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REPORT

PHASE I

SPACE STATION LONG TERM LUBRICATION ANALYSIS PHASE I PRELIMINARY TRIBOLOGICAL SURVEY

To

GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA

SEPTEMBER 21, 1990

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	Monthly Progress Report	Final Progress Draft	Final Progress Approved	Financial Management Report
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CC01/Wofford	1	1	1	0
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Marshall Space Flight Center, Alabama 35812

September 21, 1990

by

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INTRODUCTION

Increases in the size, complexity, and life requirements of satellites and space vehicles have put increasing demands on the lubrication requirements for trouble-free service. Since the development costs of large systems are high, long lives with minimum maintenance are dictated. The Space Station represents the latest level of size and complexity in satellite development; it will be nearly 100 meters in major dimensions and will have a life requirement of thirty years. It will have numerous mechanisms critical to its success, some of which will be exposed to the space environment. Designing long-life lubrication systems and choosing appropriate lubricants for these systems will be necessary for their meeting the requirements and for avoiding failures with associated dependent mechanisms. The purpose of this program was to identify the various critical mechanisms and review their designs during the overall design and development stage so that problem areas could be avoided or minimized prior to the fabrication of hardware.

The specific objectives were fourfold:

(1) To perform a tribology survey of the Space Station for the purpose of documenting each wear point as to materials involved, environmental conditions, and operating characteristics.

(2) To review each wear point (point of relative motion) as to the lubrication used and substrate materials selected in the context of its operating characteristics and the environmental conditions imposed.

(3) To make recommendations for improvement in areas where the lubricant chosen and/or where the substrate (materials of the wear couple) are not considered optimum for the application.

(4) To make or recommend simulated or full scale tests in tribological areas where the state-of-the-art is being advanced, in areas where new designs are obviously being employed and a critical review would indicate that problems are a strong possibility, and/or where excessive wear, a malfunction, or excessive leakage

would create fluid systems problems or contamination of exposed optical equipment.

The contract, which was initiated on June 24, 1985, was originally to be conducted in two Phases over a three-year period. Phase I was a preliminary tribological survey of the Space Station structure, systems, and equipment and a forecast of probable problem areas. Phase II was to be a detailed tribological survey to be conducted in concert with the maturing design. Because of the lack of availability of detailed design data and of repeated scheduling and funding delays with the overall Space Station program, the detailed tribological survey of Phase II was not initiated in January, 1987, which would have been in accordance with the original schedule. Instead, the program was halted until April, 1990, when the overall scope was modified and the program was reinstated. The modified scope has included three phases.

Phase I. Preliminary Tribology Survey, Preliminary Assessment, and Forecast of Probable Problem Areas.

The Phase I activities were conducted in accordance with the original program scope and were essentially completed by early 1987. This report summarizes the Phase I activities.

Phase II. Lubrication Evaluation of the Alpha and Beta joints.

The Phase I efforts have identified the alpha and beta joints as critical and potentially problem-prone because of their size, service life requirements, and lack of previous comparable experience. Phase II

Phase II. (cont.)

will consist of a review of these joints. The intent is to evaluate whether alpha and beta joints of the current design (incorporating reasonable modifications if found necessary) are likely to meet the requirements of consistent torque and outgassing specifications for a service life of 25 years. The review will include the lubrication methodology (grease, transfer films, or solid films) and the trade-offs considered in arriving at the methodology (maintenance intervals, outgassing, seals, friction levels, and debris generation). In addition, a review will be made of the tests already performed in support of the design and those specified for future evaluations. The results of the review, including an evaluation of the current design and recommendations for modifications or needed tests, will be documented in the Phase II section of the final report.

Phase III. Lubricant Selection Guide

Phase III will consist of preparation of a practical lubricant selection guide for use by designers of Space Station components. While the potentially available liquid and dry-film lubricants number in the hundreds, a large percentage are not practical for Space Station components because of such factors as outgassing properties, creep properties, viscosity, long-term stability, corrosive properties, or wear protection. The purpose of the Phase III effort will be to reduce the number of lubricants to a practical working number for designers to consider. Guides will be given for the selection of specific lubricants from the recommended list. The design guide will be incorporated in the final report.

This report is to document the Phase I activities. It describes the general Space Station requirements that will affect lubrication and the basic lubrication approaches available to address these requirements. The report by SRS Technologies, a major subcontractor on Phase I, is included in its entirety as Appendix A. SRS Technologies had responsibility for documenting the Space Station components and mechanisms regarding lubrication requirements.

SUMMARY

The Phase I activities began with a review of the various work packages of the primary contractors to identify tribological points of interest (SRS Technologies) and a review of pertinent literature to identify likely lubricants for use in the tribological applications (Battelle). As details of the various tribological points were identified, Battelle was to perform a review to assess the likelihood of success. Difficulties were encountered in attaining the needed design details because of the early stage of the design (details on loads and sizes were not available) and because of overall program delays. Consequently, a comprehensive review could not be made of most of the 72 specific components identified in the survey of 14 target projects. Of these, the most critical by far were the alpha and beta joints because of their size, lack of prior history, and their criticability to the Space Station. Since a change was made in contractors for these joints from the time the Phase I survey was conducted, the detailed design information obtained in the survey was useful only in a general sense. Because of the importance of these joints, the modified scope for the Phase II activities of the program concentrates specifically on these joints.

The literature review identified papers, reports, and books dealing with developments in lubricants for aerospace mechanisms. Recent advances in solid lubricants have involved the additions of antimony and antimony compounds to improve the friction and wear properties of bonded molybdenum disulfide solid lubricants. The selection criteria are based on the longevity needed and the possible deterioration of the binder from exposure to the space environment. Of the various candidate liquid (and grease) lubricants, the perfluoro ethers have come to dominate the field because of their low vapor pressure and acceptable lubricating properties. Friction and wear data and flight history data are available to assist in the selection and application of the perfluoro ethers. The Lubricant Selection Guide of Phase III will detail the specific preferred lubricants for example families of tribological contacts and provide data on advantages, disadvantages, and life-limiting considerations for their application.

SPACE STATION LUBRICATION REQUIREMENTS

The combination of size, complexity, and desired life of the Space Station is unprecedented in satellite design. As shown in Figure 1, the overall layout of the Space Station includes a central module that will be held in alignment to the surface of the earth. Large solar panels to provide power will be attached through "alpha" and "beta" joints to permit orienting the panels toward the sun. The size of the joints (approximately 3 meters in diameter for the bearing at the alpha joint) and associated structure demands that these bearings be capable of operation for the intended thirty year life. Changing the bearings would require major unacceptable provisions for astronaut time and for restraining the panel assembly. Inherent reliability of the bearing and lubrication systems for these large structures is therefore required.

The thirty year life will also expose components to 175,000 thermal cycles. The range of these cycles will be controlled primarily by the optical properties of the surfaces involved unless active thermal control is provided. Thermal cycles can affect lubricants in several ways. For liquid lubricants, the immediate effect is a change in viscosity. If the lower temperature extreme is below the pour point of the

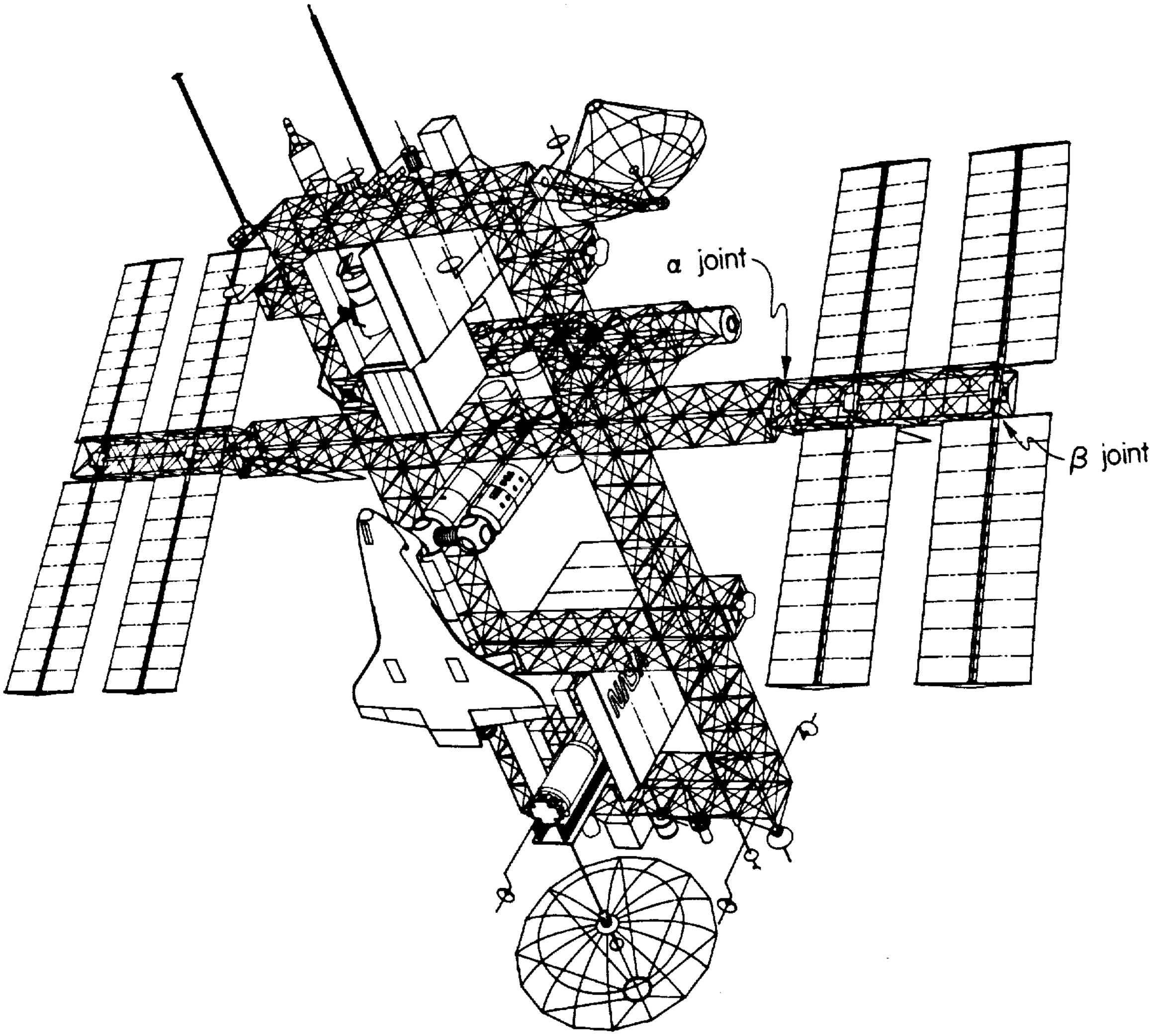


FIGURE 1. OVERALL LAYOUT OF SPACE STATION

liquid, it may be unable to reach the critical surfaces in the bearing or mechanism needing lubrication. Similarly, the high temperature extreme may lower the viscosity to a level where the lubricant cannot function properly. High temperatures can also degrade the lubricant through a variety of thermal degradation mechanisms. While dry film (solid) lubricants are relatively unaffected by temperature cycles, the binding agent must be chosen appropriately to avoid thermal degradation at the upper temperatures.

The thirty year life requirement introduces time-related lubrication degradation mechanisms, which must also be considered. Evaporation, creep, and degradation by atomic oxygen all represent potential problems that must be addressed in the design of mechanisms and selection of lubricants. Evaporation and creep of liquid lubricants present the dual problems of lubricant loss at the needed surface and of potential contamination of optical surfaces by the lost lubricant. These problems are controlled primarily by the basic chemical composition of the lubricant. Atomic oxygen, however, presents a new challenge for spacecraft design in that a variety of organic materials are attacked. Experiments on two Space Shuttle missions, Space Transportation Systems 5 and 8 (STS-5 and STS-8), provided data that showed materials containing carbon, silver, and osmium react with atomic oxygen to form volatile oxides(1). Table 1 lists the reaction efficiencies for a representative set of materials(2). Because of the reactions with organic materials, liquid lubricants and dry film lubricants having organic binders must be protected from exposure or selected with a knowledge that continual degradation will occur. In the case of thin solid films using an epoxy-based binder, exposure to atomic oxygen may degrade the binder in a matter of days(2). For practical systems requiring exposure, therefore, inorganic binders, such as silicates, may be required to avoid the problem.

TABLE 1. REACTION EFFICIENCIES OF SELECTED MATERIALS WITH ATOMIC OXYGEN IN LOW EARTH ORBIT (REFERENCE 2)

Material	**Reaction Efficiency, 10^{-24} cm^3/atom**
Kapton	3
Mylar	3.4
Tedlar	3.2
Polyethylene	3.7
Polysulfone	2.4
Graphite/epoxy	
1034C	2.1
5208/T300	2.6
Epoxy	1.7
Silicones	$< 0.02^*$
White paint A276	0.3 to 0.4^*
Black paint Z302	2.3^*
Perfluorinated polymers	
Teflon, TFE	< 0.05
Teflon, FEP	< 0.05
Carbon (various forms)	0.9 to 1.7
Silver (various forms)	Heavily attacked

*Units of mg/cm^2 for STS-8 mission. Loss is assumed to occur in early part of exposure; therefore, no assessment of efficiency can be made.

Lubricant Considerations

Lubricants can be divided into two basic classes: solid films and liquids. Both types have been used extensively in space applications. Both have advantages and disadvantages that must be carefully considered in their selection. The factors of particular importance for Space Station lubrication are considered in this section.

Solid Film Lubrication

Advantages and Disadvantages

From Reference 3, the following lists the basic advantages and disadvantages of solid film lubricants.

Advantages of Solid Lubricants

1. Do not collect grit.
2. Can be used under extremely high load conditions.
3. Excellent storage stability.
4. LOX and oxygen compatible (inorganically bonded films).
5. Suitable for use over wide temperature range.
6. Resistent to the effects of nuclear and gamma radiation.
7. No disposal problem.
8. Friction decreases with increasing load.
9. In some applications solid films will provide lubrication for the life of the parts.

Disadvantages of Solid Lubricants

1. Limited amount of lubricant available.

2. Friction coefficient higher than with hydrodynamic lubrication.
3. Provisions for the effective removal of wear debris must be provided.
4. Considerations must be given to removing heat from contact zone of bearings and gears when using solid film lubricants.
5. More expensive (costly relubrication).
6. Avoidance of contamination during coating processes and assembly of parts lubricated with solid film lubricants.
7. Elevated temperature cure cycle of some solid films will damage the mechanical properties of some materials.

Selection of Solid Lubricants

Solid lubricants provide capabilities unavailable with liquid lubricants, but they are not a universal lubricant. The requirements of some applications prevent their use entirely. Also, there is no single solid lubricant that will meet all of the requirements. Therefore, the selection of the basic class of lubricant (solid or liquid) and the specific lubricant must consider the needs of the particular application and the requirements of the system of which the application is a part.

The obvious advantages of solid films are that they add virtually no weight to the system and create virtually no problems due to outgassing. The primary disadvantages of solid films are that they have limited life and are very difficult to replenish.

The three basic solid film lubricants that have traditionally been given the most attention and used most extensively are:

- Graphite,
- Polytetrafluorethelene (PTFE), and
- Molybdenum disulfide (MoS_2).

Table 2(4) lists several bonded films and application methods. Recent work in solid films has involved some compositional variations in these lubricants primarily to

TABLE 2. BONDED SOLID FILM LUBRICANTS (REFERENCE 4)

Materials		
Binder	**Additives**	**Application Method**
Polyimide	MoS_2 + Sb_20_3	Sprayed, then heat-cured 1 hr. at 200 F, followed by 1 hr. at 575 F.
Polybenzothiazole	MoS_2 + Sb_20_3	Sprayed, then heat-cured 1 hr. at 200 F, followed by 1 hr. at 600 F.
Polybenzimidazole	MoS_2 + Sb_20_3 + Zn0	Sprayed, then heat-cured 1 hr. at 200 F, followed by 1 hr. at 575 F.
Methylphenylsilicone	MoS_2 + Sb_20_3	Sprayed, then cured at room temperature for 24 hours
Sodium silicate	MoS_2 + graphite + Au	Sprayed, then heat-cured 2 hrs. at 180 F, followed by 2-16 hrs. at 400 F.
Aluminum phosphate	$MoSe_2$ + TaS_2 + graphite	Sprayed, then heat-cured 1 hr. at 150 F, 2 hrs. at 200 F, 8 hrs. at 400 F.
Aluminum phosphate	BaF_2:CaF_2	Sprayed, then heat-cured 1 hr. at 95 C, 200 C, 300 C, 1 hr. at 800-1100 C.
Polybenzimidazole	MoS_2 + Sb_20_3 + prefused fluorides	Sprayed, then heat-cured 1 hr. at 95 C, 200 C, 300 C, 1 hr. at 800-1100 C.

achieve improved wear life and possibly reduced friction.

Bartz, Holeniski, and Xu(5) indicate that there exists optimum concentrations for MoS_2 doped with materials such as graphite and antimony compounds to yield longer wear life than attainable with single components. A comparison of wear lives as obtained in rub block experiments is given in Table 3, and the friction coefficients are presented in Table 4. Table 5 shows the test conditions. Wear lives of 100,000 cycles are possible with this approach, which should be adequate for many components of Space Station. While graphite is probably inappropriate for vacuum service. Bartz research indicates that solid films exist that should provide good service life.

Fleshauer(6) is doing extensive work in evaluation of solid films, especially MoS_2 formulations. Table 6 summarizes the wear lives obtained with three different contact conditions. The pin-on-disk tests were run at a load of 700 MPa. The results have shown that the wear life can be increased significantly if the MoS_2 is doped with antimony. Again, a wear life of 10^5 cycles is shown to be possible.

Rolling Contacts

Friction in rolling contact can be lower with solid films than with grease lubrication. Todd and Bentall(7) present data (Figure 2) that illustrate this effect. Table 7 summarizes data for solid lubricated ball bearings(7). In some ball bearings, it is possible to extend the coating life by using transfer film technology(8,9). In this technology the solid film is transferred from the bearing cage to the ball and races. The cage in essence is then the lubricant supply. Transfer film technology represents a good approach for extending the life of space bearings beyond that attained with solid lubricant coatings.

A summary of examples of successful applications of solid film lubricants to cams, gears, and bearings in spacecraft(10,11) is given in Table 8.

TABLE 3. WEAR LIFE OF SOLID FILMS (REFERENCE 5)

Material	**K Cycles 980 N (500 min^{-1})**	**980 N (1000 min^{-1})**
MoS_2	50	< 10
Graphite	< 10	< 5
$Sb(SbS_4)$	--	--
MoS_2 + $Sb(SbS_4)$	140	40
Graphite + $Sb(SbS_4)$	20	10
MoS_2 + Graphite	200	75
MoS_2 + Graphite + $Sb(SbS_4)$	500	100
Bonded Solid Lubricant	200	50

TABLE 4. STABLE FRICTION COEFFICIENT (REFERENCE 5)

		Lubricant			
Load N	Speed min^{-1}	Graphite	CSb-B	MoS_2	MSb-B
245	500	none	0.14-0.15	0.03-0.05	0.02-0.04
980	500	none	none	0.05	0.01-0.03
1470	500	none	none	none	none

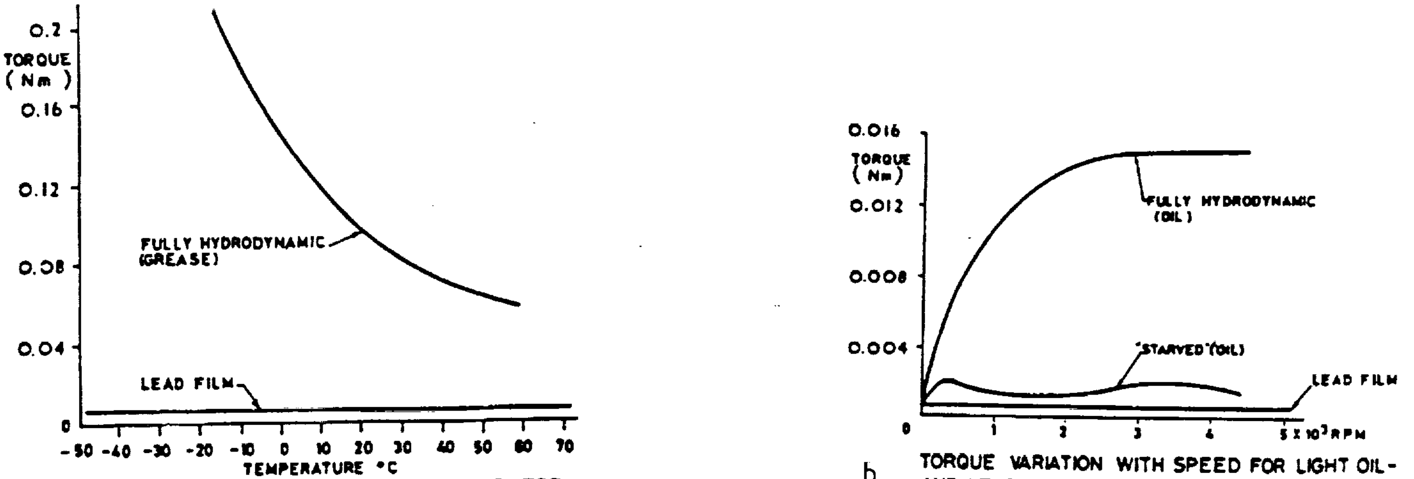
TABLE 5. EXPERIMENTAL CONDITIONS FOR DATA IN TABLES 3 AND 4 (REFERENCE 5)

Ring	
outer diameter:	0.47 mm
material:	100 CrMn6 steel
hardness:	HRC 60
roughness of surface after sandblasting:	12 μm CLA
Block	
dimensions:	24 x 15 x 6
material:	90 MnCrV8 steel
hardness:	HRC 54
roughness of surface:	1.6 μm CLA

TABLE 6. WEAR TEST RESULTS FOR MoS_2 FILMS (500 - 1000 nm THICK) FROM DIFFERENT LABORATORIES (REFERENCE 6)

Wear Life, Thousands of Revolutions		
Pin-On-Disk	**Dual-Rub-Shoe**	**Thrust-Washer**
201	19[a]	600-700
---	55[c]	800
156	60[b]	300
45	35 K[a]	900

[a]Tested in air; [b]Air or vacuum; [c]Vacuum



a. TORQUE VARIATION WITH TEMPERATURE FOR GREASE-AND LEAD FILM-LUBRICATION (60mm BALL BEARING 40N AXIAL LOAD SPEED 100r.p.m.)

b. TORQUE VARIATION WITH SPEED FOR LIGHT OIL- AND LEAD FILM-LUBRICATION (42mm BALL BEARING, 30N AXIAL LOAD, ROOM TEMPERATURE)

FIGURE 2. COMPARISON OF BALL BEARING OPERATING TORQUES SHOWING THAT SOLID FILM LUBRICATION CAN PRODUCE LOWER TORQUES THAN OBTAINED WITH LIQUIDS (REFERENCE 7)

TABLE 7. TORQUE BEHAVIOR OF SOLID LUBRICATED BALL BEARINGS (REFERENCE 7)

Method of Lubrication	**Preload (N)**	**Cumulative time at 100 rpm (min)**	**Torque (N-m x 10^{-4}) to oscillation**		**Remarks**
			Average (±)	**Peak-Peak**	
PTFE/MoS_2/ glass fiber cage, degreased races and balls	40	0	21	76	Progressive torque increase
		30	25	98	
		60	57	147	
MoS_2-coated raceways, Phenolic cage	100	0	34.5	148	Smooth start
		5	31.5	156	
		15	42	246	} trace
		30	45	282	} developing
		60	39	168	} spikes
		74	failed by excess torque		
IP lead on raceways, lead bronze cage	100	0	50	320	Spikes during run-in
		5	45	132	
		15	45	120	} very smooth
		35	45	135	} stable
		60	45	180	} torque traces
		240	failed by excess torque		

TABLE 8. SUMMARY OF SOLID FILM APPLICATIONS FOR SPACECRAFT (REFERENCE 10, 11)

Spacecraft	Item	Pitch	Material	Part Coated	Lubricant	Thickness (mm)
TRIAD	Gear Box Gears	48	Corrosion Resistent steel	Gear teeth	Coating No. 2	0.005-0.0127
	Worm	48	Corrosion Resistent steel	Gear teeth	Coating No. 2	0.005-0.0127
	Worm gear	48	Bronze	Gear teeth	Coating No. 1	0.0127-0.0254
	Miter gears	48	Titanium	Gear teeth	Coating No. 1	0.0127-0.0254
	Miter gears	48	Aluminum	Gear teeth	Coating No. 1	0.0127-0.0254
	Thrust bearing	--	Corrosion Resistent steel	Ball Raceways	Sputtered MoS_2	0.0015
	Ball bearings	--	Corrosion Resistent steel	Inner race Outer race Retainer	Coating No. 1	0.0127-0.0254
APOLLO 17	U.V. Spectrometer wavelength cam	--	----	Cam	Coating No. 2	>0.0076
	"	--	52100 steel	Drive motor R6 bearings	Coating No. 1	--
	"	--	52100 steel	Follower R.8 bearings	Coating No. 1	--
SAS-C	Worm	48	Corrosion Resistent steel	Gear teeth	Coating No. 2	0.005-0.127
	Worm gear	48	Bronze	Gear teeth	Coating No. 2	0.005-0.0127
	Bearings	--	Corrosion Resistent steel	Inner race Outer race Retainer	Coating No. 1	0.0127-0.0254
	Spur gear	48	Corrosion Resistent steel	Gear teeth	Coating No. 2	0.005-0.0127
	Spur gear	48	Aluminum	Gear teeth	Coating No. 1	0.0127-0.0254

Spacecraft Applications of Bonded Coatings(8)

Coating No. 1. Molybdenum disulfide, graphite, gold, sodium silicate.
Coating No. 2. Molybdenum disulfide, antimony trioxide, polyimide.

Liquid/Grease Lubrication

Advantages and Disadvantages

The primary advantage obtained with liquid lubricants is that bearing surfaces separated by hydrodynamic films of liquid lubricants have virtually no wear and thereby have the potential for indefinite lives. Liquid lubricants provide the viscosity needed for forming the hydrodynamic films, low shear strengths for low friction, cooling capability in recirculating systems, and the ability to minimize wear in low-speed (non-hydrodynamic) situations. Since no single lubricant can meet the often conflicting requirements of various applications for liquids, hundreds of specialty lubricants have been developed for aerospace applications(3). The primary disadvantages of liquid lubricants are the need for containment, the propensity to creep, large changes in viscosity with temperature, and loss by evaporation under vacuum conditions. The use of thickeners to form greases provides a means of retaining the liquids in the needed region, thereby addressing one of the primary disadvantages. Greases are widely used for aerospace lubricants. The loss by evaporation greatly restricts the available liquids for vacuum applications to the few chemical species having low vapor pressures. The following sections consider the evaporation rates and the lubricating performance of liquids (and greases based on these liquids) in bearing applications.

Thermo-Vacuum Evaporation

The evaporation rate of lubricants in a vacuum is a function of their molecular weight, their vapor pressure, and the temperature. The Langmiur expression(12) relates these factors and permits predicting the loss rate when the vapor pressure and temperature are known:

$$R_{evap} = \frac{P}{17.14}\left(\frac{M}{T}\right)^{1/2}$$

where,

P = vapor pressure (mm of Hg),
M = molecular weight, and
T = temperature of lubricant (°K).

The vapor pressure is strongly dependent on temperature, as shown for a perfluoro ether in Figure 3$^{(2)}$. Perfluoro ethers are among the fluids having the lowest vapor pressures and are leading candidates for satellite applications exposed to vacuum. At the top of Figure 3 is the time predicted to evaporate a film 2.5×10^{-4} cm (100 microinches) thick in accordance with the Langmiur expression. With this strong temperature dependence, two conclusions are drawn:

1. The temperature of lubricant films exposed to vacuum must be controlled to retain the lubricant.

2. Provisions must be made for the reapplication of lubricant if temperature cannot be controlled to acceptable levels.

The chemical composition of a lubricant and its molecular weight are the dominating factors in determining the resulting vapor pressures and loss rates. For vacuum applications, silicones and perfluoro ethers have lower loss rates by 4 to 5

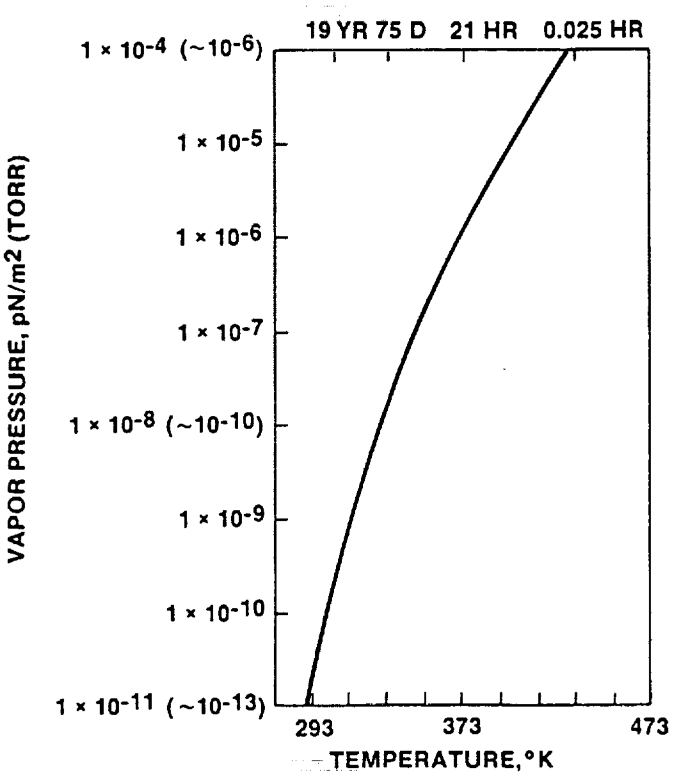


FIGURE 3. DEPENDENCE OF VAPOR PRESSURE ON TEMPERATURE FOR A PERFLUORO ETHER LUBRICANT (REFERENCE 2)

orders of magnitude compared with mineral oils (hydrocarbons) or diesters(13). On the basis of loss rates by evaporation, the selection of lubricants is limited to the perfluoro ethers or silicones -- both from the standpoint of retaining the lubricant on the bearing surfaces where they are needed and of preventing contamination of optical systems by condensation of the evaporated lubricant. As discussed in the next section, the wear performance of the various lubricants combined with the creep behavior of silicones further limits the practical choice to the perfluoro ether fluids.

Friction and Wear Performance

Among the many properties provided by liquid lubricants for bearing applications, the ability to generate hydrodynamic films to separate the surfaces in relative motion and the ability to maintain low wear rates if the operating conditions prevent film formation are two of the most important properties. Film formation capabilities are largely determined by the viscosity, which is generally high in fluids selected to have low evaporation rates. Therefore, the ability to lubricate under very thin film (boundary) conditions is the performance property of interest.

Table 9 presents a summary of comparison data obtained from LFW-1 ring-on-block tests with various lubricants and 440C rings and blocks(14). Of particular interest is the performance of the perfluoro ether (Krytox 143AB oil and Krytox 240AB grease) relative to the silicones, mineral oil, and diesters. No instances of galling were observed with the perfluoro ethers, but several instances of galling were encountered with the silicones, diesters, and mineral oils. Although the lowest wear was measured with the FS1265 silicones, its viscosity was also the highest, which may have influenced the results. The wear with the perfluoro ether was less than that measured with the mineral oils and was considered acceptable since no instances of galling occurred. As shown in Table 10, similar results were obtained in slow-speed sliding tests using a ball-on-flat geometry(15). The perfluoro ether (Fomblin Z25) had a friction coefficient tying the lowest of the five and a specific wear rate only slightly

TABLE 9. COMPARISON OF VARIOUS LUBRICANTS BASED ON WEAR OF 440C BLOCKS IN LFW-1 RING-ON-BLOCK TESTS (FROM REFERENCE 14)

Common Name	Type	Viscosity (cs at °C)	Revs (K)[a]	Scar Width (mm) (mm)
Versilube F50	Methylchlorophenylsilicone	52/38	10.4[b]	1.52[b]
FS1265	Fluorosilicone	300/25	> 1 x 10^3	0.76
SF1147	Methylalkylpolysiloxane	49/25	30.8[b]	1.52[b]
SRG40	Mineral	27/38	> 1 x 10^3	2.03
Krytox143AB	Perfluoralkylpolyether	85/38	> 1 x 10^3	1.78
L245-x	Diester	20/25	2.1[b]	0.76[b]
P-10	Diester + 5% TCP	15/38	> 1 x 10^3	1.27
Andok-C	Mineral Oil Grease	--	40.8[b]	1.27[b]
Krytox 240AB	Perfluoroalkylpolyether Grease	--	> 1 x 10^3	1.27

a. Revolutions to reach friction coefficient of 0.33 at 667N (150 lb) load, in thousands.

b. Test terminated because of galling; scar width at time of galling

TABLE 10. FRICTION AND WEAR RESULTS WITH EN31 STEEL BALLS SLIDING ON EN31 STEEL DISKS IN PRESENCE OF FIVE DIFFERENT LUBRICANTS (REFERENCE 15)

Lubricant	Vapour Pressure at 20° C (torr)	Description and Comments	Mean Friction Coefficient	Specific Wear Rate ($m^3/Nm \times 10^{-15}$)
Apiezon C	4×10^{-9}	Mineral oil with no additives. Used as a reference oil	0.20	0.93
BP 135	7.9×10^{-9}	Synthetic, tri-ester base. Boundary lubricant and anti-oxidant additives.	0.12	1.04
BP 110	3.7×10^{-8}	Mineral oil base, high viscosity. Refined to give low vapour pressure. Boundary lubricant additives.	0.13	0.41
KG80	$< 10^{-8}$	Petroleum base with boundary lubricant additive, Tricresyl-phosphate. Also anti-oxidant.	0.13	0.69
Fomblin Z25	$< 5 \times 10^{-12}$	Synthetic fluorinated oil. High density, low surface tension. High temperature/viscosity index. No boundary lubricant additives.	0.12	0.49

Notes:

1. EN31 is equivalent to 52100 steel.
2. Total load on three balls was 4N.
3. Sliding speed was 3×10^{-3} m/s.

higher than the lowest recorded (a mineral oil with boundary lubricant additives). Based on friction and wear results such as these, a much lower propensity to creep, and satisfactory flight experience, the perfluoro ethers have displaced the silicones in spacecraft applications(16).

Besides the Krytox and Fomblin fluids, the Bray Oil Co. has produced a series of lubricants by further distilling and refining the Fomblin fluid base stock to produce Bray 815Z oil and 3L38RP grease, which have had flight experience in spacecraft mechanisms. The products are now available through the Bray Products Division of Burmah-Castrol, Inc. Braycote 601 is the new designation for the 3L38RP grease.

IDENTIFICATION OF SPECIFIC TRIBOLOGICAL COMPONENTS

SRS Technologies, as a major subcontractor on the Space Station Long Term Lubrication Analysis program, undertook the effort to identify the specific wear/bearing points in the overall Space Station and obtain design information to permit a review from a tribology standpoint. From the relatively broad range of assemblies, components, and mechanisms, a group of 14 target projects were identified as being likely to contain wear points of interest. A listing of these 14 target projects is presented in Table 11. A discussion of the efforts to attain detailed design data are presented on pages 22 through 29 of the SRS Technologies report in Appendix A. Specific tribological components identified in the survey are summarized in Table 2, pages 35 through 39 of the SRS Technologies report. While 72 specific components were identified, insufficient details were available at the time the survey was done to permit a review of their likely performance.

While sufficient design details were not forthcoming, the survey clearly identified the large alpha and beta joints to be critical components without comparable prior flight performance. Therefore, the bearings comprising these joints are worthy of more detailed examination. The design of the hundreds of other tribological contacts will range in difficulty from relatively routine (conservative designs with flight history) to the complexity and size of the alpha and beta joints. To assist the process, the preparation of a lubrication guide for use by the designers as a practical guide for choosing lubricants suitable for various types of applications appeared to be a useful and attainable goal. Therefore, the remainder of the program was structured to be:

Phase II.	Evaluation of Lubrication of the alpha and beta joints
Phase III.	The preparation of a lubricant guide for NASA and/or contractors to use in selecting and evaluating component lubrication techniques.

TABLE 11. SUMMARY OF TARGET PROJECTS IN SPACE STATION

- OMV Mechanisms
- Mobile Servicing Center
- SS Control Moment Gyro
- MDAC Berthing Mechanism
- GE Compressor
- Rockwell Rotary Joint Mechanism
- MDAC Rotary Joint Mechanism
- Sperry Rotary Joint Mechanism
- Space Station Alpha Rotary Joint Mechanism
- Space Station Propulsion Thruster/Storage Tank Assembly
- Space Station Solar Array and Solar Dynamic Concentrator
- OMV and Payload Mechanisms
- Antenna System Rotary Joints
- Health Maintenance Facility

REFERENCES

1. Leger, L.J., Visentine, J.T., and Schliesing, J.A., "A Consideration of Atomic Oxygen Interactions with Space Station", AIAA 23rd Aerospace Sciences Meeting, January 14-17, 1985, AIAA Paper 85-0476.

2. Leger, L.J., and Dufrane, K.F., "Space Station Lubrication Considerations", Proceedings 21st Aerospace Mechanism Symposium (NASA Conference Publication No. 2470), April 29-May 1, 1987, pp. 285-294.

3. McMurtrey, E.L., "Lubrication Handbook for the Space Industry", NASA Technical Memorandum NASA TM-86556, December, 1985.

4. Martin, P., Jr., "A Survey of Solid Lubricant Technology", U.S. Army Weapons Command, AD741764, March, 1972.

5. Bartz, W.J., Holinski, R., and Xu, J., "Wear Life and Frictional Behavior of Bonded Solid Lubricants", Lubrication Engineering, December 1986, pp. 762-769.

6. Fleischauer, P.D., Hilton, M.R., and Bauer, R., "Effects of Microstructure and Adhesion on Performance of Sputter-Deposited MoS_2 Solid Lubricant Coatings; conducted for Wright Research and Development Center, WPAFB, Contract No. F04701-88-C-0089, Aerospace Report No. TOR-0090(5064)-2, January 15, 1990.

7. Todd, M.J., and Bentall, R.H., "Lead Film Lubrication in Vacuum", European Space Tribology Lab., Risley, U.K. and European Space Tribology Center, Noordwijk, Holland.

8. Scott D., and Blackwell, J., "Sacrificial Cage Materials for the In-Situ Lubrication of Rolling Bearings", paper presented at the European Space Tribology Symposium, Frascati, 9-11 April 1975.

9. Kannel, J.W., Gleeson, J.B., Dufrane, K.F., "Battelle Self Lubricating Insert Configuration (BASIC) Retainer", Earth-to-Orbit Conference, May, 1990, Huntsville, AL.

10. Lansdown, A.R., "Low Temperature Lubrication", Swansea Tribology Center, prepared for European Space Agency, 27 April 1978.

11. Matley, R.A., "Lubrication of Space Systems", Lub. Eng. 34 (2), 79, 1978.

12. Dushman, S., Scientific Foundations of Vacuum Technique, Special Edition, John Wiley and Sons, Inc., New York, NY, 1962, p. 18.

13. Hamilton, D.B., and Ogden, J.S., "The Evaporation of Various Lubricant Fluids in Vacuum", (ASLE Preprint, 1972).

14. Babecki, A.J., Grenier, W.G., and Haehner, C.L., "Liquid and Grease Lubricants for Space Applications", Goddard Space Flight Center Materials Technology Report MTR No. 313-003, December 1976, N81-71132.

15. Thomas, A., "Boundary Lubrication of Steel by Various Oils of Low Vapor Pressure", Proceedings of the Second Space Tribology Workshop, European Space Agency, 1980, Risley, U.K., pp. 65-68.

16. Briscoe, H.M., "Some Considerations on Lubricants for use in Spacecraft", Spacecraft Materials in Space Environment, European Space Agency ESA SP-178, 1982, pp. 27-34.

BIBLIOGRAPHY

Liquid Lubricants

Babecki, A.J., Grenier, W.G., Haehner, C.L., "An Evaluation of Liquid and Grease Lubricants for Spacecraft Applications", Materials Technology Report, Dec 1976, Materials Control and Applications Branch, Goddard Flight Center.

Hafner, E.R., "Proper Lubrication - The Key to Better Bearing Life (part 3), Extreme Operating Conditions", Mechanical Engineering, Vol. 99 (no. 12), pages 35-40, Dec. 1977.

Paris, J., Szydlo, S.T., "Lubricating Miniature Bearings", Machine Design, July 1989.

Progress Report , "The Performance of Fomblin Z25 Oil in Ball Bearing Operating in Vacuum", European Space Tribology Lab., Risley, U.K., July 1983.

Stevens, K.T., "The Torque Behavior of Grease-Lubricated Angular Contact Bearings Operating at Low Speeds", European Space Tribology Lab., Risley, U.K..

Thomas, A., "Boundary Lubrication of Steel by Various Oils of Low Vapor Pressure", Proceedings of Second Space Tribology Workshop, European Space Tribology Lab., Risley, U.K., Dec. 1980.

Zaretsky, E.V., Schuller, F.T., Coe, H.H., "Lubrication and Performance of High-Speed Rolling-Element Bearings", prepared for the 1985 Annual Meeting of the American Society of Lubrication Engineers, Las Vegas, Nevada, 6-9 May 1985.

Spacecraft Lubricants

Babecki, A.J., Grenier, W.G., Haehner, C.L., "An Evaluation of Liquid and Grease Lubricants for Spacecraft Applications", Materials Technology Report, Dec. 1976, Materials Control and Application Branch, Goddard Flight Center.

Baxter, B.H., "The Use of MoS_2 Loaded Greases in Antenna Despin Mechanisms under Simulated Space Conditions", Proceedings of European Space Agency Symposium on Spacecraft Materials, 2-5 Oct. 1979.

Benzing, R.J., Strang, J.R., Capt., USAF, "Failure Mode Analysis of Lubricated Satellite Components", Nonmetallic Materials Div., Lubricants and Tribology Branch, AFML/MBT, Wright-Patterson AFB, OH 45433, July 1973.

Briscoe, H.M., "Some Considerations on Lubricants for Use in Spacecraft", European Space Agency, European Space Research and Technology Center, Noordwijk, Netherlands.

Briscoe, H.M., Todd, M.J., "Considerations on Lubrication of Spacecraft Mechanisms", European Space Agency, European Space Research and Technology Center, Noordwijk, Netherlands, The 17th Aerospace Mechanisms Symposium, pages 19-38.

Brouwer, G.F., "Lubrication of a Stainless Steel Actuating Cable", Proceedings of Second Space Tribology Workshop, European Space Tribology Lab., Risley, U.K., Dec. 1980.

Guertin, L.J., "Lubrication on the Space Shuttle Orbiter", 15th National SAMPE Technical Conference, Cincinnati, OH, 4-6 Oct. 1983.

Guidelines for Space Materials Selection, European Space Research and Technology Center, Product Assurance Division, Noordwijk, The Netherlands, July 1976.

Hadley, H., "Mechanisms of U.K. Radiometers Flown on Nimbus 5 and 6 with Particular Reference to Bearings, Pivots and Lubrication", Proceedings of the 14th Aerospace Mechanisms Symposium, pages 101-110.

Investigation of Torque Anomaly in Oscillating PDM Bearings, Contract Report, European Space Agency, Risley, U.K., May 1981.

Jantzen, Dr. E., "A Dry Lubrication System for Space-Proofed Bearings", paper presented at the European Space Tribology Symposium, Frascati, 9-11 April 1975.

Lansdown, A.R., "Low Temperature Lubrication", Swansea Tribology Center, prepared for European Space Agency, 27 April 1978.

Leger, L.J., Dufrane, K., "Space Station Lubrication Considerations", Proceedings 21st Aerospace Mechanism Symposium (NASA Conference Publication No. 2470), April 29-May 1, 1987, pp. 285-294.

Loewenthal, S.H., Schuller, F.T., "Feasibility Study of a Discrete Bering/Roller Drive Rotary Joint for the Space Station", NASA Technical Memorandum 88800, Lewis Research Center, Cleveland, OH., July 1986.

McMurtrey, E.L., "Lubrication Handbook for the Space Industry", NASA Technical Memorandum, TM-86556, May, 1983.

MoS_2 Helps Prevent "Tennis Elbow" in Space Shuttle Manipulator Arm, Amax, Vol XXVI (no.1), May 1984, Climax Molybdenum Co., New York.

Spacecraft Materials in a Space Environment, European Space Agency, Paris, France, July 1982.

Stevens, K.T., "Some New Observations on Wear in Oil-Lubricated Satellite Ball Bearings", Proceedings of Second Space Tribology Workshop, European Space Tribology Lab., Risley, U.K., Dec. 1980.

Todd, M.J., "Solid Lubrication of Ball Bearings for Spacecraft Mechanisms", Tribology International, Vol. 15 (no. 6), pages 331-337, Dec. 1982.

Ward, W.E., "Evaluation of a 90-mm Bore Bearing Operating in a Simulated Space Environment", Air Force Wright Aeronautical Lab., Wright Patterson AFB, OH., 45433, Presented at the 38th Annual Meeting in Houston Texas, 24-28 April 1983.

Ward, W.E., "Evaluation of 100-mm Bore Bearings After Accelerated Testing in a Simulated Space Environment", Technical Report, July 1979, Nonmetallic Div., Fluids, Lubricants and Elastomers Branch, Air Force Materials Lab., Wright-Patterson AFB, OH., 45433.

Solid Lubricants

Bartz, W.J., Holinski, R., Xu, J., "Wear Life and Frictional Behavior of Bonded Solid Lubricants", Lubrication Engineering, Vol. 42 (no. 12), pages 762-770, Dec. 1986.

Cerini, J.P., Devine, G.M., "Development of Improved High Temperature Solid Lubricant Concepts, phase I", General Technology, 2560 Prescott Road, Havertown, PA 19083-1301, May 1990.

Todd, M.J., Bentall, R.H., "Lead Film Lubrication in Vacuum", European Space Tribology Lab., Risley, U.K. and European Space Tribology Center, Noordwijk, Holland.

Citations From the Engineering Index Database, "Solid Lubricants: Graphite, Polymers, Fluorides, and General Studies (Feb. 82 - Nov. 85)", Battelle Reports Library, 505 King Ave., Columbus, OH 43201.

Citations From the Engineering Index Database, "Solid Lubricants: Graphite, Polymers, Fluorides, and General Studies (Feb. 82 - Nov. 84)", Battelle Reports Library, 505 King Ave., Columbus, OH 43201.

Didziulis, S.V., Fleischauer, P.D., "Effects of Chemical Treatments on SiC surface composition and Subsequent MoS_2 Film Growth", The Aerospace Corp., Chemistry and Physics Laboratory, Prepared for Defense Advanced Research Projects Agency, Arlington VA 22209.

Fleischauer, P.D., Lince, J.R., Bertrand, P.A., "Electronic Structure and Lubrication Properties of MoS_2: A Qualitative Molecular Orbital Approach", The Aerospace Corp., Chemistry and Physics Laboratory, Prepared for Space Systems Div. Air Force Systems Command, Los Angeles Air Force Base, L.A., CA 90009-2960.

Fleischauer, P.D., Hilton, M.R., Bauer, R., "Effects of Microstructure and Adhesion on Performance of Sputter-Deposited MoS_2 Solid Lubricant Coatings", Chemistry and Physics Lab., The Aerospace Corp., prepared for Wright Research and Development Center, Wright-Patterson AFB, 15 Jan. 1990.

Fleischauer, P.D., Hilton, M.R., Bauer, R., "Effects of Microstructure and Adhesion on Performance of Sputter-Deposited MoS_2 Solid Lubricant Coatings", The Aerospace Corp., Chemistry and Physics Laboratory, Prepared for Wright Research and Development Center, Wright Patterson Air Force Base, OH 45433.

Gardos, M.N., "Self-Lubricating Composites for Extreme Environment Applications", Tribology International, Vol. 15 (no. 5), pages 273-283, Oct. 1982.

Klenke, C.J., "Tribological Performance of MoS_2 - B_2O_3 Compacts", Tribology International, Vol. 23 (no. 1), pages 23-26, Feb. 1990.

Lansdown, A.R., "Molybdenum Disulfide Lubrication", A Continuation Survey 1979-80, Swansea Tribology Center, U.K., European Space Agency Contract no 2261/74.

Martin, P., Jr., "A Survey of Solid Lubricant Technology", Technical Report, Research, Development and Engineering Directorate, U.S. Army Weapons Command, March 1972.

Scott, D. and, Blackwell, J., "Sacrificial Cage Materials for the In-Situ Lubrication of Rolling Bearings", paper presented at the European Space Tribology Symposium, Frascati, 9-11 April 1975.

Spalvins, T., "Sputtering and Ion Plating for Aerospace Applications", NASA Technical Memorandum 81726, prepared for the National Conference of the American Electroplaters' Society, Boston, MA, June 28 - July 2, 1981.

Thomas, A., Todd, M.J., Garnham, A.L., "Current Status of Lead Lubrication of Ball Bearings", Proceedings of the Second Space Tribology Workshop, ESTL, Risley, U.K., 15-17 October 1980.

Todd, M.J., "A Method for the Calculation of Torque in Dry-Lubricated Ball Bearings Including the Influence of Temperature and Fit", Proceedings of Second Space Tribology Workshop, European Space Tribology Lab., Risley, U.K., 15-17 Oct. 1980.

Todd, M.J., "Solid Lubrication of Ball Bearings for Spacecraft Mechanisms", Tribology International, Vol. 15 (no. 6), pages 31-337, Dec. 1982.

White, C., Todd, M.J., "Torque Properties of Oscillating Dry-Lubricated Ball Bearings in Vacuum", European Space Tribology Lab., Risley, U.K., Sept. 1983.

Slip Rings

Anderson, J.C., Roberts, E.W., "Satellite Slip Ring Performance - A Summary of ESTL Work 1974-81", European Space Tribology Lab., Risley, U.K., Aug 1982.

Anderson, J.C., "The Wear and Electrical Characteristics of Some Dry Lubricated Slip Ring/Brush Contacts", Proceedings of Second Space Tribology Workshop, European Space Tribology Lab., Risley, U.K., 15-17 Oct 1980.

Roberts, E.W., "A Review of Sliding Electrical Contacts for Space Application", European Space Tribology Lab., Risley, U.K., Oct 1981.

Gears

ESTL Progress Report for 1982, European Space Tribology Lab., Risley, U.K., March 1984.

First European Space Mechanisms and Tribology Symposium, Proceedings of a Symposium held at Neuchatel, Switzerland, 12-14 Oct 1983.

Stevens, K.T., "The Tribology of Gears for Satellite Applications", Proceedings of the First European Space Mechanisms and Tribology Symposium, Neuchatel, Switzerland, 12-14 Oct 1983.

Stevens, K.T., "The Wear of Small Plyacetal and Polyimide Gears in Vacuum", European Space Tribology Lab., Risley, U.K..

Transport Studies

Ahlborn, G.H., "Lubricant Barrier Film Contaminated Ball Bearings - A Bearing Life Threat?", Lubrication Engineering, Vol. 35 (no. 12), 12 Dec 1979, pages 677-686.

Fleischauer, P.D., Marten, H.D., "Surface Creep of Mineral Oil on Inner Ring of Momentum Wheel Bearing", presented at the 40th Annual Meeting in Las Vegas, Nevada, 6-9 May 1985, Lubrication Engineering, Vol. 42 (no. 5), pages 300-304.

Fote, A.A., Slade, R.A., Feuerstein, S., "Barriers to the Surface Transport of Oil", Interim Report prepared for Space and Missile Systems Org., 18 Feb 1977, Air Force Systems Command, Los Angeles Air Force Station.

Fote, A.A., Slade, R.A., Feuerstein, S., "The Prevention of Lubricant Migration in Spacecraft", Wear, Vol. 51 (no. 1), pages 67-75, 1 Nov 1978.

Fote, A.A., Slade, R.A., Feuerstein, S., "Behavior of Thin Oil Films in the Presence of Porous Lubricant Reservoirs", Wear, Vol. 46 (no. 2), pages 377-385, 2 Feb 1978.

Hamilton, D.B., Ogden, J.S., "The Evaporation of Various Lubricant Fluids in Vacuum", presented as an American Society of Lubrication Engineers paper at the ASME/ASLE International Lubrication Conference, New York City, 9-12 Oct 1972.

Miscellaneous Articles

Anacapri, Italy, "Europe May Barter for External Payloads on NASA/International Space Station", Aviation Week and Space Technology, 10 July 1989, pages 29-30.

Brahney, J.H., "Large Payload Launch Vehicles Examined", Aerospace Engineering, April 1985, pages 28-33.

Brahney, J.H., "Space Station: an investment in scientific research", Aerospace Engineering, Aug. 1985, pages 27-31.

Brahney, J.H.,-"Space Station's Biggest Challenge: servicing satellites in orbit", Aerospace Engineering, March 1985, pages 9-13.

Buckley, D.H., "Tribological Systems as Applied to Aircraft Engines", prepared for the 60th AGARD Structure and Materials Panel Meeting, San Antonio, TX, 21-26 April 1985.

Davis, K., Keller, M., Martin, R., "Accelerated Life Prediction Techniques", Final Report for Period 31 July 1978 - 31 May 1981, Materials Lab., Air Force Wright Aeronautical Lab., Wright-Patterson AFB, OH, 45433.

Feuerstein, S., Forster, A.S., "A Concept of Despin Mechanical Assembly Life Testing Involving Total Characterization", Aerospace Corp., prepared for Space and Missile Systems Org., Los Angeles Air Force Station, L.A., CA 90045, 29 July 1975.

Holt, D.J., "Will Solar Dynamic Power Be Used for the Space Station?", Aerospace Engineering, Sept. 1985, pages 49-55.

Lauer, J.L., "Structure of Solid Surfaces in Wear Situation", Final Report to Air Force Office of Scientific Research, 17 Oct. 1984.

McCarty, L.H., "Space Station Rotary Joint Eliminates Stiffness Dead Band", Design News, 15 Feb. 1988, pages 160-161.

APPENDIX A

SRS TECHNOLOGIES SUBCONTRACTOR REPORT

SRS/STG TR90-84

Space Station
Long Term Lubrication Study
Final Report

June, 1990

BY

EDWARD. E. MONTGOMERY

SRS Purchase Contract Number: G-9038
NASA Contract: NAS8-36655

APPROVED BY: Jay H. Laue
Jay H. Laue
Director, Aerospace Systems

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C. W. Mead
General Manager, Systems Technology Group

Foreword

This document was prepared by SRS Technologies under subcontract to Battelle Columbus Laboratories for work relating to the "Space Station Long Term Lubrication Study" for the Materials and Processes Laboratory at NASA's George C. Marshall Space Flight Center. The work was performed under the supervision of Mr. Keith Dufrane, the Battelle project manager and the NASA COTR, Mr. Fred Dolan. It presents a comprehensive final reporting of the Phase I activities of this project. The study was performed by SRS during the period from August, 1985 to May, 1990. The SRS contract manager is Jay H. Laue of SRS Technologies' Systems Technology Group, Aerospace Systems Directorate, in Huntsville, Alabama. The SRS project leader is Edward E. Montgomery. Other significant contributors at SRS included:

James C. Pearson, Jr.
Rod Myers
Anthony Stone
Cynthia Koontz

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1.0 INTRODUCTION

Under subcontract to Battelle Columbus Laboratories (SRS purchase contract G-9038) SRS performed selected activities in support of the "Space Station Long Term Lubrication Study" (NAS8-36655), a contract effort with the Materials and Processes Laboratory at MSFC/NASA. Mr. Fred Dolan is the NASA COTR, Mr. Keith Dufrane is the BCL Project Leader, and Mr. Edward Montgomery is the SRS Project Leader.

The Space Station Long Term Lubrication Study (LTLS) is part of the Advanced Development Program (ADP) within the Space Station Program. In fiscal Year 1985, the ADP was initiated to accelerate the development of a series of new technologies. Its objectives were to enhance the performance of the Space Station, reduce the life cycle cost during the operations phase, and reduce the risk that might be encountered with new technologies during the development phase.

1.1 Background

Work on the contract began on August 1, 1985. The project was scheduled to be conducted over a 3-year time frame in two phases. Phase I was a preliminary analysis conducted in parallel with the preliminary design phases of the Space Station program. Phase II was to be a more detailed analysis conducted during Phase C/D when the design became more established. Phase I was to conclude 20 months into the study (April 1987) and be based primarily on design data packages planned to be released along with the Space Station Phase B SDR in September 1986. However, the Space Station program schedule began to slip significantly. In addition, major configuration changes continued to occur. As a result, the design information was not maturing to a level sufficient to support the kinds of analyses planned in the LTLS. An interim approach was taken in which the LTLS utilized preliminary design data resulting from other ADP programs in lieu of mainstream SSF design review packages (which were not available). The problem became evident as early as October 1986 when it was first addressed in monthly progress reports to the government. In April, 1987, at the originally planned date for conclusion of the phase I activities, effort was suspended on the study to allow the Space Station program schedule to catch up. Unfortunately, further SSF slippages and major redesign efforts continued to keep the Long Term Lubrication Study dormant through the original LTLS contract end date in August, 1988.

In October, 1988, an SRS representative attended a Space Station Space Environmental Effects Data Exchange meeting at MSFC which included a lubrication concerns topic on the agenda. Otherwise, no effort was expended on the contract by SRS after April, 1987 until April, 1990. At that time, NASA extended the LTLS contract schedule and, subsequently, a new subcontract was negotiated between SRS and BCL. The scope and deliverables of the renegotiated effort were reduced from previous subcontract. During the renegotiations, it was mutually agreed that one of the previously established deliverables, a magnetic tape containing data from SRS survey results for use by Battelle in performing tribological assessments in Phase II, would no longer be a significant benefit to BCL or NASA. The remaining deliverable for SRS would be this final report.

1.2 Objectives/Approach

The overall objective of the Space Station Long Term Lubrication Study was:

> "to assure NASA that all Space Station mechanical, electrical, and electromechanical equipment will function as intended for their required lives."

The goals of the study were to document and evaluate each wear point on the Space Station and assist in the improvement/resolution of suspected excessive wear or high maintenance areas. The prime duties for SRS were to gain access to design data for each wear point and assemble, organize, and document tribological data for analysis and evaluation. Battelles's prime duties were to analyze and evaluate each wear point and report on the estimated life of the hardware and the probability of success.

The Phase I approach established for the SRS activities included five major tasks:

1.2.1.1 Develop a system/component work breakdown structure for the Space Station to identify major moving mechanical assemblies.

1.2.1.2-4 Identify wear points and operating characteristics as to materials and surface treatments, lubrication scheme, operating characteristics, and environments.

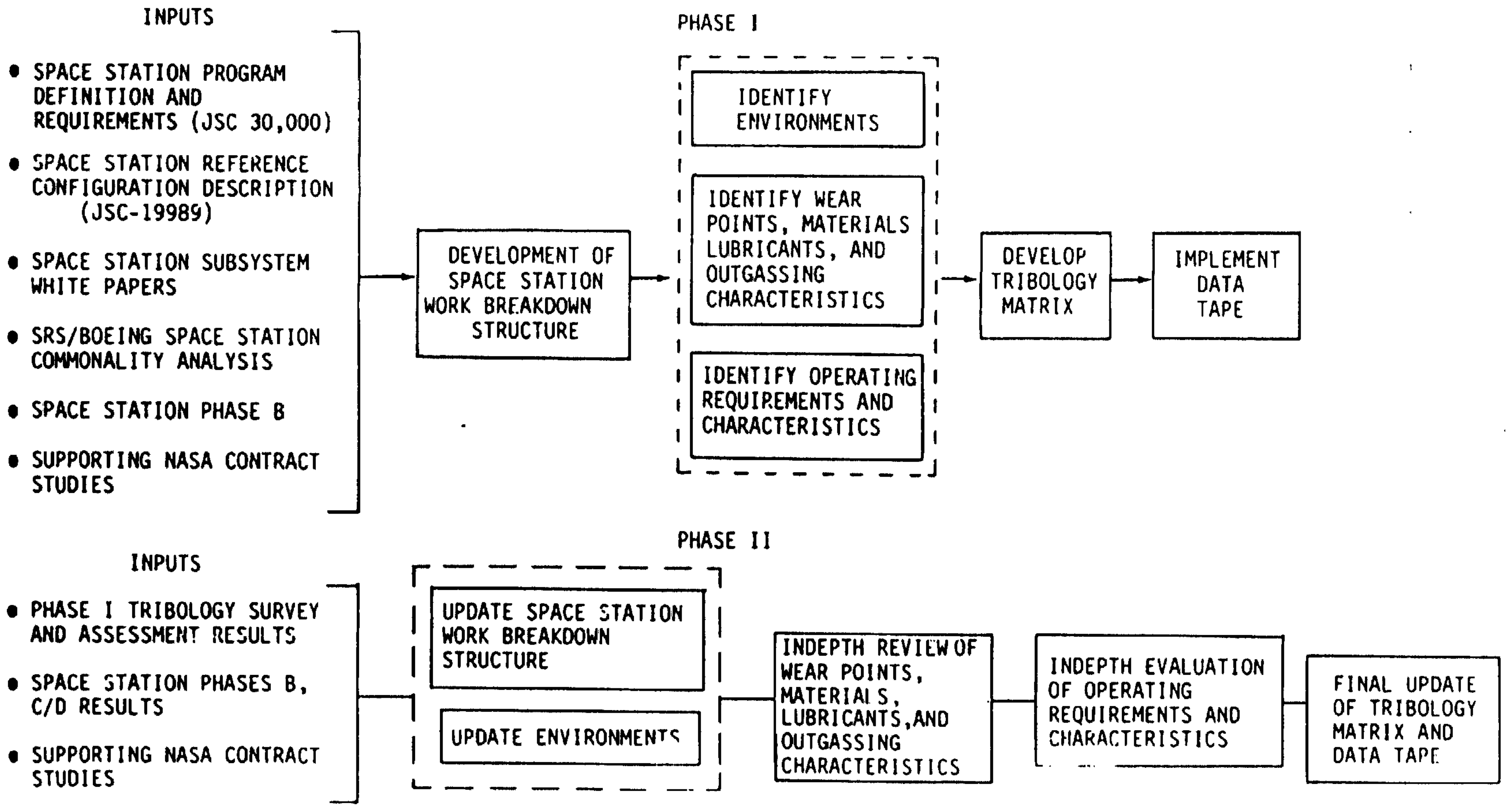
1.2.1.4 Indicate the location of potentially contamination-causing fittings, lubricants, and bearing materials.

1.2.1.5 Develop a detailed tribology matrix containing the synthesized data to support the tribology assessment.

1.2.3.3 Implement a survey data tape on the NASA/MSFC computer system to include the results of the tribology survey and assessment.

Phase II tasks for SRS were originally planned to accomplish an update of these same tasks after the release of Space Station Phase B SDR data packages and again near the Phase C/D Space Station Preliminary Design Review. Figure 1 illustrates the logic flow of this approach. SRS deliverables were to include a comprehensive work breakdown structure for the Space Station identifying major moving mechanical assemblies (MMA), a complete list of operating characteristics, materials, and environments for each identified MMA used to support tribology assessment, an identification of potential contamination sources on Space Station (location and distribution of greases and lubricants), a data tape containing the results of the tribology survey and assessment, and an identification of high priority areas for further long-term lubrication study.

SPACE STATION LONG-TERM LUBRICATION APPROACH
(SRS)



INPUTS

- SPACE STATION PROGRAM DEFINITION AND REQUIREMENTS (JSC 30,000)
- SPACE STATION REFERENCE CONFIGURATION DESCRIPTION (JSC-19989)
- SPACE STATION SUBSYSTEM WHITE PAPERS
- SRS/BOEING SPACE STATION COMMONALITY ANALYSIS
- SPACE STATION PHASE B
- SUPPORTING NASA CONTRACT STUDIES

DEVELOPMENT OF SPACE STATION WORK BREAKDOWN STRUCTURE

PHASE I

IDENTIFY ENVIRONMENTS

IDENTIFY WEAR POINTS, MATERIALS LUBRICANTS, AND OUTGASSING CHARACTERISTICS

IDENTIFY OPERATING REQUIREMENTS AND CHARACTERISTICS

DEVELOP TRIBOLOGY MATRIX

IMPLEMENT DATA TAPE

INPUTS

- PHASE I TRIBOLOGY SURVEY AND ASSESSMENT RESULTS
- SPACE STATION PHASES B, C/D RESULTS
- SUPPORTING NASA CONTRACT STUDIES

PHASE II

UPDATE SPACE STATION WORK BREAKDOWN STRUCTURE

UPDATE ENVIRONMENTS

INDEPTH REVIEW OF WEAR POINTS, MATERIALS, LUBRICANTS, AND OUTGASSING CHARACTERISTICS

INDEPTH EVALUATION OF OPERATING REQUIREMENTS AND CHARACTERISTICS

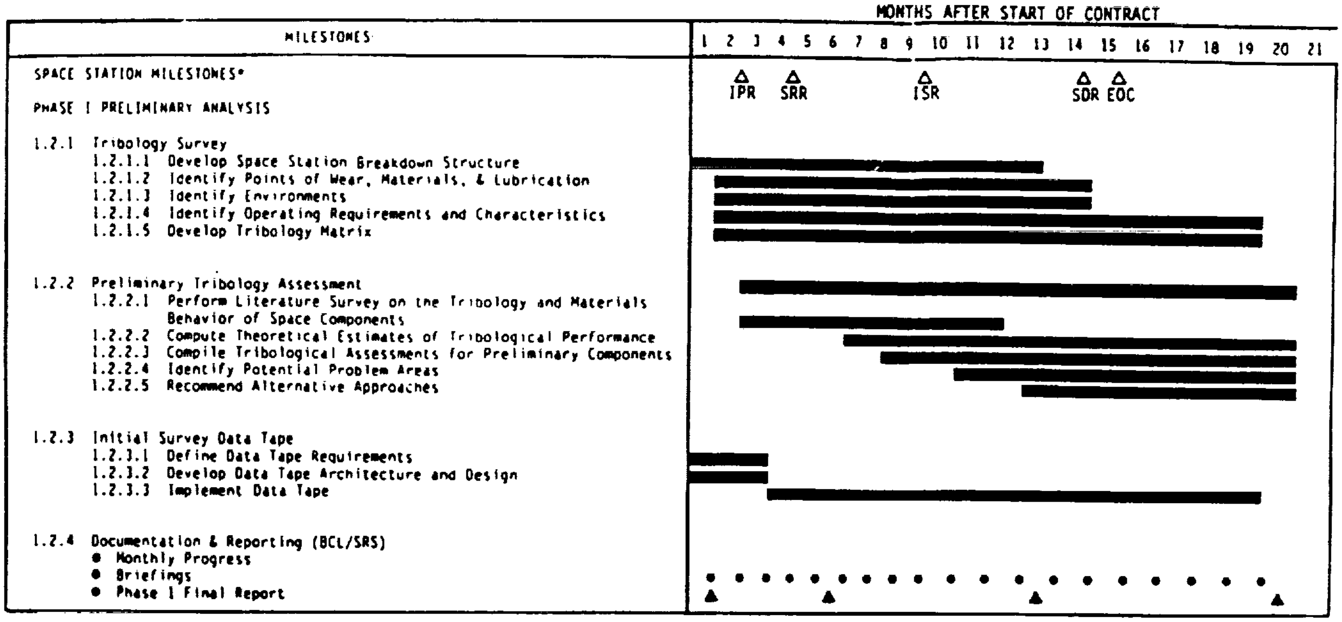
FINAL UPDATE OF TRIBOLOGY MATRIX AND DATA TAPE

1.3 Project Schedule

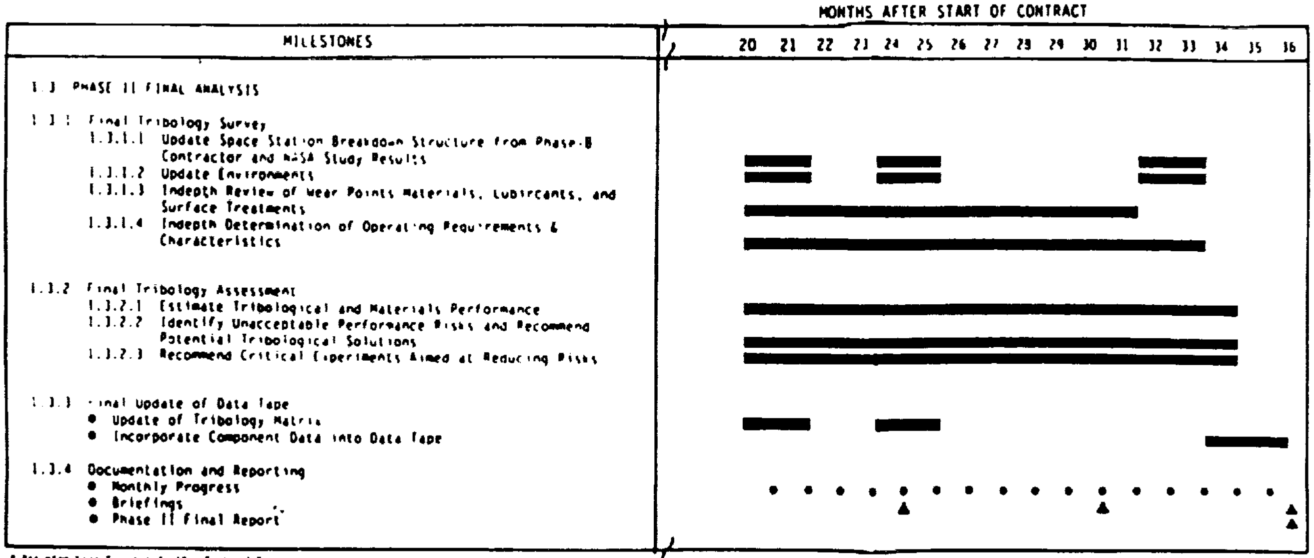
The original schedule for Phases I and II of the Space Station Long Term Lubrication Study and major milestones are shown in Figure 2. Also shown on the figure are the dates of major Space Station Program milestones as planned at the start of the study. Close coordination was planned between the activities of this study and the progress of design activities. Figures 3 through 6 show the expected publication dates for major outputs of the four major space station work packages.

Figure 2. Planned Phase I and II Project Schedules

SCHEDULE PHASE I

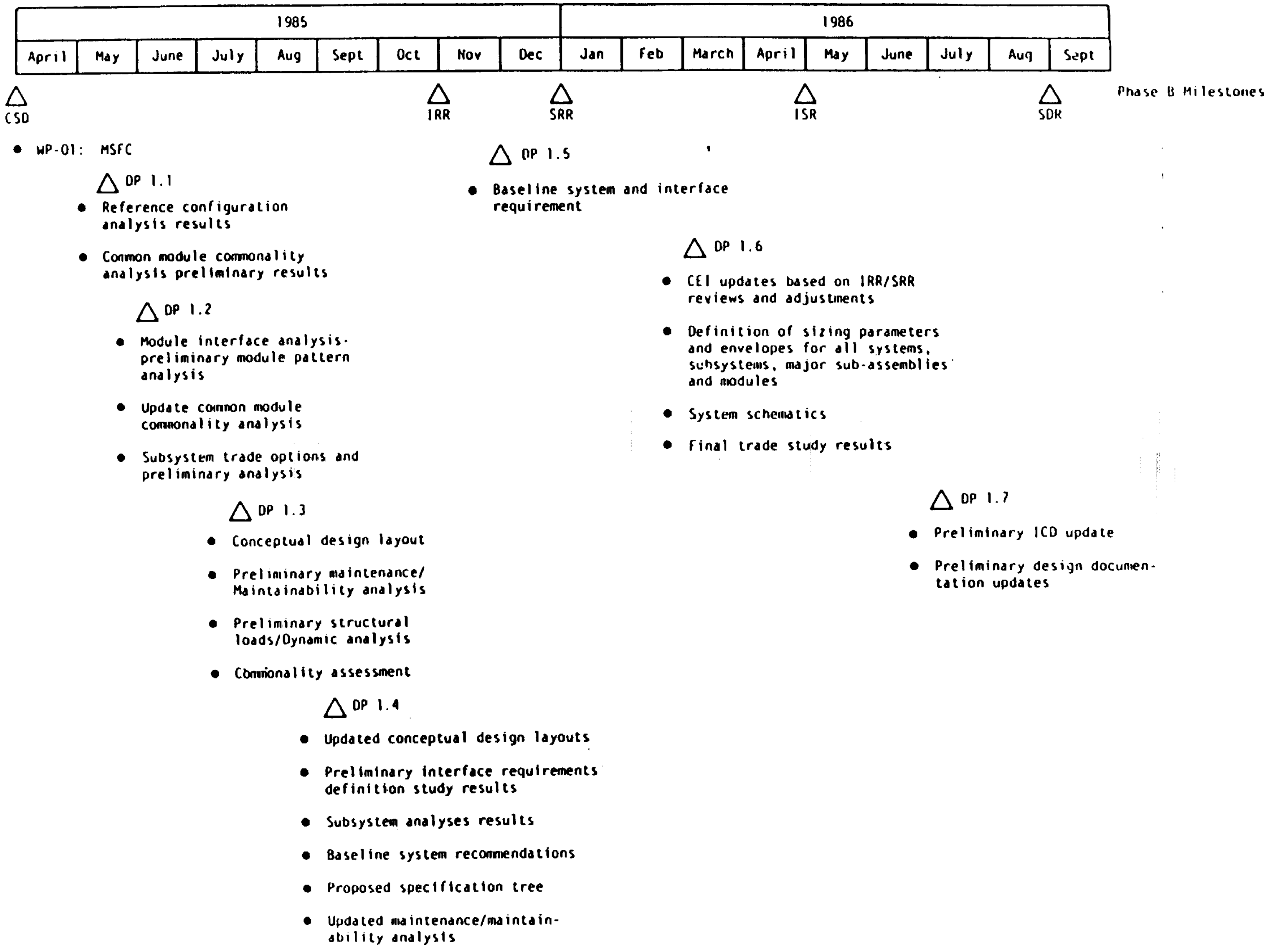


SCHEDULE PHASE II



* Assuming Long Term Lubrication Contract Start
5 Months After Space Station Contract Start Date

FIGURE 1-3. PROPOSED MILESTONE SCHEDULE FOR LONG TERM LUBRICATION STUDY



1985									1986								
April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept

- WP-01: MSFC

DP 1.1

- Reference configuration analysis results
- Common module commonality analysis preliminary results

DP 1.2

- Module interface analysis-preliminary module pattern analysis
- Update common module commonality analysis
- Subsystem trade options and preliminary analysis

DP 1.3

- Conceptual design layout
- Preliminary maintenance/Maintainability analysis
- Preliminary structural loads/Dynamic analysis
- Commonality assessment

DP 1.4

- Updated conceptual design layouts
- Preliminary interface requirements definition study results
- Subsystem analyses results
- Baseline system recommendations
- Proposed specification tree
- Updated maintenance/maintainability analysis

DP 1.5

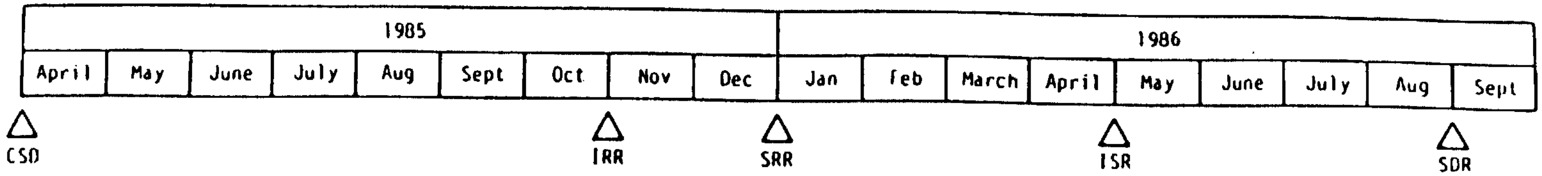
- Baseline system and interface requirement

DP 1.6

- CEI updates based on IRR/SRR reviews and adjustments
- Definition of sizing parameters and envelopes for all systems, subsystems, major sub-assemblies and modules
- System schematics
- Final trade study results

DP 1.7

- Preliminary ICD update
- Preliminary design documentation updates



- WP 02 JSC

△ DP 2.1

- Reference configuration analysis results
- Preliminary trades study results
- Conceptual design lay-outs and/or approaches for WP Hardware/Software elements

△ DP 2.2

- Overall configuration(s) sizing parameters and general arrangement of components and major assemblies for Space Station
- Trade study results
- Preliminary structural loads/ Dynamic analysis results

△ DP 2.3

- Preliminary overall architecture analysis
- Preliminary IDMS, system sizing and requirements definition
- Update conceptual design layouts for all WP elements

△ DP 2.4

- Subsystem and major assembly cost data
- Preliminary ICD's for the Space Station major assemblies, modules, and subsystems
- Preliminary baseline system recommendations
- Trade study results
- Preliminary specification tree

△ DP 2.5

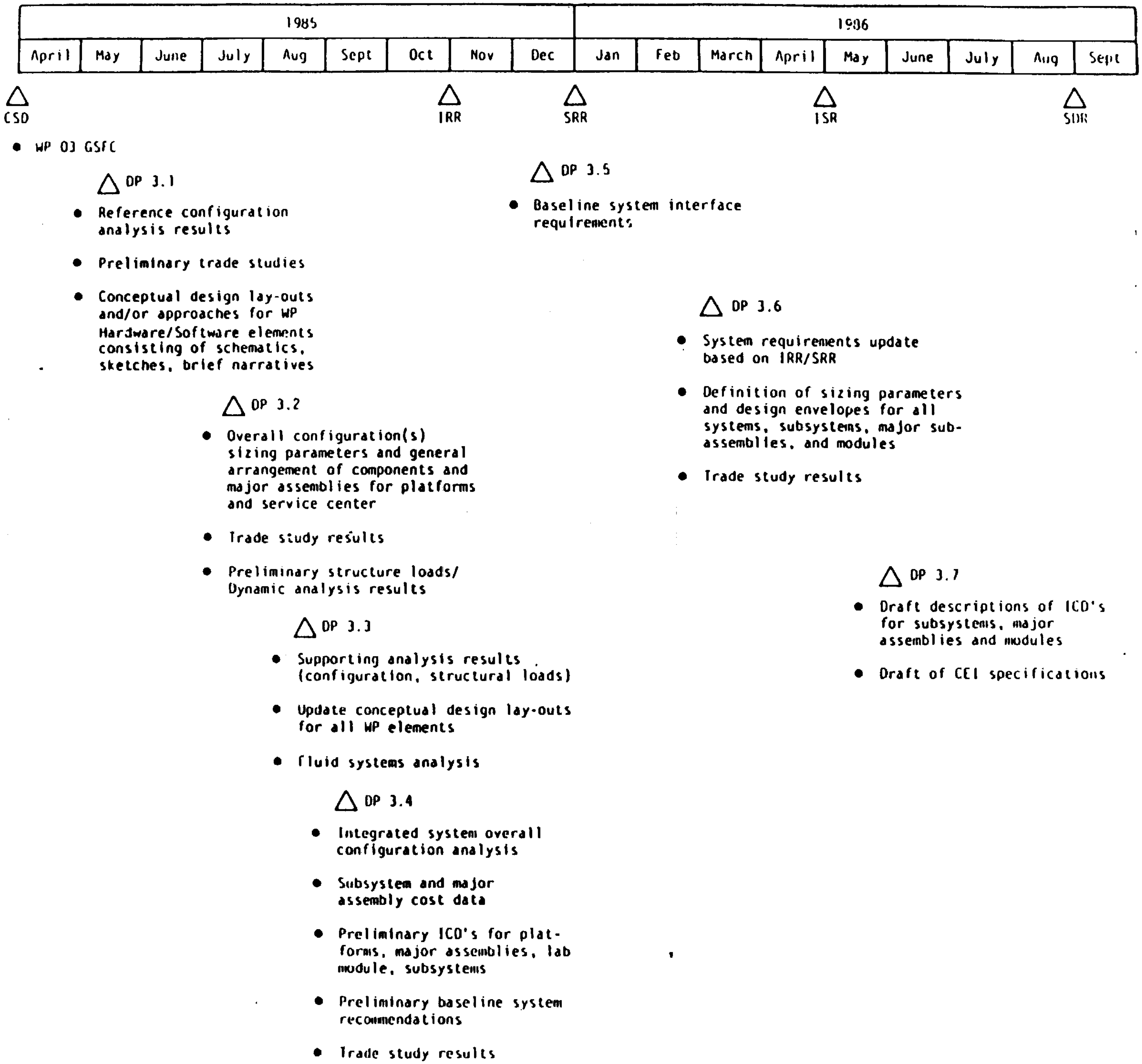
- Baseline system interface requirements

△ DP 2.6

- Definition of sizing parameters and design envelopes for all systems, subsystems, major subassemblies, and modules

△ DP 2.7

- Draft descriptions of ICD's for subsystems, major assemblies, and modules



- WP 03 GSFC

DP 3.1

- Reference configuration analysis results
- Preliminary trade studies
- Conceptual design lay-outs and/or approaches for WP Hardware/Software elements consisting of schematics, sketches, brief narratives

DP 3.2

- Overall configuration(s) sizing parameters and general arrangement of components and major assemblies for platforms and service center
- Trade study results
- Preliminary structure loads/ Dynamic analysis results

DP 3.3

- Supporting analysis results (configuration, structural loads)
- Update conceptual design lay-outs for all WP elements
- Fluid systems analysis

DP 3.4

- Integrated system overall configuration analysis
- Subsystem and major assembly cost data
- Preliminary ICO's for platforms, major assemblies, lab module, subsystems
- Preliminary baseline system recommendations
- Trade study results

DP 3.5

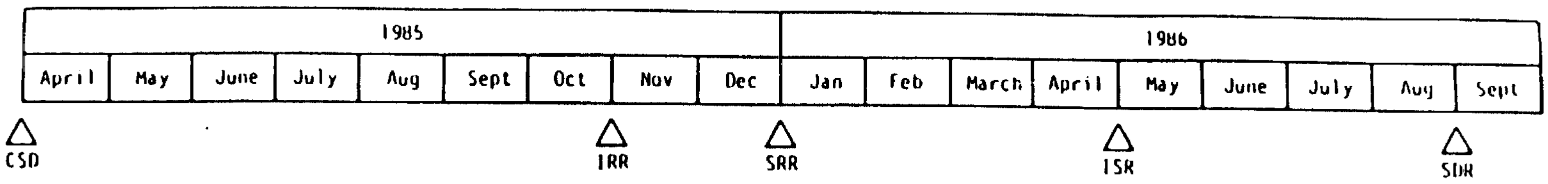
- Baseline system interface requirements

DP 3.6

- System requirements update based on IRR/SRR
- Definition of sizing parameters and design envelopes for all systems, subsystems, major subassemblies, and modules
- Trade study results

DP 3.7

- Draft descriptions of ICO's for subsystems, major assemblies and modules
- Draft of CEI specifications



- WP-04 LeRc

△ DP 4.1

- Reference Space Station and platform configuration analysis results
- Preliminary trade studies
- Preliminary definition of the overall architecture of solar dynamic and photovoltaic-based power systems

△ DP 4.2

- Overall sizing parameters and general arrangement of WP components for Space Station and platform
- Update DP 4-1
- Trade studies

△ DP 4.3

- Detailed architecture of power system within modules, attached payloads, and subsystem attach areas
- WP trades update
- Update conceptual design for all WP elements

△ DP 4.4

- Integrated overall architecture analysis
- Preliminary subsystem cost estimates of solar dynamic and photovoltaic-based power systems
- Preliminary definition of standard power system parts list
- Trade study results
- Proposed specification tree

△ DP 4.5

- Baseline system interface requirements

△ DP 4.6

- System requirements updates based on IRR/SRR reviews and adjustments
- Definition of sizing parameters and design envelopes for all systems, subsystems, subassemblies, and modules
- Initial ICD's
- Trade study results

△ DP 4.7

- Draft of ICD's for subsystems, major assemblies, and modules

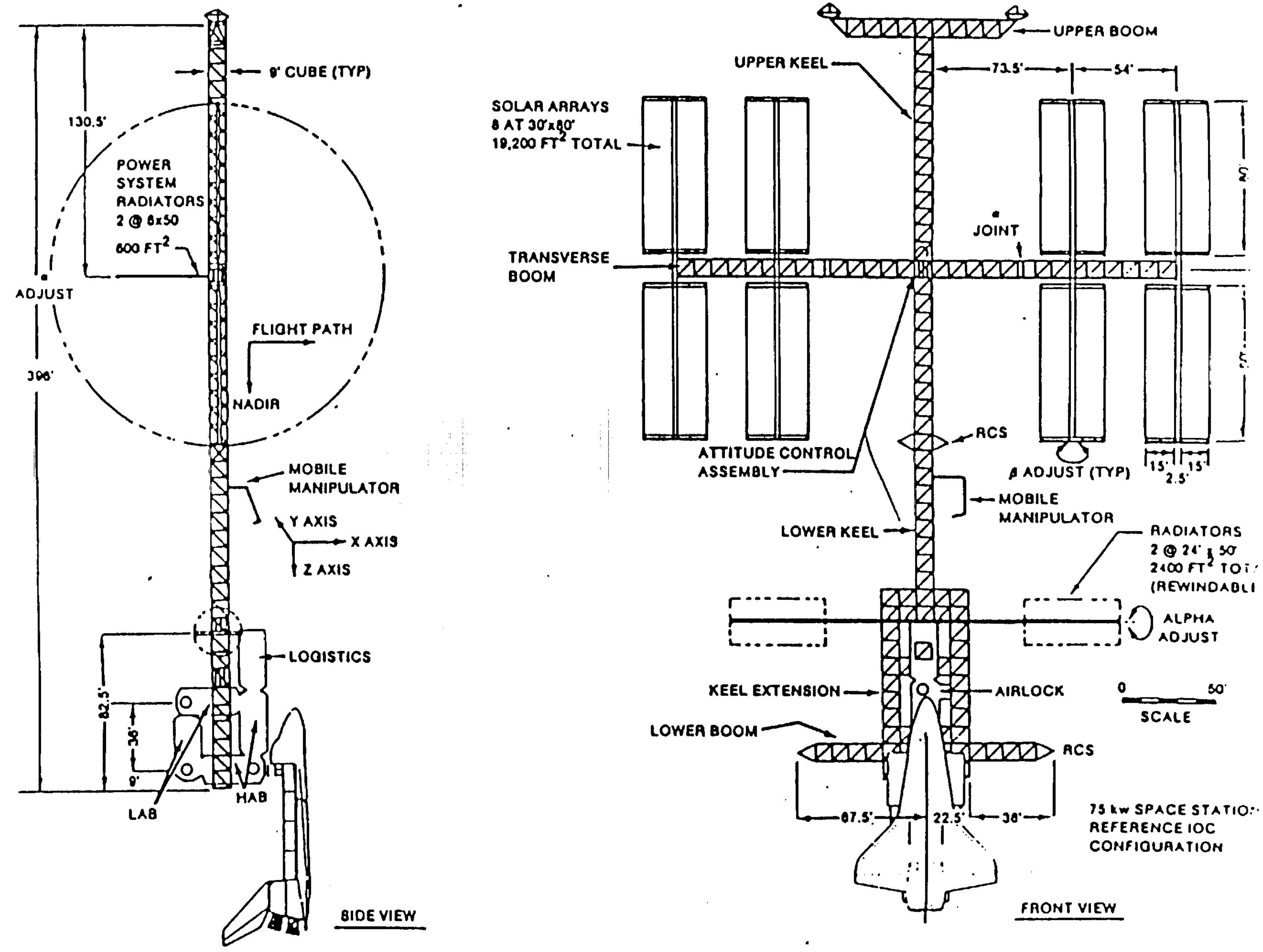
2.0 TECHNICAL ACCOMPLISHMENTS

During the Phase I efforts, a number of achievements occurred despite the difficulties in obtaining solid detailed design information. Some of the results are no longer applicable due to differences in the station configuration at the start of the study and now, the "75 kW Space Station reference IOC" concept represented in Pre-Phase B White Papers document and the current Space Station Freedom Configuration. Also, atomic oxygen effects were just coming under close analysis through data obtained from shuttle experiments. Since the time of these analyses, the understanding of physical mechanisms and orbital environments has increased significantly and may advance further in the near future as the results of the recently recovered Long Duration Exposure Facility are analyzed and documented. The results of the task activities are presented in greater detail in the following sections of this report. Included are discussions of the development of a Space Station Work Breakdown Structure, environment identification, wear points, materials, lubricants, & outgassing, operating requirements and characteristics, and the data tape.

2.1 Development of Space Station Work Breakdown Structure

A comprehensive listing of the Work Breakdown including all major system, subsystems, equipment, was developed and used as the basis for for identifying wear points and critical lubrication concerns. The Space Station IOC reference configuration shown in figure 7 served as the baseline configuration for this analysis. This configuration is based on a set of deployed linear trusses constituting the keel and booms to which the modules, subsystems, and equipment are connected. It contains numerous mechanisms and joints that provide interfaces with and support to external payloads and equipment for various experiments and servicing functions (e.g., satellite, orbital/space transfer vehicle, and orbital maneuvering vehicle servicing). Phase I of this program began about the time Phase B of the Space Station program began in which there were still a number of parallel contractors involved in each work package. SRS obtained design data products from the Martin Marietta and Boeing Work Package efforts early in the study and compared these with the reference configuration. Some variances occurred as can be expected, especially at the lower levels. It should be noted that there existed an official Space Station Work Breakdown Structure for the program, the top levels of which are shown in figure 8. For the purposes of this study it was necessary to modify the program WBS which includes functional elements (e.g., safety, reliability, etc.). The WBS for this study was intended as a cataloging tool to promote a complete identification of wear points in space hardware and therefore only includes the breakdown of on-orbit hardware items. Much similarity exists in the two items. Figure 9 depicts the difference in those structures at the top level. Both agree at the program level and the project level definition was retained in anticipation of continuing further with WP-1 than the others.

The basic concept of the hierarchical network as shown in figure 10 was used to identify the Space Station breakdown structure levels and contents. The use of this system to catalog and describe the large number of equipment hardware items in the space station provided a systematic approach which was easily automated for computer analyses of the interrelationships of all elements within a breakdown structure level. Figure 11 illustrates the manner in which each level is subdivided to provide a detailed listing of components and parts for identifying wear points. The WBS structure levels were defined along the approach NASA uses.



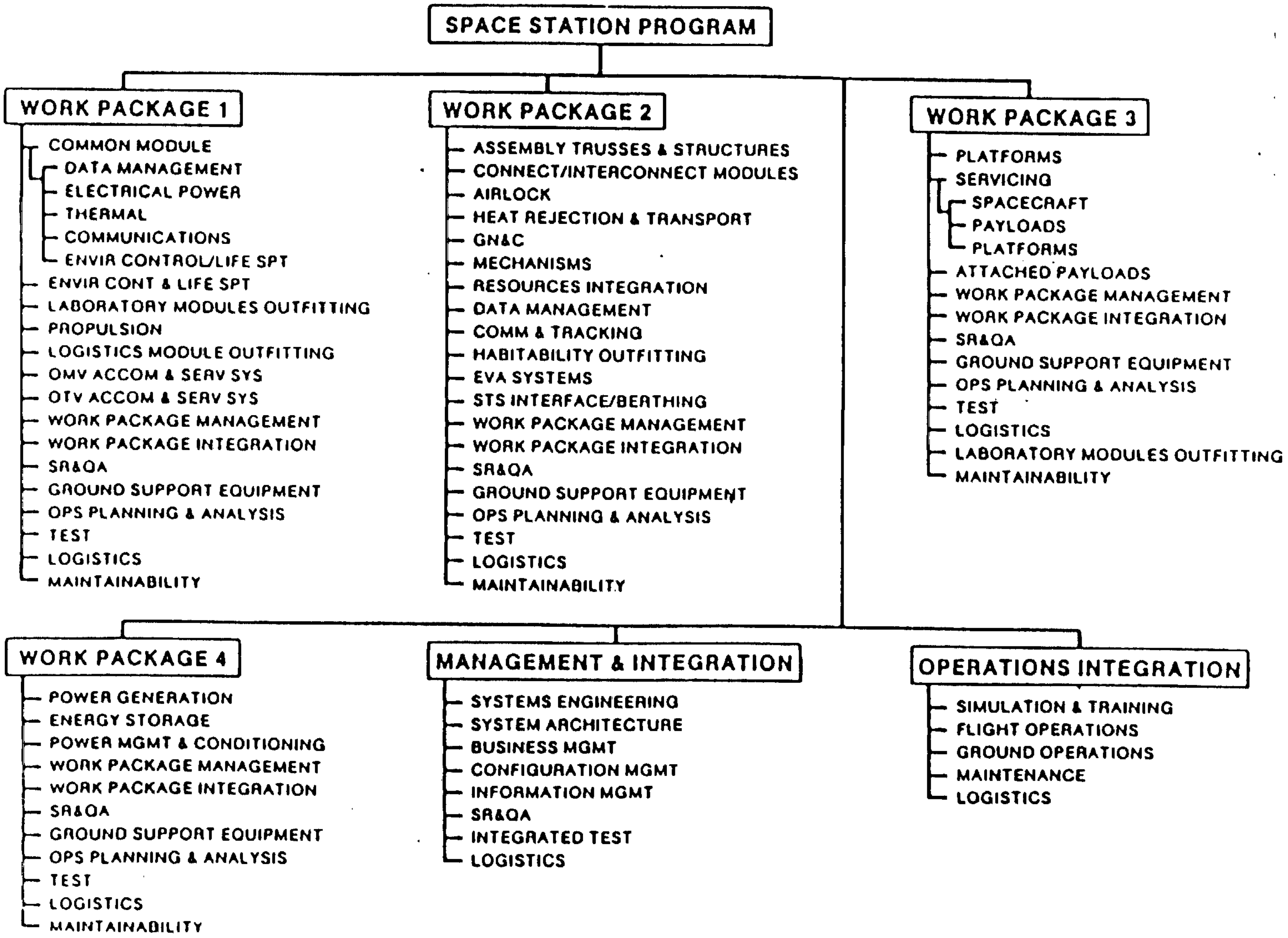
SIDE VIEW

FRONT VIEW

75 kw SPACE STATIO
REFERENCE IOC
CONFIGURATION

Preliminary Space Station Work Breakdown Structure

DEVELOPMENT PHASE



SPACE STATION PROGRAM

WORK PACKAGE 1
- COMMON MODULE
  - DATA MANAGEMENT
  - ELECTRICAL POWER
  - THERMAL
  - COMMUNICATIONS
  - ENVIR CONTROL/LIFE SPT
- ENVIR CONT & LIFE SPT
- LABORATORY MODULES OUTFITTING
- PROPULSION
- LOGISTICS MODULE OUTFITTING
- OMV ACCOM & SERV SYS
- OTV ACCOM & SERV SYS
- WORK PACKAGE MANAGEMENT
- WORK PACKAGE INTEGRATION
- SR&QA
- GROUND SUPPORT EQUIPMENT
- OPS PLANNING & ANALYSIS
- TEST
- LOGISTICS
- MAINTAINABILITY

WORK PACKAGE 2
- ASSEMBLY TRUSSES & STRUCTURES
- CONNECT/INTERCONNECT MODULES
- AIRLOCK
- HEAT REJECTION & TRANSPORT
- GN&C
- MECHANISMS
- RESOURCES INTEGRATION
- DATA MANAGEMENT
- COMM & TRACKING
- HABITABILITY OUTFITTING
- EVA SYSTEMS
- STS INTERFACE/BERTHING
- WORK PACKAGE MANAGEMENT
- WORK PACKAGE INTEGRATION
- SR&QA
- GROUND SUPPORT EQUIPMENT
- OPS PLANNING & ANALYSIS
- TEST
- LOGISTICS
- MAINTAINABILITY

WORK PACKAGE 3
- PLATFORMS
- SERVICING
  - SPACECRAFT
  - PAYLOADS
  - PLATFORMS
- ATTACHED PAYLOADS
- WORK PACKAGE MANAGEMENT
- WORK PACKAGE INTEGRATION
- SR&QA
- GROUND SUPPORT EQUIPMENT
- OPS PLANNING & ANALYSIS
- TEST
- LOGISTICS
- LABORATORY MODULES OUTFITTING
- MAINTAINABILITY

WORK PACKAGE 4
- POWER GENERATION
- ENERGY STORAGE
- POWER MGMT & CONDITIONING
- WORK PACKAGE MANAGEMENT
- WORK PACKAGE INTEGRATION
- SR&QA
- GROUND SUPPORT EQUIPMENT
- OPS PLANNING & ANALYSIS
- TEST
- LOGISTICS
- MAINTAINABILITY

MANAGEMENT & INTEGRATION
- SYSTEMS ENGINEERING
- SYSTEM ARCHITECTURE
- BUSINESS MGMT
- CONFIGURATION MGMT
- INFORMATION MGMT
- SR&QA
- INTEGRATED TEST
- LOGISTICS

OPERATIONS INTEGRATION
- SIMULATION & TRAINING
- FLIGHT OPERATIONS
- GROUND OPERATIONS
- MAINTENANCE
- LOGISTICS

Figure 9. Redefined LTLS Work Breakdown Structure

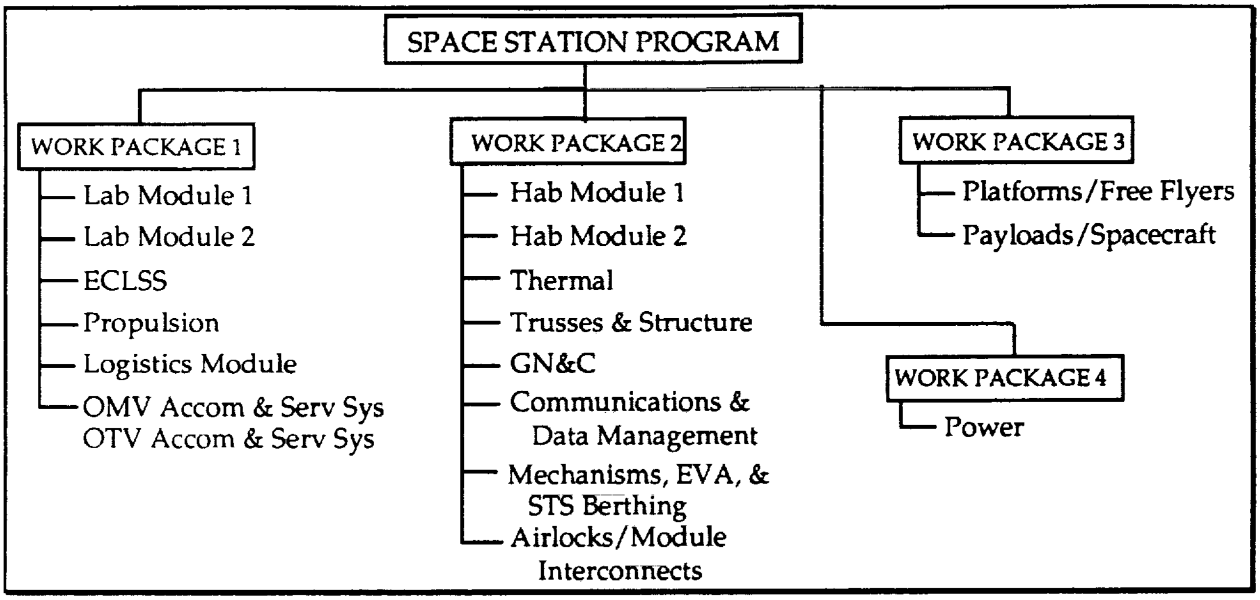


Figure 10. Hierarchy for Development of SSF Systems, Subsystems, and Component Listing

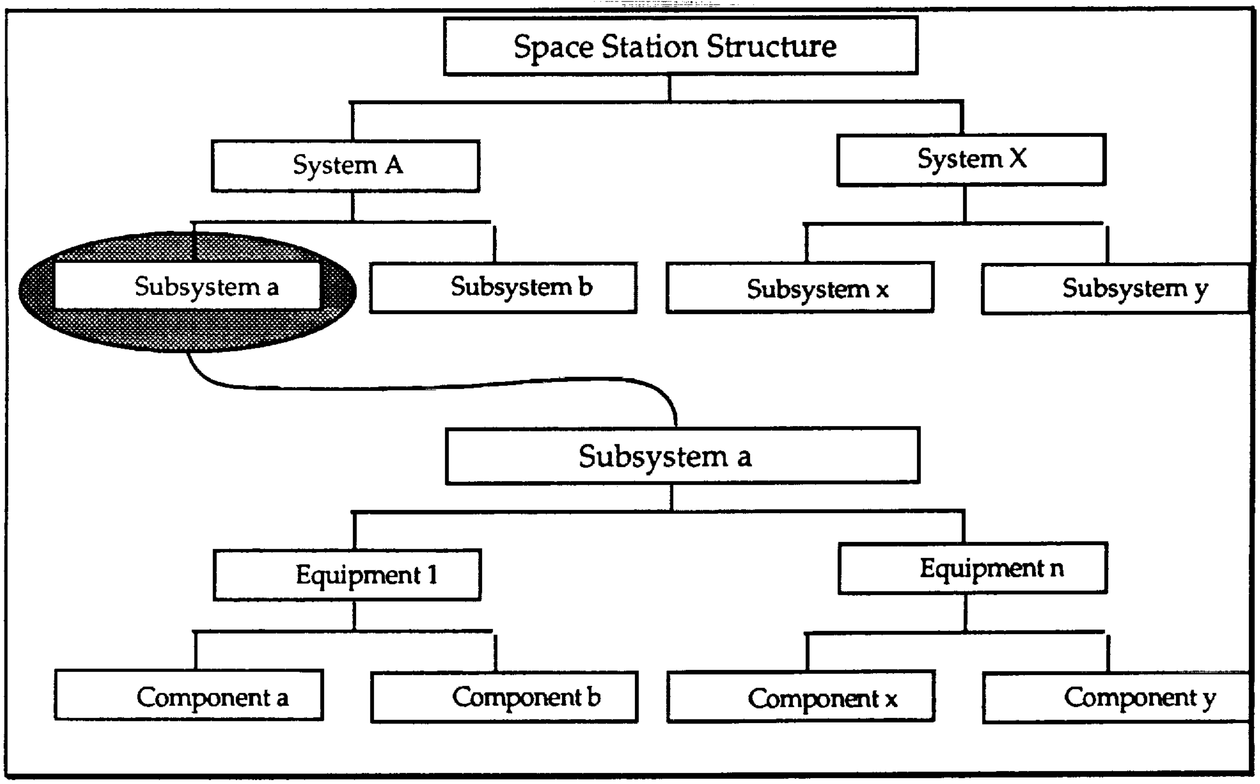
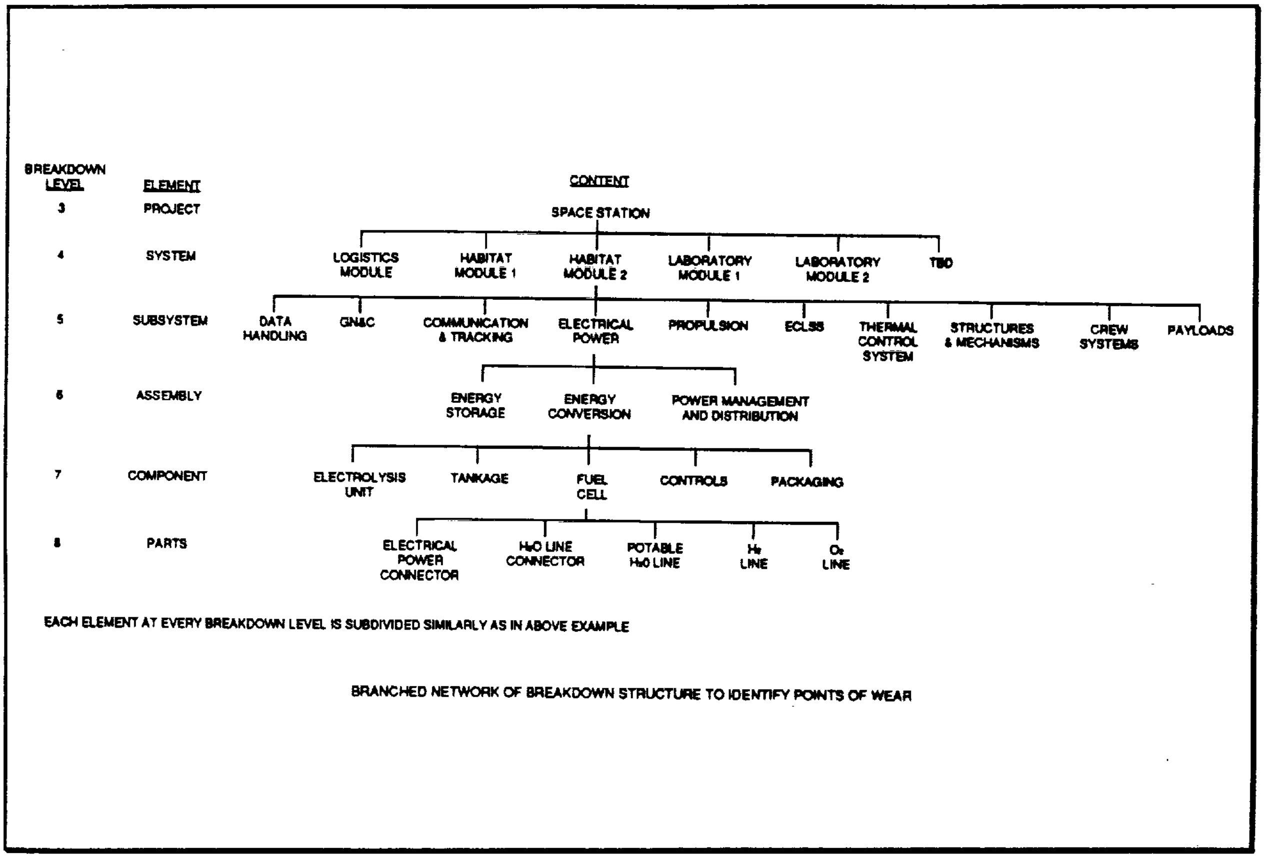


Figure 11. Branched Network of Breakdown Structure to identify Points of Wear



The development of the LTLS WBS began at the program level 2 and proceeded with analysis of each element at a level to identify major pieces of equipment at that level. The depth to which the tree could be defined was limited by the availability of design information (related to the maturity of the design) and study resources. The "Space Station Reference Configuration Description" document (JSC-19989) addressed the growth of the manned and unmanned station concepts and contained a configuration evaluation and subsystem definition of the IOC configuration. Being the most comprehensive and programmatically substantial source of reference information at the time the study began, it was used as a guideline for the definition of levels 3-6. Similarly, a companion volume, the "Space Station Subsystem White Papers" document (JSC-20054), was used in the definition of the 7-8 levels of the WBS. Even so, it was not possible to complete the WBS for all work packages completely down to the 7th or 8th levels. Instead, the structure was defined to the 4th and 5th level, which are the System/modules and subsystems, then an evaluation of the elements was performed to determine the major Moving Mechanical Assemblies (MMAs). These were selected in a process of evaluation in which each element was assessed against the selection criteria shown in figure 12. Those elements which registered in the largest number of criteria categories, for which significant design data existed, and were Work Package 1 elements were prioritized and selected for further WBS level definition and evaluation.

Figure 12. Criteria for Ranking Risks or Probability of Failure

Code	Selection Criteria
0	SELECTION CRITERIA NOT APPLICABLE.
1	OPERATES UNDER HIGH LOADS/CONTACT STRESSES, FREQUENT OR CONSTANT. MOTION, ENVIRONMENTAL EXTREMES, AND/OR HIGH DUTY CYCLES.
2	POTENTIAL SOURCE FOR CONTAMINATION RESULTING FROM PREMATURE FAILURE.
3	MISSION OR LIFE CRITICAL IF PREMATURE FAILURE OCCURS.
4	UNIQUE PRELIMINARY DESIGN CONCEPT/NEW TECHNOLOGY INVOLVED.
5	WILL OR LIKELY TO REQUIRE MAINTENANCE/REFURBISHMENT.

EXAMPLES:

00000: No elements of selection criteria applicable.

10000: WBS component only operates under high loads/contact stresses, frequent or constant motion, environmental extremes, and/or high duty cycles.

02340: WBS component is a potential source of contamination resulting from premature failure, is mission or life critical if premature failure if premature failure occurs, and involves a unique preliminary design concept or new technology.

2.2 Environment Identification

Establishment of the environments for each wear point was required for the assessment of performance and life characteristics of the particular surfaces of interest in the identified wear points. In general, environments enclosing surfaces in relative motion can be different depending on the duty cycle of the mechanism. For example, when the mechanism is not operating, the environment may be at a different temperature and pressure than when the mechanism is operating. Mechanisms at rest may, however, be under static load and, depending on materials and environments, failures such as long term stress corrosion may occur. If high loads and;or high relative speeds are present such as in the contacts of high speed rolling bearings, temperature in the contacts will be vastly different from those for static conditions. These thermal environments and temperature cycling set stringent requirements on long term lubricants and the ability of the lubricants to provide the necessary elastohydrodynamic for proper lubrication at operation temperature. In general, the life of these contact surfaces is dependent on the elastohydrodynamic conditions in the contacts which is a complex function of load levels, speeds, and operating environment.

In some specific applications, such as the Space Station refrigeration systems, the lubrication system for refrigerant compressors may require isolation to prevent lubricant contamination of evaporator and condenser surfaces. In some designs this may involve dynamic seals in a refrigerant and high temperature lubricant environment. These environments must be identified and characterized to support wear and life assessments of these components. Other mechanisms, such as external fluid rotary joints and docking mechanisms, will have external surfaces exposed to the space environment for long periods of time. Lubricants used for these applications must therefore be compatible with these environments. The assessment of environmental effects on contacts and/or wear point performance, durability, and life requires a definition of these environments over the entire duty cycle of the mechanism and/or component.

The objectives of this effort were to identify the environment for each wear point over the duty cycle of the mechanism, characterize the environment for assessment of wear point durability and life, provide comprehensive rationale to support findings, data base, and documentation requirements. Environments over the complete duty cycle were determined for each Space Station MMA component.

These environments were then characterized to determine the specific environmental components that affected wear point performance and durability.

Many components, such as thermal control coolant pumps, essentially operate continuously at relatively steady loads. Other components, such as docking mechanisms and latches, may not operate over several times per year. Mechanisms such as Space Station Solar Array actuators and drive mechanisms will operate several times per orbital period. These are examples of mechanisms that have relatively steady environments and large fluctuations in environments depending on duty cycles. Surfaces exposed to the orbital environment (latches, docking probes, etc.) will be exposed to many elements that could cause surface degradation leading to loss of performance and decreased durability. The space environmental effects most likely to affect materials and lubricants in Low Earth Orbit are:

- Vacuum Outgassing (1 X 10^{-6} to 1 X 10^{-7} Torr (per specification SP-R-0022A)
- Solar Radiation
  - Proton - 2.9 X 10^3 rad (c), Energy >100 keV to 2.2 X 10^3 rad (Si)
  - Electron - 7.5 X 10^5 rad (C), Energy >40 keV to 6.8 X 10^5 rad (Si)
  - Ultraviolet - 55,000 Sun Hours
- Atomic Oxygen
  - Concentration - Approximately 1 X 10^9 atoms/cm^3 @ 290 nmi. altitude
  - Exposure - perpendicular to Flight Path
    - 2.36 X 10^{15} atoms/cm^2/sec
    - 3.5 X 10^{20} atoms/cm^2 in 41.0 hours
- Micrometeoroids - 8200 impacts/m^2 (mass < 10-12 gm)
- Meteoroids & Debris - 4 impacts/m^2 (diameter > 0.01 cm)
- Thermal Cycles - 58,500 over 10 years

The space vacuum has varied effects on materials depending on the material characteristics. For example, it has a beneficial effect on the fatigue life of alloys susceptible to stress corrosion (removed or absorbed molecules eliminating the electrolyte). Vacuum and thermal effects can cause removal of surface gases from materials with detrimental effects. Losses of absorbed gases for materials in sliding surfaces can cause appreciable changes in friction coefficients. Lubrication characteristics may also change significantly when exposed to space vacuum over long periods of time. A lubricant's volatility is a function of its vapor pressure, and vapor pressure is related inversely to molecular weight. In general, lower weight fractions of a lubricant will be lost through vaporization before the heavier constituents. This does not necessarily mean that those with very low vapor pressure and evaporation rates will give the longest life in vacuum service. The only conclusive means in determining lubricant service life in vacuum is by experimentation. Long term tests of grease type lubricants are underway at MSFC and will provide valuable information for the assessment of long term vacuum effect on these lubricants.

In low earth orbit the principal source of electromagnetic radiation is the sun. Solar radiation covers the wave length region from around 0.01 µm to greater than 10^4 µm. This region includes low energy gamma ray, x-ray, UV, visible, infrared, and microwave photons with an energy density of 1353 W/m^2. In developing the solar environments for specific components the location of the component relative to the sun and earth is important as well as shading and/or blockage from adjacent structures. For estimates of material degradation due to sun exposure, total exposure times will be estimated based on orbital time averages of solar exposure for each mechanism. Solar flux distributions for outer surfaces of the Space Station will be developed by Phase B contractors for thermal design of SSF. This will be the principal source of data for this environmental information. In specific cases where data may not be available, SRS has the capability to develop this information.

The trapped particles of the South Atlantic Anomaly are essentially electrons and protons trapped in magnetic flux lines an reach a low point at about 30 degrees inclination or greater, there will be approximately five passes through this anomalous area each 24 hours. Material degradation occurs through ionization of the atoms or molecules by the electrons and energy deposition in the materials by protons.

Atomic oxygen effects on materials and surface degradation is a strong function of the direction of the surface with respect to the velocity vector. The greatest amount of degradation occurs on the forward surface of the STS Orbiter perpendicular to the velocity vector. Therefore, atomic oxygen fluxes must be estimated based on the relative location of the surface of interest. Materials experiments have been flown on many STS flights and data reported in the literature. The recently retrieved Long Duration Exposure Facility should provide some very relevant information from AO experiment results.

During the LTLS study, the responsibility for leading space station propulsion system design was being transferred to JSC. Mr. Walt Karakulko at NASA/JSC was contacted and provided these guidelines on operating characteristics of the space station thruster/storage tank assembly.

gaseous fuel: <3000 psi; (20 deg. F.)<T<(150 deg. F)

liquid fuel: 400-500 psi; (20 deg. F.)<T<(150 deg. F)

2.3 Identification of Wear Points

In this section, the activities performed in pursuit of the tribology survey data and the MMA's identified in this process are discussed. This first subsection summarizes these activities and includes a list of the MMA's selected. Succeeding subsections discuss each MMA separately .

2.3.1 Summary

From a relatively broad range of assemblies, components, and mechanisms, a group of items were selected for focus in the evaluation and assessment activities. For these items, a contacts were established, usually with the NASA technical monitor and the contractor (or subcontractor) performing technology studies or advanced developments for the items. In many cases SRS met with project leaders and discussed lubrication concerns directly with the individuals involved in the studies. This was made possible in most cases by scheduling splinter sessions in conjunction with SS Phase B Work Package Reviews and SS Advanced Development Program Reviews held at MSFC. The list of areas below comprise this set of target projects.

Collection of data and survey of lubrication aspects of:
o OMV Mechanisms,
o Mobile Servicing Center,
o SS Control Moment Gyro,
o MDAC Berthing Mechanism,
o GE Compressor,
o Rockwell Rotary Joint Mechanism,
o MDAC Rotary Joint Mechanism,
o Sperry Rotary Joint Mechanism,
o Space Station Alpha Rotary Joint Mechanism,
o Space Station Propulsion Thruster/Storage Tank Assembly,
o Space Station Solar Array and Solar Dynamic Concentrator,
o OMV and Payload Mechanisms,
o Antenna System Rotary Joints, and
o Health Maintenance Facility.

Lubrication issues, although of concern to all such projects, were not the main goal of most of these projects. Typically, the objectives were to assess relevant technologies in areas like mechanisms, power generation, or LOX/LH2 propulsion concepts and produce proof-of-concept prototypes. Therefore, the effort which these projects could put forth in coordinating with the LTLS was limited. In all cases, SRS, in conjunction with the COTR for this study, Mr. Fred Dolan, sent written requests for pertinent information and provided lubrication survey forms. In several instances, the projects were able to make an assessment and provide very useful feedback. In other cases, the projects provided data products (technical reports, concept descriptions, design drawings, etc.) which allowed SRS to perform assessments for lubrication concerns connected with the item. Also, through alternate sources and basic research, enough information was obtained to make some evaluation. Some projects never reached a level of maturity to support definition of all the the structural, mechanical, lubricant selection, outgassing information necessary for a complete survey of the concern. Looking forward to updates planned for later in the LTLS project, SRS retained these items in the tribology data base with as much information as was available.

In addition, SRS continued to track the the global program to monitor for the identification of additional lubrication concerns/items as they became apparent. Those activities included acquisition and assessment for wear points in Boeing WP-1 and SS ADP Review Data, participation in Space Station Materials Sub-Panel Meeting at NASA/Langley Research Center, communications with MSFC, Phase B contractors, and ADP's to obtain environment and operating characteristics of MMA's, and coordination with ADP centers to request inclusion of the completed Survey Forms as part of Phase C/D PDR data requirements.

At the Langley Materials Sub-Panel Meeting, the issue of design maturity and the timeliness of LTLS study products was addressed. In response to the need for a tribology assessment for the Major Moving Mechanical Assemblies (MMA's) prior to their respective Critical Design Reviews (CDRs), the LTLS study aproach was revised. The initial approach was based on making use of Design data published in Preliminary Design Review (PDR) data packages. However, this data has been neither complete nor mature enough to support a tribology assessment. It has been determined a more direct method of obtaining environmental and operating characteristics of the MMAs is needed if the tribology assessments are to be made before CDR.

To resolve this problem, the tribology survey forms previously developed in this study for in-house use, were sent to the responsible COTR's and contractors prior to design reviews. Letters of explanation and Survey Forms were sent to:

- o Sperry -Alpha and Beta Rotary Joints
- o Boeing -Gimballed Radiator and Two Phase Thermal Bus
- o Grumman -Space Erectable Radiator and Two Phase Thermal Bus
- o General Electric -Compressor for SS Refrigeration system
- o MacDonnell Douglas -Berthing Mechanism

In addition, a letter and survey form encouraging their inputs to this study were sent to David Thomasson of the Huntsville Boeing office. Boeing Aerospace Company is an MSFC WP-1 Prime Contractor. Also, a complete set of the red-books containing the presentation materials from the Space Station Advanced Development Program Review were obtained and reviewed for information indicating possible Major Moving Mechanical Assembly candidates for further lubrication study in this program.

2.3.2 Orbital Maneuvering Vehicle & Mobile Servicing Center

John Forbes/MSFC, the manager for Orbital Maneuvering Vehicle (OMV) Mechanisms was contacted and agreed to follow through in providing wear point information towards the objective of developing a survey response. The OMV became an LTLS topic of focus when SRS attended the annual review of the Grumman Aerospace "Advanced Orbital Servicing Technology" effort at MSFC on June 24. No hardware design activities pertinent to this study were identified as part of that AOST study, but during the review suggestions were made to research the mechanisms on the Mobile Remote Manipulator System (MRMS) and the Orbital Maneuvering Vehicle (OMV). SRS followed up in the pursuit of lubrication aspects of the mechanisms on the Mobile Remote Manipulator System (MRMS) and the Orbital Maneuvering Vehicle (OMV) by contacting Luther Powell, then director of the MSFC Space Station Program Office. He provided SRS with a contact in the MRMS program-Brian Erb of the NASA Johnson Space Center. JSC was to develop the base with SPAR of Canada providing the manipulator arm. In initial discussions with Mr. Erb, he indicated project was still very much in the conceptual phase, but he would do some checking and call back on the availability of data. Later, Brian Erb (also of the Canadian Research Council) was sent LTLS survey forms and forwarded them to appropriate technologists. There was no further response from that source. Additional discussions with Zack Thompson, Stan MacIntyre, and Tom Byrd of MSFC indicated there was some potential for lubrication issues associated with fluid, electrical, and payload quick disconnects. In a follow-up to that meeting, Tom Byrd of NASA/MSFC indicated three design areas with possible lubrication concerns and agreed to supply pertinent data on:

(1) 3-point latch mechanism for Space Telescope,
(2) Fluid coupling for propulsion system, and
(3) Payload gimbaling.

Also, on July 16, 1986, SRS sent a letter to Mr. Jeffrey Corbin of Martin Marietta requesting contacts to provide data on OMV/OTV Accommodations items relating to docking mechanisms and pumps from their Phase B work:

2.3.3 Space Station Control Moment Gyro

Early conversations with Lewis Cook, COTR for this Bendix project indicated that a survey was underway for supporting mechanisms with an expected time of completion is two weeks. In the Attitude Control and Stabilization session of an ADP program review held later, Mr. Cook of MSFC presented the status of a Control Moment Gyro design activity. Parts of this system were currently on order for a CMG prototype. However, only limited design data pertinent to lubrication was available.

2.3.4 GE Compressor

Lockheed Missiles and Space Company studies of mechanical assemblies in the Thermal Storage Unit and Refrigerator System focused on the GE compressor. Mr. Rudy Trabanino of NASA/JSC agreed to forward a survey data form to the appropriate individuals at the General Electric operations in Houston. A survey was sent for the advanced development program they were pursuing on a Compressor for the Space Station Refrigeration system. Later, Mr. Trabinino requested additional survey forms to send to General Electric. During the project, GE Houston operations underwent a cut in workforce. The original request and form may have been lost.

2.3.5 Truss & Rotary Joint Mechanism

Discussions with Leon Smith of the McDonnell Douglas Astronautics Company identified Lockheed Missiles and Space Company as the provider of a rotary joint design as part of the Work Package 2 Phase B activity. However, not enough detail was then available to justify a survey. The competition sensitive nature of the design/configuration was expected to limit the availability of significant design information until mid to late 1987.

Lubrication survey data forms were provided to Mr. Harley Rockoff of Rockwell for their Rotary Joint Mechanism work. A second request was made as a result of an Space Station Advanced Development Program Review meeting held at LaRC.

Conversation with Fred Jankowski of NASA/MSFC indicated that little pertinent information to support a tribological analysis of the McDonnell Douglas Rotary Joint Mechanism was available at the ADP review. Detail drawings were only beginning to be prepared at the time.

John Gustasson of NASA/LaRC was contacted and agreed to send a package of documentation containing all available design information on the Space Station Truss and Joint Designs being sponsored by LaRC.

Mr. Obie Bradley of the NASA Langley Research Center provided SRS with a report on testing and design drawings of three Rotary Joint Mechanism concepts. Upon Evaluation of the Sperry Alpha Rotary Joint Design Drawings, seven areas of potential wear problems were identified:

(1) Power/Signal Transfer Bearing
(2) Pinion Gear/Bearing Housing Gear Interface
(3) Shaft Bearing (P/N 3HKR102 P7)
(4) Pinion Bearing (P/N KAA10 AG)
(5) Follower Bearing (P/N KB020 CPO)
(6) ß Solar Array Joint 36 inch Bearing Assembly
    (Alternate Construction)
(7) Alpha Solar Array Joint 108 inch Bearing Assembly
    (Alternate Construction)

Along with the preliminary survey data forms, other pertinent drawings and specifications were sent to Battelle Columbus Laboratories for further tribology assessment.

Harold Bush of NASA/LaRC) was contacted and agreed to send a package of documentation containing all available design information. SRS received a data package on a preferred truss concept (several were still being considered). After review of this package, additional information on a few specifics was requested.

The rotary joints in the antenna system had similarities to the Ball Aerospace and Sperry designs in the solar array application. Jim Kelly of NASA/JSC, agreed to send lubrication reports and drawings on the shuttle KU band antenna gimbal system. That system was produced by Hughes Aircraft in El Segundo, California.

2.3.6 Berthing Mechanism

The McDonnell Douglas Astronautics Company began Berthing Mechanism design activities in mid 1986. In July, at the request of SRS, Mr. Fred Jankowski MSFC/EP33 forwarded a survey data form to MDAC for completion. Results were expected on or about August 1986.

2.3.7 Radiator

Through Mr. Richard Parish of NASA/JSC, LTLS survey forms were distributed to appropriate individuals at the Boeing Aerospace Company for the Two Phase TCS and Gimbal Radiator and Grumman for the Two Phase TCS and Space Erectable Radiator. In follow-up discussions it was reported that they were being prepared and might be available within a month.

2.3.8 Coarse Pointing Mechanism

In telephone contacts with Kevin Grady of the NASA Goddard Space Flight Center, the Coarse Pointing Mechanism project was still in a very conceptual stage. He suggested contacting the work package 2 contractors General Electric and Ball Brothers again around the first of September when more mature data may be available.

2.3.9 Propulsion System Thrusters

Mr. Ralph Burns MSFC/EP33 provided SRS with a data package containing a schematic and drawing of portions of the space station thruster/storage tank assembly. SRS reviewed this information to identify possible wear point candidates. Initially, potential areas of concern included O-rings, V-seals, K-seals, screw threads, fuel/oxidizer quick disconnects, and solenoid and latching valves. In the end, the SRS evaluations resulted in the identification of 36 wear points with possible long-term lubrication concerns. The points identified were associated with the fuel and oxygen solenoid valves, the oxygen and nitrogen latching valves, and the thruster assembly.

During this time, the responsibility for leading space station propulsion system design was being transferred to JSC. Walt Karakulko at NASA/JSC was contacted and provided these guidelines on operating characteristics.

gaseous fuel: <3000 psi; (20 deg. F.)<T<(150 deg. F)
liquid fuel: 400-500 psi; (20 deg. F.)<T<(150 deg. F)

On July 16,1986 SRS sent a letter to Mr. Jeffrey Corbin of Martin Marietta requesting contacts to provide data on items from their Phase B work on the Space Station Propulsion System including an electromechanical solenoid quick disconnect fitting, thruster valves, isolation valves, and propellant/pressurant quick disconnects.

2.3.10 Solar Array

Mr. Wayne Bartlett of the NASA Lewis Research Center provided SRS with three sets of detailed notes on lubrication aspects of the LMSC Space Station Solar Array. His notes included a drawing and addressed mechanical assemblies at the base of the array connecting to the Beta joint. Another set of notes prepared by Mr. Rick Elms of LMSC identified a large number of wear points and proposed lubricants for locations on the array, base, and deployment mechanism. Also included was a copy of a memo from Mr. Fred Dolan MSFC/EH14 to Ann Whitaker MSFC/EH12 on the lubrication recommendations for the Solar Electric Propulsion / Solar Array Flight Experiment dated February 15, 1979. Although the depth of information was limited in these notes, they were sufficient to identify the location of potential lubrication concerns and some candidate lubricants for evaluation. From this information, SRS identified a number of wear points and collected tribology data associated with the items. SRS concentrated mainly on the component description and materials summary. Mr. Bartlett later met with SRS contract representatives, providing survey forms completed by Rocketdyne also on components of the Solar array structure. The information was complementary since Rocketdyne concentrated on operating characteristics and also served to verify the points identified. Mr. Bartlett anticipated sending more detailed drawings/pictures of the individual components as they became available. A total of eight wear points were identified and surveyed in connection with the solar array and solar dynamic generator components.

2.3.11 Health Maintenance Facility

The in-flight clinical medical care facility onboard the Space Station was still in the definition process, according to Mr. James Logan, Medical Operations Branch Chief, at NASA's Johnson Space Center when he was contacted by SRS. Some small pumps were potential sources of lubrication concerns, but design candidates had not yet been defined.

2.4 Operating Requirements and Characteristics

Lubrication schemes may be classified according to the general type of lubricants, whether dry film or fluids. Typical dry film lubricants include MoS_2, Teflon, and graphite. Typical fluid lubricants include oil and greases. Determining the type of lubrication scheme for a specific element and the performance characteristics of the lubricant to reduce surface wear is an important factor in support of tribology assessments. However, the type of lubrication scheme depends on the operating characteristics of the component such as loads, rotational speeds, relative velocities and environment. Consequently, a characterization of lubricants and operating characteristics was necessary.

Lubricants operating near optical or thermal control surfaces were assessed against the outgassing requirements defined in SP-R-0022A, "General Specification Vacuum Stability Requirements of Polymeric Material for Spacecraft Application". This outgassing requirement restricts the use of polymeric materials near critical optical and thermal control surfaces to those materials having a maximum volatile condensed material (VCM) content of 0.1 percent and a total mass loss (TML) of 1.0 percent or less when tested under the following controlled test conditions:

- o Pressure: 10-6 torr or less
- o Temperature of Specimen: 125 deg. C - 1 deg. C
- o Temperature of Condensable Plates: 25 deg. C - 1 deg. C
- o Vacuum Exposure Time: 24 hours

Representative outgassing data for typical greases and lubricants are listed in Table 1. SP-R-0022A defines specific procedures for NASA approval of polymeric material selected for application near optical and thermal control surfaces. These procedures served as a baseline guide to evaluate the performance characteristics of lubricants identified during the survey. The pertinent survey data base data consisted of listing:

- o Manufacturer's trade name
- o Manufacturer of the material
- o Thermal vacuum stability (VCM and TML) data
- o Rationale for use of material which failed outgassing requirement.

OUTGASSING DATA FOR TYPICAL GREASES AND LUBRICANTS

Material	MFR Code	%TML	%CVCM	Cure Time	Cure Temp	Atmos	Application
Aerodag G Colloidal Graphite/Isopropyl Alcohol	ACH	1.78	.11	24H	25	Air	Lubricant
Aerodag G Colloidal Graphite/Isopropyl Alcohol	ACH	2.05	.04	24H	60	Air	Lubricant
Aerodag M Colloidal MOS2/Isopropyl Alcohol	ACH	4.97	.19	24H	25	Air	Lubricant
Apiezon C Oil Vacuum Degassed	BID	81.19	47.47	1H	65	E-2	Grease
Apiezon H Hydrocarbon Grease	BID	.25	.02				Grease
Apiezon L Grease	BID	.04	.01				Grease
Apiezon M Grease Vacuum Degassed	BID	.34	.29	1H	65	E-2	Lubricant
Apiezon N Grease	BID	.08	.00				Grease
Apiezon T Grease	BID	.76	.12				Grease
Black Magic Moly Spray/Foil - Aerosol MOS2	SPR	.27	.02	24H	25	Air	Lubricant
Brayco 813 Clear Oil Batch EIA3	BOC	.74	.32				Lubricant
Brayco 815Z Clear Oil Batch DLM3	BOC	.03	.00				Lubricant
Braycote 3L-38 Grease Batch DLD1 White	BOC	.07	.03				Grease
Braycote 3L-38 Grease White	BOC	.07	.03	7H	100	E-6	Lubricant
Braycote 3L-38-MS Grease Batch DLG1 Gray	BOC	.04	.01				Grease
Braycote 3L-38-RP Grease Batch CLT7 Yellow	BOC	.09	.04				Grease
Braycote 3L-38-ZN Grease Batch ELM4 Black	BOC	.02	.01				Lubricant
Braycote 803 Grease Batch ELJ12 White	BOC	.24	.13				Grease
Crown 6065 Green TRE Aerosol Coating/F	CIP	.52	.09	20M	177	Air	Lubricant
				24H	121	E-3	
C6-1103 Silicone Grease	DCC	.17	.00				Grease
DC 20-057 Silicone Optical Coupling Compound	DCC	.86	.27				Grease
Dri-Slip Powdered Lubricant - Aerosol	MMM	10.73	4.60				Lubricant
Drilube 822 Fluorosilicone Lubricating Grease	DRI	6.51	2.47				Lubricant
Eccoslip TM-24 Low Friction Epoxy	EMC	.40	.00	1H	66	Air	Epoxy Lube
				1H	80	Air	
				24H	116	Air	
EKKCEL WR-25 Aromatic Polyester/TFE Blend Tan	CRB	.01	.00				Solid Lube
Envex 1000	ROG	1.94	.01				Bearing Material
Envex 1000	ROG	1.74	.01	24H	204	Air	Bearing Material
Envex 1000X	ROG	1.87	.01	24H	204	Air	Bearing Material
Envex 1000X Polyimide	ROG	1.83	.00				Bearing Material
Envex 1115	ROG	1.67	.01				Bearing Material
Envex 1115	ROG	1.29	.03	24H	204	Air	Bearing Material
Envex 1228	ROG	1.29	.00				Bearing Material
Envex 1228	ROG	1.25	.02	24H	204	Air	Bearing Material
Envex 1315	ROG	2.03	.00				Bearing Material
Envex 1315	ROG	1.36	.02	24H	240	Air	Bearing Material
Fluokem Dry Film Lubricant Aerosol	BAP	15.05	7.59	7D	25	Air	Lubricant
Fluoroglide FB Aerosol Dry Film Lubricant/F	CHE	9.49	3.09	7D	25	Air	Lubricant
Fluorosint 500 Mica Filled TFE	PPC	.05	.00				Bearing Material
GE 1147 Methyl Alkyl Silicone Lube Oil	GEC	4.28	2.41				Oil
Hi-Vac Grease	DCC	1.52	.34				Lubricant/Grease
Hi-Vac Grease 970V Silicone	DCC	.73	.22				Lubricant/Grease

2.5 Tribology Matrix / Data Tape

The results of the tribology survey and assessment were to be stored on a data tape implemented on the MSFC computer system. The RFP required the delivery of the data tape at the completion of Phase II. However, SRS proposed an option to implement the data tape during the conduct of Phase I and incrementally update the data tape as more mature data became available. By implementing the data tape early in the study, it was hoped a listing of major Space Station elements could be provided to MSFC facilitating later updating efforts. Supporting this option, a lubrication evaluation tool was to be made available to the MSFC for use in identifying probable problem areas early into the Space Station studies. This would to support test plan development and conduct in critical, deficient, or advanced technologies areas.

A description of the proposed formats of the data tape and descriptions of the individual data items to be recorded are discussed below. The actual format of the tape would have been to a small degree dependent on the computer system on which it was to be loaded. It was assumed that the Univac 1100 Series computers at MSFC would be the host system. After the start of the study, MSFC upgraded the central computer facility with a Cray mainframe. However, no significant impacts on the data tape plans resulted from another computer being chosen since interfaces to Univac peripherals and systems were retained. The SRS staff maintains familiarity with all the major computer systems at MSFC.

The standard tapes used in the MSFC tape library are the 9 Track, 1600 BPI, 10-inch diameter magnetic tapes. The tapes were planned to be recorded in a standard format, such as unlabeled Univac COPY, G format (the format of COSMIC UNIVAC NASTRAN TAPES), or the standard Univac COPIN format. SRS staff have used these formats when transferring data recorded on tapes from several sources including COSMIC, the UAH Univac, and IBM machines to MSFC computers.

The organization of the data was structured to take on a matrix format. The results of the tribology survey were to be synthesized into a row column table. The tribology matrix included an identification of the components, points of wear, and data in five major categories: structural, lubrication, environment, operating conditions and characteristics, and failure mechanisms and consequences. An illustration of the planned matrix structure is provided in figure 13. Shown is a representative of a fluid coupling design presented in JSC-19989. The fluid coupling has been broken down to the structured element level, and materials, surface finishes, environments, and oeprating characteistics have been identified.

Characteristic / Point of Wear	Structural		Lubrication			Environment		Operating Conditions				Failure Mechanism/Consequences	
	Material	Surface Finish	Type	Designation	Outgassing Characteristics	Type	Effects on Operating Performance	Loads/ Stresses	Torque	Rotational Speeds	Required Life	Mechanism	Consequences
Ammonia Fluid Coupling Seal	Virgin TFE teflon Against 316 Stainless Steel	6-8 μ inch molded 6-8 μ inch polished	Dry	Unlubricated	OK	NH$_3$ inside Air outside	•Corrosive to certain material •Leads to corrosion failure and coupling failure		8655 inch-pounds	1 Rev/90 min	10 yrs	Wear, corrosion	Leakage to habitable areas could cause health problems

3.0 CONCLUSIONS

Upon completion of the Phase I activities, the information was organized into the tribology matrix format and compiled into a preliminary tribology matrix as depicted as table 2 in the following pages. The information necessary to provide meaningful indications of failure mechanisms and consequences was not available and was deleted from the format. Originally, there were planned to be two updates to the matrix. Those updates were eliminated in the renegotiations of the contracted effort. Since the LTLS program was brought to focus on a few items early in the program, there no longer existed a need for a computer system to host and manipulate vast amounts of data. Early data base programming efforts using the RIM 5 relational data base software were discontinued when it became apparent that a different scope was prudent in the data requirements of the project. Appendix A contains the individual data sheets prepared from the survey results for each of the line items summarized below.

Most of the wear points identified were in conjunction with the RCS thruster assemblies and the solar array. A few wear points were identified for the Beta Joint, the Solar Dynamic Concentrator, and pumps in the fluid control system.

Survey	Function	Description	Contact	Lubrication	Load, Life, and Motion	Sun/Temperature (deg F)	Operating Conditions	Comment
Number 1 Contractor: Sperry	SHAFT BEARING DRIVE ASSEMBLY	Shaft Bearing P/N 3HKR102P7	Surface #1 440 C Surface Finish Set by Sperry Surface #2 440 c Surface Finish Set by Sperry	Lubrication Scheme: Fluid Lubricant Micronic 601 SP R 0022A Compatible ○ Yes ● No	Operating 11 Peak 20 Life (years) 20 Rotate Speed (rpm) 0.5 Oscillation Type None	Exposure: None Percent Time: 0 % Low: 8 F High: 105 F Environment Vacuum	DN value at 8 Rpm min	Single15mm bore ball bearing (catalog number 3HKR102P7 by MPB Corp) 400 lb max static load capacity. Cage is Conrad machined phenolic.
Number 2 Contractor: Rocketdyne	Solar array deployment.	Bearings in PV array deployment motor	Surface #1 Unspecified Surface Finish Surface #2 Unspecified Surface Finish	Lubrication Scheme: Fluid Lubricant Braycote 601 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 1200 Oscillation Type Unspecified	Exposure Continuous Percent Time: 100 % Low: -112 F High: 176 F Environment Vacuum		STS Cargo Bay vibration qualification level.
Number 3 Contractor: Rocketdyne	Rotating nut for solar array mast extension	PV array mast canister rotating nut	Surface #1 Unspecified Surface Finish Surface #2 Unspecified Surface Finish	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 2 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 50 % Low: 112 F High: 176 F Environment Vacuum		STS Cargo Bay qualification vibration level
Number 4 Contractor: Rocketdyne	Provide fine pointing actuation of Solar Dynamic Concentrator reflector.	Actuator motor bearings,threads,nuts	Surface #1 TBD steel Surface Finish TBD Surface #2 TBD steel Surface Finish TBD	Lubrication Scheme: Fluid Lubricant TBD SP R 0022A Compatible ○ Yes ● No	Operating 100 Peak 200 Life (years) 10 Rotate Speed (rpm) 60 Oscillation Type Intermittent	Exposure: None Percent Time: 0 % Low: -140 F High: 140 F Environment Vacuum	< 1 Hz continuous oscillation.	for additional information, contact Sundstrand Energy Systems, Rockford,, Illinois, 61125. Dual faulure tolerant electromechanical actuator
Number 5 Contractor: Rocketdyne	Solar Dynamic Concentrator deployment latch catch mechanism.	Catch Journal	Surface #1 TBD Surface Finish Unspecified Surface #2 TBD Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant TBD SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 15 Rotate Speed (rpm) 0 Oscillation Type Intermittent	Exposure: Intermittent Percent Time: 70 % Low: 0 F High: 0 F Environment Vacuum		Required to function only during deployment or retraction of concentrator. Journal bearing with <0.5 inch radius
Number 6 Contractor: Rocketdyne	Fine Pointing for the Solar Dynamic Concentrator	Universal Joint Journal Bearings	Surface #1 TBD Al Surface Finish Unspecified Surface #2 TBD Al Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 15 Rotate Speed (rpm) 0.16667 Oscillation Type TBD	Exposure: Intermittent Percent Time: 70 % Low: -150 F High: 150 F Environment Vacuum	Continuous, low load, low velocity, random motion	Journal bearing radius given as "TBD 2 inches".
Number 7 Contractor: Rocketdyne	Concentrator Reflector Deployment	Hinge Needle Bearing	Surface #1 TBD Surface Finish Unspecified Surface #2 TBD Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 100 Peak 150 Life (years) 15 Rotate Speed (rpm) 0.16667 Oscillation Type None	Exposure Intermittent Percent Time: 70 % Low: -150 F High: 150 F Environment Vacuum	Required to function only during deployment and retraction on-orbit.	Roller bearing
Number 8 Contractor: Rocketdyne	Alternator foil journal and thrust bearings for the Closed Brayton Cycle Solar Dynamic Power Generation Power Conversion Unit.	Rotor/Housing Interface	Surface #1 Rotor Journal Surface Finish Unspecified Surface #2 Foil Leaves Surface Finish Unspecified	Lubrication Scheme: Fluid Lubricant Helium/Xenon (MW=40) SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 30 Rotate Speed (rpm) 32000 Oscillation Type Continuous	Exposure: None Percent Time: 0 % Low: 100 F High: 300 F Environment Pressurized	Rotor lubricant inventory is approximately 4 lbs of lubricant. Operating load is given as "approximately 100 kW Shaft". Pressure in housing is 20 to 60 psi.	Journal Bearing with 2.726 inch radius operating at a 760 fps relative velocity.Volatile fluid is contained in welded housing. Extreme operating conditions may include temps -100
Number 9 Contractor: Rocketdyne	Pump to circulate radiator fluid. The Radiator Coolant Pump Package of the Solar Dynamic Power Generation System has an integrated motor shaft/impeller Centrifugal Pump.	Hydrodynamic Journal Bearings	Surface #1 Motor Shaft Surface Finish Unspecified Surface #2 Housing Journal Surface Finish Unspecified	Lubrication Scheme: Fluid Lubricant FC75 Immersion SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 20 Rotate Speed (rpm) 0 Oscillation Type Continuous	Exposure: None Percent Time: 0 % Low: 0 F High: 100 F Environment Pressurized	High temperature of 200 deg F in extreme operating conditions. Operating load glen as "2 lb/sec 60 psid".	Hundreds of pounds of volatile coolant/lubricant contained in sealed coolant loop at 10-20 psi. A Moog pump qualified for Peacekeeper program under consideration
Number 10 Contractor: Rocketdyne	To position the Propulsion System thruster assembly solenoid valve when solenoid is not engaged.	Ends of spring at shaft and spring stop	Surface #1 Unspecified Surface Finish Unspecified Surface #2 Unspecified Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 0 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 11 Contractor: Rocketdyne	Fluid connector for Propulsion System thruster assembly.	Screw threads on propellant feed lines	Surface #1 Male connector Surface Finish Unspecified Surface #2 Female connector Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 0 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 12 Contractor: Rocketdyne	Affect motion of the valve shaft on the Propulsion System thruster assembly solenoid valve.	Electromagnetic Plates	Surface #1 Fixed Plate Surface Finish Unspecified Surface #2 Moving Plate Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 0 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 13 Contractor: Rocketdyne	Permit or restrict fluid flow in the solenoid valve head of the Propulsion System thruster assembly.	Valve Seals/Stems	Surface #1 Valve Seat Surface Finish Unspecified Surface #2 Valve Stem Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 0 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 14 Contractor: Rocketdyne	Guide motion of valve stem in solenoid valve of the Propulsion System thruster assembly.	Valve Shaft Guides	Surface #1 Valve Stem Surface Finish Unspecified Surface #2 Valve Shaft Guides Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 0 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 15 Contractor: Rocketdyne	To form a connection between tubing and the dummy spark igniter in the Propulsion SYstem thruster assembly.	Dummy spark igniter/tubing connection	Surface #1 Tygon tubing Surface Finish Unspecified Surface #2 Dummy Spark Igniter Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 0 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		

Survey	Function	Description	Contact	Lubrication	Load, Life, and Motion	Surf/Temperature (deg F)	Operating Conditions	Comment
Number 16 Contractor: Rockeldyne	hardare attachment device. Hex head bolt asembly in the valve bracket assembly of the Propulsion SYstem thruster assembly.	Screw threads/bolt	Surface #1 Screw threads Surface Finish Surface #2 Hex head bolt Surface Finish Unspecified	Lubrication Scheme: Fluid Lubricant MoS2 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 0 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure Unspecified Percent Time: 0 % Low: 0 F High 0 F Environment Unspecified		
Number 17 Contractor: Rocketdyne	hardware attachment device. screwbolt assembly in the Propulsion System thruster assembly power head.		Surface #1 Screw threads Surface Finish Unspecified Surface #2 Screw Cap Socket Surface Finish Unspecified	Lubrication Scheme: Fluid Lubricant MoS2 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 0 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time 0 % Low: 0 F High: 0 F Environment Unspecified		Socket torqued to 22 (+/- 1) inch-lbs
Number 18 Contractor: Rocketdyne	Swagelock to a union (CRES) in propellant fluid line connectors of the Propulsion System thruster assembly.	contact surfaces and screw threads	Surface #1 Screw threads Surface Finish Unspecified Surface #2 Unspecified Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 0 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 19 Contractor: Rocketdyne	To seal the fuel line connection between the fuel solenoid valve and the valve assembly bracket in the Propulsion System thruster assembly.	V Seal	Surface #1 V-Seal-Inco 718 Surface Finish Teflon Coating Surface #2 Valve Assy Bracket Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Teflon SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 0 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 20 Contractor: Rocketdyne	Seal the connection between the Propulsion system thruster assembly power head and combustion chamber.	V Seal	Surface #1 V-Seal-Inco 718 Surface Finish Modified Gold Plat Surface #2 Power Head Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 0 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 21 Contractor: Rocketdyne	Seal the threaded connection between the Dummy Spark Igniter and the Power Head in the Propulsion System thruster assembly.	K Seal	Surface #1 K Seal Surface Finish Unspecified Surface #2 Power Head Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 0 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified	Lubricant is under pressure at the contact surface and in vacuum at the outer edge of the contact surface.	
Number 22 Contractor: Rocketdyne	"O" ring seal for the threaded connector on the Dummy Spark Igniter of the Propulsion System thruster assembly.	Two flat ring seals	Surface #1 Unspecified Surface Finish Unspecified Surface #2 Unspecified Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 0 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 23 Contractor: Moog	Valve guides for the Oxygen Solenoid Valve of Propulsion system	Poppet/Plunger Teflon Guides	Surface #1 Poppet Surface Finish Teflon Coating Surface #2 Plunger Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Teflon SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 0 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 24 Contractor: Moog	Position the Oxygen Solenoid Valve of the ARPCS control system in the Space Station Propulsion System when the solenoid is not engaged.	Low stress helical spring	Surface #1 Helical Spring Surface Finish Unspecified Surface #2 Valve Seat Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: None Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 25 Contractor: Moog	Valve seat for the Oxygen Solenoid Valve of the ARPCS control system in the Space Station Propulsion system.	Valve head / seat contact	Surface #1 Valve seat Surface Finish Unspecified Surface #2 Valve Head Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Polyimide (Vespel) SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: None Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 26 Contractor: Moog	Seal Oxygen Solenoid Valve Components in the ARPCS control system of the Space Station Propulsion system.	Seven O-rings	Surface #1 O Ring Surface Finish Unspecified Surface #2 Various Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: None Percent Time: 0 % Low: 0 F High: 0 F Environment Pressurized		
Number 27 Contractor: Moog	Connector in the Oxygen Solenoid Valve of the Space Station Propoulsion System	Screw Threads	Surface #1 Screw threads Surface Finish Unspecified Surface #2 Thread Grooves Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 28 Contractor: Moog	O-Ring seal between latching mechanism casing and plunger mechanism of the Oxygen and Nitrogen Latching Valve in th ARPCS Control System of the Space Station Propulsion System	O- ring seal	Surface #1 Casing mechanism Surface Finish Unspecified Surface #2 plunger mechanism Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: None Percent Time: 0 % Low: 0 F High: 0 F Environment Pressurized		
Number 29 Contractor: Moog	Assembly and Adjustment threaded connectors in the Oxygen and Nitrogen Latching Valve of the ARPCS Control System in the Space Station Propulsion System	Scre Threads	Surface #1 Screw Threads Surface Finish Unspecified Surface #2 Thread Grooves Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 30 Contractor: Moog	Filter Seal in the Oxygen and Nitrogen Latching Valve in the ARPCS Control System of the Space Station Propulsion SYstem	Surface contact	Surface #1 filter seal Surface Finish Unspecified Surface #2 filter seal Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: None Percent Time 0 % Low: 0 F High: 0 F Environment Pressurized		

Survey	Function	Description	Contact	Lubrication	Load, Life, and Motion	Sun/Temperature (deg F)	Operating Conditions	Comment
Number 31 Contractor: Moog	O Ring between end cap mechnism and Valve Adjustment mechanism in the Oxygen and Nitrogen Latching Valve of the ARPCS Control System in the Space Station Propulsion system	O-Ring	Surface #1 O-Ring Surface Finish Unspecified Surface #2 End cap/Valve adjust Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure:None Percent Time: 0 % Low: 0 F High: 0 F Environment Pressurized		
Number 32 Contractor: Moog	Seal the Oxygen & Nitrogen Latching Valve casing from the electric drive motor in the ARPCS COntro System of the Space Station Propulsion System	Belleville Spring Seal	Surface #1 Bville Spring Inner Surface Finish Unspecified Surface #2 Bville Spring Outer Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 0 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure:Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 33 Contractor: Moog	O Ring to seal the Relief Valve to the motor case in the ARPCS Control System Oxygen and Niotrogen Latching Valve of Space Station Propulsion System	O-Ring	Surface #1 O-Ring Surface Finish Unspecified Surface #2 Relief Valve Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure:None Percent Time: 0 % Low: 0 F High: 0 F Environment Pressurized		
Number 34 Contractor: Moog	Electric Drive motor actuator for the Oxygen and Nitrogen Latching Valve in the Space Station Propulsion System ARPCS Control System	Bearings/Planetary Gears	Surface #1 Unspecified Surface Finish Unspecified Surface #2 Unspecified Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure:Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 35 Contractor: Lockheed	Wire Wrap transfers power and data across Beta Joint	Relative Motion & Contact w/ Structure	Surface #1 Wire Wrap Surface Finish Unspecified Surface #2 Axle Housing Surface Finish Unspecified	Lubrication Scheme: None Plann Lubricant SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0.00000405 Oscillation Type Continuous	Exposure:Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		
Number 36 Contractor: Lockheed	Beta Joint Control Motor and Gearbox	Bearings / Gears	Surface #1 Unspecified Surface Finish Unspecified Surface #2 Unspecified Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure:None Percent Time: 0 % Low: 0 F High: 0 F Environment Vacuum		
Number 37 Contractor: Lockheed	Main Bearings in the housing of the Beta Joint of the Electrical Power System	Main Bearings	Surface #1 Inner Race Surface Finish Unspecified Surface #2 Outer Race Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure:Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		
Number 38 Contractor: Lockheed	Bearings in pump of water supply assembly of water electrolysis system	Bearings	Surface #1 Surface Finish Unspecified Surface #2 Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure:Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 39 Contractor: Lockheed	Cable fair lead pulleys in blanket tensioning and guidewire system of solar array of electrical power	Cable fair lead pulleys	Surface #1 pin/al Surface Finish Unspecified Surface #2 bushing/al Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type	Exposure:Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		
Number 40 Contractor: Lockheed	Drive motors in line pointing mechanism of solar dynamic system of electrical power system	Drive motors	Surface #1 Surface Finish Unspecified Surface #2 Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Working Fluid SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type	Exposure:Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 41 Contractor: Lockheed	Gearbox of line pointing mechanism in solar dynamic system in electrical power system	Gearbox	Surface #1 Surface Finish Unspecified Surface #2 Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Working Fluid SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure:Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 42 Contractor: Lockheed	Ballscrew in line pointing mechanism of solar dynamic system of electrical power system	Ballscrew	Surface #1 Surface Finish Unspecified Surface #2 Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Working Fluid SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type	Exposure:Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 43 Contractor: Lockheed	Actuator-to-concentrator I/F of line pointing mechanism of solar dynamic system of electrical power system	Actuator-to-concentrator I/F	Surface #1 Surface Finish Unspecified Surface #2 Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Working fluid SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure:Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 44 Contractor: Lockheed	Gas or foil bearings in heat engine of solar dynamic system of electrical power system	Gas or foil bearings	Surface #1 Surface Finish Unspecified Surface #2 Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Working fluid SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure:Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 45 Contractor: Lockheed	Mast base spider bushing in mast canister of solar array of electrical power	Mast base spider bushing	Surface #1 spider bushing/Al. Surface Finish Unspecified Surface #2 spider/Al. Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Intermittent	Exposure:Intermittent Percent Time: 63 % Low: 0 F High: 0 F Environment Vacuum	Radiation type: NASA TM-86460 Normal operating environment 160 °F	

Survey	Function	Description	Contact	Lubrication	Load, Life, and Motion	Sun/Temperature (deg F)	Operating Conditions	Comment
Number 46 Contractor: Lockheed	Longer on end fiting in mast canister of solar array of electrical power	Fiting to spider Al. to Al.	Surface #1 On end fiting/Al. Surface Finish Unspecified Surface #2 Pin to spider/Al. Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Intermittent	Exposure: Intermittent Percent Time: 63 % Low: 0 F High: 0 F Environment Vacuum	Radiation type: NASA TM-86460 Normal operating Environment 160°F	
Number 47 Contractor: Lockheed	Mast element/deployer interface in mast canister of solar array of electical power	Mast element to deployer interface	Surface #1 mast ele roller/Al Surface Finish Unspecified Surface #2 Deployer nut thread Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Intermittent	Exposure: Intermittent Percent Time: 63 % Low: 0 F High: 0 F Environment Vacuum	Radiation Type: NASA TM-86460 Normal Operating Environment 160°F	
Number 48 Contractor: Lockheed	Deployer nutring ballbearings in mast canister of solar array of electrical power	Deployer nutring ballbearings	Surface #1 nutring bearings/SS Surface Finish Unspecified Surface #2 Nutring bearings/SS Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Intermittent	Exposure: Intermittent Percent Time: 63 % Low: 0 F High: 0 F Environment Vacuum	Radiation Type: NASA TM-86460 Normal Operating Environment 160°F	
Number 49 Contractor: Lockheed	Batten corner fiting in mast of solar array of electrical power	Batten corner fiting	Surface #1 fitting roller/Al. Surface Finish Unspecified Surface #2 fitting cup/Al. Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Intermittent	Exposure: Intermittent Percent Time: 63 % Low: 0 F High: 0 F Environment Vacuum	Radiation Type: NASA TM-86460 Normal Operating Environment: 160°F	
Number 50 Contractor: Lockheed	Bearing in pump of pressure control assembly of water electrolysis system	Bearings	Surface #1 Surface Finish Unspecified Surface #2 Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified	Operating Load: 300 psi, 180°F, Intermittent as req'd	
Number 51 Contractor: Lockheed	Motor pinion gear in cover blanket preload system of solar array of electrical power	Motor pinion gear	Surface #1 Worn gear/Al. Surface Finish Unspecified Surface #2 Latch member/SS Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		
Number 52 Contractor: Lockheed	Motor ballbearings in ocver blanket preload system of solar array of electrical power	Motor ballbearings	Surface #1 Bearings/SS Surface Finish Unspecified Surface #2 Race/SS Surface Finish Unspecified	Lubrication Scheme: Fluid * Lubricant Braycote 601 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		* Grease
Number 53 Contractor: Lockheed	Latch system in cover blanket preload system of solar array of electrical power	Latch system	Surface #1 pins in latch/Al. Surface Finish Unspecified Surface #2 Bushing in latch/Al. Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		
Number 54 Contractor: Lockheed	Negator spimgs to rage reel in blanket tensioning and guide wire system in solar array in electrical power	Negator springs to rage reel	Surface #1 hub/Al or Delrin Surface Finish Unspecified Surface #2 Axle/Al. Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 * SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		* None for Delrin Hub
Number 55 Contractor: Lockheed	Limit switches in array motors of solar array of electrical power	Limit switches	Surface #1 Pins/SS Surface Finish Unspecified Surface #2 Brackets/SS Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		
Number 56 Contractor: Lockheed	Interface/Mast canister to beta drive in mast canister of solar array of electical power	Interface/Mast canister to beta drive	Surface #1 Mast canister/SS&Al. Surface Finish Unspecified Surface #2 Beta drive/Al Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		
Number 57 Contractor: Lockheed	Rotor ballbearings in mast motor drive assembly of solar array of electrical power	Rotor ball bearings	Surface #1 Bearings/SS Surface Finish Unspecified Surface #2 Race/SS Surface Finish Unspecified	Lubrication Scheme: Fluid * Lubricant Braycote 601 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		* Grease
Number 58 Contractor: Lockheed	Clutch or solenoid in locking mechanism of beta joint of electrical/mechansims	clutch or solenoid	Surface #1 clutchpin Surface Finish Unspecified Surface #2 sleeve Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		
Number 59 Contractor: Lockheed	Pin puller piston or solenoid pistion in launch support and release for box ends of solar array of electrical power	Pin puller piston or solenoid piston	Surface #1 Piston/Al Surface Finish Unspecified Surface #2 Sleeve/Al. Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		
Number 60 Contractor: Lockheed	Bearings in centrifugal pump of H2 pump/separator of fluid control system	Bearings	Surface #1 Surface Finish Unspecified Surface #2 Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified		Operating Load 60 psi, 140°F, Continuous

Survey	Function	Description	Contact	Lubrication	Load, Life, and Motion	Sun/Temperature (deg F)	Operating Conditions	Comment
Number 62 Contractor: Lockheed	Deployer guide in mast canister of solar array of electrical power	Deployer guide	Surface #1 Fixed dep. gu./delri Surface Finish Unspecified Surface #2 Mast ele. roller/al. Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant None SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		
Number 61 Contractor: Lockheed	Bearings in pump of coolant pump of fluid control system	Bearings	Surface #1 Surface Finish Unspecified Surface #2 Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified	Operating Load: 60 psi, 180°F, continuous	
Number 63 Contractor: Lockheed	Bearings in pump of coolant control assembly of water electrolysis system	Bearings	Surface #1 Surface Finish Unspecified Surface #2 Surface Finish Unspecified	Lubrication Scheme: Unspecifie Lubricant Unspecified SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Unspecified Percent Time: 0 % Low: 0 F High: 0 F Environment Unspecified	Operating Load: 300 psi, 180°F, continuous	Pumps water or fluorinert through electrolyzer
Number 64 Contractor: Lockheed	Interface/containment box to mast in containment box of solar array of electrical power	Interface/containment box to mast	Surface #1 Contain box/SS & Al. Surface Finish Unspecified Surface #2 Mast/Al. Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		
Number 65 Contractor: Lockheed	Motor drive pinion gear in array containment box positioning system of solar array of electrical power	Motor drive pinion gear	Surface #1 * Surface Finish Unspecified Surface #2 Actuator/SS Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		* Motor drive pinion or worm gear/Al,
Number 66 Contractor: Lockheed	Positioner system in array containment box positioning system of solar array of electrical power	Polsitioner system	Surface #1 pins in pos. sys./Al Surface Finish Unspecified Surface #2 Bushing in p.s./Al Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		
Number 67 Contractor: Lockheed	Motor ball bearings in array containment box positioning system of solar array of electrical power	Motor ball bearings	Surface #1 Bearings/SS Surface Finish Unspecified Surface #2 Race/SS Surface Finish Unspecified	Lubrication Scheme: Fluid * Lubricant Braycote 601 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		* Grease
Number 68 Contractor: Lockheed	Latch and release mechanism in array containment box positioning system of solar array of electrical power	Latch and release mechanism	Surface #1 Latch/Al Surface Finish Unspecified Surface #2 Release/Al Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		Mechanism holds box position
Number 69 Contractor: Lockheed	Box-to-mast hinges system in array containment box positioning system of solar array of electrical power	Box-to-mast hinges system	Surface #1 Pin/Al. * Surface Finish Unspecified Surface #2 Bushings/Al. * Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		* In box-to-mast hinges system
Number 70 Contractor: Lockheed	Pinion gear in mast canister of solar array of electrical power	Pinion gear	Surface #1 * Surface Finish Unspecified Surface #2 * * Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		* Deployer nut ring gear Al. ** Drive assembly pinion gear/SS
Number 71 Contractor: Lockheed	Pinion gear in mast canister of solar array of electrical power	Pinion gear	Surface #1 * Surface Finish Unspecified Surface #2 * * Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		* Deployer nut ring gear/AL ** Drive assembly pinion gear/SS
Number 72 Contractor: Lockheed	Cables to rage reel in blanket tensioning and guideline wire system of solar array of electrical power	Cables to rage reel	Surface #1 Hub/Al or Delrin Surface Finish Unspecified Surface #2 Axle/AL Surface Finish Unspecified	Lubrication Scheme: Dry Film Lubricant Everlube 620 * SP R 0022A Compatible ○ Yes ● No	Operating 0 Peak 0 Life (years) 10 Rotate Speed (rpm) 0 Oscillation Type Unspecified	Exposure: Intermittent Percent Time: 64 % Low: 0 F High: 0 F Environment Vacuum		* none for Delrin hub

4.0 REFERENCES

Dolan, F., "Space Station Long Term Lubrication Studies Contract, 'Kickoff' Meeting", Presentation Charts, National Aeronautics and Space Administration, MSFC/EH14, August 1985.

"Space Station Long Term Lubrication, Orientation Briefing" Presentation Charts, Battelle Columbus Laboratories and SRS Technologies, August 28, 1985.

"Space Station Reference Configuration Description", JSC-19989.

"Space Station Subsystem White Papers", JSC-20054.

"General Specification Vacuum Stability Requirements of Polymeric Material for Spacecraft Application", SP-R-0022A.

Appendix A

Survey Forms

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

1

Contractor: Sperry
Survey Number: 1
WBS Number: 1116112224131
Survey Date: 6/18/86
Function: SHAFT BEARING DRIVE ASSEMBLY
Description: Shaft Bearing P/N 3HKR102P7

Surface #1		Surface #2	
Contact Surface	440 C	Contact Surface	440 c
Surface Finish	Set by Sperry	Surface Finish	Set by Sperry
Surface Treatment		Surface Treatment	

Lubrication Scheme: Fluid
Lubricant: Micronic 601
SP R 0022A Compatible? ○ Yes ● No
Required Life: 20 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating 11 lb Peak 20 lb Preload 1 lb

Rotational Speed: 0.5 rpm
Oscillation: None
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: None
% Time: 0
Low Temperature: 8 degrees F
High Temperature: 105 degrees F

Environment: Vacuum
Gas:
Liquid:

Operating Conditions: DN value at 8 Rpm-min.

Non-Operating Conditions:

Comment: Single15mm bore ball bearing (catalog number 3HKR102P7 by MPB Corp.). 400 lb max static load capacity. Cage is Conrad machined phenolic.

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

2

Contractor: Rocketdyne

Survey Number: 2

WBS Number: 16.2.2.1

Survey Date: 8/15/86

Function: Solar array deployment.

Description: Bearings in PV array deployment motor

Surface #1	**Surface #2**
Contact Surface: Unspecified	Contact Surface: Unspecified
Surface Finish:	Surface Finish:
Surface Treatment:	Surface Treatment:

Lubrication Scheme: Fluid

Lubricant: Braycote 601

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 1200 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Continuous

% Time: 100

Low Temperature: -112 degrees F

High Temperature: 176 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment: STS Cargo Bay vibration qualification level.

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

3

Contractor: Rocketdyne

Survey Number: 3

WBS Number: 16.2.2.1

Survey Date: 8/15/86

Function: Rotating nut for solar array mast extension

Description: PV array mast canister rotating nut

Surface #1		Surface #2	
Contact Surface	Unspecified	Contact Surface	Unspecified
Surface Finish		Surface Finish	
Surface Treatment		Surface Treatment	

Lubrication Scheme: Dry Film

Lubricant: Everlube 620

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb Peak: 0 lb Preload: 0 lb

Rotational Speed: 2 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Intermittent

% Time: 50

Low Temperature: -112 degrees F

High Temperature: 176 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment: STS Cargo Bay qualification vibration level

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

4

Contractor: Rocketdyne

Survey Number: 4

WBS Number:

Survey Date: 8/13/86

Function: Provide fine pointing actuation of Solar Dynamic Concentrator reflector.

Description: Actuator motor bearings,threads,nuts

Surface #1		Surface #2	
Contact Surface	TBD steel	Contact Surface	TBD steel
Surface Finish	TBD	Surface Finish	TBD
Surface Treatment	TBD	Surface Treatment	TBD

Lubrication Scheme: Fluid

Lubricant: TBD

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 100 lb; Peak 200 lb; Preload 0 lb

Rotational Speed: 60 rpm

Oscillation: Intermittent

Frequency: 2 cycles/sec

Amplitude: 0 inches

Sun Exposure: None

% Time: 0

Low Temperature: -140 degrees F

High Temperature: 140 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions: <.1 Hz continuous oscillation.

Non-Operating Conditions: NSTS Cargo Bat Environments

Comment: for additional information, contact Sundstrans Energy Systems, Rockford, Illinois, 61125. Dual faulure tolerant electromechanical actuator.

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

5

Contractor: Rocketdyne
Survey Number: 5
WBS Number:
Survey Date: 8/13/86
Function: Solar Dynamic Concentrator deployment latch catch mechanism.
Description: Catch Journal

Surface #1		Surface #2	
Contact Surface	TBD	Contact Surface	TBD
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film
Lubricant: TBD
SP R 0022A Compatible? ○ Yes ● No
Required Life: 15 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating: 0 lb
Peak: 0 lb
Preload: 0 lb

Rotational Speed: 0 rpm
Oscillation: Intermittent
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: Intermittent
% Time: 70
Low Temperature: 0 degrees F
High Temperature: 0 degrees F

Environment: Vacuum
Gas:
Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment: Required to function only during deployment or retraction of concentrator. Journal bearing with <0.5 inch radius

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

6

Contractor Rocketdyne
Survey Number 6
WBS Number
Survey Date 8/13/86
Function Fine Pointing for the Solar Dynamic Concentrator
Description Universal Joint Journal Bearings

Surface #1		Surface #2	
Contact Surface	TBD Al	Contact Surface	TBD Al
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme Dry Film
Lubricant Unspecified
SP R 0022A Compatible? ○ Yes ● No
Required Life 15 years

Total Mass Loss 0 %
CVCM 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed 0.16667 rpm
Oscillation TBD
Frequency 0 cycles/sec
Amplitude 0 inches

Sun Exposure Intermittent
% Time 70
Low Temperature -150 degrees F
High Temperature 150 degrees F

Environment Vacuum
Gas
Liquid

Operating Conditions Continuous, low load, low velocity, random motion.

Non-Operating Conditions

Comment Journal bearing radius given as "TBD 2 inches".

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

Contractor: Rocketdyne

Survey Number: 7

WBS Number:

Survey Date: 8/13/86

Function: Concentrator Reflector Deployment

Description: Hinge Needle Bearing

Surface #1		Surface #2	
Contact Surface	TBD	Contact Surface	TBD
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 15 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 100 lb Peak 150 lb Preload 0 lb

Rotational Speed: 0.16667 rpm

Oscillation: None

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Intermittent

% Time: 70

Low Temperature: -150 degrees F

High Temperature: 150 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions: Required to function only during deployment and retraction on-orbit.

Non-Operating Conditions:

Comment: Roller bearing

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

8

Contractor: Rocketdyne
Survey Number: 8
WBS Number:
Survey Date: 8/15/86

Function: Altenator foil journal and thrust bearings for the Closed Brayton Cycle Solar Dynamic Power Generation Power Conversion Unit.

Description: Rotor/Housing Interface

Surface #1		**Surface #2**	
Contact Surface	Rotor Journal	Contact Surface	Foil Leaves
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Fluid
Lubricant: Helium/Xenon (MW=40)
SP R 0022A Compatible? ○ Yes ● No
Required Life: 30 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating 0 lb
Peak 0 lb
Preload 0 lb

Rotational Speed: 32000 rpm
Oscillation: Continuous
Frequency: 1060 cycles/sec
Amplitude: 0 inches

Sun Exposure: None
% Time: 0
Low Temperature: 100 degrees F
High Temperature: 300 degrees F

Environment: Pressurized
Gas: Helium/Xenon (MW=40)
Liquid:

Operating Conditions: Rotor lubricant inventory is approximately 4 lbs of lubricant. Operating load is given as "approximately 100 kW Shaft". Pressure in housing is 20 to 60 psi.

Non-Operating Conditions:

Comment: Journal Bearing with 2.726 inch radius operating at a 760 fps relative velocity.Volatile fluid is contained in welded housing. Extreme operating conditions may include temps -100 deg F to 400 deg F.

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

9

Contractor: Rocketdyne
Survey Number: 9
WBS Number:
Survey Date: 8/15/86

Function: Pump to circulate radiator fluid. The Radiator Coolant Pump Package of the Solar Dynamic Power Generation System has an integrated motor shaft/impeller Centrifugal Pump.

Description: Hydrodynamic Journal Bearings

	Surface #1	Surface #2
Contact Surface	Motor Shaft	Housing Journal
Surface Finish	Unspecified	Unspecified
Surface Treatment	Unspecified	Unspecified

Lubrication Scheme: Fluid
Lubricant: FC75 Immersion
SP R 0022A Compatible? ○ Yes ● No
Required Life: 20 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating 0 lb
Peak 0 lb
Preload 0 lb

Rotational Speed: 0 rpm
Oscillation: Continuous
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: None
% Time: 0
Low Temperature: 0 degrees F
High Temperature: 100 degrees F

Environment: Pressurized
Gas:
Liquid: FC75 Immersion

Operating Conditions: High temperature of 200 deg F in extreme operating conditions. Operating load gien as "2 lb/sec 60 psid".

Non-Operating Conditions: Low temperature extreme of -100 deg F in non-operating mode.

Comment: Hundreds of pounds of volatile coolant/lubricant contained in sealed coolant loop at 10-20 psi. A Moog pump qualified for Peacekeeper program under consideration

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

10

Contractor Rocketdyne

Survey Number 10

WBS Number

Survey Date 8/4/86

Function To position the Propulsion System thruster assembly solenoid valve when solenoid is not engaged.

Description Ends of spring at shaft and spring stop

Surface #1		Surface #2	
Contact Surface	Unspecified	Contact Surface	Unspecified
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme Unspecifie

Lubricant Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life 0 years

Total Mass Loss 0 %

CVCM 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed 0 rpm

Oscillation Unspecified

Frequency 0 cycles/sec

Amplitude 0 inches

Sun Exposure Unspecified

% Time 0

Low Temperature 0 degrees F

High Temperature 0 degrees F

Environment Unspecified

Gas

Liquid

Operating Conditions

Non-Operating Conditions

Comment

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

11

Contractor: Rocketdyne

Survey Number: 11

WBS Number:

Survey Date: 8/5/86

Function: Fluid connector for Propuslion System thruster assembly.

Description: Screw threads on propellant feed lines

	Surface #1		Surface #2
Contact Surface	Male connector	Contact Surface	Female connector
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 0 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

Contractor: Rocketdyne

Survey Number: 12

WBS Number:

Survey Date: 8/5/86

Function: Affect motion of the valve shaft on the Propulsion System thruster assembly solenoid valve.

Description: Electromagnetic Plates

	Surface #1		**Surface #2**
Contact Surface	Fixed Plate	Contact Surface	Moving Plate
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 0 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 0 lb   Peak 0 lb   Preload 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

13

Contractor: Rocketdyne

Survey Number: 13

WBS Number:

Survey Date: 8/5/86

Function: Permit or restrict fluid flow in the solenoid valve head of the Propulsion System thruster assembly.

Description: Valve Seats/Stems

	Surface #1		Surface #2
Contact Surface	Valve Seat	Contact Surface	Valve Stem
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 0 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

14

Contractor: Rocketdyne

Survey Number: 14

WBS Number:

Survey Date: 8/5/86

Function: Guide motion of valve stem in solenoid valve of the Propulsion System thruster assembly.

Description: Valve Shaft Guides

Surface #1		Surface #2	
Contact Surface	Valve Stem	Contact Surface	Valve Shaft Guides
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 0 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

Contractor: Rocketdyne
Survey Number: 15
WBS Number:
Survey Date: 00/00/00

Function: To form a connection between tubing and the dummy spark igniter in the Propulsion SYstem thruster assembly.

Description: Dummy spark igniter/tubing connection

	Surface #1		Surface #2
Contact Surface	Tygon tubing	Contact Surface	Dummy Spark Igniter
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie
Lubricant: Unspecified
SP R 0022A Compatible? ○ Yes ● No
Required Life: 0 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed: 0 rpm
Oscillation: Unspecified
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: Unspecified
% Time: 0
Low Temperature: 0 degrees F
High Temperature: 0 degrees F

Environment: Unspecified
Gas:
Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

16

Contractor: Rocketdyne

Survey Number: 16

WBS Number:

Survey Date: 8/5/86

Function: hardare attachment device. Hex head bolt asembly in the valve bracket assembly of the Propulsion SYstem thruster assembly.

Description: Screw threads/bolt

	Surface #1	Surface #2
Contact Surface	Screw threads	Hex head bolt
Surface Finish		Unspecified
Surface Treatment		Unspecified

Lubrication Scheme: Fluid

Lubricant: MoS2

SP R 0022A Compatible? ○ Yes ● No

Required Life: 0 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb Peak: 0 lb Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

17

Contractor: Rocketdyne
Survey Number: 17
WBS Number:
Survey Date: 8/4/86

Function: hardware attachment device. screw/bolt assembly in the Propuslion System thruster assembly power head.

Description:

Surface #1		Surface #2	
Contact Surface	Screw threads	Contact Surface	Screw Cap Socket
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Fluid
Lubricant: MoS2
SP R 0022A Compatible? ○ Yes ● No
Required Life: 0 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating: 0 lb
Peak: 0 lb
Preload: 0 lb

Rotational Speed: 0 rpm
Oscillation: Unspecified
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: Unspecified
% Time: 0
Low Temperature: 0 degrees F
High Temperature: 0 degrees F

Environment: Unspecified
Gas:
Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment: Socket torqued to 22 (+/- 1) inch-lbs.

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

18

Contractor Rocketdyne

Survey Number 18

WBS Number

Survey Date 8/6/86

Function Swageloack to a union (CRES) in propellant fluid line connectors of the Propulsion System thruster assembly.

Description contact surfaces and screw threads

	Surface #1		Surface #2
Contact Surface	Screw threads	Contact Surface	Unspecified
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme Unspecifie

Lubricant Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life 0 years

Total Mass Loss 0 %

CVCM 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed 0 rpm

Oscillation Unspecified

Frequency 0 cycles/sec

Amplitude 0 inches

Sun Exposure Unspecified

% Time 0

Low Temperature 0 degrees F

High Temperature 0 degrees F

Environment Unspecified

Gas

Liquid

Operating Conditions

Non-Operating Conditions

Comment

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

19

Contractor: Rocketdyne

Survey Number: 19

WBS Number:

Survey Date: 8/5/86

Function: To seal the fuel line connection between the fuel solenoid valve and the valve assembly bracket in the Propulsion System thruster assembly.

Description: V Seal

	Surface #1		Surface #2
Contact Surface	V-Seal-Inco 718	Contact Surface	Valve Assy Bracket
Surface Finish	Teflon Coating	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film

Lubricant: Teflon

SP R 0022A Compatible? ○ Yes ● No

Required Life: 0 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb Peak: 0 lb Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

20

Contractor: Rocketdyne

Survey Number: 20

WBS Number:

Survey Date: 8/5/86

Function: Seal the connection between the Propulsion system thruster assembly power head and combustion chamber.

Description: V Seal

Surface #1		Surface #2	
Contact Surface	V-Seal-Inco 718	Contact Surface	Power Head
Surface Finish	Modified Gold Plated	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 0 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

21

Contractor: Rocketdyne

Survey Number: 21

WBS Number:

Survey Date: 8/5/86

Function: Seal the threaded connection between the Dummy Spark Igniter and the Power Head in the Propulsion System thruster assembly.

Description: K Seal

Surface #1		Surface #2	
Contact Surface	K Seal	Contact Surface	Power Head
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 0 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions: Lubricant is under pressure at the contact surface and in vacuum at the outer edge of the contact surface.

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

22

Contractor: Rocketdyne
Survey Number: 22
WBS Number:
Survey Date: 8/4/86

Function: "O" ring seal for the threaded connector on the Dummy Spark Igniter of the Propulsion System thruster assembly.

Description: Two flat ring seals

	Surface #1	Surface #2
Contact Surface	Unspecified	Unspecified
Surface Finish	Unspecified	Unspecified
Surface Treatment	Unspecified	Unspecified

Lubrication Scheme: Unspecifie
Lubricant: Unspecified
SP R 0022A Compatible? ○ Yes ● No
Required Life: 0 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating: 0 lb
Peak: 0 lb
Preload: 0 lb

Rotational Speed: 0 rpm
Oscillation: Unspecified
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: Unspecified
% Time: 0
Low Temperature: 0 degrees F
High Temperature: 0 degrees F

Environment: Unspecified
Gas:
Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

23

Contractor: Moog

Survey Number: 23

WBS Number:

Survey Date: 8/6/86

Function: Valve guides for the Oxygen Solenoid Valve of Propulsion system

Description: Poppet/Plunger Teflon Guides

Surface #1		Surface #2	
Contact Surface	Poppet	Contact Surface	Plunger
Surface Finish	Teflon Coating	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film

Lubricant: Teflon

SP R 0022A Compatible? ○ Yes ● No

Required Life: 0 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

24

Contractor: Moog

Survey Number: 24

WBS Number:

Survey Date: 8/6/86

Function: Position the Oxygen Solenoid Valve of the ARPCS control system in the Space Station Propulsion System when the solenoid is not engaged.

Description: Low stress helical spring

	Surface #1		Surface #2
Contact Surface	Helical Spring	Contact Surface	Valve Seat
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 0 lb

Peak 0 lb

Preload 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: None

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

25

Contractor Moog

Survey Number 25

WBS Number

Survey Date 8/6/86

Function: Valve seat for the Oxygen Solenoid Valve of the ARPCS control system in the Space Station Propulsion system.

Description: Valve head / seat contact

Surface #1		Surface #2	
Contact Surface	Valve seat	Contact Surface	Valve Head
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme Dry Film

Lubricant Polyimide (Vespel)

SP R 0022A Compatible? ○ Yes ● No

Required Life 10 years

Total Mass Loss 0 %

CVCM 0 %

Loads: Operating 0 lb

Peak 0 lb

Preload 0 lb

Rotational Speed 0 rpm

Oscillation Unspecified

Frequency 0 cycles/sec

Amplitude 0 inches

Sun Exposure None

% Time 0

Low Temperature 0 degrees F

High Temperature 0 degrees F

Environment Unspecified

Gas

Liquid

Operating Conditions

Non-Operating Conditions

Comment

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

26

Contractor: Moog
Survey Number: 26
WBS Number:
Survey Date: 8/18/86

Function: Seal Oxygen Solenoid Valve Components in the ARPCS control system of the Space Station Propulsion system.

Description: Seven O-rings

	Surface #1		Surface #2
Contact Surface	O Ring	Contact Surface	Various
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie
Lubricant: Unspecified
SP R 0022A Compatible? ○ Yes ● No
Required Life: 10 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating 0 lb
Peak 0 lb
Preload 0 lb

Rotational Speed: 0 rpm
Oscillation: Unspecified
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: None
% Time: 0
Low Temperature: 0 degrees F
High Temperature: 0 degrees F

Environment: Pressurized
Gas: Oxygen
Liquid: LOX

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

27

Contractor: Moog

Survey Number: 27

WBS Number:

Survey Date: 8/19/86

Function: Connector in the Oxygen Solenoid Valve of the Space Station Propoulsion System

Description: Screw Threads

	Surface #1	Surface #2
Contact Surface	Screw threads	Thread Grooves
Surface Finish	Unspecified	Unspecified
Surface Treatment	Unspecified	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb Peak: 0 lb Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

28

Contractor: Moog

Survey Number: 28

WBS Number:

Survey Date: 8/15/86

Function: O-Ring seal between latching mechanism casing and plunger mechanism of the Oxygen and Nitrogen Latching Valve in th ARPCS Control System of the Space Station Propulsion System

Description: O- ring seal

	Surface #1		Surface #2
Contact Surface	Casing mechanism	Contact Surface	plunger mechanism
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: None

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Pressurized

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

29

Contractor: Moog

Survey Number: 29

WBS Number:

Survey Date: 8/15/86

Function: Assembly and Adjustment threaded connectors in the Oxygen and Nitrogen Latching Valve of the ARPCS Control System in the Space Station Propulsion System

Description: Scre Threads

Surface #1		Surface #2	
Contact Surface	Screw Threads	Contact Surface	Thread Grooves
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

30

Contractor: Moog

Survey Number: 30

WBS Number:

Survey Date: 8/15/86

Function: Filter Seal in the Oxygen and Nitrogen Latching Valve in the ARPCS Control System of the Space Station Propulsion SYstem

Description: Surface contact

	Surface #1		Surface #2
Contact Surface	filter seal	Contact Surface	filter seat
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: None

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Pressurized

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

31

Contractor Moog

Survey Number 31

WBS Number

Survey Date 8/13/86

Function O Ring between end cap mechnism and Valve Adjustment mechanism in the Oxygen and Nitrogen Latching Valve of the ARPCS Conttrol System in the Space Station Propulsion system

Description O-Ring

Surface #1		Surface #2	
Contact Surface	O-Ring	Contact Surface	End cap/Valve adjust
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme Unspecifie

Lubricant Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life 10 years

Total Mass Loss 0 %

CVCM 0 %

Loads: Operating 0 lb

Peak 0 lb

Preload 0 lb

Rotational Speed 0 rpm

Oscillation Unspecified

Frequency 0 cycles/sec

Amplitude 0 inches

Sun Exposure None

% Time 0

Low Temperature 0 degrees F

High Temperature 0 degrees F

Environment Pressurized

Gas

Liquid

Operating Conditions

Non-Operating Conditions

Comment

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

32

Contractor: Moog
Survey Number: 32
WBS Number:
Survey Date: 8/12/86

Function: Seal the Oxygen & Nitrogen Latching Valve casing from the electric drive motor in the ARPCS COntro System of the Space Station Propulsion System

Description: Bellevile Spring Seal

Surface #1		Surface #2	
Contact Surface	Bville Spring Inner	Contact Surface	Bville Spring Outer
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie
Lubricant: Unspecified
SP R 0022A Compatible? ○ Yes ● No
Required Life: 0 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating: 0 lb
Peak: 0 lb
Preload: 0 lb

Rotational Speed: 0 rpm
Oscillation: Unspecified
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: Unspecified
% Time: 0
Low Temperature: 0 degrees F
High Temperature: 0 degrees F

Environment: Unspecified
Gas:
Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

33

Contractor: Moog

Survey Number: 33

WBS Number:

Survey Date: 00/00/00

Function: O Ring to seal the Relief Valve to the motor case in the ARPCS Control System Oxygen and Niotrogen Latching Valve of Space Station Propulsion System

Description: O-RIng

	Surface #1	Surface #2
Contact Surface	O-RIng	Relief Valve
Surface Finish	Unspecified	Unspecified
Surface Treatment	Unspecified	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: None

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Pressurized

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

34

Contractor: Moog

Survey Number: 34

WBS Number:

Survey Date: 8/12/86

Function: Electric Drive motor actuator for the Oxygen and Nitrogen Latching Valve in the Space Staion Propulsion System ARPCS Control System

Description: Bearings/Planetary Gears

	Surface #1		Surface #2
Contact Surface	Unspecified	Contact Surface	Unspecified
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

35

Contractor Lockheed

Survey Number 35

WBS Number

Survey Date 3/1/86

Function: Wire Wrap transfers power and data across Beta Joint

Description: Relative Motion & Contact w/ Structure

	Surface #1		Surface #2
Contact Surface	Wire Wrap	Contact Surface	Axle Housing
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme None Plann

Lubricant

SP R 0022A Compatible? ○ Yes ● No

Required Life 10 years

Total Mass Loss 0 %

CVCM 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed 0.00000405 rpm

Oscillation Continuous

Frequency 0 cycles/sec

Amplitude 0 inches

Sun Exposure Intermittent

% Time 64

Low Temperature 0 degrees F

High Temperature 0 degrees F

Environment Vacuum

Gas

Liquid

Operating Conditions

Non-Operating Conditions

Comment

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

36

Contractor: Lockheed

Survey Number: 36

WBS Number:

Survey Date: 3/1/86

Function: Beta Joint Control Motor and Gearbox

Description: Bearings / Gears

Surface #1

Contact Surface: Unspecified

Surface Finish: Unspecified

Surface Treatment: Unspecified

Surface #2

Contact Surface: Unspecified

Surface Finish: Unspecified

Surface Treatment: Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 0 lb

Peak 0 lb

Preload 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: None

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

37

Contractor: Lockheed

Survey Number: 37

WBS Number:

Survey Date: 3/1/86

Function: Main Bearings in the housing of the Beta Joint of the Electrical Power System

Description: Main Bearings

	Surface #1		Surface #2
Contact Surface	Inner Race	Contact Surface	Outer Race
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Intermittent

% Time: 64

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

38

Contractor: Lockheed

Survey Number: 38

WBS Number:

Survey Date: 3/1/86

Function: Bearings in pump of water supply assembly of water electrolysis system

Description: Bearings

Surface #1

Contact Surface:

Surface Finish: Unspecified

Surface Treatment: Unspecified

Surface #2

Contact Surface:

Surface Finish: Unspecified

Surface Treatment: Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

Contractor: Lockheed

Survey Number: 39

WBS Number:

Survey Date: 3/1/86

Function: Cable fair lead pulleys in blanket tensioning and guidewire system of solar array of electrical power

Description: Cable fair lead pulleys

	Surface #1		Surface #2
Contact Surface	pin/al	Contact Surface	bushing/al
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film

Lubricant: Everlube 620

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation:

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Intermittent

% Time: 64

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

40

Contractor: Lockheed

Survey Number: 40

WBS Number:

Survey Date: 3/1/86

Function: Drive motors in fine pointing mechanism of solar dynamic system of electrical power system

Description: Drive motors

	Surface #1		Surface #2
Contact Surface		Contact Surface	
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Working Fluid

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb   Peak: 0 lb   Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation:

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

41

Contractor: Lockheed

Survey Number: 41

WBS Number:

Survey Date: 3/1/86

Function: Gearbox of fine pointing mechanism in solar dynamic system in electrical power system

Description: Gearbox

Surface #1		Surface #2	
Contact Surface		Contact Surface	
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Working Fluid

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 0 lb   Peak 0 lb   Preload 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

42

Contractor: Lockheed

Survey Number: 42

WBS Number:

Survey Date: 3/1/86

Function: Ballscrew in fine pointing mechanism of solar dynamic system of electrical power system

Description: Ballscrew

Surface #1	**Surface #2**
Contact Surface:	Contact Surface:
Surface Finish: Unspecified	Surface Finish: Unspecified
Surface Treatment: Unspecified	Surface Treatment: Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Working Fluid

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed: 0 rpm

Oscillation:

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

43

Contractor: Lockheed

Survey Number: 43

WBS Number:

Survey Date: 3/1/86

Function: Actuator-to-concentrator I/F of fine pointing mechanism of solar dynamic system of electrical power system

Description: Actuator-to-concentrator I/F

Surface #1		Surface #2	
Contact Surface		Contact Surface	
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Working fluid

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb Peak: 0 lb Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

44

Contractor: Lockheed

Survey Number: 44

WBS Number:

Survey Date: 3/1/86

Function: Gas or foil bearings in heat engine of solar dynamic system of electrical power system

Description: Gas or foil bearings

Surface #1		Surface #2	
Contact Surface		Contact Surface	
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Working fluid

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

45

Contractor: Lockheed

Survey Number: 45

WBS Number: 1.1.4.3.16.16.1.2.2

Survey Date: 3/1/86

Function: Mast base spider bushing in mast canister of solar array of electrical power

Description: Mast base spider bushing

	Surface #1		Surface #2
Contact Surface	spider bushing/Al.	Contact Surface	spider/Al.
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film

Lubricant: Everlube 620

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Intermittent

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Intermittent

% Time: 63

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:
Radiation type: NASA TM-86460
Normal operating environment 160 °F

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

Contractor: Lockheed
Survey Number: 46
WBS Number: 1.1.4.3.16.16.1.2.3
Survey Date: 3/1/86
Function: Longer on end fitting in mast canister of solar array of electrical power
Description: Fitting to spider Al. to Al.

	Surface #1		Surface #2
Contact Surface	On end fitting/Al.	Contact Surface	Pin to spider/Al.
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film
Lubricant: Everlube 620
SP R 0022A Compatible? ○ Yes ● No
Required Life: 10 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating: 0 lb
Peak: 0 lb
Preload: 0 lb

Rotational Speed: 0 rpm
Oscillation: Intermittent
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: Intermittent
% Time: 63
Low Temperature: 0 degrees F
High Temperature: 0 degrees F

Environment: Vacuum
Gas:
Liquid:

Operating Conditions:
Radiation type: NASA TM-86460
Normal operating Environment: 160°F

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

47

Contractor: Lockheed
Survey Number: 47

WBS Number: 1.1.4.3.16.16.1.2.4
Survey Date: 3/1/86

Function: Mast element/deployer interface in mast canister of solar array of electrical power

Description: Mast element to deployer interface

	Surface #1		Surface #2
Contact Surface	mast ele. roller/Al.	Contact Surface	Deployer nut thread
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film
Lubricant: Everlube 620

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating: 0 lb
Peak: 0 lb
Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Intermittent
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: Intermittent
% Time: 63

Low Temperature: 0 degrees F
High Temperature: 0 degrees F

Environment: Vacuum
Gas:
Liquid:

Operating Conditions:
Radiation Type: NASA TM-86460
Normal Operating Environment: 160°F

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

Contractor: Lockheed
Survey Number: 48
WBS Number: 1.1.4.3.16.16.1.2.1
Survey Date: 3/1/86
Function: Deployer nutring ballbearings in mast canister of solar array of electrical power
Description: Deployer nutring ballbearings

Surface #1		**Surface #2**	
Contact Surface	nutring bearings/SS	Contact Surface	Nutring bearings/SS
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film
Lubricant: Everlube 620
SP R 0022A Compatible? ○ Yes ● No
Required Life: 10 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed: 0 rpm
Oscillation: Intermittent
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: Intermittent
% Time: 63
Low Temperature: 0 degrees F
High Temperature: 0 degrees F

Environment: Vacuum
Gas:
Liquid:

Operating Conditions: Radiation Type: NASA TM-86460
Normal Operating Environment: 160°F

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

Contractor Lockheed

Survey Number 49

WBS Number 1.1.4.3.16.16.1.1.1

Survey Date 3/1/86

Function Batten corner fitting in mast of solar array of electrical power

Description Batten corner fitting

Surface #1		Surface #2	
Contact Surface	fitting roller/Al.	Contact Surface	fitting cup/Al.
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme Dry Film

Lubricant Everlube 620

SP R 0022A Compatible? ○ Yes ● No

Required Life 10 years

Total Mass Loss 0 %

CVCM 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed 0 rpm

Oscillation Intermittent

Frequency 0 cycles/sec

Amplitude 0 inches

Sun Exposure Intermittent

% Time 63

Low Temperature 0 degrees F

High Temperature 0 degrees F

Environment Vacuum

Gas

Liquid

Operating Conditions
Radistion Type: NASA TM-86460
Normal Operating Environment: 160°F

Non-Operating Conditions

Comment

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

50

Contractor Lockheed

Survey Number 50

WBS Number

Survey Date 3/1/86

Function: Bearing in pump of pressure control assembly of water electrolysis system

Description: Bearings

Surface #1		Surface #2	
Contact Surface		Contact Surface	
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme Unspecifie

Lubricant Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life 10 years

Total Mass Loss 0 %

CVCM 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed 0 rpm

Oscillation Unspecified

Frequency 0 cycles/sec Amplitude 0 inches

Sun Exposure Unspecified

% Time 0

Low Temperature 0 degrees F

High Temperature 0 degrees F

Environment Unspecified

Gas

Liquid

Operating Conditions: Operating Load: 300 psi, 180°F, Intermittent as req'd

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

51

Contractor Lockheed

Survey Number 51

WBS Number

Survey Date 3/1/86

Function Motor pinion gear in cover blanket preload system of solar array of electrical power

Description Moter pinion gear

Surface #1		Surface #2	
Contact Surface	Worn gear/Al.	Contact Surface	Latch member/SS
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme Dry Film

Lubricant Everlube 620

SP R 0022A Compatible? ○ Yes ● No

Required Life 10 years

Total Mass Loss 0 %

CVCM 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed 0 rpm

Oscillation Unspecified

Frequency 0 cycles/sec

Amplitude 0 inches

Sun Exposure Intermittent

% Time 64

Low Temperature 0 degrees F

High Temperature 0 degrees F

Environment Vacuum

Gas

Liquid

Operating Conditions

Non-Operating Conditions

Comment

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

52

Contractor: Lockheed

Survey Number: 52

WBS Number:

Survey Date: 3/1/86

Function: Motor ballbearings in ocver blanket preload system of solar array of electrical power

Description: Motor ballbearings

Surface #1		Surface #2	
Contact Surface	Bearings/SS	Contact Surface	Race/SS
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Fluid *

Lubricant: Braycote 601

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Intermittent

% Time: 64

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment: * Grease

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

53

Contractor: Lockheed
Survey Number: 53
WBS Number:
Survey Date: 3/1/86
Function: Latch system in cover blanket preload system of solar array of electrical power
Description: Latch system

Surface #1		Surface #2	
Contact Surface	pins in latch/Al.	Contact Surface	Bushing in latch/Al.
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film
Lubricant: Everlube 620
SP R 0022A Compatible? ○ Yes ● No
Required Life: 10 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed: 0 rpm
Oscillation: Unspecified
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: Intermittent
% Time: 64
Low Temperature: 0 degrees F
High Temperature: 0 degrees F

Environment: Vacuum
Gas:
Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

54

Contractor: Lockheed

Survey Number: 54

WBS Number:

Survey Date: 3/1/86

Function: Negator spirngs to rage reel in blanket tensioning and guide wire system in solar array in electrical power

Description: Negator springs to rage reel

Surface #1

Contact Surface: hub/Al or Delrin

Surface Finish: Unspecified

Surface Treatment: Unspecified

Surface #2

Contact Surface: Axle/Al.

Surface Finish: Unspecified

Surface Treatment: Unspecified

Lubrication Scheme: Dry Film

Lubricant: Everlube 620 *

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Intermittent

% Time: 64

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment: * None for Delrin Hub

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

55

Contractor: Lockheed

Survey Number: 55

WBS Number:

Survey Date: 3/1/86

Function: Limit switches in array motors of solar array of electrical power

Description: Limit switches

Surface #1		Surface #2	
Contact Surface	Pins/SS	Contact Surface	Brackets/SS
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film

Lubricant: Everlube 620

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Intermittent

% Time: 64

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

56

Contractor Lockheed

Survey Number 56

WBS Number

Survey Date 3/1/86

Function Interface/Mast canister to beta drive in mast canister of solar array of electical power

Description Interface/Mast canister to beta drive

Surface #1		Surface #2	
Contact Surface	Mast canister/SS&Al.	Contact Surface	Beta drive/Al
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme Dry Film

Lubricant Everlube 620

SP R 0022A Compatible? ○ Yes ● No

Required Life 10 years

Total Mass Loss 0 %

CVCM 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed 0 rpm

Oscillation Unspecified

Frequency 0 cycles/sec

Amplitude 0 inches

Sun Exposure Intermittent

% Time 64

Low Temperature 0 degrees F

High Temperature 0 degrees F

Environment Vacuum

Gas

Liquid

Operating Conditions

Non-Operating Conditions

Comment

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

57

Contractor: Lockheed

Survey Number: 57

WBS Number:

Survey Date: 3/1/86

Function: Rotor ballbearings in mast motor drive assembly of solar array of electrical power

Description: Rotor ball bearings

Surface #1

Contact Surface: Bearings/SS

Surface Finish: Unspecified

Surface Treatment: Unspecified

Surface #2

Contact Surface: Race/SS

Surface Finish: Unspecified

Surface Treatment: Unspecified

Lubrication Scheme: Fluid *

Lubricant: Braycote 601

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb Peak: 0 lb Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Intermittent

% Time: 64

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment: * Grease

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

58

Contractor: Lockheed

Survey Number: 58

WBS Number:

Survey Date: 3/1/86

Function: Clutch or solenoid in locking mechanism of beta joint of electrical/mechansims

Description: clutch or solenoid

Surface #1		Surface #2	
Contact Surface	clutchpin	Contact Surface	sleeve
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

59

Contractor: Lockheed
Survey Number: 59
WBS Number:
Survey Date: 3/1/86

Function: Pin puller piston or solenoid pistion in launch support and release for box ends of solar array of electrical power

Description: Pin puller pistion or solenoid pistion

	Surface #1		Surface #2
Contact Surface	Piston/Al	Contact Surface	Sleeve/Al.
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film
Lubricant: Everlube 620
SP R 0022A Compatible? ○ Yes ● No
Required Life: 10 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating: 0 lb
Peak: 0 lb
Preload: 0 lb

Rotational Speed: 0 rpm
Oscillation: Unspecified
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: Intermittent
% Time: 64
Low Temperature: 0 degrees F
High Temperature: 0 degrees F

Environment: Vacuum
Gas:
Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

60

Contractor: Lockheed

Survey Number: 60

WBS Number:

Survey Date: 3/1/86

Function: Bearings in centrifugal pump of H2 pump/separator of fluid control system

Description: Bearings

Surface #1

Contact Surface:

Surface Finish: Unspecified

Surface Treatment: Unspecified

Surface #2

Contact Surface:

Surface Finish: Unspecified

Surface Treatment: Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment: Operating Load: 60 psi, 140°F, Continuous

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

61

Contractor: Lockheed

Survey Number: 61

WBS Number:

Survey Date: 3/1/86

Function: Bearings in pump of coolant pump of fluid control system

Description: Bearings

Surface #1		Surface #2	
Contact Surface		Contact Surface	
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb Peak: 0 lb Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions: Operating Load: 60 psi, 180°F, continuous

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

62

Contractor: Lockheed

Survey Number: 62

WBS Number:

Survey Date: 3/1/86

Function: Deployer guide in mast canister of solar array of electrical power

Description: Deployer guide

Surface #1		Surface #2	
Contact Surface	Fixed dep. gu./delri	Contact Surface	Mast ele. roller/al.
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Unspecifie

Lubricant: None

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Intermittent

% Time: 64

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

63

Contractor: Lockheed

Survey Number: 63

WBS Number:

Survey Date: 3/1/86

Function: Bearings in pump of coolant control assembly of water electrolysis system

Description: Bearings

Surface #1

Contact Surface:

Surface Finish: Unspecified

Surface Treatment: Unspecified

Surface #2

Contact Surface:

Surface Finish: Unspecified

Surface Treatment: Unspecified

Lubrication Scheme: Unspecifie

Lubricant: Unspecified

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb Peak: 0 lb Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Unspecified

% Time: 0

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Unspecified

Gas:

Liquid:

Operating Conditions: Operating Load: 300 psi, 180°F, continuous

Non-Operating Conditions:

Comment: Pumps water or fluorinert through electrolyzer

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

64

Contractor: Lockheed
Survey Number: 64
WBS Number:
Survey Date: 3/1/86

Function: Interface/containment box to mast in containment box of solar array of electrical power

Description: Interface/containment box to mast

Surface #1		Surface #2	
Contact Surface	Contain box/SS & Al.	Contact Surface	Mast/Al.
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film
Lubricant: Everlube 620
SP R 0022A Compatible? ○ Yes ● No
Required Life: 10 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed: 0 rpm
Oscillation: Unspecified
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: Intermittent
% Time: 64
Low Temperature: 0 degrees F
High Temperature: 0 degrees F

Environment: Vacuum
Gas:
Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

65

Contractor: Lockheed

Survey Number: 65

WBS Number:

Survey Date: 3/1/86

Function: Motor drive pinion gear in array containment box positioning system of solar array of electrical power

Description: Motor drive plinion gear

	Surface #1		Surface #2
Contact Surface	*	Contact Surface	Actuator/SS
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film

Lubricant: Everlube 620

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating 0 lb

Peak 0 lb

Preload 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Intermittent

% Time: 64

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment: * Motor drive pinion or worm gear/Al.

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

66

Contractor: Lockheed

Survey Number: 66

WBS Number:

Survey Date: 3/1/86

Function: Positioner system in array containment box positioning system of solar array of electrical power

Description: Poistioner system

Surface #1

Contact Surface: pins in pos. sys./Al

Surface Finish: Unspecified

Surface Treatment: Unspecified

Surface #2

Contact Surface: Bushing in p.s./Al

Surface Finish: Unspecified

Surface Treatment: Unspecified

Lubrication Scheme: Dry Film

Lubricant: Everlube 620

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Intermittent

% Time: 64

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

67

Contractor Lockheed

Survey Number 67

WBS Number

Survey Date 3/1/86

Function Motor ball bearings in array containment box positioning system of solar array of electrical power

Description Motor ball bearings

Surface #1

Contact Surface Bearings/SS

Surface Finish Unspecified

Surface Treatment Unspecified

Surface #2

Contact Surface Race/SS

Surface Finish Unspecified

Surface Treatment Unspecified

Lubrication Scheme Fluid *

Lubricant Braycote 601

SP R 0022A Compatible? ○ Yes ● No

Required Life 10 years

Total Mass Loss 0 %

CVCM 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed 0 rpm

Oscillation Unspecified

Frequency 0 cycles/sec

Amplitude 0 inches

Sun Exposure Intermittent

% Time 64

Low Temperature 0 degrees F

High Temperature 0 degrees F

Environment Vacuum

Gas

Liquid

Operating Conditions

Non-Operating Conditions

Comment * Grease

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

68

Contractor: Lockheed
Survey Number: 68
WBS Number:
Survey Date: 3/1/86

Function: Latch and release mechanism in array containment box positioning system of solar array of electrical power

Description: Latch and release mechanism

Surface #1		Surface #2	
Contact Surface	Latch/Al	Contact Surface	Release/Al
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film
Lubricant: Everlube 620
SP R 0022A Compatible? ○ Yes ● No
Required Life: 10 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating: 0 lb
Peak: 0 lb
Preload: 0 lb

Rotational Speed: 0 rpm
Oscillation: Unspecified
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: Intermittent
% Time: 64
Low Temperature: 0 degrees F
High Temperature: 0 degrees F

Environment: Vacuum
Gas:
Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment: Mechanism holds box position

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

69

Contractor: Lockheed

Survey Number: 69

WBS Number:

Survey Date: 3/1/86

Function: Box-to-mast hinges system in array containment box postioning system of solar array of electrical power

Description: Box-to-mast hinges system

Surface #1	**Surface #2**
Contact Surface: Pin/Al. *	Contact Surface: Bushings/Al. *
Surface Finish: Unspecified	Surface Finish: Unspecified
Surface Treatment: Unspecified	Surface Treatment: Unspecified

Lubrication Scheme: Dry Film

Lubricant: Everlube 620

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb

Peak: 0 lb

Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Intermittent

% Time: 64

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment: * in box-to-mast hinges system

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

70

Contractor: Lockheed

Survey Number: 70

WBS Number:

Survey Date: 3/1/86

Function: Pinion gear in mast canister of solar array of electrical power

Description: Pinion gear

Surface #1		**Surface #2**	
Contact Surface	*	Contact Surface	* *
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film

Lubricant: Everlube 620

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb Peak: 0 lb Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Intermittent

% Time: 64

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:
* Deployer nut ring gear Al.
** Drive assembly pinion gear/SS

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

71

Contractor: Lockheed
Survey Number: 71
WBS Number:
Survey Date: 3/1/86

Function: Pinion gear in mast canister of solar array of electrical power

Description: Pinion gear

Surface #1		Surface #2	
Contact Surface	*	Contact Surface	* *
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film
Lubricant: Everlube 620
SP R 0022A Compatible? ○ Yes ● No
Required Life: 10 years

Total Mass Loss: 0 %
CVCM: 0 %

Loads: Operating 0 lb Peak 0 lb Preload 0 lb

Rotational Speed: 0 rpm
Oscillation: Unspecified
Frequency: 0 cycles/sec
Amplitude: 0 inches

Sun Exposure: Intermittent
% Time: 64
Low Temperature: 0 degrees F
High Temperature: 0 degrees F

Environment: Vacuum
Gas:
Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment:
* Deployer nut ring gear/AL
** Drive assembly pinion gear/SS

SPACE STATION LONG TERM LUBRICATION STUDY
SURVEY FORM

72

Contractor: Lockheed

Survey Number: 72

WBS Number:

Survey Date: 3/1/86

Function: Cables to rage reel in blanket tensioning and guideline wire system of solar array of electrical power

Description: Cables to rage reel

	Surface #1		Surface #2
Contact Surface	Hub/Al or Delrin	Contact Surface	Axle/AL
Surface Finish	Unspecified	Surface Finish	Unspecified
Surface Treatment	Unspecified	Surface Treatment	Unspecified

Lubrication Scheme: Dry Film

Lubricant: Everlube 620 *

SP R 0022A Compatible? ○ Yes ● No

Required Life: 10 years

Total Mass Loss: 0 %

CVCM: 0 %

Loads: Operating: 0 lb Peak: 0 lb Preload: 0 lb

Rotational Speed: 0 rpm

Oscillation: Unspecified

Frequency: 0 cycles/sec

Amplitude: 0 inches

Sun Exposure: Intermittent

% Time: 64

Low Temperature: 0 degrees F

High Temperature: 0 degrees F

Environment: Vacuum

Gas:

Liquid:

Operating Conditions:

Non-Operating Conditions:

Comment: * none for Delrin hub