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ORBITAL TRANSFER VEHICLE (OTV) ENGINE STUDY, PHASE A - EXTENSION

CONTRACT NO. NAS8-32996

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INTRODUCTION AND SUMMARY

The initial Phase A Orbital Transfer Vehicle (OTV) Engine Study Program was structured to identify candidate OTV engine cycle concepts and design configurations, to evaluate and assess the characteristics and capabilities of the candidates, and to determine an interim engine power cycle and engine configuration which can best meet the goals and requirements of the OTV program. In that initial portion of the study program parametric OTV engine data (performance, weight, cost) were generated and made available to OTV system contractors.

The OTV engine will be used to power the Orbital Transfer Vehicle that is carried into low earth orbit by the Space Shuttle. The OTV engine has the major objectives of high payload capability, high reliability, low operating cost, reusability, and operational flexibility. The OTV engine study is based upon 1980 technology. Preliminary cost data were also generated during initial Phase A studies.

Recognizing the reliability potential of the expander engine cycle and taking full advantage of continuing evaluation studies, through Phase B definition, by both vehicle and engine contractors, Rocketdyne recommended that both the staged combustion and expander engine cycles be continued through the OTV Vehicle Definition phase.

The current Phase A-Extension of the OTV engine study program will provide additional expander and staged combustion cycle data that will lead to design definition of the OTV engine. The proposed program effort will optimize the expander cycle engine concept (consistent with identified OTV engine requirements), investigate the feasibility of kitting the staged combustion cycle engine to provide extended low thrust operation, and conduct in-depth analysis of development risk, crew safety, and reliability for both cycles. Additional tasks will address costing of a 10K thrust expander cycle engine and support of OTV systems study contractors.

The detailed study objectives are to:

1. Prepare and submit a study plan for this extension
2. Perform pre-point design studies to optimize thrust chamber geometry and cooling, engine cycle variations and controls for an advanced expander cycle engine
3. Investigate the feasibility and design impact of kitting the staged combustion cycle engine to provide extended low thrust operation and identify the required new technology
4. Provide an in-depth analysis of development risk, crew safety, and reliability for both the staged combustion and advanced expander OTV engine candidates
5. Prepare a Work Breakdown Structure, Planning and Detailed Cost for a 10K advanced expander cycle engine
6. Provide engine parametric data book and support to the OTV systems studies contractors and define and clarify engine design characteristics and options
7. Prepare a comprehensive report at the conclusion of this study extension containing sketches, graphs, tables, technical details, and programmatic information resulting from the study.

Previous contractual study efforts conducted by Rocketdyne and Aerojet (NAS8-32996 and NAS8-32999), and in-house sponsored programs conducted at Rocketdyne have provided a large data base for OTV-type engines in terms of both parametric and specific design point information. It is planned to make full use of these data to make the OTV study as comprehensive as possible.

The contracted extension effort includes five additional technical tasks and one reporting task. A scheduling for these tasks is shown in Fig. 1. The program began with an orientation briefing at NASA-MSFC to disucss details of the work to be accomplished. At this briefing, Rocketdyne presented the approach of the program study plan, identified all tasks, their objectives, expected results, man-hour allotments, and program milestones.

As indicated in Fig. 1, Task 8 was completed during this report period and effort was started on Tasks 9, 10, and 11. Task 12 effort continued. Approximately 45 percent of the total planned man-hours have been expended in above efforts. This work is discussed in the main body of this report.

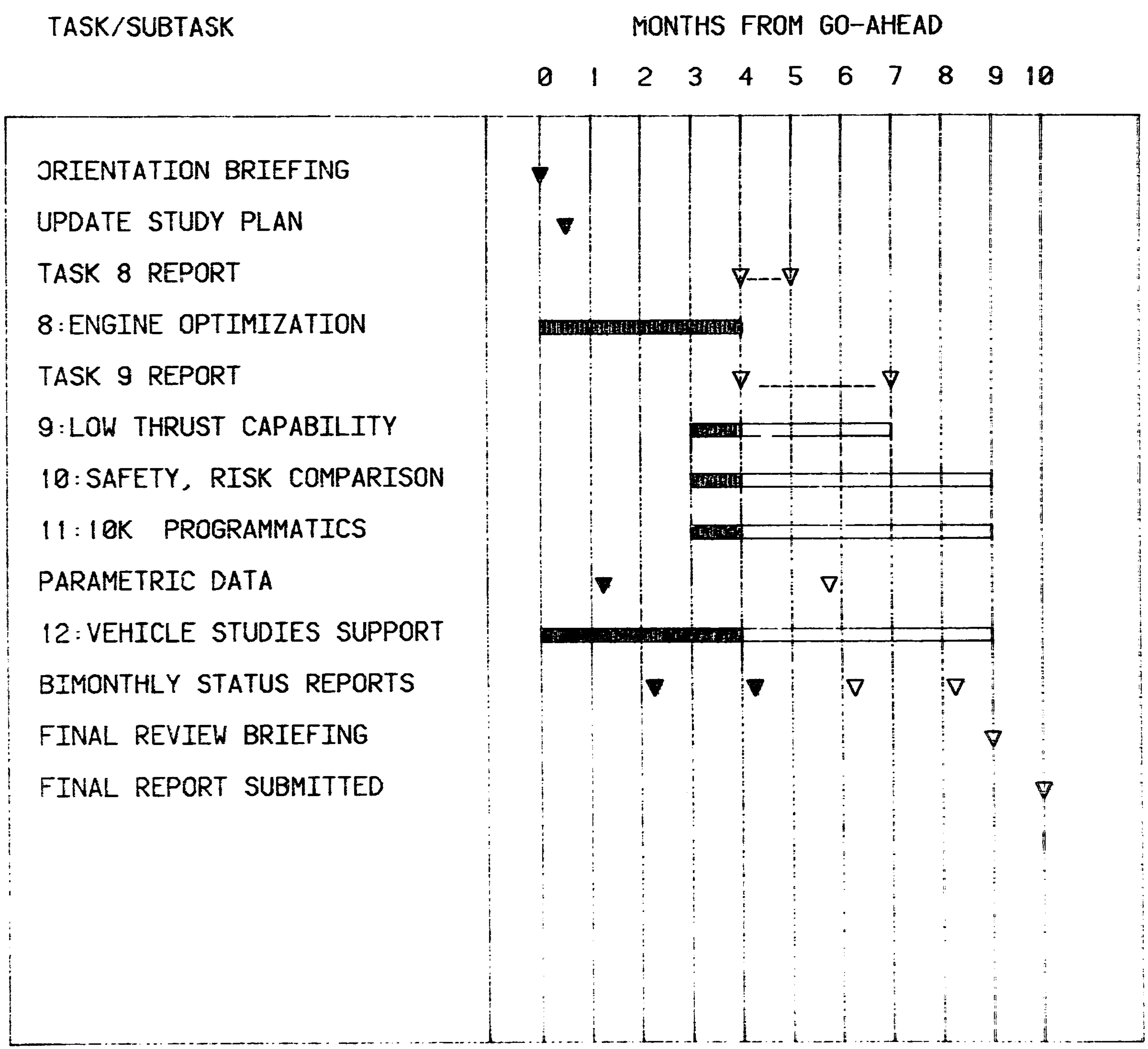

Figure 1. OTV Phase A-Extension, Program Schedule

DISCUSSION

TASK 8. ADVANCED EXPANDER CYCLE ENGINE OPTIMIZATION

The overall objective of this task is to optimize the performance of the expander cycle engines with vacuum thrusts of 10K, 15K, and 20K with a maximum retracted length of 60 inches at a mixture ratio of 6:1. Maximization of payload delivery will be one of the primary goals of the study task for which performance/weight partials derived from NASA's TMX-73394 will be used during simplified mission analysis. The information generated will form the basis for subsequent point design studies. The schedule for Task 8 is shown in Fig. 2.

As indicated in Fig. 2, all subtasks of the Advanced Expander Cycle Optimization Task have been completed. A detailed report documenting the effort is in preparation and is scheduled for release 30 November 1979, two weeks later than originally scheduled.

TASK 9. ALT "ATE LOW THRUST CAPABILITY

Initial investigative activity has been started to determine specific low thrust (approximately 1K to 2K lbs) operating environment. This includes mixture ratio variations and trade studies which will determine heat transfer requirements on the major combustion devices.

Turbopump operation under low thrust conditions will next be examined and evaluated.

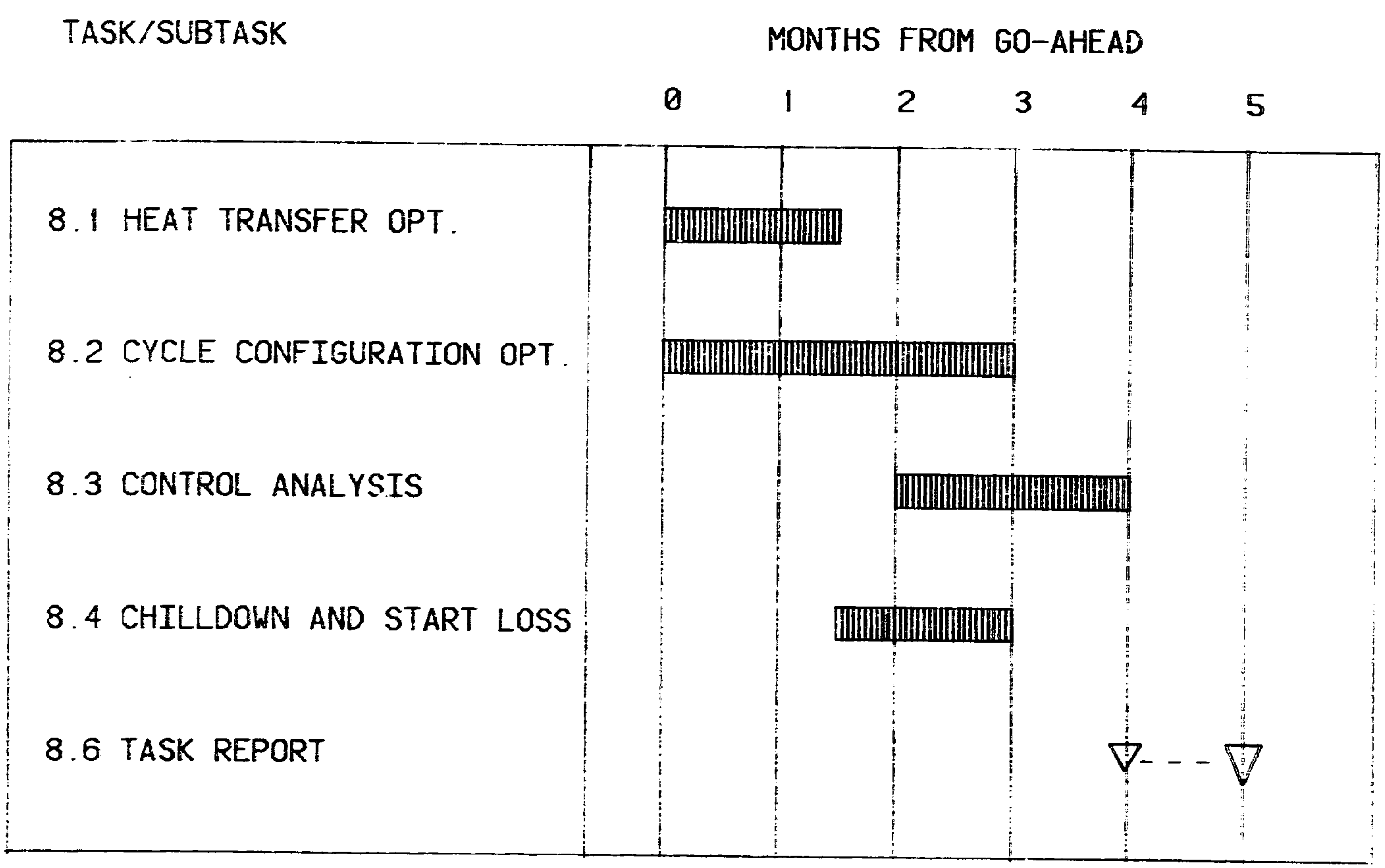

Figure 2. Task 8 Schedule
Advanced Expander Cycle Optimization

TASK 10. SAFETY, RELIABILITY AND DEVELOPMENT RISK COMPARISON

The objective of this task is to perform comparative analyses in the following areas: (1) crew safety, (2) mission success, and (3) development risk with respect to DDT&E program schedule advances or slippages.

The comparisons, listed in Table 1, are being performed for both the staged combustion and the expander cycles, and cover the following number of engines per vehicle:

TABLE 1. CYCLE COMPARISONS

VEHICLE PROPULSION SYSTEM CONFIGURATION	A	B	C	D	E
NUMBER OF ENGINES IN VEHICLE	1	2	2	3	3
THRUST PER ENGINE (K LBS)	15	15	15	10	10
NUMBER OF ENGINES REQUIRED FOR CREW SAFETY	1	1	2	1	2
NUMBER OF ENGINES REQUIRED FOR MISSION SUCCESS	1	2	2	2	3

During the report period a methodology for the first two task areas has been generated. The methodology is shown in a block diagram in Fig. 3; a typical, preliminary result is shown in Fig. 4.

Since the absolute values of the principal parameters, crew safety reliability goal and mission success reliability goal are not specified at the present time, the approach is to show the dependence of these reliabilities as a function of program cost.

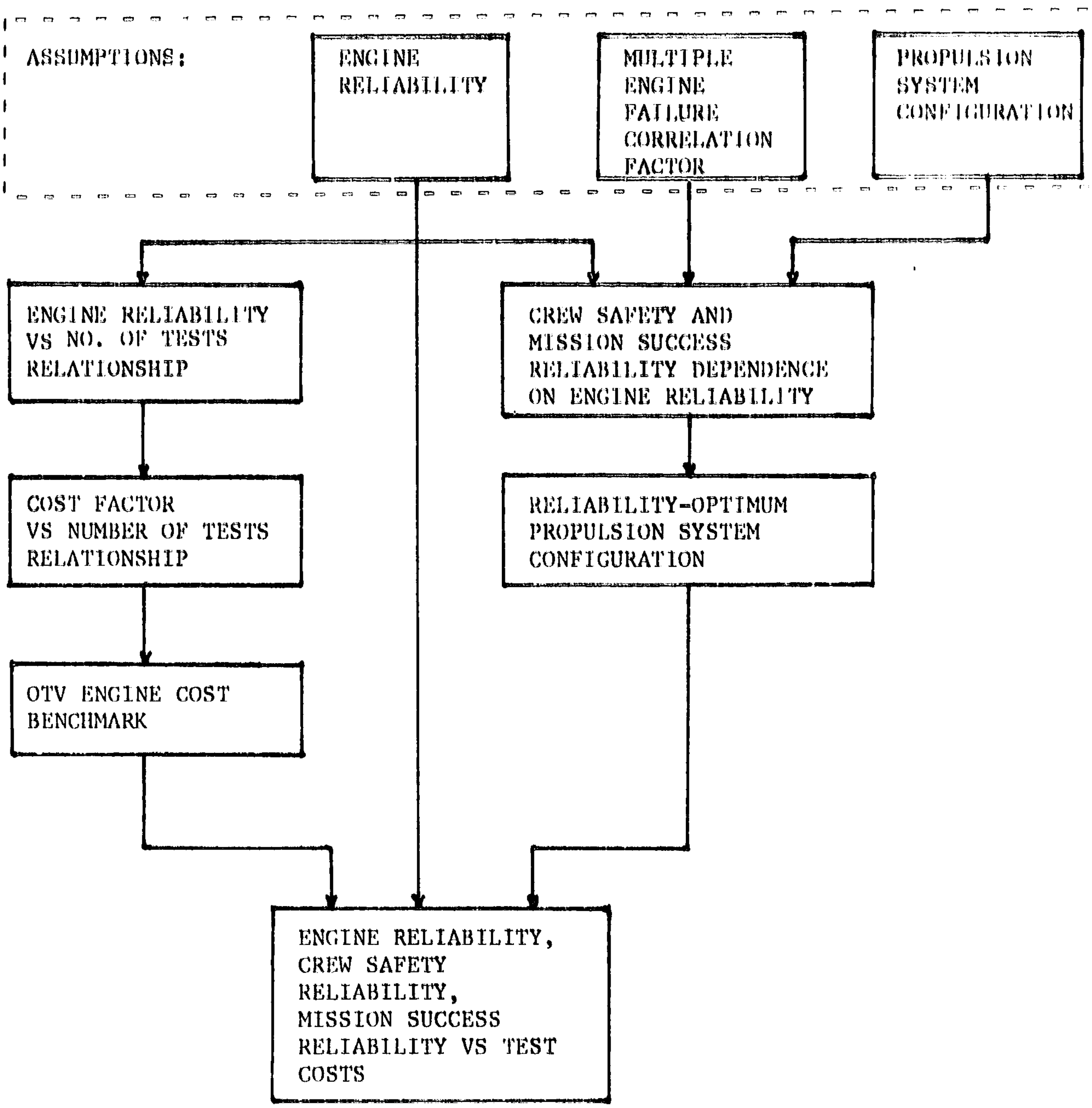

Figure 3. Crew Safety and Mission Success Reliabilities vs Cost

Propulsion System Configuration: D

Multiple Engine Failure
Correlation Factor: 5%

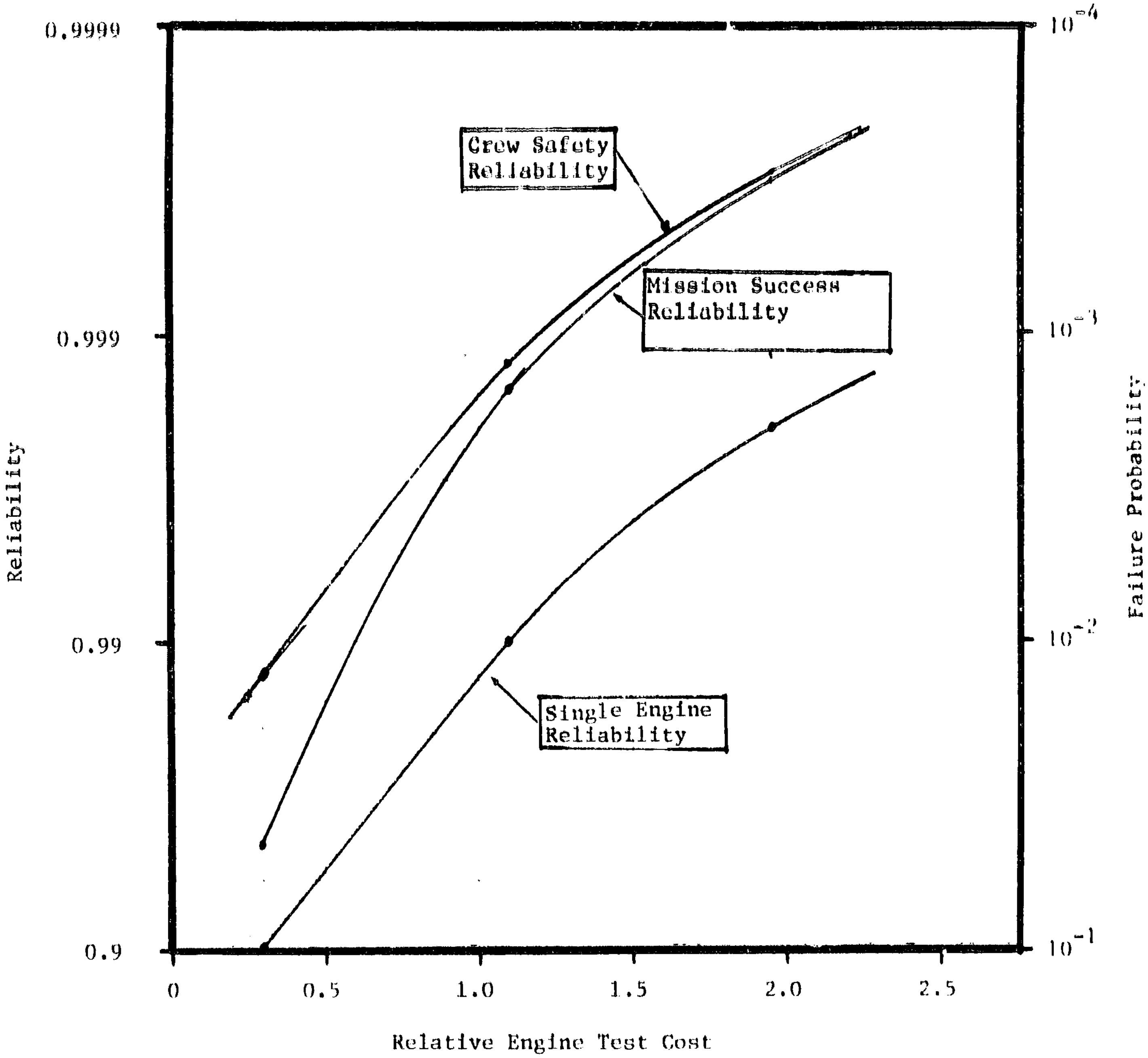

Figure 4. Preliminary Crew Safety and Mission Success vs Relative Engine Test Cost

Figure 4 presents the crew safety and mission success reliabilities vs engine test cost for propulsion system configuration D. The curves were calculated for a multiple engine failure correlation factor of 5 percent. This factor is defined as the ratio of those engine failures in a multiple engine installation which could affect the entire propulsion system to all engine failures.

For the parameters chosen in Fig. 4, the calculations indicate an increase in engine testing cost by a factor of about 2 for an increase in crew safety or mission success reliability of 10.

The analysis will be extended to cover a wider range of parameters and to include estimates of differences in engine reliabilities between staged combustion and expander cycle.

TASK 11. COST AND PLANNING COMPARISON

Cost and schedule data for a 10K lb thrust expander cycle engine are being assembled.

TASK 12. VEHICLE SYSTEMS STUDIES SUPPORT

As a result of the expander cycle engine optimization studies completed under Task 8, chamber pressure updates for this engine cycle have been affected. Parametric engine performance, envelope, and weight data reflecting the higher achievable chamber pressures are being generated and will be released to the vehicle contractors on dates approximately indicated on the program schedule in Fig. 1.