and type (4 samples required - random sampling)

   b. Identify weld-metal composition (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis

   a. Metallographic evaluation and micrographs of fuel-sump alloy (2 specimens required - random sampling)

   b. Metallographic evaluation, macrographs, and micrographs of welds (2 specimens required - random sampling)

5. Physical and Mechanical Property Tests

   a. Hardness test fuel-sump alloy (2 specimens required - random sampling)

   b. Microhardness traverse of welds (2 specimens required - random sampling)

TEST PLAN

A-8 Sustainer Engine: Engine-Mount Brackets and Frame (Item 1h)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing

   a. X-ray all welds

   b. Penetrant inspect welds

3. Chemical Analysis

   a. Identify bracket alloy composition and type (4 samples required - random sampling)

   b. Identify weld alloy composition (4 samples required - random sampling)

   c. Identify alloy composition of mounting bolts (4 samples required)

4. Metallographic and Microscopic Analysis

   a. Metallographic evaluation of bracket alloy (2 specimens required - random sampling)

   b. Metallographic evaluation of welds, macrographs, and micrographs (4 specimens required - include bracket welds and bracket-to-engine welds)

   c. Metallographic evaluation of bolt alloy and micrographs (2 specimens required - 1 each of shank and head areas)

5. Physical and Mechanical Property Analysis

   a. Tensile test bracket alloy (3 specimens required - random sampling)

b. Tensile test mounting bolt (2 bolts required)

c. Microhardness traverse of welds (4 specimens required - 2 specimens from bracket welds, 2 specimens from bracket-to-engine welds)

TEST PLAN

A-9 Sustainer Engine: IPN Tank and Bladder (Item 1i)

1. General Description and Observations

a. Include all items applicable in Section III-A

b. IPN Tank and Bladder shall be examined both as a unit and individually

2. Nondestructive Testing - 100% NDT inspection of all welds in both tank and bladder - mark all significant defects for metallographic evaluation and record location

3. Chemical Analysis

a. Identify tank alloy composition and type (4 samples required - random sampling)

b. Identify tank weld-metal composition (4 samples required - random sampling)

c. Identify alloy composition and type used in each half of bladder (8 samples required - random sampling - 4 samples from each half of bladder)

d. Identify bladder weld-metal composition (4 samples required - random sampling)

e. Identify nonmetallic support ring (2 samples required)

4. Metallographic and Microscopic Analysis

a. Metallographic evaluation and micrographs of tank alloy (2 samples required - random sampling)

b. Metallographic evaluation, macrographs, and micrographs of

welds (3 samples required, 1 each from girth weld, bracket welds, and fitting welds)

c. Metallographic evaluation and micrographs of alloy used in each half of bladder (4 samples required - random sampling - 2 from each half)

d. Metallographic evaluation, macrographs, and micrographs of bladder girth weld (2 samples required - random sampling)

e. Metallographic evaluation and macrographs or micrographs of all significant weld defects found by NDT

5. Physical and Mechanical Property Analysis

a. Tensile test IPN tank alloy (3 samples required - random sampling)

b. Tensile properties of tank girth weld (6 samples required - random sampling - 3 with weld bead intact - 3 with weld bead ground flush)

c. Tensile properties of each half of bladder (6 samples required - random sampling - 3 from each half)

d. Tensile properties of bladder girth weld (6 samples required - random sampling- 3 with weld bead intact - 3 with weld bead ground flush)

e. Hardness test of tank alloy (6 samples required - random sampling - 2 samples from base metal - 4 samples from welds - microhardness traverse of welds required)

f. Hardness test of bladder alloys (6 samples required - random sampling - 2 from base alloy of each half - 2 from weld - microhardness traverse of weld required)

TEST PLAN

A-10 Sustainer Engine: Air Bottle and Line (Item 1j)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing

   a. X-ray all welds in bottle

   b. Penetrant inspect welds

3. Chemical Analysis

   a. Identify bottle alloy composition and type (4 samples required - random sampling)

   b. Identify composition of weld alloy (4 samples required - random sampling)

   c. Identify air-line alloy composition and type (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis

   a. Metallographic evaluation and micrographs of bottle alloy (2 samples required - longitudinal and transverse samples)

   b. Metallographic evaluation, macrographs, and micrographs of welds (2 samples required)

   c. Metallographic evaluation and micrographs of air-line alloy (2 samples required - random sampling)

5. Physical and Mechanical Property Analysis

   a. Tensile test of air-bottle alloy (3 samples required)

   b. Hardness test of air-bottle alloy (2 samples required - random sampling)

c. Microhardness traverse of welds (2 samples required - random sampling)

TEST PLAN

A-11 Sustainer Engine: Propellant Pump Impellers (Item 1k)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing

   a. X-ray all welds

   b. Penetrant inspect welds

3. Chemical Analysis

   a. Identify impeller alloy composition and type (8 samples required - 4 each from oxidizer and fuel impellers)

   b. Identify weld alloy composition (8 samples required - 4 each from oxidizer and fuel impellers)

4. Metallographic and Microscopic Analysis

   a. Metallographic evaluation and micrographs of impeller alloys (4 samples required - 2 each from oxidizer and fuel impellers)

   b. Metallographic evaluation, macrographs, and micrographs of welds (4 samples required - 2 each from oxidizer and fuel impellers)

5. Physical and Mechanical Property Analysis

   a. Hardness test - (4 samples required - 2 each from oxidizer and fuel impellers)

   b. Microhardness traverse of welds (4 samples required - 2 each from oxidizer and fuel impellers)

TEST PLAN

B-1 Magnesium-Alloy Section: Body (Item 2a)

1. General Description and Observations - Include 11 items applicable in Section III-A

2. Nondestructive Testing

a. 100% NDT inspection of all welds on surface of magnesium-alloy section

b. X-ray all welds

c. Penetrant inspect welds

d. Conductivity scan welds, mark all significant defects for metallographic evaluation, and record location

3. Chemical Analysis

a. Identify base metal composition and type (4 samples required - random sampling)

b. Identify weld metal composition (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis

a. Metallographic evaluation and micrographs of base metal (3 samples required - random sampling, include section through ribs or stringers)

b. Metallographic evaluation and micrographs and macrographs of welds (4 samples required - random sampling)

c. Metallographic evaluation and micrographs or macrographs of all significant weld defects found by NDT

5. Physical and Mechanical Property Analysis

a. Tensile properties of base metal (3 samples required - random sampling - tensile axis parallel to longitudinal axis of magnesium-alloy section)

b. Tensile properties of weld (6 samples required - random sampling - 3 samples with weld bead intact, 3 with weld bead ground flush)

c. Hardness test (6 samples required - 2 samples from base metal - 4 from welds - microhardness traverse of welds required)

d. Analysis of protective coatings and sealants on welded and/or bolted joints

e. Analysis of protective coatings on inboard surfaces

f. Vibration damping analysis

Note: Analysis of vibration damping characteristics of the magnesium-alloy structure is not included in this test plan, but should be considered as a possible additional evaluation under the contingency plan discussed in Section VI-C.

TEST PLAN

B-2 Magnesium-Alloy Section: Hatch (Item 2b)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing

   a. X-ray all welds

   b. Penetrant inspect welds

3. Chemical Analysis

   a. Identify base metal composition and type (4 samples required - random sampling)

   b. Identify weld metal composition (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis

   a. Metallographic evaluation and micrographs of base metal (5 samples required - 2 random samples, 1 sample each from typical rib section, stringer section, and access port flange)

   b. Metallographic evaluation and micrographs and macrographs of welds (6 samples, 1 each from access port flanges and each body weld)

5. Physical and Mechanical Property Analysis

   a. Tensile test of base metal (3 samples required - random sampling)

   b. Hardness test (6 samples required - 2 random samples - 4 weld samples - microhardness traverse on weld samples required)

   c. Analysis of protective coatings and sealants on welded and/or bolted joints

d. Analysis of protective coating on inboard surfaces

e. Vibration damping analysis

TEST PLAN

C-1 Tanks: Oxidizer (Item 3a)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing

a. 100% NDT inspection of all welds on tank surface required

b. X-ray all welds

c. Penetrant inspect welds

d. Conductivity scan welds, mark all significant defects for metallographic evaluation and record location.

3. Chemical Analysis

a. Identify composition of tank alloy (4 samples required - random sampling)

b. Identify composition of weld metal (4 samples required - random sampling from longitudinal and circumferential welds)

c. Identify protective coatings and sealants on welded and/or bolted joints

d. Identify protective coatings on interior of tank

4. Metallographic and Microscopic Analysis

a. Metallographic evaluation and micrographs of tank alloy (2 samples required - random sampling)

b. Metallographic evaluation and micrographs and macrographs of welds (6 samples required - 2 each from single longitudinal welds, single circumferential welds, double circumferential welds)

c. Metallographic evaluation and micrographs or macrographs of all significant weld defects found by NDT

5. Physical and Mechanical Property Analysis

a. Tensile tests of base metal (3 samples required - random sampling - tensile axis parallel to longitudinal axis of tank)

b. Tensile tests of welds

1) Single welds (12 samples required - random sampling - 3 samples each from longitudinal and circumferential welds with weld bead intact - 3 samples each from longitudinal and circumferential welds with weld ground flush)

2) Double welds at bulkhead (6 samples required - 2 samples from base metal - 4 samples from welds - microhardness traverse of welds required)

c. Hardness test (6 samples required - 2 samples from base metal - 4 samples from welds - microhardness traverse of welds required)

TEST PLAN

C-2 Tanks: Fuel (Item 3b)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing

a. 100% NDT inspection of all welds on tank surface required

b. X-ray all welds

c. Penetrant inspect welds

d. Conductivity scan welds, mark all significant defects for metallographic evaluation and record location

3. Chemical Analysis

a. Identify composition of tank alloy (4 samples required - random sampling)

b. Identify composition of weld metal (4 samples required - random sampling from longitudinal and circumferential welds)

4. Metallographic and Microscopic Analysis

a. Metallographic evaluation and micrographs of tank alloy (2 samples required - random sampling)

b. Metallographic evaluation and micrographs and macrographs of welds (6 samples required - 2 each from single longitudinal welds, single circumferential welds, double circumferential welds)

c. Metallographic evaluation and micrographs or macrographs of all significant weld defects found by NDT

5. Physical and Mechanical Property Analysis

a. Tensile tests of base metal (3 samples required - random sampling - tensile axis parallel to longitudinal axis of tank)

b. Tensile tests of welds

1) Single welds (12 samples required - random sampling - 3 samples each from longitudinal and circumferential welds with weld bead intact - 3 samples each from longitudinal and circumferential welds with weld ground flush)

2) Double welds at bulkhead (6 samples required, random sampling - 3 samples weld intact, 3 samples weld ground flush)

TEST PLAN

D Bolted Junctures (Item 4)

1. General Description and Observations

   a. Include all items applicable in Section III-A

   b. Note use of tape, sealants, gaskets, etc.

   c. Examine for corrosion between dissimilar metals

2. Nondestructive Testing - None required

3. Chemical Analysis

   a. Identify tape material used as sealant (4 samples required)

   b. Identify sealing gaskets and compounds

   c. Identify bolt alloy composition (4 samples required)

4. Metallographic evaluation and micrographs of each different type of bolt or fastener (two samples from each type bolt or fastener - total number of samples undetermined)

5. Physical and Mechanical Property Analysis

   a. Tensile test each different type of bolt or fastener (3 bolts or fasteners of each type are to be tested where possible - total number of tests undetermined)

   b. Shear tests of fasteners may be substituted for tensile tests or added to test plan if shear-strength appears critical to application

   c. Hardness test (2 samples from each type bolt or fastener - total number of tests undetermined)

   d. Solution potential measurements for susceptibility to galvanic attack (2 samples required)

TEST PLAN

E-1Tank Pickups: Fuel Tank Pickup (Item 5a)

1. General Description and Observations

   a. Include all items applicable in Section III-A

   b. Note particularly method of attachment to tank

2. Nondestructive Testing - None required

3. Chemical Analysis - Identify pickup alloy composition and type (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis - Metallographic evaluation and micrographs of pickup alloy (2 samples required - random sampling)

5. Physical and Mechanical Property Analysis - Hardness test of pickup alloy (2 samples required - random sampling)

TEST PLAN

E-2 Tank Pickups: Oxidizer Tank (Item 5b)

1. General Description and Observations

   a. Include all items applicable in Section III-A

   b. Note particularly method of attachment to tank

2. Nondestructive Testing - None required

3. Chemical Analysis - Identify pickup alloy composition and type (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis - Metallographic evaluation and micrographs of pickup alloy (2 samples required - random sampling)

5. Physical and Mechanical Property Analysis - Hardness test of pickup alloy (2 samples required - random sampling)

TEST PLAN

F-1 Tank Filler Ports: Fuel Tank (Item 6a)

1. General Description and Observations

   a. Include all items applicable in Section III-A

   b. Note particularly method of construction and system used to prevent galvanic attack

2. Nondestructive Testing

   a. X-ray all welds

   b. Penetrant inspect all welds

3. Chemical Analysis

   a. Identify filler-port alloy composition and type (4 samples required - random sampling)

   b. Identify any protective coatings or sealants

4. Metallographic and Microscopic Analysis

   a. Metallographic evaluation and micrographs of filler-port alloy (2 samples required - random sampling)

   b. Metallographic evaluation, macrographs, and micrographs of filler-port tank weld junction (2 samples required - random sampling)

5. Physical and Mechanical Property Analysis

   a. Hardness test of filler-port alloy (2 samples required - random sampling)

   b. Microhardness traverse of filler port - tank weld junction (2 samples required)

TEST PLAN

F-2 Tank Filler Ports: Oxidizer Tank (Item 6b)

1. General Description and Observations

   a. Include all items applicable in Section III-A

   b. Note particularly method of construction and means used to prevent galvanic attack

2. Nondestructive Testing

   a. X-ray all welds

   b. Penetrant inspect all welds

3. Chemical Analysis

   a. Identify filler-port alloy composition and type (4 samples required - random sampling)

   b. Identify any protective coatings or sealants

4. Metallographic and Microscopic Analysis

   a. Metallographic evaluation and micrographs of filler-port alloy (2 samples required - random sampling)

   b. Metallographic evaluation, macrographs, and micrographs of filler-port tank weld junction (2 samples required - random sampling)

5. Physical and Mechanical Property Analysis

   a. Hardness test of filler-port alloy (2 samples required - random sampling)

   b. Microhardness traverse of filler port - tank weld junction (2 samples required)

TEST PLAN

G-1 Tank Bulkheads: Fuel Tank (Item 7a)

1. General Description and Observations

   a. Include all items applicable in Section III-A

   b. Note especially evidence of method of manufacture

2. Nondestructive Testing

   a. X-ray all welds

   b. Penetrant inspect welds

   c. Conductivity scan selected areas

3. Chemical Analysis

   a. Identify bulkhead alloy composition and type (4 samples required - random sampling)

   b. Identify weld alloy composition (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis

   a. Metallographic evaluation and microscopy of bulkhead alloy (2 specimens required - random sampling)

   b. Metallographic evaluation, macrographs, and micrographs of welds (2 specimens required - random sampling)

5. Physical and Mechanical Property Analysis

   a. Tensile test bulkhead alloy (6 specimens required - 3 each from radial and circumferential directions)

   b. Tensile test welds (6 specimens required - random sampling - 3 specimens with weld bead intact - 3 specimens with weld bead ground flush)

c. Hardness test of bulkhead alloy (2 specimens required - random sampling)

d. Microhardness traverse of welds (2 specimens required - random sampling)

TEST PLAN

G-2 Tank Bulkheads: Oxidizer Tank (Item 7b)

1. General Description and Observations

   a. Include all items applicable in Section III-A

   b. Note especially evidence of method of manufacture

2. Nondestructive Testing

   a. X-ray all welds

   b. Penetrant inspect welds

   c. Conductivity scan selected areas

3. Chemical Analysis

   a. Identify bulkhead alloy composition and type (4 samples required - random sampling)

   b. Identify weld alloy composition (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis

   a. Metallographic evaluation and microscopy of bulkhead alloy (2 samples required - random sampling)

   b. Metallographic evaluation, macrographs, and micrographs of welds (2 samples required - random sampling)

5. Physical and Mechanical Property Analysis

   a. Tensile test bulkhead alloy (6 samples required - 3 each from radial and circumferential directions)

   b. Tensile test welds (6 samples required - random sampling - 3 samples with weld bead intact - 3 with weld bead ground flush)

c. Hardness test of bulkhead alloy (2 samples required - random sampling)

d. Microhardness traverse of welds (2 samples required - random sampling).

TEST PLAN

H Outside Paint (Item 8)

1. General Description and Observations

   a. Include all items applicable in Section III-A

   b. Note evidence of wear, deterioration, holidays, lack of adhesion of coatings

2. Nondestructive Testing - Determine paint thickness

3. Chemical Analysis - Determine composition and type of paint and primer (8 samples required - 4 each from paint and primer)

4. Metallographic and Microscopic Analysis - None required

5. Physical and Mechanical Property Analysis

   a. Determine corrosion protection effectiveness of paint system

   b. Determine adhesion of paint system

   c. Determine environmental resistance of paint system

   d. Determine heat resistance of paint system

TEST PLAN

I-1 Tank Baffles: Fuel Tank (Item 9a)

1. General Description and Observations

   a. Include all items applicable in Section III-A

   b. Note shape and distribution of baffles

2. Nondestructive Testing

   a. X-ray all welds

   b. Penetrant inspect welds

3. Chemical Analysis

   a. Identify baffle alloy composition and type (4 samples required - random sampling)

   b. Identify weld alloy composition (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis

   a. Metallographic evaluation and micrographs of baffle alloy (2 samples required - random sampling)

   b. Metallographic evaluation, macrographs, and micrographs of welds (2 samples required - random sampling)

5. Physical and Mechanical Property Analysis

   a. Tensile test of baffle alloy (3 samples required - random sampling)

   b. Hardness test of baffle alloy (2 samples required - random sampling)

TEST PLAN

I-2 Tank Baffles: Oxidizer Tank (Item 9b)

1. General Description and Observations

   a. Include all items applicable in Section III-A

   b. Note shape and distribution of baffles

2. Nondestructive Testing

   a. X-ray all welds

   b. Penetrant inspect welds

3. Chemical Analysis

   a. Identify baffle alloy composition and type (4 samples required - random sampling)

   b. Identify weld alloy composition (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis

   a. Metallographic evaluation and micrographs of baffle alloy (2 samples required - random sampling)

   b. Metallographic evaluation, macrographs, and micrographs of welds (2 samples required - random sampling)

5. Physical and Mechanical Property Analysis

   a. Tensile test of baffle alloy (3 samples required - random sampling)

   b. Hardness test of baffle alloy (2 samples required - random sampling)

TEST PLAN

J-1 Wings: Panel (Item 10a)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing - None required

3. Chemical Analysis

a. Identify alloy composition and type (4 samples required - random sampling)

b. Identify composition of pins and rivets

4. Metallographic and Microscopic Analysis - Metallographic evaluation and micrographs and macrographs (5 samples required - 1 longitudinal and 1 traverse section - samples to include ribs; 1 sample from mounting tongues; 1 sample each from headless rivets (pins) and flathead rivets)

5. Physical and Mechanical Property Analysis

a. Tensile tests (6 samples required - 3 longitudinal and 3 traverse to plate rolling direction)

b. Hardness tests (2 samples required - random sampling)

TEST PLAN

J-2 Wings: Support Frame (Item 10b)

1. General Description and Observation - Include all items applicable in Section III-A

2. Nondestructive Testing

   a. X-ray support frame

   b. Penetrant inspect support frame

3. Chemical Analysis

   a. Identify support-frame alloy composition and type (4 samples required - random sampling)

   b. Identify support-frame gasket material (4 samples required - random sampling)

   c. Identify support-frame metal cover (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis - Metallographic evaluation and micrographs of support-frame alloy (4 samples required - 2 from body of frame - 2 from arms of frame)

5. Physical and Mechanical Property Analysis

   a. Hardness test (4 samples required - 2 from wing support-frame body - 2 from arms of frame)

   b. Tensile Test (6 samples required - 3 from wing support-frame body - 3 from arms of frame)

TEST PLAN

K Nose Ogive (Item 11)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing - None required

3. Chemical Analysis

a. Identify ogive alloy composition and type (4 samples required - random sampling)

b. Identify rivet alloy composition (4 samples required)

4. Metallographic and Microscopic Analysis

a. Metallographic evaluation and micrographs of ogive alloy (2 samples required - longitudinal and transverse sections)

b. Section through riveted assembly to demonstrate fitup, sealants, etc. (macrographs required)

5. Physical and Mechanical Property Analysis

a. Tensile test (3 samples required - random sampling - tensile axis parallel to longitudinal axis of component)

b. Hardness test (2 samples required - random sampling)

c. Solution potential measurements for susceptibility to galvanic attack (2 samples required)

TEST PLAN

L Bearings: All high-rpm applications (Item 12)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing - None required

3. Chemical Analysis

a. Identify alloy composition and type used in bearings including: balls or rollers, races, housings, and bushings (4 samples required from each bearing component - total number of samples not determined)

b. Identify composition and type of lubricants (2 samples required from each lubricant - total number of samples not determined)

4. Metallographic and Microscopic Analysis

a. Metallographic evaluation and micrographs of each alloy used in bearings including: balls or rollers, races, housings, and bushings (2 specimens required from each bearing component - total number of specimens not determined)

b. Macrograph of bearing cross-section (1 specimen required of each type bearing - total number of specimens not determined)

5. Physical and Mechanical Property Analysis

Hardness test all bearing components including: balls or rollers, races, housings, and bushings (2 specimens required from each bearing component - total number of specimens not determined)

TEST PLAN

M Control Surfaces (Item 13)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing - None required

3. Chemical Analysis - Identify alloy composition and type (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis - Metallographic evaluation and micrographs (2 samples required - random sampling - include full cross-section thickness)

5. Physical and Mechanical Property Analysis

   a. Hardness test (2 samples required - random sampling)

   b. Tensile test (3 samples required - random sampling, tensile axis parallel to principal forming direction)

TEST PLAN

N Aft-Fairing (Item 14)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing

   a. X-ray welds

   b. Penetrant inspect welds

3. Chemical Analysis

   a. Identify aft-fairing alloy composition and type (4 samples required - random sampling)

   b. Identify weld metal (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis

   a. Metallographic evaluation and micrographs of aft-fairing alloy (2 samples required)

   b. Metallographic evaluation, macrographs, and micrographs of welds (2 samples required - random sampling)

5. Physical and Mechanical Property Analysis

   a. Tensile test (3 samples required - random sampling - tensile axis parallel to longitudinal axis of component)

   b. Tensile test welds (6 samples required - random sampling; 3 samples with weld bead intact; 3 with weld bead ground flush)

   c. Hardness test (2 samples required - random sampling)

   d. Microhardness traverse of welds (2 samples required - random sampling)

TEST PLAN

0 Boattail (Item 15)

1. General Description and Observations - Include all items applicable in Section III-A

2. Nondestructive Testing

a. X-ray all welds

b. Penetrant inspect welds

3. Chemical Analysis

a. Identify boattail alloy composition and type (4 samples required-random sampling)

b. Identify weld metal composition (4 samples required - random sampling)

4. Metallographic and Microscopic Analysis

a. Metallographic evaluation and micrographs of boattail alloy (2 samples required - random sampling)

b. Metallographic evaluation, macrographs, and micrographs of welds (2 samples required - random sampling)

5. Physical and Mechanical Property Analysis

a. Tensile test boattail alloy (3 samples required - random sampling - tensile axis parallel to longitudinal axis of component

b. Hardness test (2 samples required - random sampling)

c. Microhardness traverse of welds (2 samples required - random sampling)

## V. QUALIFICATIONS

### A. Facilities

It is desirable that the test program be performed by a single contractor who possesses all the facilities and equipment necessary for the tasks outlined herein. The contractor must have capabilities for removing, sectioning, and machining samples from the hardware. Samples so identified as to make them Unclassified may, if necessary, be sent to different subcontractors for specialized tests. However, proper identification would be needed to relate results back to the correct location on the hardware. Excessive subcontracting should be discouraged and every effort made to ensure continuity and consistency of the test results by limiting the number of contractors involved.

It is desirable that the prime contractor maintain and operate a complete, integrated materials-testing laboratory. Quality-assurance, quality-control, or process-control laboratories would not suffice, due to the broad scope and unusual investigative nature of the work. Normal engineering, research, or development laboratories (metallic and non-metallic) maintained by major aerospace contractors would be acceptable, as would laboratory facilities of many universities and nonprofit research institutions.

The nature of this program is such as to require closer than normal liaison between the sponsoring agency and the contractor to enable guidance and assistance during the program. Routine conferences between contractor and sponsor will be more important than in normal research and development programs in order to ensure complete attainment of the program objectives. To enhance communications and at the same time reduce travel expenditures,

it is recommended that preferential consideration be given to contractors located not too distant from the contracting agency.

B. Personnel

The selection of personnel to be assigned to the program is of course important to successful completion of the objectives. Maximum exploitation of materials technology can only be achieved by personnel experienced in a broad range of aerospace materials and processes. Meaningful comparison with US technology must be done by individuals thoroughly familiar with current materials and manufacturing processes used in the industry.

Proper evaluation of the test results as described in Section IV will require a staff of engineers and scientists experienced in several separate but related technical disciplines. This is estimated to require a minimum of 21 man-months of direct technical effort. The requisite scientific and engineering staff should include persons in the categories listed below. All should normally possess a B.S. degree and 5 to 10 years experience relevant to their field of specialization, but the degree is not felt to be a mandatory requirement. Higher degrees should not be necessary for these personnel. The categories are as follows:

Physical Metallurgist

Analytical Chemist

Welding Engineer

Processes and Finishes Engineer

Manufacturing Engineer

Process Metallurgist

Structural Engineer

Structural Vibrations Specialist

In addition, sufficient experienced support personnel (mechanics, technicians, machinists, etc.) must be available to provide for disassembly, removal, sectioning, specimen machining, and mechanical, physical, and nondestructive testing as specified in the Detailed Test Plan, Section IV. It will also be helpful for the contractor to have available for consultation as necessary (but not assigned directly to the program) experienced technical personnel in the following categories:

Tooling Engineer

Missile Propulsion Engineer

Flight Dynamics Engineer

Mechanical Engineer (with experience in bearings and lubricants)

It is desirable that the program be directed by an experienced full-time program manager possessing the following minimum qualifications:

1. Background and experience in aerospace materials and processes with a minimum of 10 years directly related experience.
2. Demonstrated managerial ability.
3. Complete insight into and understanding of the aims, objectives, scope, and purpose of the program.

C. Security

The contractor's facilities and personnel must be cleared to use and store documentary material and hardware of a classified nature in connection with this program. The security classification involved will be Secret, and No Foreign Dissemination should be specified. Complete security requirements are specified in the appropriate DD 254 forms accompanying the hardware.

Material generated under the program should be tentatively assigned a security classification consistent with the input or reference data up to and including Secret. Final security classification will be determined by the sponsor.

The test program will be facilitated by allowing specimens, when removed from the classified hardware and identified only by a code number with no direct reference to the specific hardware, to be Unclassified.

# VI. RECOMMENDATIONS AND ESTIMATES

## A. Hardware and Associated Items

Maximum exploitation of the materials and fabrication processes will require the hardware to be physically located at the contractor's facility. The repeated observations and comparisons that must be made on the hardware throughout the span of the program would make remote location of the items impractical and uneconomical. Moreover, continual close association with the actual hardware by the personnel making the observations and conclusions is highly desirable.

The program personnel should have access to all available documentation relating to this or similar hardware. This includes any maintenance, service, or operating instruction manuals which may be available, as well as results from prior exploitation efforts.

## B. Documentation

It is recommended that Monthly Letter Reports to the sponsor be required. These should summarize briefly current activities, progress toward overall goals, and difficulties that may have been encountered. In particular, should the method of fabrication of any component not be established clearly by the routine analysis, the sponsor must be informed of this problem in the next Monthly Letter.

It is recommended that detailed technical documentation of the program be confined to a single Final Technical Report, to be due in draft form 12 months after program initiation and in final form one month after sponsor approval of the draft. That document should summarize thoroughly and methodically the studies undertaken and the results obtained. Format for the

report is established by existing documentation. Efforts should be made to present the data in a form that will be of value to missile designers in the US defense community, as well as to the sponsor's specific needs.

C. Program Schedule and Manpower Requirements

The following schedule is estimated to be reasonable for performance of the program described herein. (1) Detailed tests and observations can be begun approximately one month after receipt of the hardware, and will require a period of six months thereafter. (2) Evaluations, conclusions, and assessments can be begun four months after receipt of hardware, and should be completed six months thereafter or ten months after receipt of hardware. (3) Work on the Final Report draft should begin nine months after receipt of hardware and be completed for delivery of the draft twelve months after receipt of hardware. (4) Presuming sponsor approval of the draft within a month, delivery of the Final Report should be scheduled for fourteen months after receipt of the hardware. (5) The hardware can be returned to the sponsor promptly upon approval of the Final Report draft.

Manpower requirements for performance of the program are estimated as follows. (1) The testing and observation phase will require an estimated 32 man-months of direct technical manpower. (2) The evaluation phase will require approximately 21 man-months of direct technical manpower. (3) The above figures specifically exclude provision for required supplementary services, such as administration, clerical work, and report preparation. (4) Likewise, no provision is included here for the travel expenses that will be involved.

The program, as set forth herein, is felt to cover adequately the predictable requirements for conducting a thorough analysis of the hardware

to achieve the program goals. It should be noted, however, that it is impossible to specify in advance all the areas and tests which may provide useful information; others are very likely to become evident only after the program is underway. In order to make provision for exploiting these unforeseen areas of investigation, it is desirable to have available a procedure whereby additional tests and evaluations can be identified and added to the overall program. It is therefore recommended that a contingency fund be provided for use by the sponsor to authorize tests and evaluations not specifically detailed in Section IV. Each specific additional series of tests requested will be identified and assigned a Task number by the Contractor's Program Manager and submitted to the sponsor with a justification of its potential value to the program and an estimate of its cost. The sponsor will then approve or disapprove the request. A reasonable estimate of the contingency fund would be approximately ten percent of the total program cost.

D. Related Information

Efforts should be made to find and use existing information to supplement the data derived from this study. A brief survey of the open literature and inquiries to selected government agencies should be made in hopes of acquiring data to assist in assessing such items as costs and production rates. For instance, a listing of the alloys (by composition) with estimated tonnages produced by the foreign technology would be helpful in making some of the evaluations required. It is suggested, therefore, that contacts be arranged with Foreign Technology Division, Wright-Patterson AFB, Ohio, and perhaps other agencies.

E. Vibration Testing

No practical method is known for deriving the vibrational characteristics of the structure as a whole (which in this case involve frequencies on the order of 1 Hz) from the vibration damping properties of the basic structural materials, as determined according to E-5 of Section III. For this reason, there is recommended a ground vibration test of the entire structure to obtain certain of the data necessary for a complete structural analysis of the entire vehicle. It is felt that this type of test is beyond the scope of the materials exploitation program set forth in this report, but could, however, either be conducted under the contingency plan outlined in Section VI-C above or as a separate program.

The following test requirements are suggested.

A ground vibration test will be conducted to determine the structural vibration characteristics of the primary structure as well as the vibration response of the shell modes. These tests will be conducted for several fuel loadings. The slosh effects of the fuel, and the fuel and structural dampings will be recorded at resonances.

The ground vibration tests will be conducted using hydraulic shakers capable of at least 2,400 pounds of force and electromechanical shakers capable of at least 150 pounds of force throughout a frequency range of approximately 0 to 150 Hz.

A complete data-acquisition system will be used to record the response frequencies, mode shapes, damping effects, and slosh effects of the vehicle. Multi-accelerometers will be permanently attached to the surface, and roving surveys made of the structure.

An estimated cost for the above testing is $10,000-$12,000. This includes tabulation of the raw data but not the resulting structural analysis required.

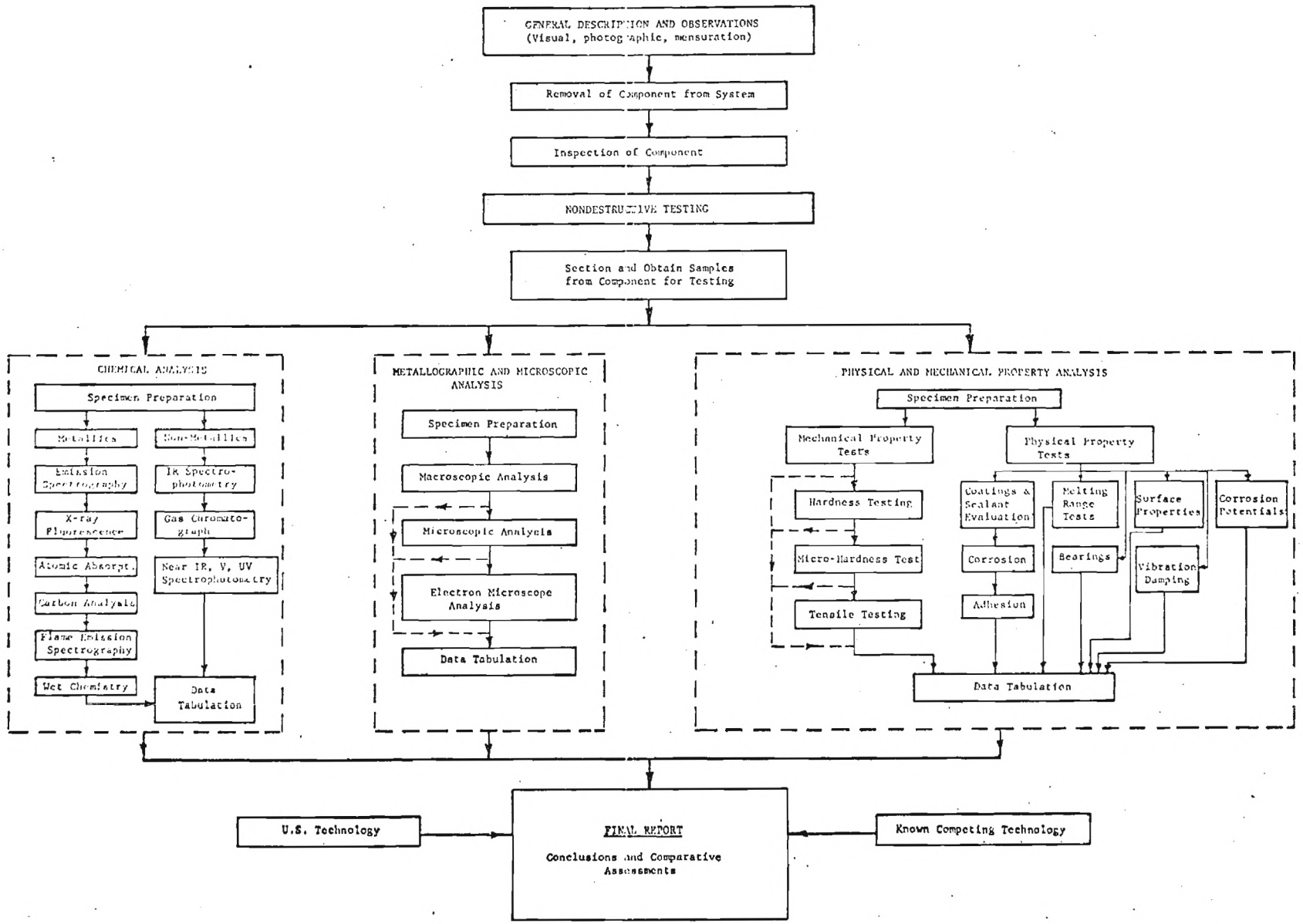


Figure 1. Flow chart for component testing.

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13. ABSTRACT

A detailed plan is set forth for examination and testing of a specific item of non-US-made hardware, aimed at extracting information concerning the materials technology and manufacturing techniques displayed by this hardware.

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| Manufacturing Techniques | | | | | | |