ADDENDUM

DEVELOPMENT PLAN AND COST ESTIMATE

FOREWORD

This addendum to RTD-TDR-63-4057, A Study of an Orbital Maintenance and Material Transfer Shuttle, presents the Development Plan and Cost Estimate to produce two shuttle vehicles.

The work was administered under the direction of the Site Support Branch of the Aero Propulsion Laboratory, Research and Technology Division, Wright-Patterson Air Force Base, Ohio. Mr. John Tackis served as project engineer for the Air Force.

The study was performed between February and October 1963 by the Spacecraft Organization, Lockheed-California Company. Mr. Ray Goodall was the project engineer responsible for the study. A number of program development specialists participated in the work presented in this addendum. The principal contributor was Mr. H. J. Steffen.

ABSTRACT

This document is an addendum to RTD-TDR-63-4057, A Study of an Orbital Maintenance and Material Transfer Shuttle. The basic report presents a preliminary design of a one-man shuttle vehicle used to transport personnel and material between large space stations and to perform in-space maintenance operations. This addendum presents a Development Plan and a Cost Estimate for producing two shuttles. The development plan shows that the first operational flight could take place 28 months from go-ahead. A total cost of $15,000,000 is estimated. No new test facilities are required for the development of the shuttle.

This technical documentary report has been reviewed and is approved.

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Section 1

DEVELOPMENT PLANNING AND COSTS

1.1 DEVELOPMENT PLANS

Known planning and costing factors were applied during the tradeoff and system evaluation studies to achieve a low-cost, early-IOC vehicle. Upon selection of the vehicle to be treated in detail, determination of the relative cost effectiveness of the system, and formulation of the engineering development plan of Fig. 1, the cost increment analysis was made. The development plan shows major milestones and interrelationships of design, test programming, production, and flight test of the shuttle system. Major span-controlling subsystem developments are shown in more detail, including their programming into the simulation and ground test vehicles. Development plans were based on the use of current technology and developed hardware wherever possible. The 1967 time-period was used as a basis for programming. Expensive development effort was kept at a minimum.

1.2 VEHICLE DEVELOPMENT

The shuttle development and test program centers about the analysis, design, and testing necessary to demonstrate that mission reliability and crew safety requirements are satisfied. Failure modes will be identified and careful analysis made of potential hazards and the impact they may have on crew safety and mission success. Steps will be taken to eliminate or minimize these areas through improved design or operational procedures. The extent and amount of testing are tailored to these requirements. Reliability will be established through analysis and allocation of requirements and will be demonstrated by testing of components, subsystems, integrated systems, and the complete vehicle. Design baselines for evaluation of performance will be developed progressively from subsystem specifications to component specifications and design drawings. The shuttle development and test program differs from that normally associated with missiles and aircraft in that the amount of flight test is extremely limited. For this reason, reliance must be placed on results of ground testing. Required changes resulting from the test program will be incorporated in the operational system.

1.3 SUBSYSTEM DEVELOPMENT

Spaceframe

Spaceframe development will progress through preliminary design and completion of spaceframe specifications, development of test requirements, and design release for manufacturing. Structural component development tests will be performed in conformance with test requirements. Structural tests will be performed on critical and representative components. Particular attention will be given to those components that are exposed and must operate in space environment. Lubricants, seals, and bearings will be tested under simulated space environment.

Attitude and Stability Controls

The control system will be developed through system analysis and simulation with the aid of a fixed-base simulator computer program. A fixed-base simulator-trainer will be constructed by incorporating prototype hardware as it becomes available. Mission profile studies will be conducted throughout the complete flight regime. During this phase, simulated docking tests will play an important role.

Reaction Control Propulsion

The reaction control propulsion subsystem will be progressively developed, on the basis of subsystem specifications, through component development tests, full-scale mockup (Propulsion Test Article, PTA), system development tests, and Preliminary Flight Rating Tests (PFRT). PFRT systems will be provided for use in the static firing vehicle.

Other Subsystems

The power supply and distribution, navigation and guidance, communication, and docking subsystems will be developed in a manner similar to those discussed above. They are not span-controlling subsystems and are therefore not discussed further.

1.4 MANUFACTURING

The planning, tool design, tooling fabrication, assembly and checkout processes are well within the state-of-the-art for the aerospace industry. Construction is essentially aluminum frame and single aluminum skin construction with insulation adaptable to standard manufacturing techniques.

1.5 VEHICLE TEST

The first production article, essentially a structural shell, will be used as a static test vehicle. Static loads will be applied to design ultimate and pressure cycling and failsafe tests will be performed. The second production article incorporating complete systems will be used for subsystem tests and complete systems integration tests. It will be maintained through the remainder of the program to checkout required changes. The third production article will be used for reaction control propulsion static firing.

It will incorporate the initial PFRT system. The static firing will be performed on a soft mount to validate propulsion performance in the pitch, yaw, and roll modes, and with the thrust in three directions. The static firing vehicle will then be sent to the launch site for booster compatibility and radio frequency checks. The fourth production article will be used for validation of the environmental system and for man-machine compatibility demonstrations. The environmental performance will be tested on simulated missions in simulated space environment. The man-machine integration tests check man in the loop, his performance, habitability, and maintenance functions. The fifth production article is the first flight vehicle. The first operational shuttle incorporating changes resulting from the development test program will be available for delivery at the end of the second year after program go-ahead.

1.6 COST ANALYSIS

Tables 1 and 2 present a manhour spread by major elements and a cost analysis summary, respectively. Costs were accumulated for major-systems elements outlined in the development plan. Inasmuch as the shuttle vehicle will be a rider in a development flight of another vehicle, pro-rated flight test costs were not included.

Section 2

TEST FACILITY REQUIREMENTS

Test facilities currently available at governmental and aerospace industrial facilities are considered adequate to perform the anticipated test program. Specific facilities required are indicated below.

Structural - Mechanical

Component - A structural and mechanical research laboratory with capabilities for materials properties investigation, static tests of structural assemblies, vibration and fatigue tests, elevated temperature testing and environmental testing. Special tests on seals, lubricants and bearings will require an altitude chamber capable of 1×10^{-9} mm Hg with an approximate size of 2 ft 0 in. diameter by 2 ft 6 in. long clear working space.

Vehicle - Tie down area, structural steel, and loading and instrumentation equipment for vehicle static and dynamic tests. In addition, an H_2O pressure cycling unit and water tank (approximately 7 ft in diameter by 9 ft high) will be required for pressure cycling and fail-safe tests.

Reaction Control Propulsion

The propulsion system development will require a complete liquid rocket motor development facility with both sea level and altitude engine hot firing cells, control and component development test areas and complete environmental supporting equipment, such as vacuum chambers and testing equipment for vibration, acceleration, shock and temperature tests.

Vehicle Subsystems and Integration Testing

The radar and communication equipment will require basic electrical-electronic instrumentation and an antenna pattern range.

The stability and control equipment will require basic instrumentation for bench tests and analog computer facilities for design verification. The electrical distribution and power system will require basic electrical instrumentation.

The testing of the propulsion system in the vehicle will require a soft mount and instrumentation capable of handling 200 pounds of force in the pitch, yaw, and roll modes and thrust in three directions. Liquid rocket propellant handling facilities for hot runs will also be required.

Testing of the environmental control system will require basic pneumatic test equipment and an environmental chamber capable of 1×10^{-6} mm Hg, temperatures from 100° to 400°F and approximately 8 ft x 8 ft x 10 ft in size.

For man-machine compatability and vehicle performance tests it is recommended that a docking simulator (Ref. RTD-TDR-63-4292, Methodology for Evaluation and Validation of a Mechanical Rendevous Subsystems) capable of the required degrees of freedom be used.

Complete vehicle system integration will require basic electrical and mechanical test equipment and instrumentation.

FIGURE 1

ENGINEERING DEVELOPMENT PLAN

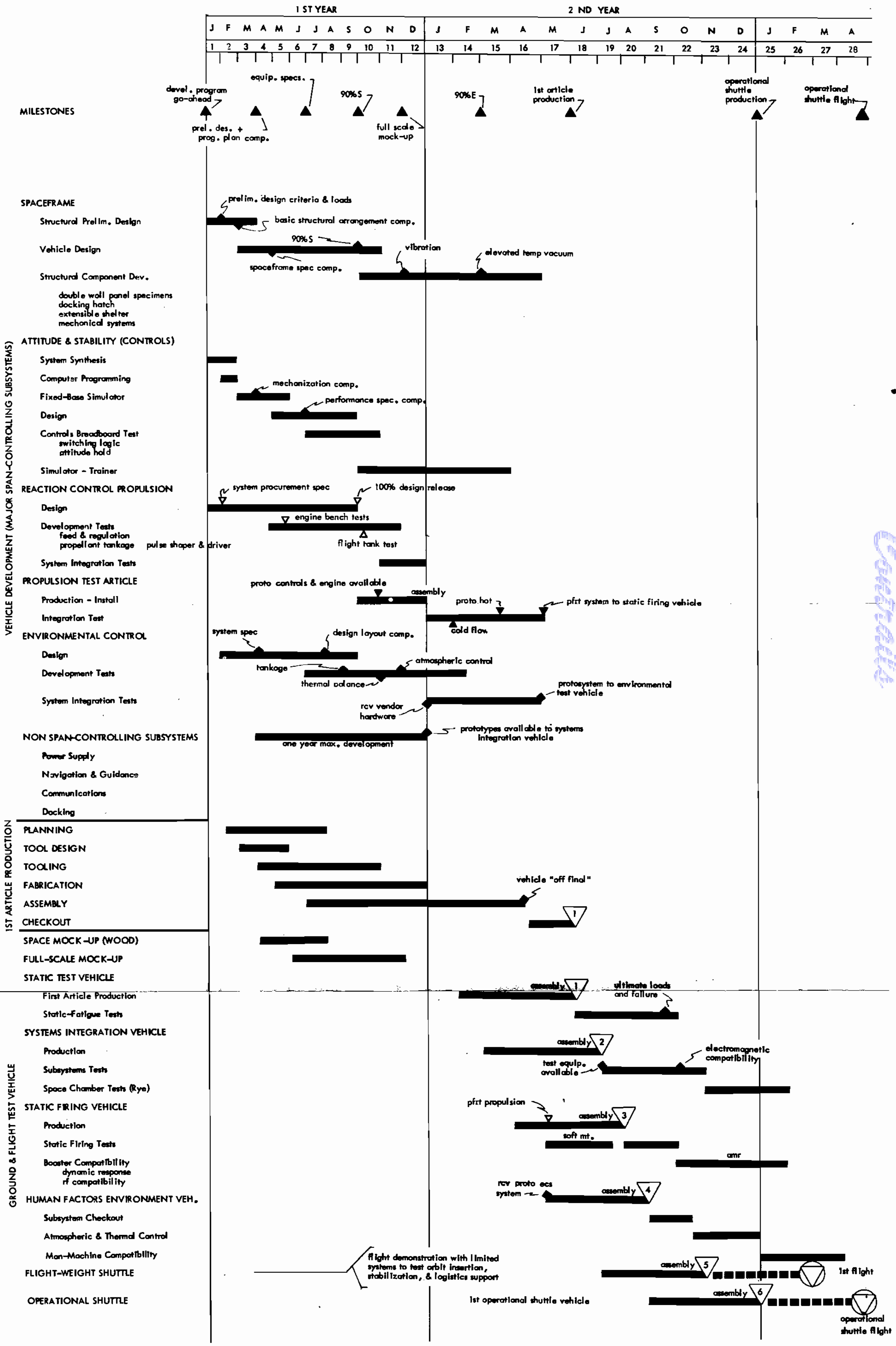

Table 1

MANLOADING SUMMARY

MONTHS FROM GO-AHEAD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	TOTAL MAN-MONTHS	TOTAL HOURS (154 HRS/MO)
PROJECT ENGINEERING Design, Subsystem Interface and Support	35	44	55	75	98	120	130	135	140	140	130	115	105	99	93	87	81	75	68	61	54	47	41	35	29	24	23	23	2162	332,948
SYSTEM INTEGRATION Subsystem Integration and Simulation	40	40	40	40	40	36	31	26	21	20	15	15	15	15	15	10	10	10	10	10	10	10	10	10	10	10	10	10	539	83,006
REACTION CONTROL PROPULSION Engine, Feed and Regulation Pressurization and Tankage Development and Mfg.	12	30	41	52	63	77	88	99	110	119	124	125	124	118	108	95	82	67	52	39	27	18	13	11	10	10	10	10	1734	267,036
SUBSYSTEM DEVELOPMENT ECS, Guidance and Navigation Power Supply, Instrumentation and Display				10	14	18	22	25	28	32	35	38	42	45	43	37	30	24	17	12	8	5	5	5	5	5	5	5	515	79,310
GROUND SUPPORT EQUIPMENT Special Test Equipment and Ground Handling			5	9	13	16	18	21	24	27	29	32	33	32	30	26	22	17	13	11	9	7	6	5	4	3	2	2	416	64,064
MANUFACTURING 2-Mock Ups 4-Ground Test Articles 2-Flight Articles				5	8	13	22	31	40	51	63	77	93	106	111	111	108	100	86	72	58	45	33	22	12				1267	195,118
GROUND AND RELIABILITY TESTING	3	3	5	6	8	10	12	15	19	23	27	30	33	37	41	45	51	58	64	70	74	77	77	75	72	65	51	33	1084	166,936
TOTAL	90	117	146	197	244	290	323	352	382	412	423	432	445	452	441	411	384	351	310	275	240	209	185	163	142	117	101	83	7717	1,188,418

Table 2

COST SUMMARY ANALYSIS

	LABOR HOURS	RATE (dollars/hr)	LABOR DOLLARS	MATERIAL DOLLARS	TOTAL DOLLARS
PROJECT ENGINEERING	332, 948	12.00	3, 995, 376		3, 995, 376
SYSTEM INTEGRATION	83, 006	12.00	996, 072		996, 072
REACTION CONTROL PROPULSION	267, 036	12.00	3, 204, 432	800, 000	4, 004, 432
SUBSYSTEM DEVELOPMENT	79, 310	12.00	951, 720	150, 000	1, 101, 720
GROUND SUPPORT EQUIPMENT	64, 064	11.00	704, 704	300, 000	1, 004, 704
MANUFACTURING	195, 118	7.70	1, 502, 409	500, 000	2, 002, 409
GROUND & RELIABILITY TESTING	166, 936	12.00	2, 003, 232		2, 003, 232
TOTAL	1, 188, 418		$13, 357, 945	$1, 750, 000	$15, 107, 945