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PRELIMINARY ANALYSIS OF AN INTEGRATED LOGISTICS SYSTEM FOR OSSA PAYLOADS

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Volume IV

Supportability Analysis of The 1.8m Centrifuge

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1.0 INTRODUCTION

1.1 PURPOSE

This document addresses supportability issues for the 1.8 M centrifuge in the Life Science Research Facility. The analysis focuses on reliability and maintainability and the potential impact on supportability and affordability.

1.2 SCOPE

This analysis was performed in support of the Office of Space Science and Applications (OSSA) effort to incorporate integrated logistics support in all facets of their various payload programs. This analysis outlines standard logistics engineering methodologies that will be applied to all OSSA payload programs. These methodologies are applied to the 1.8 M centrifuge. Additionally, the importance of specified operational requirements are highlighted. They are the basis for establishing system design requirements.

The centrifuge is only one of several major pieces of equipment intended to form the nucleus of the specimen holding and management facility. Specimen habitats must fit all elements: Habitat Holding Unit; 1.8 and 3.75 M Centrifuges; Multipurpose Work Bench; Equipment Cleaner; possibly others. Significant supportability issues will arise in areas of reliability, maintainability and commonality which, if resolved, could affect significant operational and logistics savings. The current Supportability Analysis approach should be applied to the entire specimen holding and management facility.

1.8 M Centrifuge designs now exist only at the level of conceptual design, but specific logistics concerns, which must be addressed in depth during upcoming Phase B Definition and Preliminary Design Studies, can already be identified.

2.0 OBJECTIVES AND REQUIREMENTS

2.1 OBJECTIVES

The science objectives for the 1.8 M centrifuge are as follows:

- o Evaluate the requirements for artificial gravity during long duration human space missions.
- o Assess the impacts of long-term fractional gravity associated with future lunar and Mars bases.
- o Determine the role of gravity in basic biological processes.
- o Provide a controlled acceleration environment for unambiguous and thorough life science studies of microgravity.
- o Provide a 1-G environment to supply a source of specimens that are thoroughly adapted to the spacecraft environment prior to experimental use.

These objectives are based on the NASA White Paper: Research Centrifuge Requirements for the Space Station, NASA ARC, June 1986. Figure 2-1 shows a drawing of the 1.8 M centrifuge.

2.2 REQUIREMENTS

The requirements for the 1.8 M centrifuge are listed in Table 2-1 through 2-4. These requirements are based on the following documents:

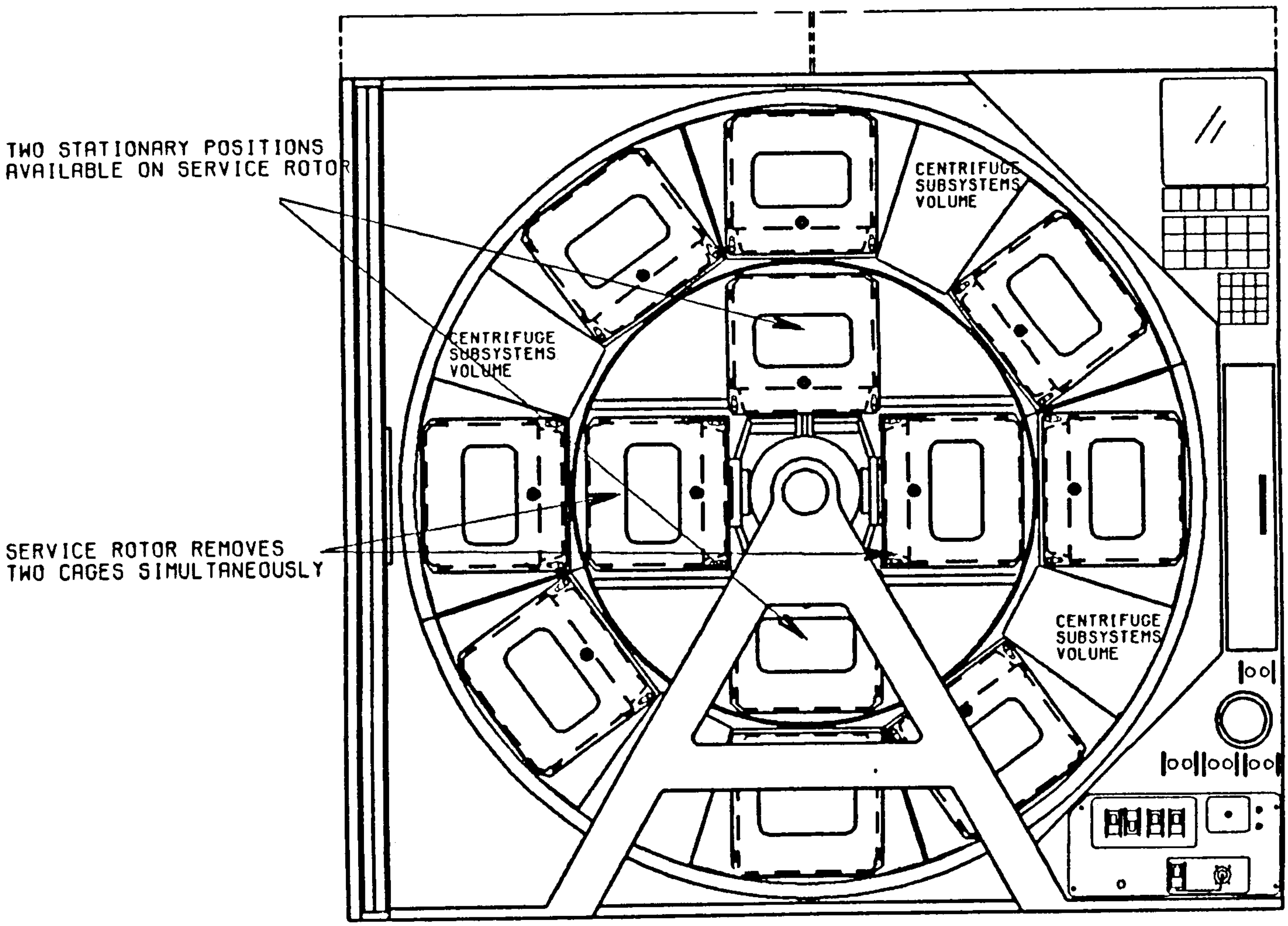

Fig. 2-1 Drawing of 1.8 M Centrifuge

- o Red Book: A Reference Payload for the Life Science Research Facility, TM 89188, August 1986
- o White Paper: Research Centrifuge Requirements for the Space Station, NASA ARC, June 1986.
- o Space Station Program Definition and Requirements Document (PDRD), JSC 30000
- o Derived Requirements

Table 2-1 SYSTEM REQUIREMENTS

- o Create artificial gravity to support science research.
- o Main rotor accommodate small plants and rodents and their consumable supplies.
- o Provide for power and data transfer across rotating hub.
- o Secondary rotor and service robot retrieves and replaces experiment packages.
- o Secondary rotor accommodates short-term experiments.
- o Counterrotating inertia wheel automatically compensates for torque and momentum generated by main and secondary rotors.
- o Automatic balancing system.

C-2

Table 2-2 REQUIREMENTS IMPOSED BY SCIENCE USERS

- Create $\leq 10^{-3}$G variation in G-level onboard the centrifuge.
- Provide automated servicing capability to retrieve and replace experiment packages.
- Monitor and control each experiment package.
- Provide necessary utilities to each experiment package.
- Accommodate modular equipment which is functionally shared with holding facilities, workstation, equipment washer, and other science equipment.
- Monitor and control centrifuge operating parameters.

Table 2-3 SCIENCE REQUIREMENTS

- Create .001 G to 2.0 G at the centrifuge perimeter.
- Accelerate at rates from .01 Gs to .25 Gs.
- Maintain live specimens in a healthy and stress-free environment.
- Accommodate small plants and rodents.
- Rotate continuously.

Table 2-4 DESIGN REQUIREMENTS IMPOSED BY SPACE STATION PROGRAM

- Emit $\leq 10^{-5}$G vibration to the Space Station.
- Operate below acoustic limit.
- Meet electromagnetic interference requirement.
- Compensate torque and momentum with a 3% residual.
- Design for a life of 25 years with periodic servicing.
- Enclose centrifuge in a safety, acoustical, and visual barrier.
- Monitor and control centrifuge system operating parameters.
- Provide for on-orbit integration or relocation within the pressurized modules.
- Allow access to pressurized module shell.
- Orient centrifuge spin axis along the Space Station Y-axis to minimize gyroscopic torques.

3.0 SUPPORTABILITY ISSUES

3.1 GENERAL

A preliminary analysis of the 1.8 M centrifuge has identified several supportability issues. This document does not address all supportability issues, but discusses the salient issues that a logistics engineer would address in this phase of system acquisition for the centrifuge and the Life Science Research Facility. During Phase B of the acquisition cycle, the logistics engineer focuses on design influence to reduce future support requirements and costs. The logistics engineer interfaces with the design engineer and the systems engineer to discuss and resolve the issues.

3.2 RELIABILITY

Reliability requirements for the centrifuge are general in nature, i.e., design for a life of 25 years with periodic servicing, and rotate continuously. The requirement to rotate continuously is imposed because some experiments require specimens to be exposed to continuous gravity over the duration of the experiment. Unscheduled servicing would compromise experimental results. If unscheduled maintenance is not acceptable, then the specifications should clearly state this. This would drive designers to make all critical components in the centrifuge redundant. Figure 3-1 is a

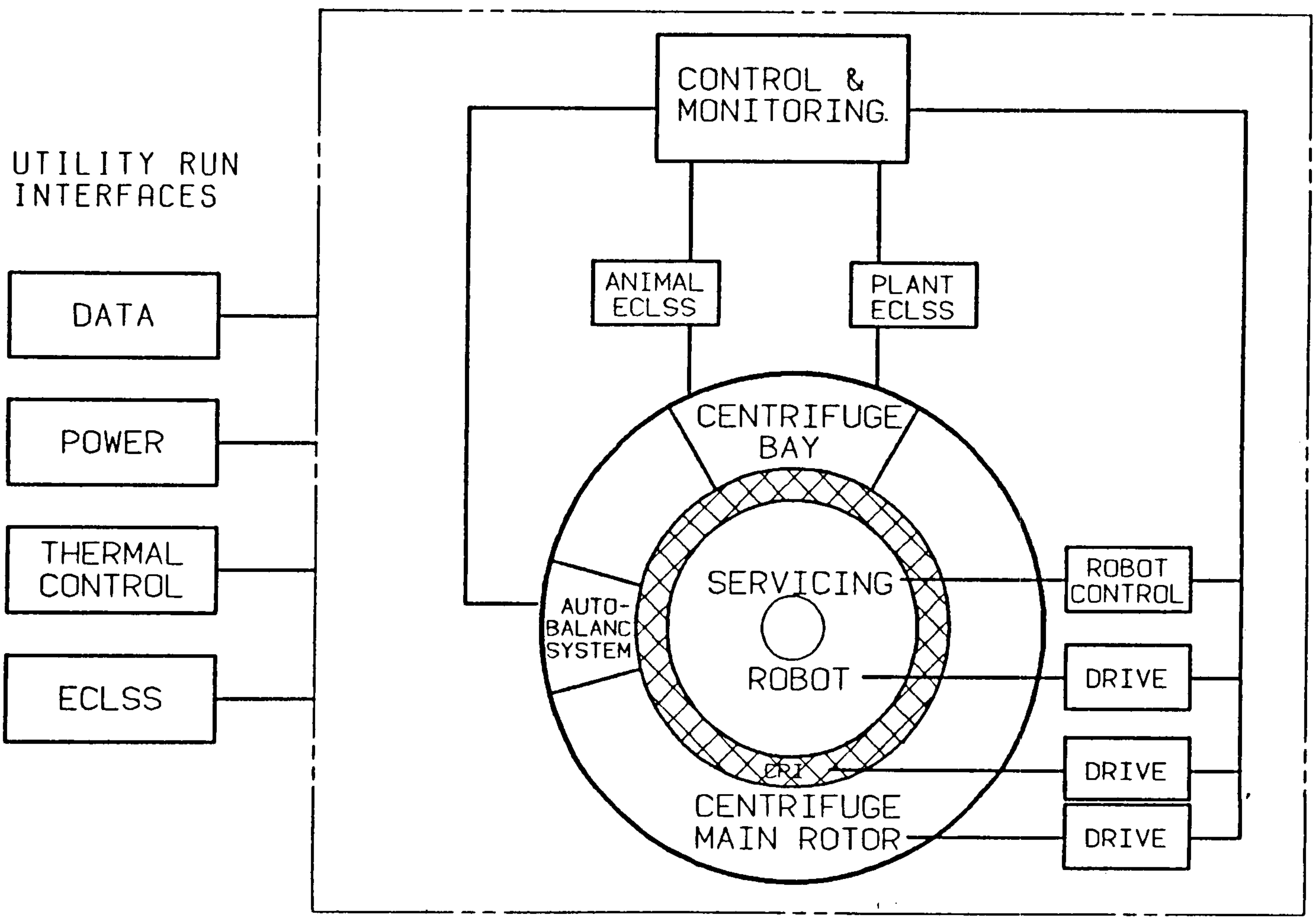

Fig. 3-1 Schematic of 1.8 M Centrifuge

Table 3-1 COMPONENT/SYSTEM MTBF

Component MTBF (Yrs)	Resulting System MTBF (Yrs)
25	2.8
20	2.2
15	1.7
10	1.1
5	0.6
4	0.44
3	0.33
2	0.22
1	0.11

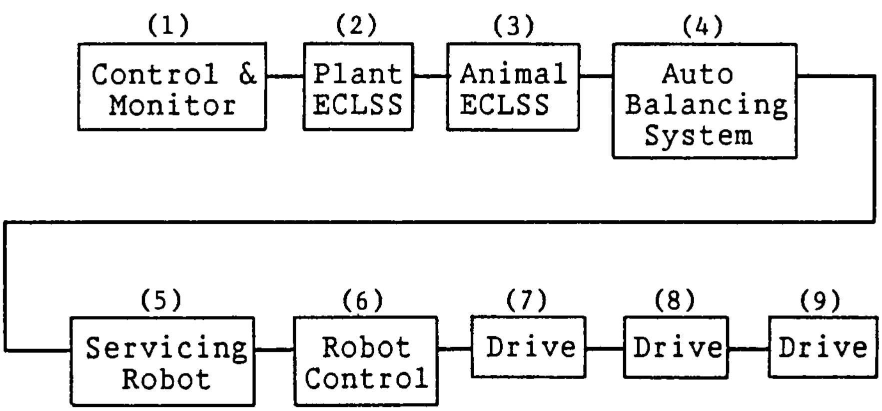

Fig. 3-2 Series Relationship

schematic of the 1.8 M centrifuge. The schematic shows nine system components. A cursory analysis indicates that all nine components must operate for mission success criteria to be met. Since there is no redundancy of these functions, it yields a series reliability network. Figure 3-2 shows the series relationship. Any component failure brings the entire system down. Table 3-1 shows the system sensitivity to a series relationship of this nature. If component Mean Time Between Failure (MTBF) is 25 years, the resulting system MTBF would be 2.8 years. If the system components are designed with a MTBF of 4 years, the system would have an MTBF of .44 years, or less time than is required to complete an experiment. The resulting unscheduled maintenance requirements would seriously impact mission accomplishment. Design of the centrifuge will require component redundancy to ensure mission success.

3.3 MAINTAINABILITY

Maintainability is a key design consideration for the 1.8 M centrifuge. All critical components within the centrifuge will be functionally packaged and designed as ORUs. The centrifuge will incorporate BIT/BITE to isolate failures to the ORU level. On-orbit repair of centrifuge ORUs will be analyzed. If centrifuge ORUs are chosen for on-orbit repair, then they will be designed to be tested with test equipment that is available on the Space Station. Test equipment will isolate failures to the subassembly level, and spares will be available on the Space Station. The capability to replace failed ORUs while the centrifuge is operating will be analyzed in conjunction with required/available on-board storage space. Other maintainability considerations are training and technical data requirements. These considerations will be applied to all candidate subsystems and incorporated as design requirements. A specific example is the ball bearing suspension system that has been chosen as the leading option for the suspension system. The ball bearing system requires that its oil system be serviced at a 5-year interval. The logistician will assess the impact on support equipment requirements, skills required to perform the servicing, time required to perform the tasks, and contamination or other hazards involved.

3.4 COMMONALITY

Commonality in design will be emphasized to reduce logistics requirements and cost. The current centrifuge concept requires three drive motors, one for each of the rotors: the main rotor, the service rotor, and the compensator. Each motor is different due to different torque requirements. No motor redundancy is planned. Designers should look at the possibility of common motors. Commonality of design should also be considered for the power transformers and optical couplers. All standardization achieved will improve supportability of the centrifuge.

Intensive supportability analyses paralleling, and coupled to, Phase B 1.8 M centrifuge system definition and preliminary design studies will penetrate these and other potential problems in detail and in depth. They will provide the program manager with logistics planning tools to ensure the successful development and operation of the centrifuge. If, as seems likely, NASA develops the core group of specimen habitats, centrifuges, a multipurpose workbench, specimen husbandry devices and equipment cleaning hardware as a single development entity, then simultaneous, integrated, indepth supportability analyses of these payload elements will constitute an essential early step in the Life Sciences Research Facility program.

4.0 SUMMARY

The preliminary supportability analysis of the 1.8 M centrifuge has identified several key issues. All of the supportability issues have a tremendous impact on the logistics support requirements and support costs for the centrifuge. An integrated logistics support program and plan will be developed as an integrated effort with the design process. Lack of a clearly defined program could hinder the integration and support of the centrifuge and other life science equipment. Logistics engineers will interface with design and systems engineers to resolve the supportability issues. Reliability, maintainability, and commonality are interrelated and have a major impact on required logistics support in terms of skills and levels of maintenance personnel required, spares stockage, support equipment required, personnel training, and associated operations and support costs. Trade studies will be employed to obtain an optimum balance between cost and effectiveness. The trade studies will analyze reliability, maintainability, and commonality interaction and associated life-cycle cost. The centrifuge and the entire Life Sciences Research Facility are currently in a critical phase of development. The decisions made now will dictate future support requirements and costs. These requirements and costs can be minimized with an effective Integrated Logistics Support program.