TECHNOLOGY FOR SPACE STATION EVOLUTION - A WORKSHOP

PROPULSION TECHNOLOGY DISCIPLINE

JANUARY 19, 1990

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TECHNOLOGY DISCIPLINE SUMMARY FOR PROPULSION

The SSF propulsion system has a dual function–not only does it provide propulsion for orbit maintenance, cancelling disturbance torques, and back-up attitude control, it also provides an acceptable (indeed, a useful) means of disposing waste fluids from the station. The current baseline for primary propulsion is a modular hydrazine system, and the multifluid resistojet system performs the waste fluid function and also provides for a portion of the orbit-raising propulsion requirements.

The evolution scenario that resulted from the MDSSC trade studies calls for the modular hydrazine system to be replaced or supplemented by an oxygen/hydrogen primary propulsion system after Assembly Complete. This is predicated upon station growth and sufficient power and water availability. In the event that insufficient power and water in the station fluid balance exist, the technology program defined in this plan includes work in hydrazine improvements and in storable bipropellants.

Because the life cycle costs of the SSF propulsion system would be significantly lower with the O2/H2 system, those technologies are ranked highest in priority. Hydrazine improvements are second priority, followed by the common technologies that must be addressed no matter which system is selected. The propellant resupply and bipropellant technologies are lowest priority.

A key point to be made is that several of these technologies are already ongoing, and require FY91 funding to avoid a hiatus in the work, which would drive up the eventual costs and threaten the schedule.

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Propulsion System **Water Electrolysis 02/H2 System**

BACKGROUND

SCOPE - Demonstrate improved-life, high-pressure electrolysis units with simple, reliable, safe, on-orbit operating capability; on-orbit water cleanup capability; durable thrusters with improved igniters; light-weight, high pressure tankage; and high-pressure 02 and H2 compressors.

OBJECTIVES - To advance high pressure electrolysis technology in the areas of stack efficiency, dryers, phase separators, pressure control, sensors, and water pumps beyond the current capability that will be demonstrated in the JSC breadboard units to be delivered in the Spring of 1990. To understand the water cleanup requirements and then to advance the on-orbit water cleanup capability to meet these requirements. To build upon the 02/H2 thruster technology from the advanced development program in the areas of resonance igniters and extending the O/F ratio range. To develop and demonstrate light-weight graphite/epoxy tankage to a level that insures long life AND safe in-space operation. To build on the current JSC waste gas compressor technology to determine if high pressure compressors with low pressure electrolysis units is an attractive alternative to high-pressure electrolysis.

RATIONALE - Significant improvements in propellant resupply cost can be achieved by using O2/H2 propellant to perform Space Station reboost. There may also be some excess water available from the station water balance that would further reduce resupply costs. The effective specific impulse can be increased from 230 lb-sec/lbm for hydrazine to 370 lb-sec/lbm for O2/H2. Technology advancements have been made with this concept during the advanced development program and more recently in the JSC O2/H2 test bed and electrolysis breadboard contracts. The recent work has shown that the advancements mentioned above must be achieved in order for this attractive concept to be ready for operation post-AC. If this area is not funded we will not be any better off five years from now (when development should start) than we are today.

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Propulsion System **Water Electrolysis O2/H2 System**

PROGRAM PLAN

APPROACH:

1. High pressure electrolysis units--contract with suppliers to develop the needed technology in the areas of stack efficiency, phase separators, dryers, pressure control, sensors, and water pumps. Upgrade the current breadboard units with new components from these programs. Test complete electrolysis units to demonstrate 10,000 hours of operation and continue to upgrade areas that show problems.

2. Water cleanup--evaluate water cleanup requirements in subscale units and develop in-space cleanup techniques at the suppliers.

3. Thrusters---contract with suppliers to upgrade thrusters in the areas of life, ignition, and O/F range.

4. Tankage, mass flow control, and compressor--contract with suppliers to develop technology in these areas.

5. System test bed--demonstrate above improvements in JSC O2/H2 test bed as they become available. Develop database for extended-life, high-pressure H2 compatlbility. Demonstrate operating time data on flight type hardware.

DELIVERABLES:

Prototype components and assemblies. Reports and test data from supplier programs and in-house testing. Flight demonstration hardware for the electrolysis phase separators.

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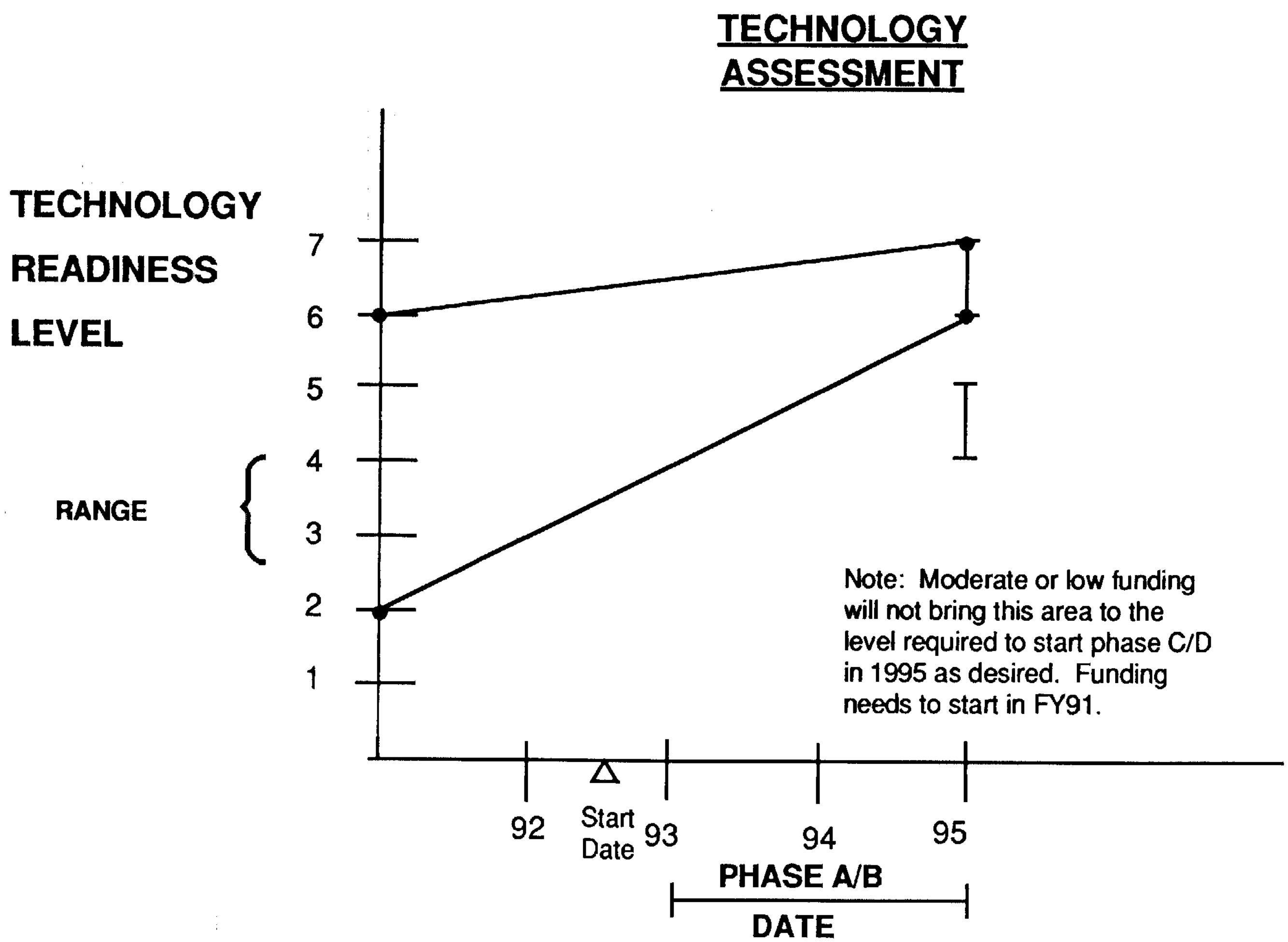
Propulsion System

Water Electrolysis O2/H2 System



Note: Moderate or low funding will not bring this area to the level required to start phase C/D in 1995 as desired. Funding needs to start in FY91.

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Propulsion System **Hydrazine System Advancements**

BACKGROUND

SCOPE - Improved-life resistojets and arcjets that will utilize the decomposition products of hydrazine to produce reboost thrust. Improved-life hydrazine thrusters and in-space propellant/pressurant resupply demonstration.

OBJECTIVES - To advance low-thrust hydrazine resistojet and arcjet technology beyond the current level of several hundred hours to a goal of 10,000 hours. To advance the life capability of moderate-thrust hydrazine thruster from the current level of 1,000,000 lb-secs to a goal of 10,000,000 lb-secs. To develop and demonstrate the technology to routinely and safety transfer hydrazine propellant and pressurants from a resupply tanker to the on-board storage tanks.

RATIONALE - Significant improvements in propellant resupply cost can be achieved by using low-thrust resistojets and arcjets to boost the specific impulse of hydrazine propellant. The effective specific impulse can be increased from about 230 lb-sec/lbm to the 400 lb-sec/bm range. These low thrust devices could then be used during long non-quiescent periods to supplement the reboost from moderate thrust devices and achieve significant propellant resupply savings. Also, improvements in the life of the moderate thrust reboost thrusters would save on logistics (spares and maintenance) costs, and on-orbit resupply via propellant transfer would save on transportation costs. Propellent transfer would require deomonstration of safe, zero leakage quick save on transportation costs. Propellent transfer would require demonstration of safe, zero leakage quick disconnects, zero-g venting, transfer pumps, and compressors for pressurant gas.

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Propulsion System **Hydrazine System Advancements**

PROGRAM PLAN

APPROACH -

1. Arcjets, resistojets; and long-life thrusters - Contract with suppliers to develop the needed technology advancements to achieve the life goals. Demonstrate life goals in sub-scale and full-scale testing.

2. In-space propellant/pressurant resupply - Contract with suppliers to develop the needed technology to demonstrate automated, safe propellant/pressurant resupply.

DELIVERABLES -

1. Test reports, final reports, and prototype units for in-house evaluation.

2. Test reports, final reports, prototype units for in-house evaluation, and flight demonstration hardware.

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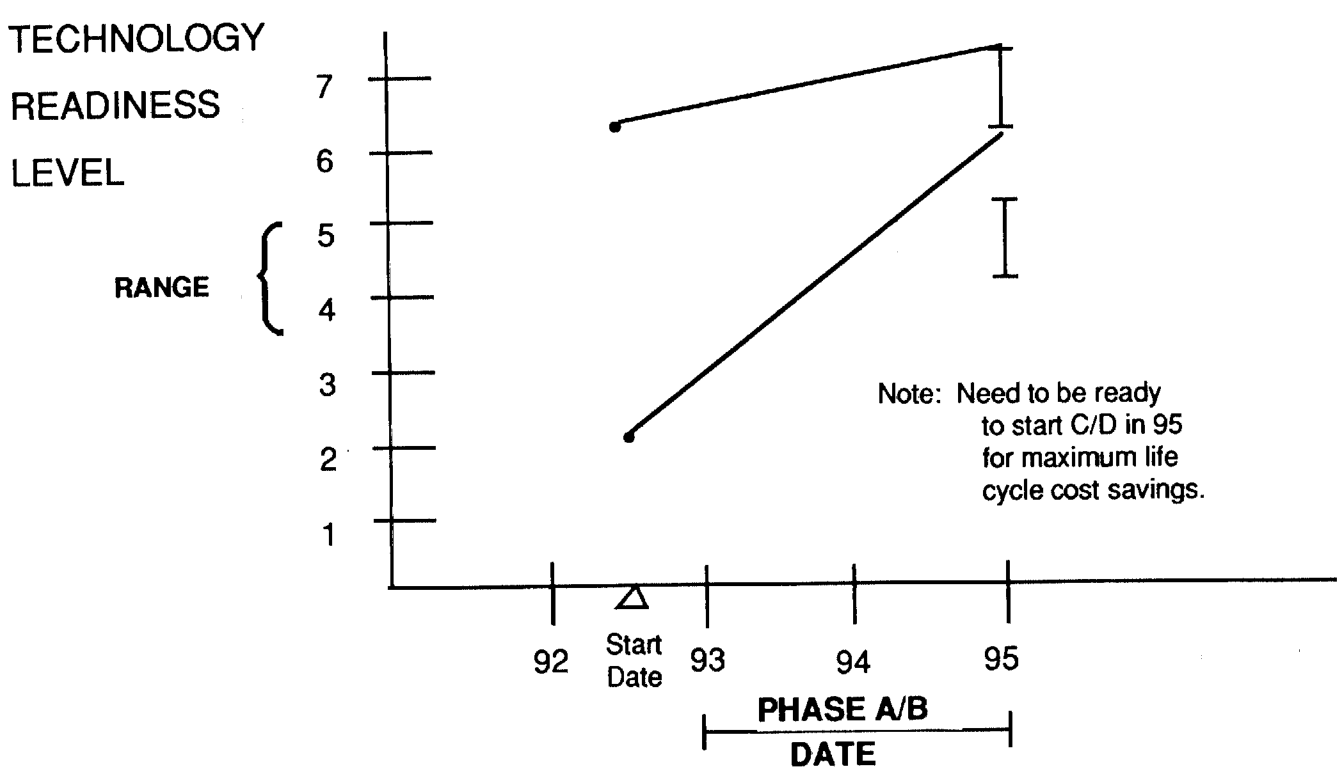
Propulsion System **Hydrazine System Advancements**

TECHNOLOGY ASSESSMENT



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Propulsion System **Common Technology**

BACKGROUND

SCOPE - Demonstrate those technologies that are considered by the panel to be "common" to all the propulsion options available to SSF. These technologies are critical to any of the options, and must be raised to at least technology level 5 in the advanced development program. The common technologies identified are: smart transducers, two-phase mass gaging, health monitoring and fault detection/isolation, cutting of liquid and gas lines without producing debris, "zero-leakage" components (including quick disconnects) and welding lines on-orbit.

OBJECTIVES - Conduct advanced development programs to produce: transducers that are capable of self-calibration while in active status; some means of propellant gaging in the space environment that can operate with both liquid and gas; a reliable, sophisticated health monitoring and fault detection/isolation system to provide the necessary long term reliability and safety that is essential to any SSF propulsion system; components and quick disconnects that will operate in space with near zero leakage; innovative ways to cut into propellant and pressurant lines without introducing debris that will contaminate the system with particles and cause valve seat leakage and other such undesirable effect; and an ability to perform welding operations on propellant and pressurant lines on orbit that is both safe and effective.

REQUIREMENTS - The technologies addressed are not new issues, but they are much more critical for very long-term, manned spacecraft than for current systems. They must be resolved for both SSF and Human Exploration Initiative missions to the moon and to Mars to be feasible. These technologies are also interdisciplinary; they do not benefit propulsion alone.

PROGRAM PLAN

APPROACH -

1. Smart transducers, two-phase mass gaging, and "zero leakage" components: Contract with suppliers to develop the hardware, and deliver to JSC for testing to demonstrate technology level 5.

2. Health monitoring and fault detection/isolation: Task order contract with WPO2 contractor to define, consistent with philosophy to be used on the SSF; then contract with vendors to supply the appropriate instrumentation and systems.

3. Cutting and welding of lines in space: contract with suppliers to develop techniques and hardware to be subsequently tested to technology level 5 at JSC.

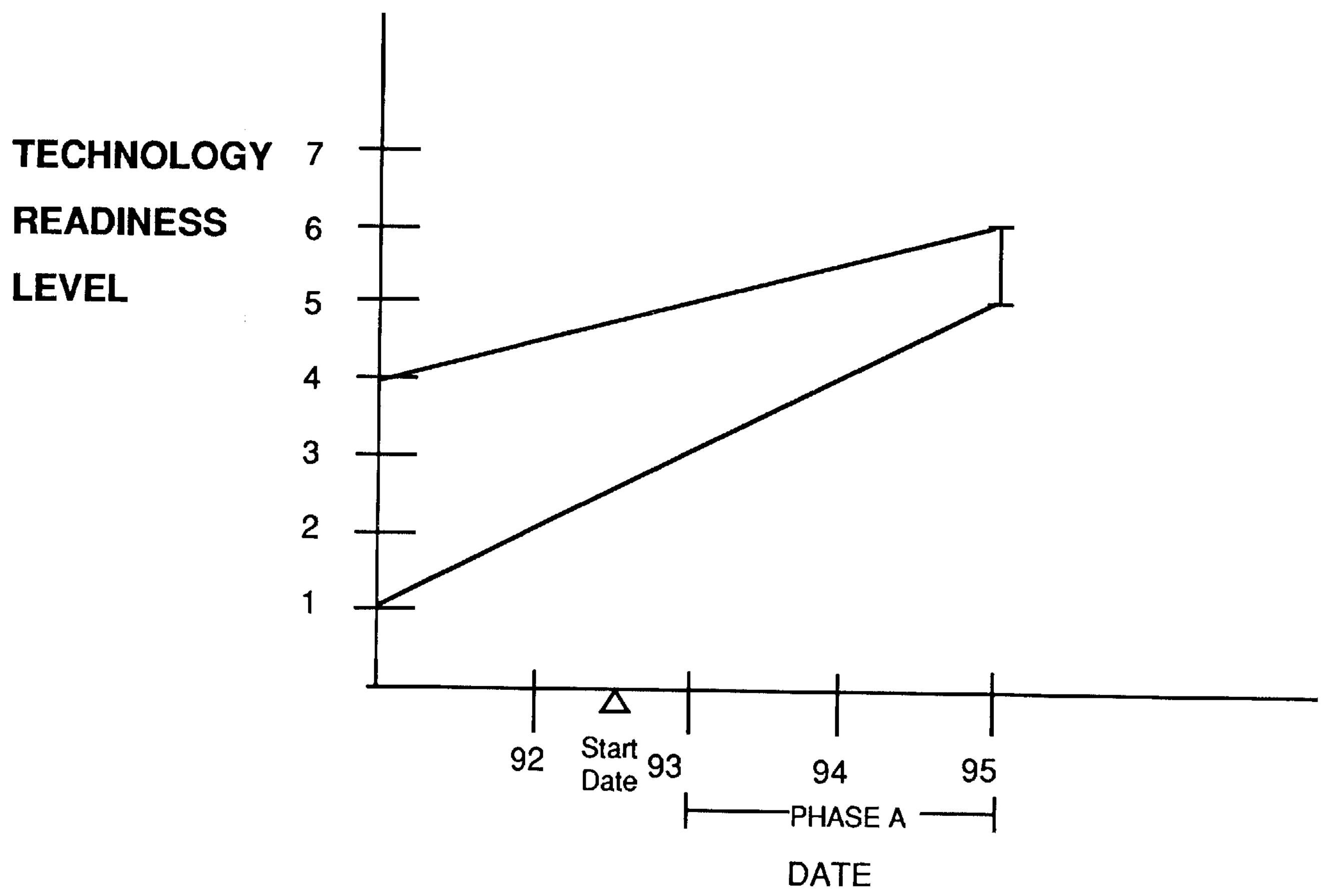
DELIVERABLES-

Prototype components and assemblies, supported by reports and test data where appropriate. In the case of health monitoring and fault detection/isolation, reports, test data, components and complete systems for integration into the SSF propulsion test bed at JSC.

Propulsion

Common Technology

TECHNOLOGY ASSESSMENT



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BACKGROUND

SCOPE - Demonstrate those technologies that relate to the function of fluids disposal from the SSF and from the LTV / LEV. These systems may have the function of fluids disposal alone or both fluids disposal and orbit-raising propulsion, as in the case of the resistojets. The specific technologies to be demonstrated relate to: Vaporizers for liquids in microgravity (encompasses water/fluid purity determination and heat sources); Resistojets,including materials compatibility and higher performance and life; Arcjets, including materials compatibility and higher performance and life; and gas compressors.

OBJECTIVES - To conduct advanced development programs to bring the technology level of these selected systems up to at least level 5 or 6.

REQUIREMENTS - The issue of fluids disposal in the vicinity of the SSF has always been a critical one. Dumping of waste fluids is not acceptable, and means are sought which combine the functions of fluids disposal and propulsion. Resistojets and arcjets are two ways of accomplishing this. The technology for both is reasonably mature, but not yet at the requisite level. Vaporizer technology is judged to be at about level 3, and may be the basis of a flight experiment to adequately demonstrate its maturity for SSF. Compressors for such fluids as hydrogen are at about technology level 4, and require additional system level demonstration in addition to some more component level work.

PROGRAM PLAN

APPROACH -

1. Vaporizers : Contract with suppliers to develop the hardware and deliver to JSC for integration into the propulsion test bed.

2. Resistojets: Contract with suppliers to develop the hardware and deliver to JSC for integration into the propulsion test bed.

3. Arcjets: Contract with suppliers to bring the level up to that of the resistojet systems, then develop the hardware and deliver to JSC for integration into the propulsion test bed.

4. Gas compressors: Contract with suppliers to develop the hardware and deliver to JSC for integration into the propulsion test bed.

DELIVERABLES -

Prototype components and assemblies, supported by reports and test data where appropriate. As required, reports, test data, components and complete systems for integration into the SSF propulsion test bed at JSC.

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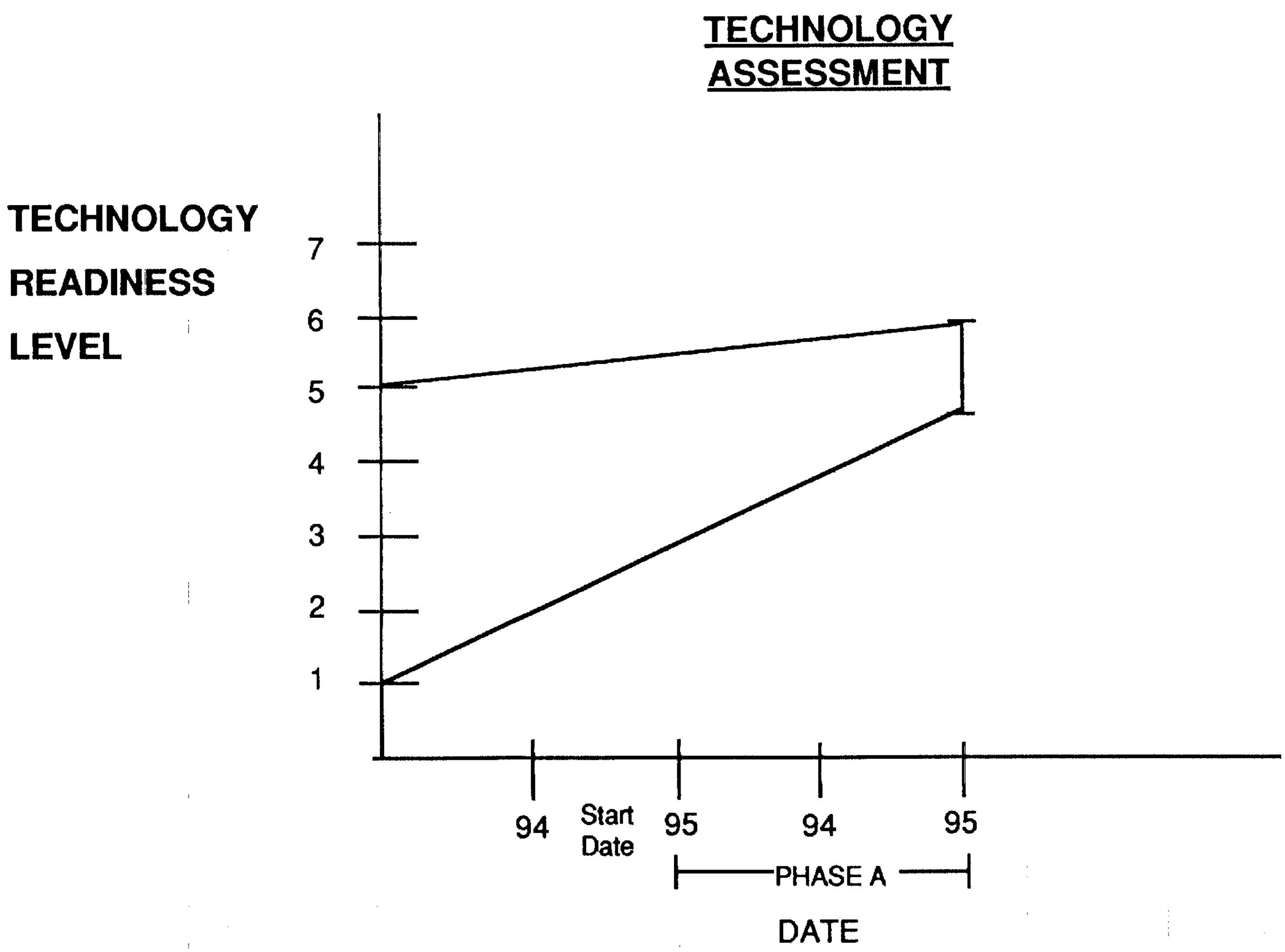
Propulsion | **Fluids Disposal**



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Propulsion System | **Storable Bipropellant System**

BACKGROUND

SCOPE - Demonstrate life and combustion stability of N204/N2H4 bipropellant thrusters. Demonstrate in-space re-supply of these propellants.

OBJECTIVES - To advance the technology level of N204/N2H4 thrusters to a level which will provide confidence that this higher specific impulse propellant combination can be used for Space Station reboost.

Areas requiring demonstration include life, combustion stability, stage ignition, and plume contamination acceptability. To develop and demonstrate the technology to routinely and safely transfer these propellants and their pressurant gases from a resupply tanker to the on-board storage tanks.

RATIONALE - Significant improvements in propellant resupply cost can be achieved by using this propellant combination to perform Space Station reboost. The specific impulse of this propellant combination is about 310 lb-sec/1 bm compared to 230 lb-sec/1bm for the baseline hydrazine system. The advantage of the N204/N2H4 combination over conventional N204/MMH is expected to be in much clearer plumes and the fact that the baseline N2H4 monopropellant system can still be retained for attitude control and reboost backup. New capability to handle MMH will not have to be added. Additional resupply costs savings can be achieved by implementing on-orbit resupply via propellant transfer rather than module change -out. This will require demonstration of safe, zero leakage quick disconnects, zero-g venting, transfer pumps, and compressors for the pressurant gas.

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Propulsion System **Storable Bipropellant System**

PROGRAM PLAN

APPROACH:

1. N204/N2H4 bipropellant thrusters--contract with supplier(s) to develop needed technology advancements to achieve life, combustion stability, stage ignition, and plume contamination goals.
2. In-space propellant/pressurant resupply--contract with suppliers to develop the needed technology to demonstrate automated, safe propellant/pressurant resupply.

DELIVERABLES:

1. Test reports final reports, and prototype units for in-house evaluation.

2. Test reports final reports, prototype units for in-house evaluation and flight demonstration.

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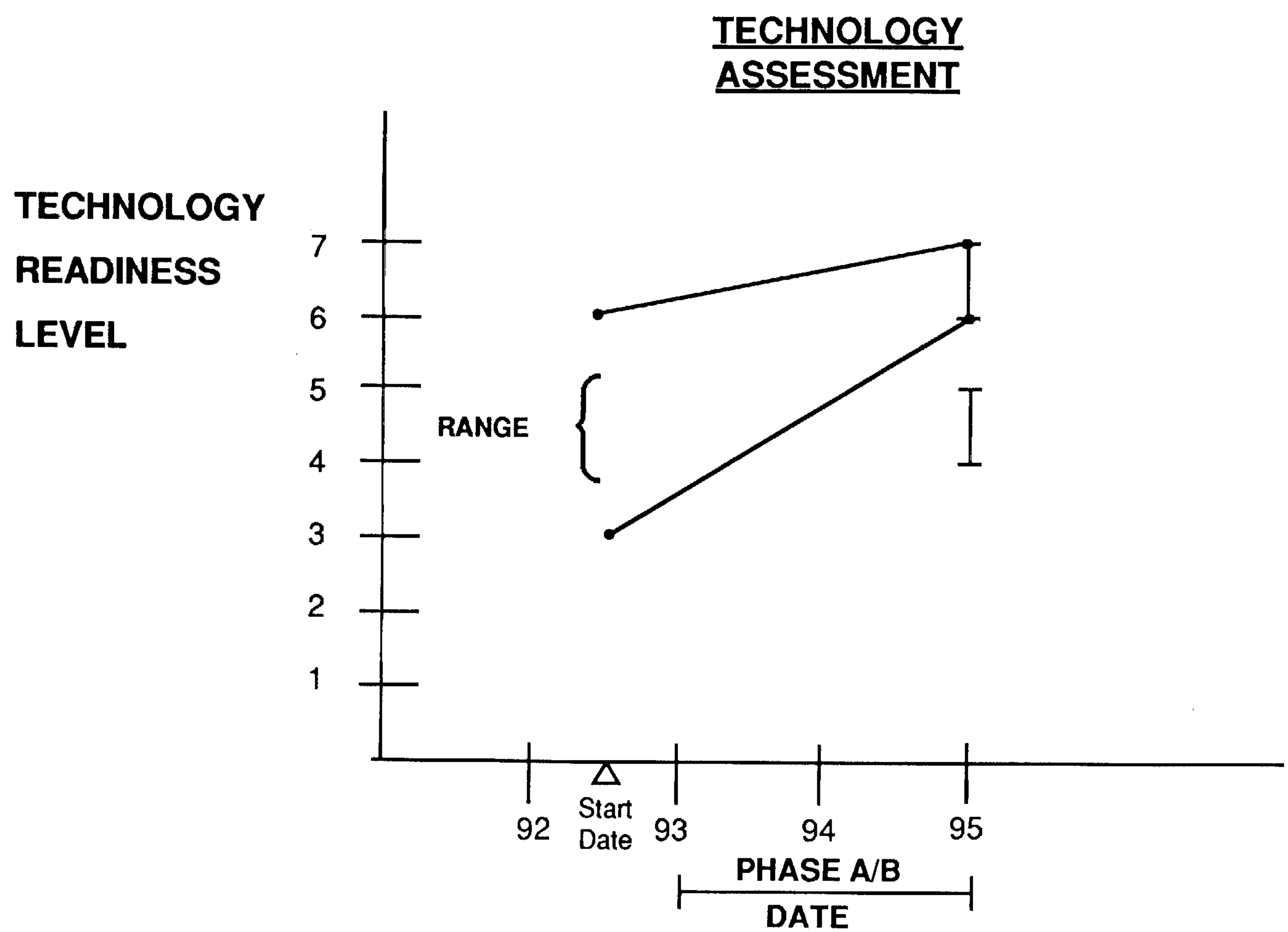
Propulsion System **Storable Bipropellant System**



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RECOMMENDATIONS/ISSUES FOR PROPULSION

RECOMMENDATIONS: In this discipline area, the first priority for funding should be all those technologies that bear on the oxygen/hydrogen propulsion system. Second priority should be given to hydrazine system advancements. Third priority should be given to the common technology tasks and to the fluid disposal technologies. Those tasks that deal with the in-space resupply of propellants should be next in priority, followed by the storable bipropellant technology work.

This is based on the proposed evolution scenario, which would retain the hydrazine modules for attitude control and contingency reboost and add the O_2/H_2 for reboost after assembly complete. The hydrazine work would be done as an upgrade that could be made to the current hydrazine modules in case O_2/H_2 is never added and to provide additional options.

ISSUES: Funding for those technologies that are on-going should be continued without a break, to avoid a hiatus in the critical areas that are needed to meet the SSF schedule.