N71-35220

SUBSYSTEM TRADE-OFF

ENVIRONMENTAL CONTROL AND LIFE SUPPORT

FOR

ORBITER PHASE B CONTRACTOR

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A description of an Environmental Control and Life Support (ECLS) subsystem for the Space Shuttle Orbiter will be presented.

Included in the description is the approach to subsystem evaluation, candidates chosen for review and candidates selected for integration into the vehicle design. Those areas within the ECLS which require advances in technology or new technology have also been identified. The selected configuration is consistent with overall program goals of maximum performance and value with a minimum of development and cost.

INTRODUCTION

The Environmental Control and Life Support (ECLS) subsystem in the orbiter provides a habitable environment for crew and equipment in the hostility of space. The ECLS must provide for the functions of:

- Shirtsleeve Environment
- Water Management
- Atmosphere Gas Supply
- Atmosphere Revitalization
- Waste Management
- Equipment Thermal Control

A block diagram of the subsystem is shown on Figure 1. The ECLS is active during the mission phases of launch, ascent, on-orbit, entry and landing, and supports two pilots and two cargo handlers. Ground Support Equipment (GSE) is utilized during prelaunch, launch and post landing activity.

The four man capacity allows for a wide latitude of mission capability ranging from seven days to thirty days. ECLS extended mission capability is achieved by the addition of modular equipment that is the same as the equipment provided in the orbiter. Provisions for this equipment addition are provided in the initial subsystem design.

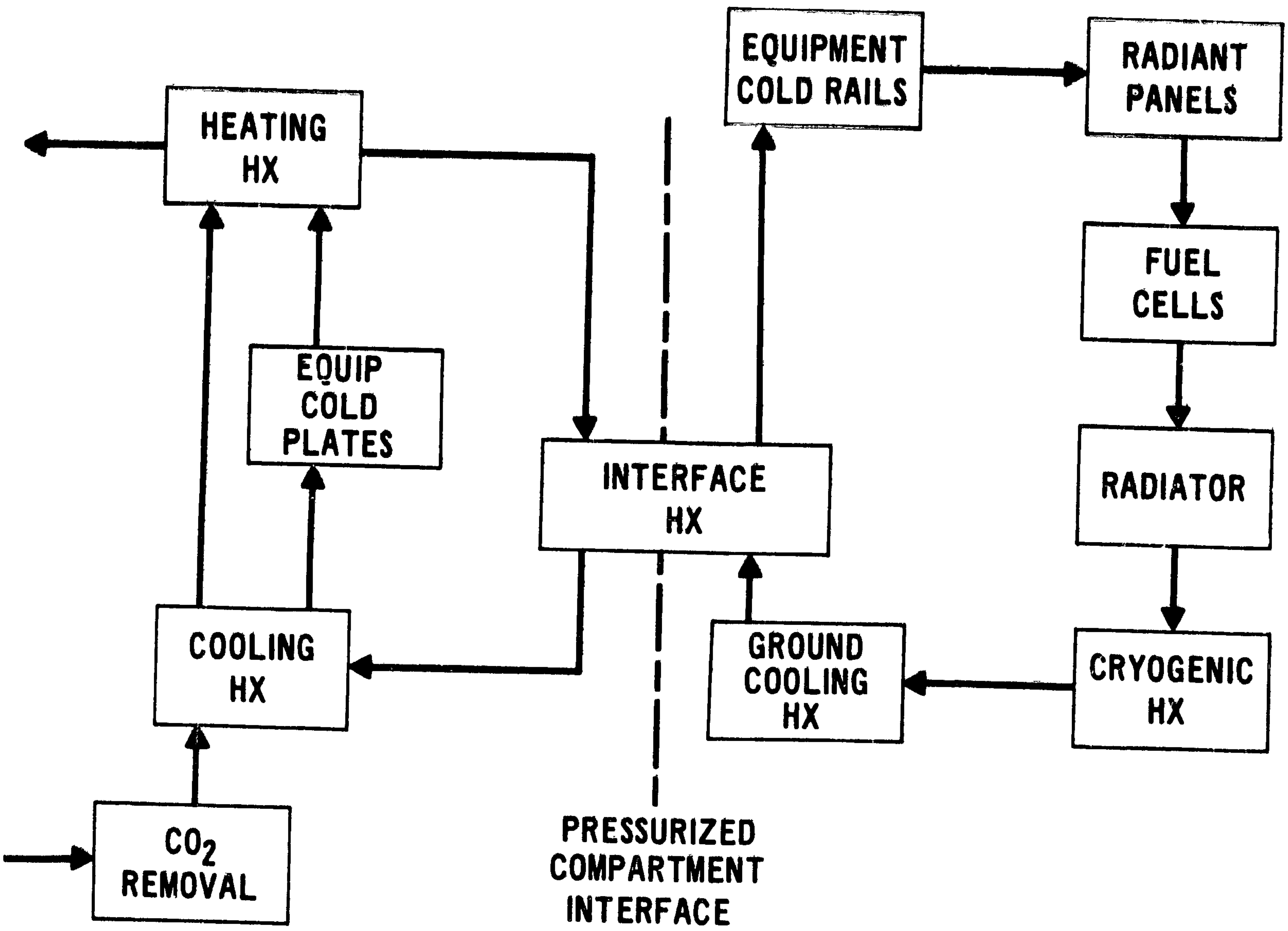

Figure 1. Orbiter ECLS Subsystem Block Diagram

REQUIREMENTS

Major requirements affecting ECLS design and the parameter value used in our approach are summarized in Table 1.

Subsystem cost is a major factor in the selection of a design. As an overall requirement, the candidates for evaluation have to be cost effective in addition to meeting performance requirements.

SUBSYSTEM DESCRIPTION

A description of the candidates selected for study for each of the ECLS assemblies is presented herein. The candidates are compared by using a set of selection criteria. The criteria are divided into three-groups-absolute, quantitative, and qualitative. All candidates must meet the absolute criteria of performance, safety, reliability and availability or they are eliminated from further consideration. The quantitative criteria are related to cost and include weight, power consumption and expendables. Qualitative criteria are composed of complexity, flexibility, maintainability, and life.

Some of the approaches, being basically a tabulation of present state-of-the-art, do not require formal evaluation.

Atmospheric Storage Assembly - Several potential candidates exist for atmospheric storage. These include subcritical, supercritical and high pressure gas. Further, combinations of storage supplies for separate subsystems using the same media such as the hydrogen/oxygen fuel cell also exist. Table 2 presents the results of the nitrogen storage portion of atmosphere storage study, conducted to determine the optimum storage configuration. Two 3000 psia filament wound composite tanks are selected for nitrogen storage on the basis of safety and equivalent cost. Table 3 shows the study results of separate versus common oxygen storage and whether that storage should be cryogenic or gaseous. The system selected utilizes the Orbit Maneuvering System subcritical storage tank for supplying oxygen during normal operation. In the event oxygen cannot be supplied to the ECLS, a 3000 psia tank of filament wound composite material construction will supply oxygen at normal use rates for a 48 hour period.

Atmosphere Pressure Control Assembly - Cabin pressure and composition control is maintained by a Skylab type two-gas controller and tripley redundant pressure relief valves. The Skylab controller is chosen because its developed and qualified status results in a lower orbiter ECLS cost.

TABLE 1

ORBITER ECLS DESIGN REQUIREMENTS

NUMBER OF CREW	4
METABOLIC HEAT	650 BTU/MAN-HR
OXYGEN USAGE	1.84 LB/MAN-DAY
CO_2 PRODUCTION	2.20 LB/MAN-DAY
URINE PRODUCED	3.45 LB/MAN-DAY
MISSION DURATION	7 DAYS (NOMINAL)
TOTAL MISSIONS/ VEHICLE	100

VEHICLE LIFE	10 YEARS
CABIN PRESSURE	10 & 14.7 PSIA
OXYGEN PARTIAL PRESSURE	3.1 PSI
CO_2 LEVEL (NOMINAL)	5.0 MM Hg
CABIN TEMPERATURE	65–75°F
HUMIDITY (DEW POINT)	46–57°F
CABIN LEAKAGE	3.5 LB/DAY

TABLE 2

ATMOSPHERE STORAGE STUDY SUMMARY

GAS	NITROGEN STORAGE			
	CRYOGENIC		HIGH PRESSURE	
CANDIDATE	SUBCRITICAL	SUPERCRITICAL	TITANIUM TANK	FILAMENT WOUND TANK
CANDIDATE NO.	6A	6B	7A	7B
HIGH PRESSURE GAS TANKAGE MATERIAL SELECTION				7B
CRYOGENIC VS HIGH PRESSURE GAS STORAGE				7B

TABLE

ATMOSPHERE STORAGE STUDY SUMMARY

GAS			OXYGEN STORAGE							
CANDIDATE	OMS - EMERGENCY		COMBINED FUEL CELL & ECLSS				SEPARATE FUEL CELL & ECLSS			
	STAINLESS STEEL TANK	FILAMENT WOUND TANK	SUB-CRITICAL	SUPER-CRITICAL	STAINLESS STEEL TANK	FILAMENT WOUND TANK	SUB-CRITICAL	SUPER-CRITICAL	STAINLESS STEEL TANK	FILAMENT WOUND TANK
CANDIDATE NO.	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
HIGH PRESSURE GAS TANKAGE MATERIAL SELECTION		$\boxed{1B^*}$				$\boxed{3B}$				$\boxed{5B^*}$
CRYOGENIC VS HIGH PRESSURE GAS STORAGE				$\boxed{2B}$						$\boxed{5B}$
COMBINED VS SEPARATE STORAGE FOR FUEL CELL & ECLSS O_2		$\boxed{1B}$								

*SELECTED BY SIMILARITY WITH 3B

Total cabin pressure is controlled by redundant absolute pressure regulators which can be manually selected for 10.0 or 14.7 psia operation. The multi-purpose range will support both Space Station rendezvous and potential EVA missions. The cabin pressure relief valves are also manually set for either 10.0 or 14.7 psia. These valves relieve cabin atmosphere overboard during launch and allow pressurization of the cabin during entry.

Partial oxygen pressure is maintained within prescribed limits and is controlled by redundant pO_2 sensors and normally closed solenoid valves on the nitrogen supply inlet.

Ventilation Provisions - Three redundant fans in the air distribution system provide ventilation. Air is drawn into the cabin air loop, through the carbon dioxide processing unit, conditioned for both humidity and temperature, and then returned to the cabin. The process flows for four men which are required for suitable humidity and CO_2 control are also adequate for cabin ventilation thus negating the need for multiple cabin fan installations.

Carbon Dioxide Removal & Humidity Control Assembly - Several approaches to carbon dioxide and humidity control are available for use. Those considered during the CO_2/humidity control study for orbiter application are:

- Lithium Hydroxide and Condenser
- Lithium Hydroxide and Desiccant
- Molecular Sieve and Condenser
- Molecular Sieve and Desiccant
- Solid Amine

Table 4 presents a summary of the trade-off results. Lithium hydroxide, in conjunction with a condensing heat exchanger, is selected for orbiter application. Each cartridge contains four man days worth of LiOH and activated charcoal and is replaced on a prescribed basis.

The area of CO_2 and humidity control may be considered for advancement in control techniques. Although a LiOH and condenser assembly is adequate and is chosen on the basis of cost through first flight, a more flexible system could be achieved with solid amine or desiccant. These approaches become attractive if multiple crew and varying mission duration mixes are considered.

TABLE 4

CO_2 AND HUMIDITY CONTROL SUBSYSTEM COMPARISON

SUBSYSTEMS	RANKED 1 TO 5, LOWEST TO HIGHEST	
	WEIGHT	COST
LiOH/CONDENSER	1	1
LiOH/DESICCANT	4	4
MOLECULAR SIEVE/CONDENSER	3	3
MOLECULAR SIEVE/DESICCANT	5	5
HS–B	2	2

Trace Contaminant - Control of contaminants is achieved in the orbiter by means of cabin leakage and activated charcoal. A cabin leakage of 3.5 pounds per day will control most of the trace gases. Activated charcoal is used to remove the larger molecules of organic contaminants. Activated charcoal is chosen on the basis of Gemini, Apollo and LM experience.

Heat Transport Assembly - Redundant water loops within the crew compartment and redundant Freon 21 coolant loops external to the crew compartment provide thermal control for crew and equipment. Heat generated within the crew compartment by the crew, $LiOH/CO_2$ reaction, avionics and other equipment, and radiation to the cabin wall is picked up by circulating water loops and transferred via interface heat exchangers to the equipment loops. The equipment loops, in addition to removing heat from the cabin, provide thermal control for the avionics equipment, fuel cells, and the landing gear wheel wells. Heat is removed from the equipment loops by the space radiator during the orbital mission phase. During the ascent and entry phases heat is removed by redundant cryogenic hydrogen heat exchangers. Hydrogen is chosen for its availability throughout the mission phases and its cooling efficiency, as shown in Figure 2.

Each of the redundant crew compartment loops has two pumps for circulating the water through the condensing and cabin heat exchangers for removal of moisture and temperature control of the atmosphere, and through cold plates and cold rails for heat removal from the avionics equipment located within the compartment. Two pumps are provided in each of the redundant equipment loops. One pump operation is necessary to provide cooling for normal orbital heat loads. For the higher heat loads encountered during ascent, entry and short orbital periods, two pumps are required. Two pumps in one loop or one pump in each loop provide the necessary cooling.

The cryogenic hydrogen heat exchanger is a potential candidate for early development. This approach is a key element in the thermal control portion of the subsystem design. Investigation is required in the areas of control, sizing and atmospheric operation.

Space Radiator Assembly - The radiator is a deployable panel which is stowed under the cargo bay door during launch and entry. In orbit, the cargo bay door is opened, the radiator is deployed, and the cargo bay door is closed. Prior to entry, the procedure is reversed. The radiator is constructed of aluminum with a low α/ϵ coating to effect radiation from both sides of the panel. The two dimensional tube pattern, combined with a bypass stagnation heat load control, provides a wide heat load range.

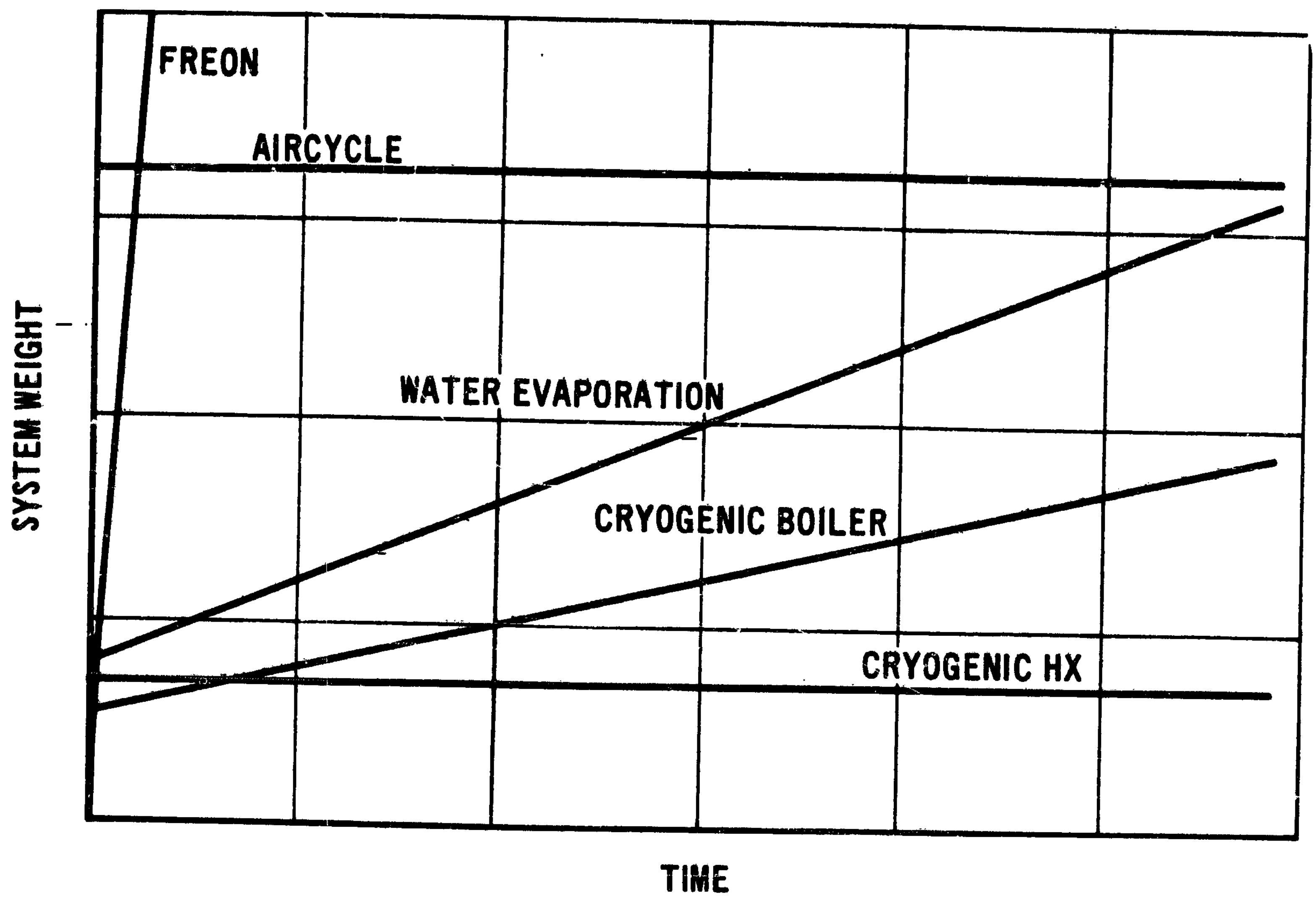

Figure 2. Environmental Control and Life Support Comparison of Cooling Approaches

Water Management - Included in water management are storage and dumping of fuel cell product water, provision of drinking water and the bacteriological control of the subsystem. The storage tanks are sized to preclude overboard dumping in the vicinity of the Space Station. Automatic operation is provided with the capability of manual override.

Both pasteurization and chemical addition are being considered for bacteriological control pending the outcome of detail design. The Skylab water system design and monitoring approach are available for adaptation into the orbiter. Skylab uses an iodine injection system in conjunction with a test solution which determines an adequate iodine content.

Waste Management Assembly - The waste management assembly provides for feces, urine and small trash collection, processing and storage. The major concern in waste management design is the area of crew acceptability. Existing waste collection systems, either in the concept or breadboard stage, are of two types. These are integrated vacuum drying and manual transfer with vacuum drying. Of the two, the integrated vacuum drying approach is more acceptable from a crew acceptability standpoint. Since the orbiter does not presently have a requirement for medical monitoring, the bag collection with manual transfer and drying is not warranted. The system selected for integration into the orbiter is similar to that used on the Space Station Prototype (SSP). In that system, feces and solid waste are collected, vacuum dried and stored in one container. Additional effort is required in the development of waste management system determining the impact of both sexes in the crew and passenger contingent.

Fire Extinguishing - Portable fire extinguishers are provided in the crew and passenger area. Some developmental work is required to verify use in zero "g". The units contain 2-5 pounds of carbon dioxide in accordance with the standard on aircraft hand fire extinguishers. A design margin is provided in the lithium hydroxide in the event a unit is discharged. The pCO_2 indicator provides visual indication to the crew as a safe pCO_2 level is achieved. Oxygen masks are worn during this period which is less than five hours. Additionally, the capability to purge the cabin with nitrogen is available. Nonflammable materials are used throughout the crew and passenger area to minimize the risk of fire.

DESIGN APPROACH

Aircraft philosophies and practices are applied to the orbiter ECLS design which result in a subsystem that meets the Space Shuttle maintainability requirements of short turnaround, ease of refurbishment and maintenance, including unscheduled maintenance. A minimum cost subsystem with maximum flexibility of design is achieved through commonality of high cost equipment. Potential ECLS orbiter and booster candidates for commonality include:

- Cabin Pressure Relief Valves
- Booster Air Tank and Orbiter Emergency Oxygen Tank
- Cryogenic Heat Exchangers
- Cooling Umbilicals
- Crew Equipment

The capability of extravehicular activity, although not directly provided in the orbiter design, was considered to the extent that it can be included in future program requirements.

Subsystem flexibility is provided in the form of add-on equipment which results in the capability to extend the orbiter mission duration.

CONCLUSIONS

The Environmental Control and Life Support subsystem provided for the Space Shuttle Orbiter satisfies the program goal of maximum performance and value, with a minimum of development and cost. This achievement is attained primarily in two ways, the first being maximum use of existing spacecraft components that meet the exacting requirements of a reusable Space Shuttle vehicle, and secondary, utilizing common or similar components and assemblies in the orbiter and booster to minimize program development costs.

The orbiter ECLS design definition has identified some areas requiring new or advancements in development. These are primarily in the fields of composite materials for pressure vessels, regenerative sorbents for humidity control, cryogenic heat exchange and its associated control, waste management and the impact of both sexes on crew make-up, and finally, spacecraft fire extinguishers for 1 "g" and zero "g" application. None of the above areas, nor the subsystem defined for the Space Shuttle orbiter, require major advances in technology along with their associated costs. Pursuit of the design definition described above will result in a viable system for the Space Shuttle Program.