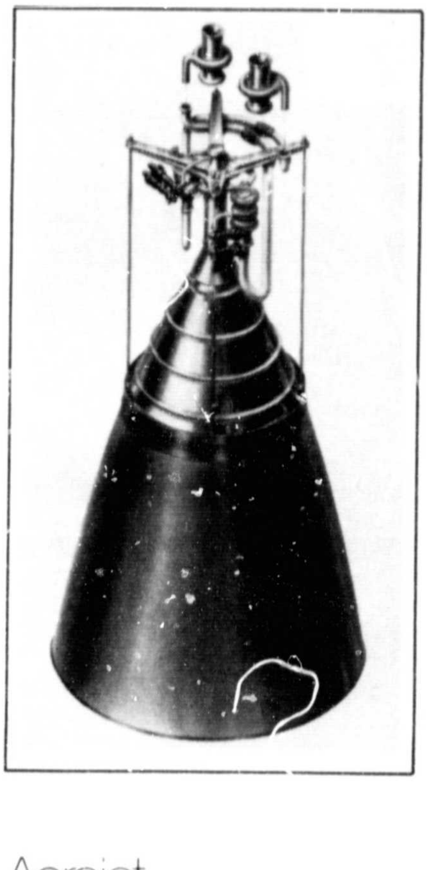
Orbital Transfer Vehicle (OTV) Advanced Expander Cycle Engine Point Design Study

Contract NAS 8-33574
Bimonthly Status Report
Report 33574-M2
February 1980

Prepared For:
George C. Marshall Space Flight Center
National Aeronautics And Space Administration



Aerojet
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Company

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ADVANCED EXPANDER CYCLE ENGINE
POINT DESIGN STUDY

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Bimonthly Status Report No. 2
1 December 1979 to 31 January 1980

Prepared for

George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

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FOREWORD

The bimonthly Status Report is submitted for the Orbital Transfer Vehicle (OTV) Advanced Expander Cycle Engine Point Design Study per the requirements of Contract NAS 8-33574, Data Procurement Document No. 578, Data Requirement No. MA-02. This work is being performed by the Aerojet Liquid Rocket Company (ALRC) for the NASA/Marshall Space Flight Center. The study authority to proceed was received 24 October 1979.

The study consists of the generation of a performance optimized engine system design for an advanced LOX/Hydrogen expander cycle engine. The analysis of the components and engine and the resulting drawings shall be of sufficient depth to produce accurate engine and component weights/envelopes, turbopump efficiencies/recirculation leakage rates, engine performance, engine control techniques, and new technology requirements.

The NASA/MSFC COR is Mr. D. H. Blount. The ALRC Program Manager is Mr. L. B. Bassham and the Study Manager is Mr. J. A. Mellish.

TABLE OF CONTENTS

FIGURE LIST

I. INTRODUCTION

A. BACKGROUND

The Space Transportation System (STS) includes an Orbit Transfer Vehicle (OTV) that is carried into low Earth orbit by the Space Shuttle. The primary function of this OTV is to extend the STS operating regime beyond the Shuttle to include orbit plane changes, higher orbits, geosynchronous orbits and beyond. The NASA and the DOD have been studying various types of OTV's in recent years. Data have been accumulated from the analyses of the various concepts, operating modes and projected missions. With the inclusion of man in these transportation scenarios, it becomes necessary to reach for the safest and fully optimized propulsion stage. To fulfill all the needs of the space transportation system with mission goals focusing on initial operating capability (IOC) in 1987, it is now timely to perform the necessary engine/system definition studies in order to initiate the engine development by 1983.

The purpose of this study is to generate a performance optimized engine system design for a man-rated advanced LOX/Hydrogen expander cycle engine. This concept, originally conceived by ALRC on the OTV, Phase A contract (NAS 8-32999), exemplifies the merging of man-rated design issues coupled with high performance, reuseability and low development risk for the OTV engine.

I, Introduction (cont.)

B. OBJECTIVES

The major objectives of the OTV Advanced Expander Cycle Engine Point Design Study are: (1) generate a performance optimized engine system design for an advanced LOX/Hydrogen expander cycle engine, and (2) provide sufficient design and analysis of the engine and components to produce accurate engine and component weights/envelopes, turbopump efficiencies/recirculation leakage rates, engine performance, engine control techniques, and new technology requirements.

Specific study objectives are:

- Prepare a study plan
- Prepare a detailed computer model of the engine to predict both the steady state and transient operation of the engine system
- Prepare mechanical design layout drawings of the following components:

  Thrust chamber and nozzle
  Extendible nozzle actuating mechanism and seal
  LOX turbopump
  LOX boost pump
  Hydrogen turbopump
  Hydrogen boost pump
  Propellant control valves

- Perform the necessary heat transfer, stress, fluid flow, dynamic and performance analysis to support the mechanical design.

- Determine effective control points and methods to control the engine operation through start and shutdown transients as well as steady state operation. These will include thrust and mixture ratio control.

- Determine optimum actuation drive methods for engine control elements.

- Prepare an engine configuration layout drawing to show the spatial arrangement of the various engine components with consideration of the SES maintainability discipline as well as engine performance.

- Prepare an engine data summary to include rigourous performance predictions and life predictions as well as engine and component weights and physical envelopes.

- Identify any new technology required to perform detailed design, construction and testing of the engine.

- Prepare and deliver computer software/documentation for the steady state/transient engine model.

- Prepare a final report at the completion of the study which documents the technical details and programmatic assessments resulting from the study.

C. STUDY PROGRAM SCHEDULE

The schedule to accomplish the ten tasks comprising the study program is shown in Figure 1. The study program is on schedule.

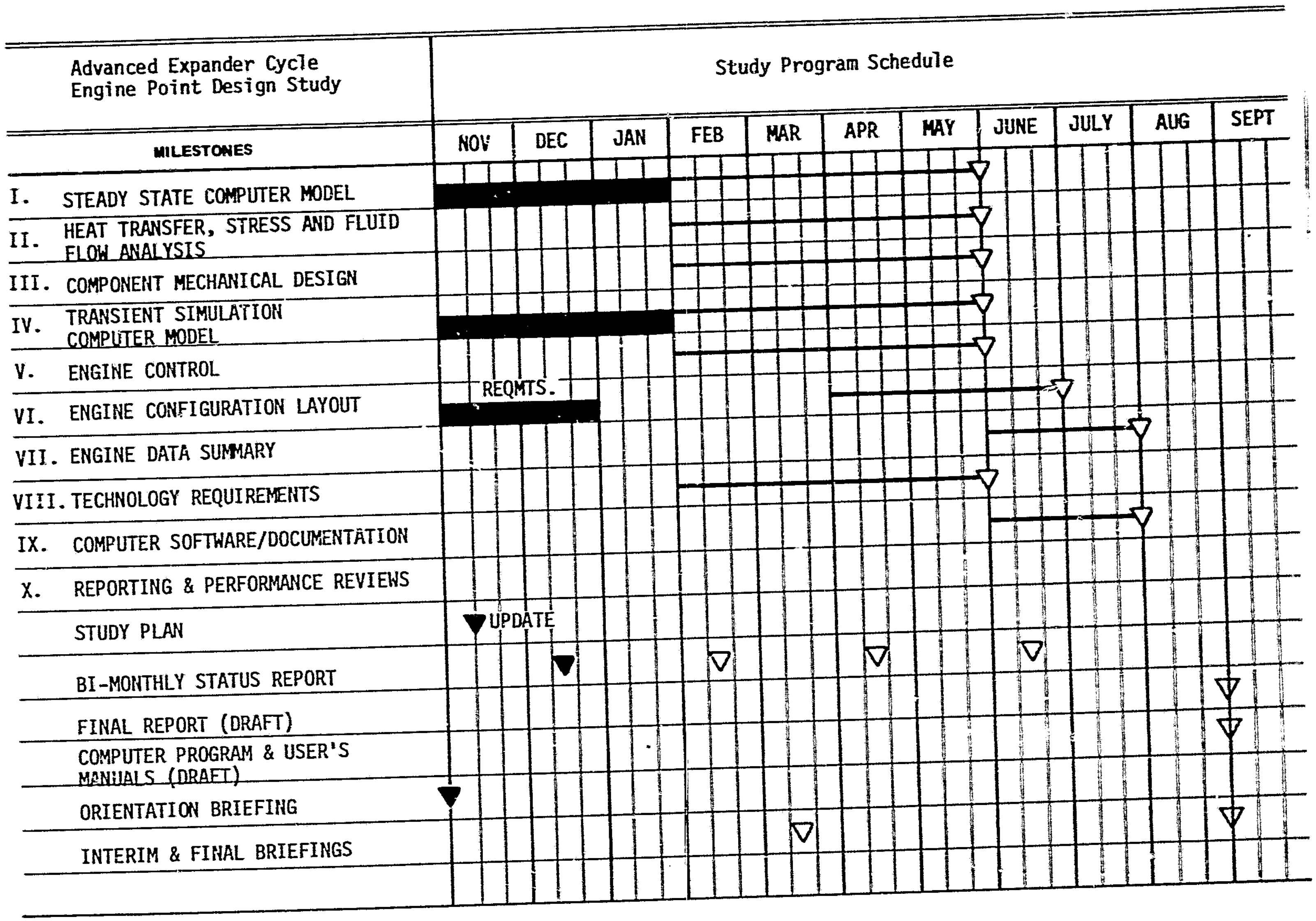

Figure 1. OTV-Engine Point Design Study Schedule

II. TECHNICAL PROGRESS

A. TASK I: STEADY STATE COMPUTER MODEL

Effort on this task continued during this reporting period and significant progress to date is summarized in Appendix A, "Liquid Engine Transient Simulation Development Status". The steady-state condition is a special case of the transient computer model.

By using a single model, ALRC insures consistency in program variable names and input data for both steady-state and transient analyses.

B. TASK II: HEAT TRANSFER STRESS AND FLUID FLOW ANALYSIS

No activity scheduled.

C. TASK III: COMPONENT MECHANICAL DESIGN

No activity scheduled.

D. TASK IV: TRANSIENT SIMULATION COMPUTER MODEL

The progress to date on this task is summarized in Appendix A.

E. TASK V: ENGINE CONTROL

No activity scheduled.

F. TASK VI: ENGINE CONFIGURATION LAYOUT

The preliminary design requirements required to initiate the other study tasks were defined during this reporting period. A Design Requirements Handbook has been prepared to document all of the design requirements for the design of the OTV Advanced Expander Cycle Engine. The design requirements include those taken from the Statement of Work (SOW) for the Point Design Study and other documents, as well as internally generated requirements. The intent is to provide the design engineers with a single document to guide their designs rather than having all of them refer to all the various basic documents. This document will be updated as the engine design matures and further requirements are defined.

A draft copy of this requirements handbook was delivered to the NASA/COR on 24 January 1980 for his review and comments.

The Design Requirements Handbook has been structured in four parts. The first section is the Design Requirements Section in which the specific design requirements for the engine are listed. This section has been formated so that eventually it will be a specification for the OTV engine.

The second section includes design guides relating to System Effectiveness and Safety. The various documents relating to man-rating and payload bay safety have been reviewed and the parts believed to be applicable to the OTV engine have been extracted. While the man-rating and safety requirements for the OTV have not been defined by the NASA, it is believed that when they are they will be similar to those included in this section. By using this approach, the provisions for man-rating will be designed into the engine from the very beginning.

The third section is the Engine Configuration Definition section. In this section all engine configuration, component operating parameters and performance data are maintained to provide the official baseline for the design until such time as the engine drawings and specifications have been put under configuration control.

II, F, Task VI: Engine Configuration Layout (cont.)

The fourth section has all properties data for propellants and combustion gases that are used in calculating performance for the engine. This data is provided to ensure that all designers use the same data in their analyses.

G. TASK VII: ENGINE DATA SUMMARY

No activity scheduled.

H. TASK VIII: TECHNOLOGY REQUIREMENTS

No activity scheduled.

I. TASK IX: COMPUTER SOFTWARE/DOCUMENTATION

No activity scheduled.

J. TASK X: REPORTING AND PERFORMANCE REVIEWS

No major activity scheduled.

III. CURRENT PROBLEMS

No problems were encountered during this reporting period.

IV. WORK PLANNED

The work planned in the next two months is summarized below.

A. TASKS I AND IV

Continue the development of the liquid engine transient simulation and steady state model and update the model as component definition gets better.

B. TASK II

Conduct all heat transfer, stress and fluid flow analyses to support the chamber, nozzle, injector, controls and turbopump component designers.

C. TASK III

Initiate design activity on all major engine components based upon the requirements and operating specifications contained in the Design Requirements Handbook.

D. TASK V

Initiate controls analyses and definition based upon starting with the output from the Phase A, Extension 1 OTV study efforts.

E. TASKS VI, VII AND IX

No activity scheduled.

F. TASK VIII

Assist in preparation of a preliminary list of critical technology requirements for an advanced expander cycle engine and submit to NASA/MSFC by 15 February 1980.

IV, Work Planned (cont.)

G. TASK X

Conduct an informal interim briefing at NASA/MSFC. This briefing is currently scheduled for mid-March and will cover the work accomplished to that date.

APPENDIX A

Liquid Engine Transient Simulation
Development Status

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APPENDIX A

FIGURE LIST

TABLE LIST

Development of the OTV Liquid Engine Transient Simulation (LETS 3) computer model is progressing per the schedule shown on Figure A-1. The preliminary computer coding has been completed for most of the major subroutines as shown on Table A-I. These subroutines are undergoing testing and debugging prior to coupling them together. The combustor and igniter subroutines have undergone extensive testing and are about 95% debugged. An example of a simulated start with the combustor and igniter are shown on Figure A-2. This case was run by specifying arbitrary injector pressure ramps just for computer code checkout purposes. Minor modifications to the code need to be made to complete the combustor checkout.

Evaluation and calibration of the model will be done using the engine system shown on Figure A-3. The system has been simplified for purposes of initial model checkout. The components being modeled, and shown on the simplified system schematic, are defined on Table A-II.

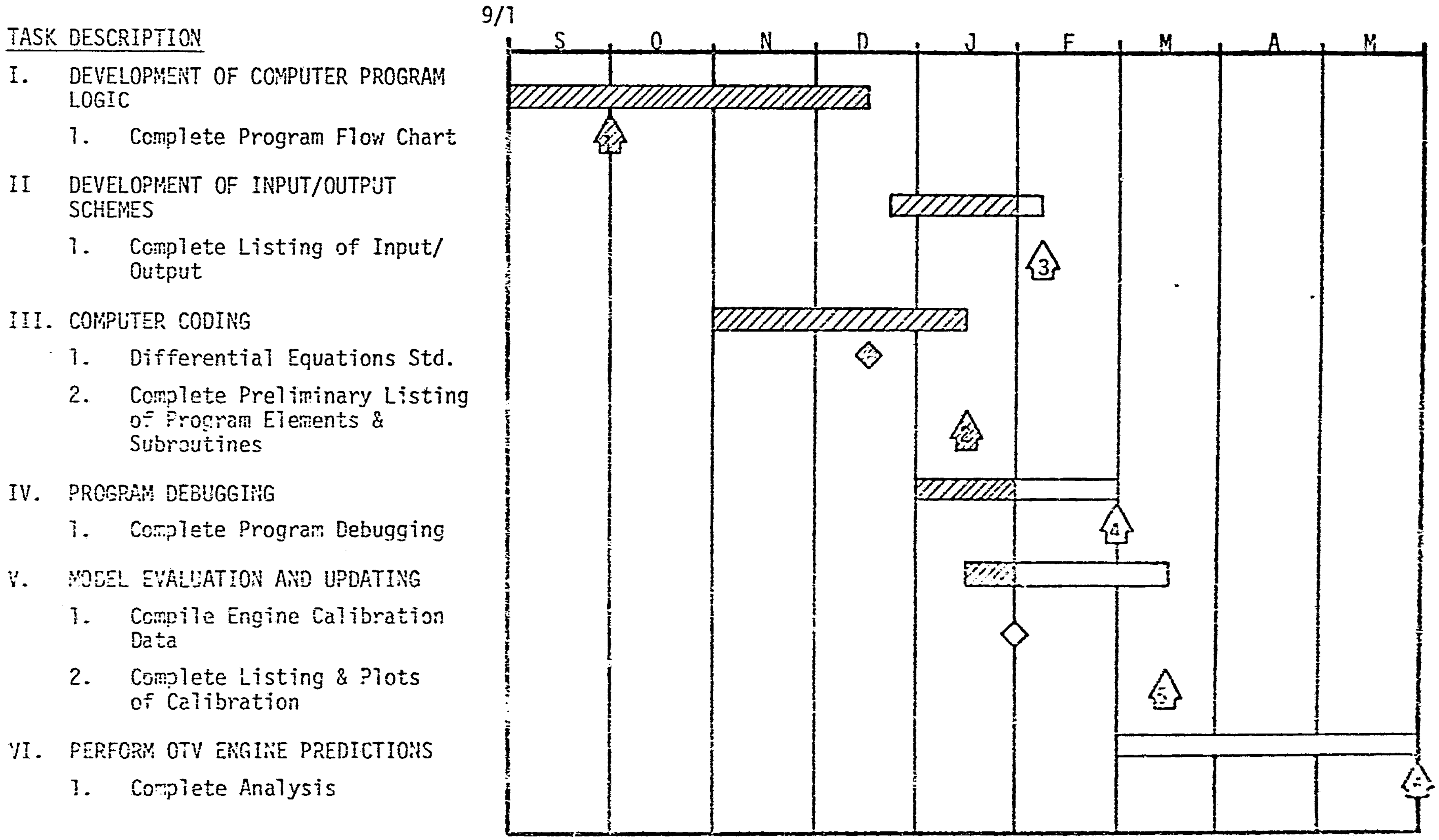

Figure A-1. OTV LETS 3 Computer Model Development Schedule

TABLE A-I

LETS3-MODEL COMPONENT STATUS

MAJOR SUBROUTINES

NAME	CODE NAME	CODED	LISTING REC'D	DEBUGGED
Area Change	A Reach	Yes	1/18/80	No
Branch	Branch	Yes	1/18/80	No
Chamber Tube		No		
Combustor	CMBSTR	Yes	1/17/80	Yes
Controller	CNTRL1	No		
Energy Release Eff.	ERE	Yes	1/17/80	Yes
Igniter Ign. Limits	IGNIT1	Yes	1/17/80	Yes
Chamber Ign. Limits	IGNIT2	Yes	1/17/80	Yes
Igniter (W/Dynamics)	IGNTR	Yes	1/17/80	Yes
Igniter (W/O Dynamics)	IGNTR2	Yes	1/17/80	Yes
Igniter Injector	INJCT	Yes	1/17/80	Yes
Injector		No		
Line	Line	Yes	1/18/80	No
Material Properties	PROPM	Yes	1/17/80	Yes
Nozzle Tube		No		
Orifice	Orifice	Yes	1/18/80	No
Pump	Pump	Yes	1/17/80	Yes
Regenerator		No		
Tank	Tank	Yes	1/17/80	Yes
Turbine	TURBIN	Yes	1/17/80	No
Turbopump Assembly	TPA	Yes	1/17/80	No
Valve	Valve	Yes	1/18/80	No
Heat Transfer Coeff.	DBTAB	Yes	1/17/80	Yes
Propellant Properties	PPROP	Yes	1/17/80	Yes
Combustion Properties	CPROP	Yes	1/17/80	Yes
Propellant Vapor Pressures	PVAP	Yes	1/17/80	Yes
Main	Main	Yes	1/18/80	No
Program Load	LOADAB	Yes	1/18/80	No
Matrix Solution	AMAT	Yes	1/18/80	No

TABLE A-I (cont.)

SUPPORTING SUBROUTINES

NAME	CODE NAME	CODED	LISTING REC'D	DEBUGGED
	EDIT	Yes	1/17/80	Yes
	ITER	Yes	1/17/80	Yes
	LINI	Yes	1/17/80	Yes
	LINIX	Yes	1/17/80	Yes
	PLTVAR	Yes	1/18/80	Yes
	LFIND	Yes	1/18/80	No
	INPUT	Yes	1/18/80	No
	INCALC	Yes	1/18/80	No
	BC	Yes	1/18/80	No

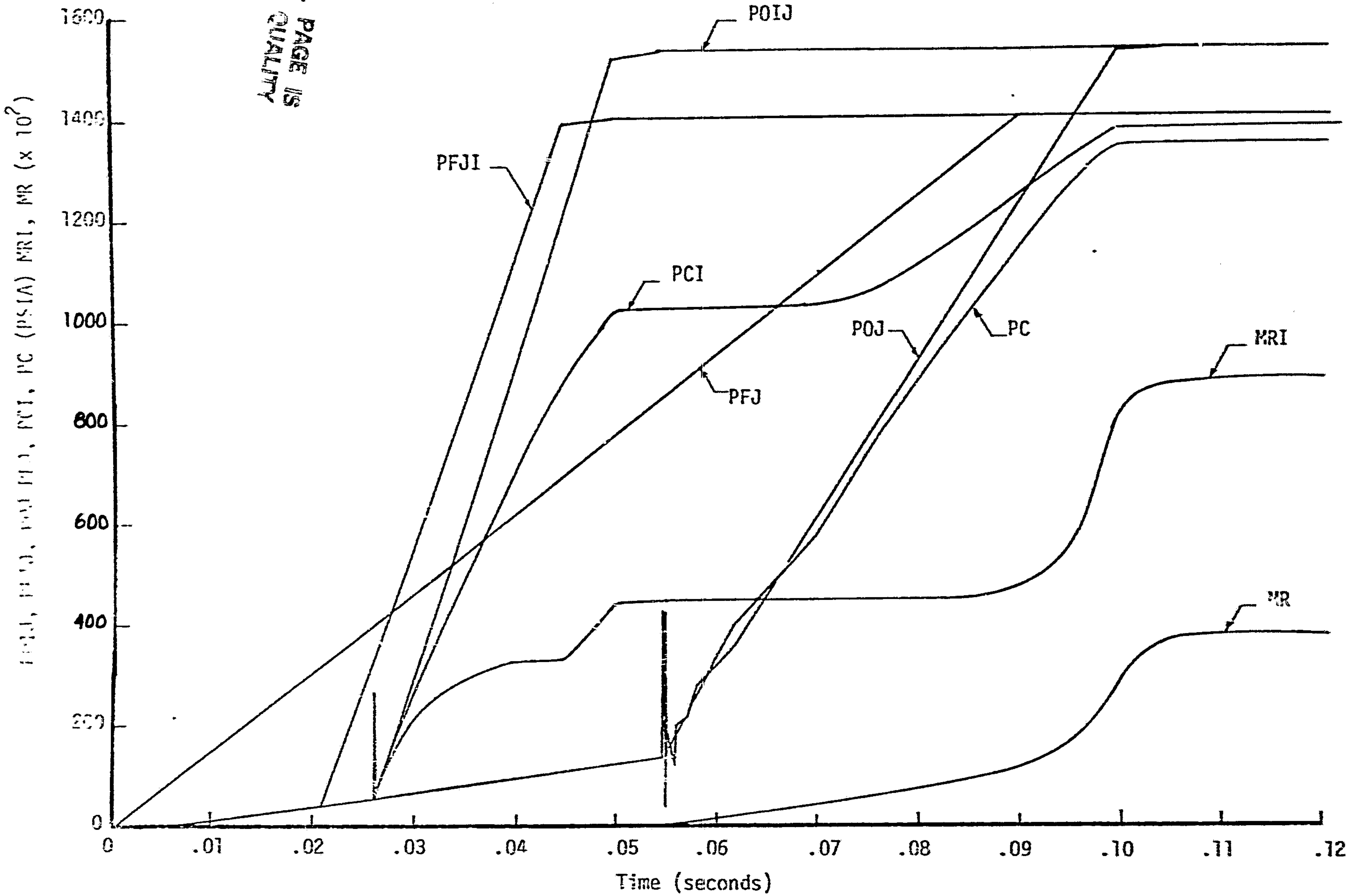

Figure A-2. Combustor and Igniter Test Case

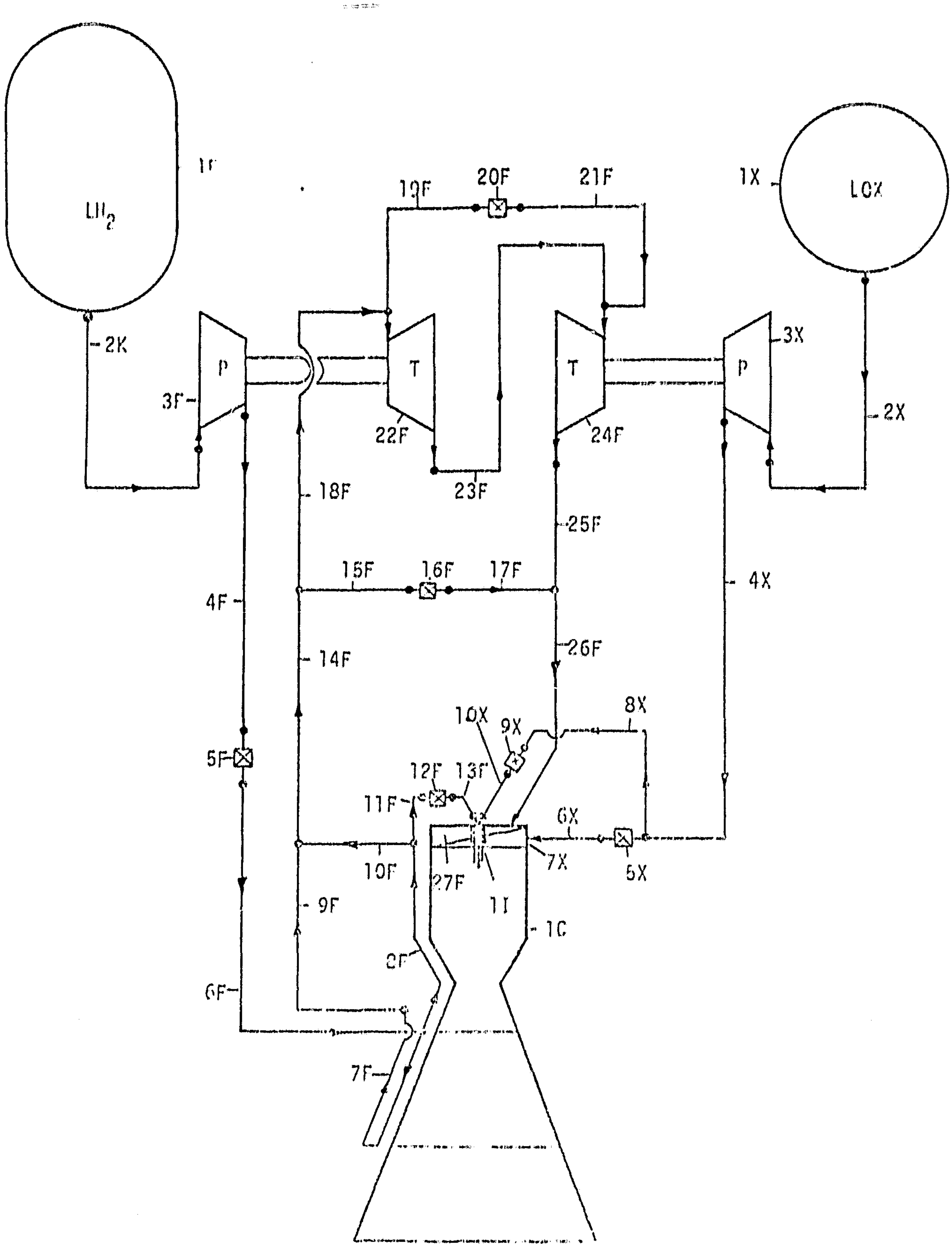

Figure A-3. Simplified System Schematic

TABLE A-II

OTV ENGINE COMPONENTS

FUEL SYSTEM

1F	Tank
2F	Tank Outlet Line/Pump Inlet Line
3F	High Pressure Fuel Turbopump
4F	Pump Discharge Line
5F	Fuel Main Shutoff Valve
6F	Chamber Coolant Jacket Inlet Line
7F	Nozzle Coolant Tube
8F	Chamber Coolant Tube
9F	Nozzle Coolant Outlet Line
10F	Chamber Coolant Outlet Line
11F	Igniter Fuel Valve Inlet Line
12F	Igniter Fuel Valve
13F	Igniter Fuel Injector Inlet Line
14F	Turbine Inlet Connecting Line
15F	Turbine Bypass Valve Inlet Line
16F	Turbine Bypass Valve
17F	Turbine Bypass Connecting Line
18F	Fuel Turbine Inlet Line
19F	Fuel Turbine Bypass Valve Inlet Line
20F	Fuel Turbine Bypass Valve
21F	Line
22F	Fuel Turbine
23F	Fuel Turbine Outlet Line/Ox Turbine Inlet Line
24F	Ox Turbine
25F	Ox Turbine Outlet Line
26F	Fuel Injector Inlet Line
27F	Fuel Injector

TABLE A-II (cont.)

OXIDIZER SYSTEM

1X	Tank
2X	Tank Outlet Line/Pump Inlet Line
3X	High Pressure Ox Turbopump
4X	Ox Turbopump Discharge Line
5X	Ox Main Shutoff Valve
6X	Ox Injector Inlet Line
7X	Ox Injector
8X	Igniter Ox Valve Inlet Line
9X	Igniter Ox Valve
10X	Igniter Ox Injector Inlet Line

COMBUSTORS

1C	Main Combustor
1I	Igniter Chamber