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# Life Sciences Space Station Planning Document: A Reference Payload for the Life Sciences Research Facility



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LIFE SCIENCES

SPACE STATION PLANNING DOCUMENT

# FOREWORD

The Space Station, projected for construction in the early 1990s, will be an orbiting, low-gravity, permanently manned facility providing unprecedented opportunities for scientific research. Facilities for Life Sciences research will include a pressurized research laboratory, attached payloads, and platforms which will allow investigators to perform experiments in the crucial areas of Space Medicine, Space Biology, Exobiology, Biospherics and Controlled Ecological life Support System (CELSS). These studies are designed to determine the consequences of long-term exposure to space conditions, with particular emphasis on assuring the permanent presence of humans in space. The applied and basic research to be performed, using humans, animals, and plants, will increase our understanding of the effects of the space environment on basic life processes. Facilities being planned for remote observations from platforms and attached payloads of biologically important elements and compounds in space and on other planets (Exobiology) will permit exploration of the relationship between the evolution of life and the universe. Space-based, global scale observations of terrestrial biology (Biospherics) will provide data critical for understanding and ultimately managing changes in the Earth's ecosystem. The life sciences community is encouraged to participate in the research potential the Space Station facilities will make possible.

This document provides the range and scope of typical life sciences experiments which could be performed within a pressurized laboratory module on Space Station. Research may also be conducted from platforms and attached payloads. Representative experiments and hardware requirements for platforms and attached payloads are identified in this document, but will be discussed more extensively in subsequent documents.

## INTRODUCTION

In his State of the Union Address of January 25, 1984, the President directed NASA "to develop a permanent manned space station...and to do it within a decade." The permanent U.S. presence in space will enable the United States to develop our next frontier -- space -- and "to follow our dreams to distant stars, living and working in space for peaceful economic and scientific gain."

Components of the initial Space Station configuration will be a scientific laboratory within a pressurized module and associated research platforms. The Life Sciences Research Facilities (LSRF) on board will permit investigations in:

Space Medicine, to understand and alleviate detrimental effects of the unique and often harsh space environment on human and animal physiology, necessary if permanent human presence in space is to be assured;

Space Biology, to study effects of space on basic life processes in animals, humans, and plants to understand the relationship between gravity and life;

Exobiology, to explore the history of the biogenic elements and compounds from their nucleosynthesis in stars to their incorporation in living species;

Biospherics, to examine living and nonliving components of the biosphere interacting on a global scale; and in

Controlled Ecological Life Support Systems (CELSS), to determine effects of the space environment on biological and nonbiological components needed for a self-sustaining life support system.

The Life Sciences Space Station Planning Committee has compiled this report describing a representative payload for research to be conducted within pressurized modules based on mission science objectives and representative experiments and equipment. The representative payload <u>does not represent the</u>

outcome of a payload selection process. In addition, facilities are being planned for remote observations from platforms and attached payloads of biologically important elements and compounds in space and on other planets (Exobiology), for space-based, observations of terrestrial biology on a global scale (Biospherics), and for other space biology research that can be performed outside the pressurized module.

Representative experiments and hardware requirements for attached payloads and platforms are identified in this document, and will be described more completely in subsequent volumes. The major mission science objectives of the NASA Life Sciences Space Station Program are: to maintain crew health and productivity during long-duration missions; to support basic research and development in life sciences on the Space Station; and to utilize Space Station as a test bed to evolve requirements for more advanced missions (e.g., a manned mission to Mars).

## PURPOSE

The purpose of the Life Sciences Space Station Planning document ("Red" Book) is to develop a reference payload for research that would be conducted within pressurized modules on a space station to define the engineering requirements (mass, power, volume, etc.). The document details the evolutionary process from science goals to objectives through experiments and hardware and resource requirements. Resource requirements validated by this document are described in mission 307 of the mission requirements data base (Section 5.0 of this report).

This report is one in a series which will address the design of and scientific rationale for certain typical life science experiments that might be conducted on an Earth-orbiting space station. This information has been collected to help ensure that Space Station designers and equipment specifiers are responsive to their users, the science community. No experiments have yet been selected for flight.

Figure 1.0. Engineering Envelope Summary

| | MASS | VOLUME | POWER |
|---|---|---|---|
| Mission requirements data base | 8500 Kg | 39.0 $M^3$ | 13.5 KW |
| Reference payload | 6050 Kg | 39.0 $M^3$ | 13.5 KW |
| Human emphasis | 4911 Kg | 37.1 $M^3$ | 14.4 KW |
| Biological emphasis | 8500 Kg | 34.4 $M^3$ | 15.4 KW |

Figure 1.0 compares the engineering envelope detailed in the Mission Requirements Data Base with the engineering requirements for these payloads: 1) a reference payload combining human and biological research; 2) a reference payload emphasizing human research; and 3) a reference payload emphasizing biological research.

## BACKGROUND

### Life Sciences Space Station Planning Meeting

The Life Sciences Space Station Planning meeting was held June 10-11, 1985 in Rosslyn, VA. Its primary purpose was to develop a typical integrated set of objectives for research which could be conducted on Space Station. Attendees included scientists from NASA centers and Headquarters and from universities (including members from NASA Life Sciences advisory committees). At the meeting, the NASA Life Sciences Program encompassing Space Medicine and Space Biology was subdivided into the following disciplines (listed alphabetically):

Behavior and Performance
Biospherics
Cardiovascular System
Calcium Homeostasis

Controlled Ecological Life Support Systems (CELSS)
Endocrinology/Fluid Electrolytes
Environmental Factors
Exercise Physiology
Exobiology
Hematology
Immunology
Metabolic Regulation
Microbiology
Muscle Physiology
Neurosciences
Pharmacodynamics
Plant Physiology
Pulmonary Physiology
Radiation Effects
Reproduction and Development

Groups of scientists from each discipline reviewed and prioritized science objectives identified previously in NASA documents and NASA-funded documents. They also provided additional science objectives.

The first draft of the "Red Book" was based on the results of this meeting.

## Life Sciences Space Station Planning Committee

Another result of the Rossyln meeting was establishment of the Life Sciences Space Station Planning Committee, which has representation from JSC and ARC and is chaired by HQ. The members are:

- Mr. Marvin R. Christensen, Former Life Sciences Space Station Coordinator, NASA Headquarters
- Dr. Gary E. Musgrave, Senior Space Station Support Scientist, MATSCO (Staff)
- Dr. Bette Siegel, Life Sciences Space Station Flight Analyst, MATSCO (Staff)

Dr. Sam Pool, Chief, Medical Sciences Division, JSC
Dr. Gerald Taylor, Life Sciences Space Station Project Scientist, JSC
Mr. Gary Primeaux, Life Sciences Space Station Project Manager, JSC
Dr. John Billingham, Chief, Life Sciences Division, ARC
Dr. Kenneth A. Souza, Assistant Chief, Life Sciences, ARC
Mr. Roger D. Arno, Project Manager, Biological Research Project, ARC

The Planning Committee first met at Johnson Space Center on September 3-4, 1985. The Committee developed and utilized the following assumptions constraining potential Life Sciences payloads that will be housed within a pressurized module during the initial operation configuration.

1. The initial operating configuration (IOC) will be phased and the space station will be "manned."

2. Research at IOC will emphasize support of "man in space."

3. Common science objectives will be developed and updated (i.e., the interim report "Red Book").

4. Investigations will be clearly tied to the objectives.

5. Human and animal research will be complementary. Basic research will also be conducted.

6. Each Center will develop experiment protocols (defined in JSC-"Blue Book" - Human Research Facility For Space Station - IOC Life Sciences Requirements - October 1985, JSC 20799 and ARC-"Green Book" - Life Sciences Research Objectives and Representative Experiments for the Space Station, Biological Research Project - Preliminary Draft 1986).

7. Human and nonhuman research facilities are to be shared equally in terms of volume and crew time.

8. The logistics module and science module will be serviced every 90 days. Equipment changeout will be minimal in the IOC phase -- no more than 10% to 15% replacement every 90 days.

9. Six crewmembers will man the Space Station. One will be a life scientist devoting one half of his or her available time per day. The remaining crewmembers will be available one-half day each per week. This will yield 800 hours of crew time available for Life Sciences Research.

10. Bioisolation for plants and animals will be at the habitat level.

11. The cost approximation will be $50K per kilogram (developed and flown). (This estimate does not include ground support equipment.)

Additional Meetings and Workshops

Additional meetings and workshops regarding Life Sciences Space Station planning have been held since the Rosslyn meeting. NASA in-house life scientists, with their colleagues from the scientific community at large, convened to review and refine science objectives and to derive key experiments and lists of supporting equipment. From these equipment lists and agreed-upon assumptions, the Planning Committee derived a representative payload for human and biological research to be conducted within a pressurized module for a "typical" year during the IOC period. Overall payload size was determined by the limiting factors of crew time and development cost (Assumptions 9 and 11). A typical year during the IOC time frame consists of four 90-day missions. (Actual experiments may last longer than 90 days.) At least two 90-day scenarios are required to cover experiments in most of the 20 disciplines of the Life Sciences Program. Some experiments may be performed more than once within a typical year in order to enhance the probabiilty of statistical significance. Two 90-day representative mission scenarios (termed mission A and mission B) were developed from representative experiments and are described in greater detail in section 3.0. Both scenarios can be supported by the reference payload with a minimal amount of equipment change out. Each scenario was to be constrained by the assumption that only 800 hours of crew time would be available for Life Sciences research during a 90-day mission. Mission A met these crew time constraints, but mission B did not. Representative mission scenarios and payload derived are described in the third section of this report. In addition, data generated from this reference payload have been incorporated into the December 1986 version of the Mission Requirements Data Base (formerly called the Langley Data Base) for mission 307. See Section 5.0.

At least two additional payloads were examined in detail. One emphasizes human research; the other emphasizes biological research. Engineering requirements for mass, power, and volume are within 20% of those specified in the Mission Requirements Data Base for mission 307 (see Figure 1.0). Details of those payloads emphasizing human or biological research are not described in this report, which focuses on development of an integrated human and biological research payload for life sciences research to be conducted on Space Station. These studies were performed to validate the concept of using a reference payload to define engineering requirements. The close comparison of the engineering requirements of two extremely different payloads validates that the data in the Missions Requirements Data Base is sufficient to accommodate a variety of payloads for Space Station.

Discipline areas not contained in the reference payload described here include Biospherics, Exobiology, and Reproduction and Development. Experiments in these disciplines will be conducted either within the module or external to it. Experiments which support these disciplines are included in Section 4.0 of this report. The representative experiments and equipment to support planning in these disciplines will be detailed in subsequent documents. If experiments in these areas are selected for inclusion within the pressurized module, there would be sufficient power, mass, and volume designated by the engineering requirements in mission 307 of the Mission Requirements Data Base to accommodate them.

As future meetings and further information reveal additional relevant considerations and constraints, payloads and scenarios will be revised and updated.

## SCOPE

The first section of this document details the science rationale and science objectives for 20 disciplines within the Life Sciences Program for Space

Station, as developed in meetings of the Planning Committee. Objectives for each discipline are in order of critical need; however, no attempt has been made to prioritize the disciplines. Therefore, the science disciplines are arranged in alphabetical order.

The second section lists titles of "representative" experiments by discipline from the two mission scenarios. These experiments were developed to meet the objectives described in section 1.0. Experiments are discussed in greater detail in the JSC "Blue Book" and ARC "Green Book" and are cross-referenced as such. This report lists only titles of experiments found within the mission scenarios. Full descriptions of these experiments and all others proposed for the 20 disciplines can be found in the "Blue Book" or the "Green Book."

In addition to experiments, this section lists projected supporting equipment for each discipline, which, in total, composes the hardware of the representative payload (with changeout of appropriate equipment needed for the respective species). Each piece of hardware was evaluated for general applicability to Life Sciences research and is annotated as either "Life Sciences Generic" or "Experiment Specific." In addition, each hardware item is identified as "rack-mounted" or "stowed."

The third section describes the 39-rack payload. Assumptions for outfitting the Life Science Payload are presented again. Two representative mission scenarios consistent with payload assumptions and representative experiments are presented in a listing of experiment titles included in each scenario. Experiments are grouped by discipline. Projected crew time requirements for each scenario are also given.

This section also details projected resources available for the Space Station science payload defined in the Mission Requirements Data Base. Estimates are given for the mass, volume, power, depth, width, and height for equipment listed in Section 2.

The fourth section includes a partial list of experiments to support disciplines not contained in mission A or mission B. Experiments in this mission may be conducted within the module or external to the module. Detailed definition of these experiments and support equipment will be presented in subsequent documents.

The fifth section is a copy of mission 307 as described in the Mission Requirements Data Base.

The sixth section lists all participants in the workshop and contributors to this document.

The seventh section lists the references used to compile this report.

## RATIONALE FOR BEHAVIOR AND PERFORMANCE EXPERIMENTS

NASA's manned missions have been characterized by highly motivated crews. So far, no overt functional impairments caused by adverse psychological responses have been reported. However, some feel that longer, increasingly complex, and relatively routine space missions involving larger, heterogeneous crews may generate psychological and social problems for which adequate solutions are not currently available. Potentially stressful factors for crews include: physical and social isolation, confinement, boredom, threat of potential hazards, and discomfort associated with crowding, lack of privacy, artificial life support, and microgravity.

Documented adverse psychological and psychophysiological responses to space flight include: transient disorientation and spatial illusions; temporary alteration of visual function; and performance degradation and sleep disturbance associated with unaccustomed work, rest, and sleep schedules. Psychological factors may also enhance symptoms of space sickness, and contribute to diminished crew performance.

Anecdotal information from U.S. and Soviet space missions includes examples of adverse psychological effects: hostility between space and ground crews, friction between crewmembers, and episodes of mental depression. Also relevant are data from operational or research situations -- such as long submarine missions, undersea habitats, and polar stations -- analogous to space missions regarding confinement, physical and social isolation, crowding, lack of privacy, and perceived danger. Research and operational monitoring have shown adverse psychological effects in such situations ranging from listlessness and depression through anxiety accompanied by psychosomatic symptoms, sleep disturbance, and fatigue, to irritability and frank hostility. Evidence for decreased psychomotor performance in certain undersea activities has also been cited.

## RATIONALE FOR BEHAVIOR AND PERFORMANCE EXPERIMENTS (CONT'D)

Unresolved problems of long-term human occupancy of a space station involve psychological and social factors in crew compatibility, motivation, and productivity, and the effects of that environment on perceptual, intellectual, and motor skills. Research will provide information to ensure the maintenance of crew health and productivity.

## BEHAVIOR AND PERFORMANCE

B-1. Conduct applied research on the biobehavioral factors affecting work performance on long-term space flights.

B-2. Develop practical strategies for optimizing individual and group performance and productivity, and for providing psychological and social support to individuals and groups in the space environment.

B-3. Integrate operational inputs to identify useful areas of study, to plan for the conduct and priorities of research, to identify methods of data gathering which are congruent with operational constraints and needs, and to evaluate results.

B-4. Verify baseline parameter data developed through ground-based research.

## RATIONALE FOR BIOSPHERIC RESEARCH EXPERIMENTS

Biospheric Research studies life as a modulating force which governs the complex cycling of materials and energy through the biosphere (or global system). To understand how life and the environment interacts on a global scale, an interdisciplinary approach that views the biosphere in its entirety is needed. Biospheric research relies on remote sensing to extrapolate ground-based, in situ parameters to a global scale. This includes studies of the influence of natural and human-caused changes in regulating the flow of chemical compounds through atmospheric, oceanic, and land processes.

Space Station based remote sensing equipment would be suitable for studying relationships between environmental parameters and animal species of economic or scientific interest, using NASA's synergistic imaging and trailing systems. Since different land cover surfaces reflect varying amounts of visible and infrared light in different regions of the electromagnetic spectrum, life scientists can utilize remotely sensed data to identify "signatures" for surface material (trees, grasses, water, etc.). High spectral resolution data (combined with high ground sampling frequency) will permit detection of variations in life-dependent compounds within and between ecosystems. Ecosystem signatures may also permit estimates of large animal populations and perhaps even of the range and migratory patterns of selected insect species.

The Remote Sensing and Public Health Project within the Biospherics Discipline is of particular relevance to Space Station. This project will use remote sensing techniques to predict the spread of particular insect species. Studies of environmental characteristics that control insect population dynamics can be used to predict occurrence of diseases transmitted by insects, such as malaria. The ability to locate disease-fostering environments around the globe may eventually permit identification of prime target areas, where appropriate countermeasures can be instituted. Space Station would provide an ideal facility to house remote sensors required to gather insect dynamics data.

# BIOSPHERICS

BS-1. Understand the biogeochemical cycling of carbon, nitrogen, phosphorus, sulfur, and trace metals by using high spectral resolution imagers.

BS-2. Determine primary biological oceanic productivity by use of Ocean Color Imager or imaging spectrometer.

BS-3. Understand and model environmental parameters which influence prevalence of vector-borne diseases using high-resolution visible and infrared or thermal data.

BS-4. Define relationships between environmental parameters and incidence and type of animal species of economic or scientific interest, using NASA's synergistic imaging and tracking systems.

## RATIONALE FOR CALCIUM HOMEOSTASIS EXPERIMENTS

Bone demineralization and negative calcium balance have been consistently reported in space flight. Other changes in calcium metabolism possibly associated with bone loss and increased risk of fracture have been observed. These changes include increased fecal loss of calcium and hypercalciuria with potential implications for formation of calcium-containing renal stones. In United States space flights as long as three months and Soviet flights as long as seven months, neither loss of bone minerals nor the resultant hypercalciuria have been associated with impaired functional capacities of astronauts. However, concern for the health, effectiveness, and safety of space crews during extended space flight requires that unknown factors concerning bone demineralization be identified.

Bone loss processes in man during space flight are poorly understood. Histomorphometric studies of bone changes in rats flown aboard Cosmos biosatellites suggest that periosteal bone formation is inhibited and endosteal bone resorption is unchanged in weight-bearing bones. However, similar studies of bone changes in humans have not been performed during space flight or during simulated weightlessness on the ground (e.g., bed rest).

Evidence of bone mineral loss in humans during space flight has been supplied by metabolic balance studies and by noninvasive measures of bone density changes. These studies indicate an overall difference between anabolic and catabolic processes, but say little concerning the changes occurring in bone during weightlessness. Metabolic balance studies in humans during bed rest show changes in calcium balance generally similar to those astronauts experienced during space flight. Increased urinary and fecal losses of calcium have been reported in each situation. It has not been shown whether fecal losses result from increased endogenous losses or decreased intestinal absorption of calcium. Noninvasive measures of bone density indicate that preferential loss of calcium from weight-bearing bone (os calcis) is common to space flight and bed rest.

## RATIONALE FOR CALCIUM HOMEOSTASIS EXPERIMENTS (CONT'D)

Trials of countermeasures to prevent bone demineralization have been conducted in crews during space flight and, more extensively, in ground-based studies of human subjects during bed rest. Although exercise is considered a promising countermeasure for Space Station, it has not completely reversed negative calcium balance or hypercalciuria experienced by astronauts. At the present time, no biochemical or mechanical remedy is available to prevent disuse osteoporosis from occurring on the Space Station.

During the era of long-term Space Station habitation we need to continue to investigate the mechanisms of disuse osteoporosis so that rational countermeasures can be developed. Additionally, the potential for the development of renal lithiasis should be investigated. Although renal lithiasis is unlikely to occur, its investigation remains critical, since stone formation in the urinary tract could present a medical emergency.

## CALCIUM HOMEOSTASIS

C-1. Differentiate the primary causal factors influencing bone changes in microgravity or reduced gravity from the homeostatic responses of the calcium regulatory system.

C-2. Determine the magnitude, rates and sites of bone mineral change resulting from exposure to microgravity.

C-3. Determine the effect of microgravity on risk factors for the development of renal stones.

C-4. Quantify the effect of dietary factors (oxalate, phosphate, etc.) on calcium absorption and secretion and renal stone risk.

C-5. Delineate the histomorphometric changes in trabecular and cortical bone across species.

C-6. Determine if bone loss resulting from microgravity is reversed following flight.

C-7. Determine the effects of microgravity on crystal growth of stone forming salts (i.e., calcium oxalate and uric acid) in vitro and in vivo.

C-8. Determine the mechanism for the observed decrease in net calcium absorption during space flight (absorption vs. secretion).

C-9. Determine the effects of microgravity on local bone changes (e.g., mechanical stress and piezoelectric stimulation, prostaglandins, blood flow).

C-10. Ascertain effects of microgravity on the chemical composition of bone.

C-11. Investigate protocols for exercise, electrical stimulation, and other countermeasures which might reduce microgravity-induced bone and muscle loss.

C-12. Correlate bone loss during space flight and ground simulation studies with loss of muscle and electrolytes.

C-13. Compare effects of microgravity with changes observed in ground-based model systems.

C-14. Determine the relationship between intestinal motility and calcium absorption in microgravity.

C-15. Determine if there is a primary renal calcium leak induced by microgravity.

C-16. Determine the relationship between microgravity and renal production and clearance of calcium regulating hormones.

## CALCIUM HOMEOSTASIS (CONTINUED)

C-17. Determine the effects of microgravity on bone cell metabolism *in vitro*.

C-18. Determine the level and duration of artificial g needed to protect the skeleton during long-duration missions and its relevance to the risk of stone formation.

C-19. Determine the effects of microgravity on the concentration and clearance of heavy metals derived from bone resorption.

## RATIONALE FOR CARDIOVASCULAR SYSTEM EXPERIMENTS

Progress has been made to prevent or control deconditioning of the cardiovascular system occuring during adaptation to space flight, but important issues remain unresolved. Evidence of cardiovascular deconditioning obtained directly from observations of astronauts and cosmonauts during and after flight has accumulated since it was first reported following the 9-hour Mercury mission. After completion of the Skylab space flight program in 1974, substantial additional data on cardiovascular effects of flights and ground-based simulations have been reported. Though human adaptability to space appears adequate for missions lasting at least 6 months, countermeasures for projected longer-term missions must be developed.

Cardiovascular deconditioning is generally agreed to be caused by weightlessness, resulting in the disappearance of the customary, gravity-induced, hydrostatic pressure gradients throughout the body. Upon exposure to zero-g, a shift in regional blood volumes occurs toward the most compliant segments of the circulation (the lungs, heart and the systemic veins), which are only partially filled at 1-g. This volume change is presumably followed by a change in total blood volume, caused by transcapillary fluid movements due to elimination of gravitationally induced intravascular and tissue pressure gradients. In a gravitational force environment, such gradients are present in all body positions and are proportional to the differences in vertical height of the various capillary beds in the systemic and pulmonary circulations associated with the different body positions. Suppression of vasopressin release accompanied by a water diuresis and natriuresis are characteristic responses early in simulated weightlessness and have been postulated in zero-g.

Attempts to prevent or control cardiovascular deconditioning have involved inflight, reentry, and postflight measures. Countermeasures include inflight exercise, lower body negative pressure (LBNP), venous occlusion, preentry fluid and electrolyte replacement, use of antigravity suits during and following reentry, and postflight support measures. Opinion is divided about the extent of protection offered by vigorous, regularly scheduled exercise, repeated LBNP, and preentry fluid and electrolyte replacements. However, standard Shuttle operating procedure is to consume water and salt within the hour prior to entry. Future research may focus on exposing man to periods of artificial gravity in preparation for return to earth.

Continuing human presence aboard Space Station will require an understanding of cardiovascular responses to space flight superior to today's knowledge. Efforts to date have concentrated on acute effects of microgravity, with only limited results available from long flights from the American and Soviet space programs. Space Station will permit collection of meaningful, statistically valid information on physiological adjustments to flight of humans of different ages, genders, and physical conditions. Complementary, more invasive studies will be performed on animals. Postflight studies should allow characterization of the type and duration of cardiovascular deconditioning to be expected upon return to earth. This data base will have important operational consequences, such as allowing the tailoring of tours of duty, flight activity patterns, and countermeasures to minimize detrimental effects of exposure to space flight. In addition, the potential for using more complex and comprehensive experimental designs opens new vistas in understanding cardiovascular processes in general for the improvement of life on earth.

## CARDIOVASCULAR SYSTEM

CS-1. Investigate cardiac and circulatory hemodynamics.

a. Central (RA, RV, LA, LV)
   - ° Chamber and wall dimensions
   - ° Function at rest
   - ° Function with stress

b. Regional (peripheral)
   - ° Arterial: Pressure; Flow
   - ° Venous capacitance

c. Vital organ flow and distribution
   - ° Pulmonary
   - ° Renal
   - ° Splanchnic
   - ° Cerebral

CS-2. Investigate biochemical and ultrastructural changes.

a. Myocardial/connective tissue ratios
b. Vascular histochemistry-microcirculation
c. Cellular organelle changes
d. Intermediary metabolism (CPK, lipid, etc.)

CS-3. Investigate reflex control mechanisms.

a. Baroreflexes
   - ° High pressure: Carotid; Aortic
   - ° Low pressure: Cardiopulmonary

b. Peripheral resistance

c. Endocrine
   - ° Renal
   - ° Central nervous system: Antidiuretic hormone
   - ° Cardiac: Atrial naturetic factor (ANF)
   - ° Neuro-autonomic: Catecholamines

CS-4. Investigate dysrhythmias.

CS-5. Investigate types of countermeasures to orthostatic intolerance.

## RATIONALE FOR CONTROLLED ECOLOGICAL LIFE SUPPORT SYSTEM (CELSS) EXPERIMENTS

A bioregenerative human life support system will be necessary for long-duration manned space flight and for planetary bases due to the impossibility of transporting sufficient single-use life support resources from the Earth. This system, which NASA calls a Controlled Ecological Life Support System (CELSS), will be required to produce food, water and air by continually recycling human and plant wastes.

Such systems appear to be feasible in theory; however, the science and engineering understanding needed for their construction is not yet complete. It will be important to extrapolate data effectively from the Plant Physiology discipline to CELSS studies to maximize oxygen and food production in crop plants and ensure that detrimental effects to plants from space flight are minimized by appropriate countermeasures.

CELSS plant growth studies have focused on developing ground plant growth conditions that maximize plant productivity. Subsequently, the complete life cycle of plants while in space must be studied to determine the effect of reduced gravity on life-cycle plant productivity. The first essential task for CELSS space research will be to compare performance of plants from seed to seed on the ground and in space, to establish a baseline for additional research. Measurements to be made in space will include nutrient uptake, rates of photosynthesis, energy efficiency, biomass productivity, water vapor production, ratios of edible to inedible biomass, and nutritional composition of biomass.

Since plant growth experiments require long duration in a microgravity environment due to time between seed germination and harvest, Space Station or an equivalent system is required to conduct such experiments. Technology transfer of plant growth techniques developed during CELSS studies may provide significant improvements in terrestrial agriculture.

## CONTROLLED ECOLOGICAL LIFE SUPPORT SYSTEM (CELSS)

CL-1. Determine the microgravity conditions for optimizing productivity of plants for CELSS applications.

CL-2. Identify and evaluate the effectiveness of countermeasures to the effects of microgravity on plant development and productivity.

CL-3. Determine and evaluate the effects of space flight on interactions among the organisms and other components of a CELSS.

## RATIONALE FOR ENDOCRINOLOGY/FLUID ELECTROLYTE EXPERIMENTS

An initial physiological consequence of weightlessness is a cephalad shift in body fluids. This redistribution of an estimated 1.5 to 2 liters of fluid from the lower extremities is detected by stretch receptors in the left atrium and interpreted by the brain as an increase in total blood volume. A physiological compensatory mechanism is set in motion which results in a decrease in plasma volume and a continuous loss of electrolytes during space flight. Head-down bed rest studies indicate that early changes in central venous pressure lead to a decrease in plasma volume. Plasma volume has not been measured during flight, but in Spacelab 1 crewmembers venous pressure was lower a day after launch than it was preflight. Fluid shifts were thought to have occurred during the first 3 to 6 hours of flight. Such changes in fluid distribution may be responsible for the observed decrease in red cell mass which persists for two weeks after landing. Soviet investigators found that erythrocyte count did not return to normal until 6 weeks after 96- to 175-day flights.

The fluid shift produces the orthostatic intolerance and decrease in blood volume associated with cardiovascular deconditioning. However, the degree of orthostatic intolerance is greater than would be predicted from the magnitude of the fluid shift. This implies that additional mechanisms are involved, possibly alterations in neural or hormonal regulation or changes in vascular properties and the manner in which body fluids are redistributed.

Research in the endocrinology/fluid electrolyte discipline may include studies on: 1) the relationship between central venous pressure and plasma volume during weightlessness; 2) the effect of long-term space flight on circadian rhythms of circulating levels of hormones and electrolytes; 3) the effects of weightlessness on hormones involved in regulation of fluid and electrolyte metabolism; 4) the effects of weightlessness and of weightlessness-induced electrolyte and muscle loss on kidney function; 5) pituitary gland function under weightless conditions; 6) the effects of countermeasures on weightlessness-induced changes in endocrine and electrolyte parameters; and 7) the characterization of the type and duration of changes in endocrinology and fluid and electrolytes upon return to earth. Information from such studies is essential for defining a baseline norm for zero-g adaptation and health.

## ENDOCRINOLOGY/FLUID ELECTROLYTE

EN-1. Determine the relationship between central venous pressure and plasma volume during weightlessness.

EN-2. Determine whether circadian rhythms of circulating levels of hormones and electrolytes are affected by long-term space flight.

EN-3. Obtain consistent data about the effects of short-term, long-term, and repeated-exposure weightlessness on hormones involved in the regulation of fluid and electrolyte metabolism.

EN-4. Measure the effects of weightlessness and of weightlessness-induced electrolyte and muscle loss on kidney function.

EN-5. Measure pituitary gland function under weightless conditions.

EN-6. Determine the role of microgravity on central controllers of various physiological systems (neurochemistry, neural metabolism, single cell responses).

# RATIONALE FOR ENVIRONMENTAL FACTORS EXPERIMENTS

Research and development in the area of environmental factors relevant to Space Station will include projects on spacecraft atmosphere, thermal exchange, extravehicular activity (EVA) including space suit atmospheres and decompression, work rates, and metabolism. In the past, each parameter -- cabin pressure, temperature, humidity, $pO_2$, $pCO_2$, suit pressure, EVA work rates, adequacy of decompression protection -- was given acceptable set points or ranges based upon 1-g laboratory data as well as some experience inflight.

As we anticipate long-term habitation in space, environmental parameters thought adequate for short-duration space flight must be reevaluated in light of possible physiological effects associated with long-term exposure to space. In addition, new technology has become available which may expand options for suit pressures and repeated EVAs and which may ultimately affect cabin environmental factors.

## ENVIRONMENTAL FACTORS

EF-1. Understand and obtain quantitative data on inert gas exchange as a function of time in space.

EF-2. Investigate the effect of the space environment on formation of bubbles in blood and other tissues.

EF-3. Understand interrelationships between various facets of space adaptation syndrome and environmental factors.

EF-4. Establish a model of thermal equilibrium as a function of time in weightlessness.

EF-5. Evaluate effects of subclinical bubbles and other EVA phenomena on blood and pulmonary parameters.

## RATIONALE FOR EXERCISE PHYSIOLOGY EXPERIMENTS

Exposure of humans to microgravity has certain dramatic effects on physiological systems involved in physical activity: cardiovascular deconditioning, muscle atrophy and bone loss. These effects, while not of major concern on short-term Shuttle missions, become increasingly crucial for long-term Space Station habitation.

Exercise is one of the most effective known measures for improving or maintaining physical conditioning. There is much information concerning effects of exercise on the body in a 1-g environment, but little is known about its effects in microgravity. From data relating to deconditioning in flight, it has been hypothesized that various types and forms of exercise may be used inflight to counteract adaptive responses to microgravity which may cause problems upon reentry to 1-g. Aerobic endurance exercise is suggested as a countermeasure to cardiovascular deconditioning. Muscle strength and endurance training exercises are proposed to counteract deleterious effects of muscle atrophy. Forms of exercise which "load the skeleton" are proposed to counteract bone mineral loss.

In the U.S. and U.S.S.R., investigators have reported that certain types of physical activities may counteract some deleterious effects of microgravity. Soviet cosmonauts on board their Salyut spacecraft have reportedly exercised for as long as 2 hours per day. The U.S. Skylab and U.S.S.R. Salyut missions attempted to relate the level of exercise to the extent of the deconditioning observed. Biomedical results from Skylab tend to confirm the hypothesis that certain types of exercise may reduce the degree of cardiovascular deconditioning and muscle atrophy. In addition, exercise has been shown to affect such psychological factors as the individual's adjustments to confined environments and work productivity, and to be useful in preventing and treating depression. Therefore, it is possible that exercise may be beneficial in facilitating psychological adaptation to long-duration space flight. However, after assessing present knowledge in this area, it becomes evident that we are only in the initial phases of understanding the potential interaction of exercise on the effects of microgravity during long-term space flights.

## EXERCISE PHYSIOLOGY

EXP-1. Delineate and document time course changes that occur in muscular performance -- force, velocity, endurance, histology, electrophysiology; include upper and lower torso.

EXP-2. Delineate and document the time course changes that occur in aerobic capacity.

EXP-3. Delineate any changes in joints such as the time course of range of motion changes and ligamentous stability changes, including load bearing and non-load bearing.

EXP-4. Determine what role muscular forces play in bone calcium metabolism.

EXP-5. Determine the effects of different types of exercise on muscles, aerobic capacity, and bone/calcium metabolism.

## RATIONALE FOR EXOBIOLOGY EXPERIMENTS

NASA's Exobiology Program is directed toward improving the understanding of the origin, evolution, and distribution of life and life-related molecules throughout the universe. The unifying concept underlying research in exobiology is that the origin and evolution of life is an integral part of the origin and evolution of stars and planets; thus, life is a product of a continuum of physical and chemical processes that started with the origin of the universe itself. Constructing a plausible pathway that leads from the origin of the universe to the establishment of a sustained biota on Earth involves the synthesis of data collected from ground-based, space and planetary investigations. In this context, the Space Station will contribute significantly, providing three new tools: enhanced observational capability; *in situ* cosmic dust collection; and a unique environment for a variety of simulations.

In the area of observational exobiology, orbiting telescopes on Space Station will expand the observable wavelength region from the far infrared to the sub-millimeter. This portion of the spectrum provides unique information about many molecules in diverse cosmic environments and to date is almost completely unexplored. Key observations within these spectral windows include the detection of extrasolar planetary systems, the study of the solar nebula and its analogs, the identification of biogenic elements and complex molecules in primitive bodies and in the atmospheres of the giant planets, the study of comets and asteroids, and the study of molecules in space.

Cosmic dust, or interplanetary dust particle (IDP), collection can benefit from large collection surfaces and long exposure times that may be achieved with the completion of the Space Station. Collected IDPs could then be studied and identified, to determine whether the dust is cometary, meteoritic, or interstellar in origin. IDPs believed to contain organic molecules of biological significance will provide important evidence concerning the cosmic evolution of biogenic elements and compounds related to the origin of life. Life scientists on the Space Station will also be in an excellent position to study the chemical processes leading to interstellar particle formation in the vacuum, radiation, and microgravity conditions of space. Grains could be artificially synthesized to study, in miniature, the formation of biogenic compounds believed to occur on the surfaces of meteorites, and in comets, solar nebulae and interstellar space and to understand the processes by which this occurs.

Space Station will also provide a uniquely useful environment for _in situ_ investigations, which are of central importance to Exobiology. By making available special conditions such as microgravity, a reasonably good vacuum with a very high pumping speed, and a solar flux that is less attenuated than that at the Earth's surface, Space Station will enable the conduct of experiments which would provide "space truth" for analogous experiments conducted in ground-based laboratories or on computers. Such experiments include the detailed study of fundamental physical and chemical processes that can occur on the surfaces of grains in interstellar dust clouds; an artificial comet; and, possibly, tests of the concept of panspermia.

## EXOBIOLOGY

EX-1. Nondestructively collect and identify the source of cosmic dust particles that represent primitive solar system and interstellar materials to analyze biogenic elements (C,H,O,N,P,S) and compounds ($H_2O$, $CO_2$, and organics), to provide knowledge on the chemical and physical evolution of the solar system and the origin of life.

EX-2. Conduct astronomical spectrophotometric observations of planetary atmospheres, comets, molecular cloud cores, diffused interstellar clouds, evolved stars, other galaxies, and nebulae to understand the origin and evolution of biogenic elements and compounds.

EX-3. Study the formation, growth, and accretion of dust grains and their interactions with interstellar gases, in space-based simulations, to trace the history of organic matter in the primitive solar system. Evaluate the significance of biologically produced organic matter in the evolution of terrestrial planets.

EX-4. Study physical and chemical reactions in the nuclei and on the surfaces of Artificial Icy Comets during exposure to the microgravity, vacuum and radiation environment of space to determine the contribution of comets to the distribution of volatile biogenic elements and compounds to the planets.

EX-5. Conduct remote observation of artificial comets to provide information on the composition of the primordial solar nebula.

EX-6. Evaluate the reactive properties of naturally occurring, high-velocity oxygen atoms in space.

EX-7. Evaluate the hypothesis that life could have been carried to Earth from outer space (panspermia) by studying factors that contribute to the ejection of microbes from planets into space, and their survival in the space environment.

## RATIONALE FOR HEMATOLOGY EXPERIMENTS

Postflight reduction in the circulating erythrocyte mass in human hematologic tissues is a significant effect of space flight. Variations in the magnitude of loss in individual crewmembers and the complicated postflight recovery kinetics suggest a complex relationship between red cell mass loss and duration of exposure to space flight. Such "anemia of space flight" is frequently accompanied by a reduction in plasma volume, apparently occurring early in the mission and sustained throughout the flight. Other, subtler, effects have been observed in the function and structure of red blood cells and the concentration of some plasma proteins.

A consistent reduction in circulating red cell mass, usually accompanied by a decrease in plasma volume (which may or may not be related) was first noted following the Gemini V and VII missions and later observed following the flights of Apollo 9, Apollo 13 through 17, Skylab, and Apollo-Soyuz Test Project (ASTP). Similar findings were reported following Salyut missions. It was initially proposed that the high concentration and partial pressure of oxygen in spacecraft led to a reduction of erythrocyte mass. This hypothesis appeared to be supported by similar observations in a barochamber study which utilized a 100% oxygen atmosphere at a total pressure of 5 psi. However, Skylab flight data did not support the concept of an oxygen-induced intravascular hemolysis. Because data seem to suggest reduced red cell production as the probable cause of inflight erythrocyte mass loss, studies investigating the possible influence of space flight on erythropoiesis should receive priority.

Since space flight anemia is dissimilar in many respects to any known anemia occuring in normal gravity, it is not known if anemia of space flight would decrease exercise tolerance of astronauts inflight as it does on Earth, or if bone marrow would respond as on Earth to life-threatening hemorrhage. Another major question is whether space flight anemia is progressive. It is critical that our understanding of space flight anemia be enhanced if we are to prevent severe and possibly irreversible hematological changes on long-duration missions.

## HEMATOLOGY

H-1. Determine sequential changes in red cell mass and erythropoietin levels.

H-2. Examine the effect of microgravity on blood and bone marrow colony forming cells: CFU-S, CFU-E, BFU-E, etc. (Conduct serial bone marrow changes on animal models.)

H-3. Determine the possible role of splenic sequestration of RBC as a possible cause of the decrease in red cell mass.

H-4. Examine *in vivo* response to erythropoietin in microgravity.

H-5. Follow iron metabolism, ferritin levels, red blood cell counts, and clearance during microgravity exposure.

H-6. Reevaluate the possible occurrence of subtle hematological effects as a result of procedures requiring prebreathing of 100% oxygen prior to EVA.

## RATIONALE FOR IMMUNOLOGY EXPERIMENTS

Immunology experiments show preliminary results suggesting that space flight can impair several types of immune responses. Changes have been seen in the areas of cell-mediated immune function and interferon production. These raise concerns about possible immunosuppression developing in individuals during long-term space flight. Unfortunately, no controlled studies have been conducted to see if space flight produces increased susceptibility to infection. Indeed, controlled human studies of this type are extremely difficult to conduct.

Modern immunologists, using precise analytical tools such as molecular and cellular biology, have identified a broad range of functions for cells of the immune system. In addition to their more traditional role of guarding the body against infection or malignancy and monitoring of self tolerance, immune effector cells appear to play a vital role in regulating other homeostatic systems. For example, there is strong evidence of immune cell involvement in homeostasis of erythropoiesis and neuroendocrine function. Futhermore, because of their diversity, circulation throughout the body, and presence in the peripheral blood, immune effector cells provide a unique opportunity for monitoring systemic changes occurring in less accessible parts of the body. Space-related systemic changes which could be studied in this way include stress reactions, bone demineralization, cardiovascular deconditioning, and space adaptation syndrome. Because such investigations make it possible to study systemic effects of the cellular and molecular levels at the same time, they may prove to be much more sensitive than current clinical evaluation of serum or urine components. Increased research opportunities available on the Space Station will make it possible to expand immunological studies to include the involvement of immune effector cells in a variety of physiological systems, while continuing to explore the effects of space flight on more traditional "defense" functions.

## IMMUNOLOGY

I-1. Measure changes in delayed type hypersensitivity. _In vivo_ skin testing will be used to demonstrate changes in the ability of the crewmember to respond to primary and to recall antigens.

I-2. Determine if space flight produces functional impairment in the ability of the immune system to respond to specific challenges including: changes in leukocyte function (chemotaxis, adherence, and phagocytic abilities), bone marrow leukocyte production, and B- and T-lymphocyte response to mitogenic challenges.

I-3. Identify underlying mechanisms responsible for any observed space-flight-related changes in the immune system including: alterations in cell proliferation due to weightlessness _per se_, or other stresses via hormonal or cellular mediators.

I-4. Determine the nature of the effect of space flight on innate and acquired immunity including: characterization of the time course and magnitude of changes that occur in differential leukocyte counts and immunoglobulin concentrations.

I-5. Determine if the effects of space flight on the immune system are completely reversible upon return to 1-g, or if repeated space flight exposures will produce cumulative effects that might compromise crew health in space or after return to 1-g.

I-6. Determine ability to generate secondary responses after long-term exposure to 0-g.

## RATIONALE FOR METABOLIC REGULATION EXPERIMENTS

During space flight the body's metabolism, which has evolved under gravity, must adapt to weightlessness. Such adaptations, known as metabolic regulation, can be studied at the cellular as well as the organism level and entail consideration of the magnitude, efficiency, regulation, and control of energy regulation.

Metabolic regulation experiments have been divided into several areas: nutrition, cell biology, sleep and performance, and circadian rhythms. Nutrition research needs to be conducted to define and characterize cumulative effects of microgravity on basal metabolic rate, vitamin requirements, metabolic efficiency, taste, odor and flavor perception, appetite maintenance, intestinal microflora, and how these changes may affect crew health. Other related research includes identification of nutritional problems, potential application of fermentation of food wastes, study of water losses under varying work loads, and the influence of work on water balance.

Research in cell biology includes studies of the effect of microgravity on the energetics and metabolism of the organism at the cellular level. Research would determine if physiological changes seen in space are due to changes in cellular regulation of reception and transport.

Sleep, body temperature, circadian rhythms, and performance may be altered due to metabolic changes in space. Research would focus on the influence of microgravity on the onset of sleep and total sleep time. Investigation of circadian rhythms will determine microgravity's effects on circadian rhythms of various physiological systems. Research into temperature regulation will investigate the influence of microgravity on the regulation of body temperature and metabolism.

# METABOLIC REGULATION

## Nutrition

MR-N-1. Develop an understanding of how diets can be manipulated to provide nutritional countermeasures to flight-related physiological problems.

MR-N-2. Quantify water intake and losses in individuals under flight conditions with varying workloads.

MR-N-3. Determine basal metabolic rates and metabolic efficiency under extended space flight so that expendable supplies (food, water, oxygen) can be predicted better and efficiently supplied.

MR-N-4. Determine the quantitative need to provide vitamins and trace minerals through dietary manipulation or supplemental administration to correct for deficiencies resulting from microgravity exposure.

## Sleep/Performance

MR-SP-1. Determine the influence of microgravity on total sleep time and the distribution of sleep.

MR-SP-2. Determine possible effects of sleep deficits on crew performance, efficiency, and mental and physical health.

MR-SP-3. Determine if microgravity influences the latency of sleep onset, measured at different times of day (with and without sleep deprivation).

## Temperature Regulation

MR-TM-1. Study the influence of microgravity on the regulation of body temperature and metabolism.

MR-TM-2. Determine whether microgravity affects the influence of homeostatic stressors (i.e., exercise, ambient temperature, pyrogen) on body temperature regulation.

MR-TM-3. Determine the influence of microgravity on central or peripheral thermoreceptor gains or thresholds.

MR-TM-4. Investigate the effect of microgravity on body size (i.e., scaling) on physiological systems such as metabolism and body composition.

## METABOLIC REGULATION (CONTINUED)

### Cell Biology

MR-CB-1. Determine the role/effect of microgravity on the structure and function of organisms at the cellular level.

MR-CB-2. Determine the role/effect of microgravity on the energetics and metabolism of the organism at the cellular level.

MR-CB-3. Determine if physiological changes in space are due to changes in cellular regulation of receptors and transport.

MR-CB-4. Determine the role/effect of microgravity on growth and homeostasis of the organism at the cellular level.

### Circadian Rhythms

MR-CR-1. Determine if circadian rhythms of various physiological systems are influenced by microgravity (i.e., period, phase, mean, amplitude).

MR-CR-2. Determine the effect of microgravity on crew performance and adaptability to work schedules.

MR-CR-3. Determine if the timing influences of environmental synchronizers (temperature, light, gravity) are affected by microgravity. If so, where are these effects localized (i.e., on receptors or central controllers)?

MR-CR-4. Determine the role of microgravity adaptation on cross-adaptation to other aspects of flight, temperature, ambient pressure, etc.) of the environment?

## RATIONALE FOR MICROBIOLOGY EXPERIMENTS

The Space Transportation System (STS) program began a new era of reusable spacecraft. As this greatly enhanced the danger of buildup of microbes across missions, a microbial contamination control plan was implemented to assure a safe microbiological environment for crewmembers and to assess the buildup of microorganisms in the Orbiter. Cross-contamination among members of the same crew in such programs is highly probable, but this has not been demonstrated unequivocally. However, contamination of the spacecraft by microorganisms from crewmembers and contamination of crewmembers by bacteria from the spacecraft have been documented.

Epidemiological principles and previous space flight studies indicate a high probability of cross-contamination among crewmembers during long missions, such as the 90- and 180-day missions planned for Space Station. An individual's microflora are often maintained by internal and external environmental factors. Sudden, insidious changes in the balances existing among the microflora can have unpredictably deleterious effects. Thus, there is a need to study the microfloral changes of crewmembers involved in the missions.

## MICROBIOLOGY

MI-1. Determine if Space Station missions affect crew microflora.

MI-2. Establish the microbial distribution and accumulation levels in the Space Station.

MI-3. Determine alterations in biological characteristics of various microbial isolates, e.g., antibiotic susceptibilities.

## RATIONALE FOR MUSCLE PHYSIOLOGY EXPERIMENTS

In the absence of gravity during space flight, the skeletal muscles, especially those used for locomotion, maintaining posture, and counteracting gravity on earth, tend to atrophy. Manifestations of atrophy include reduction of muscle volume, mass, strength, exercise capacity, and neuromuscular coordination. Other flight studies, indicating marginal or negative balances of nitrogen or potassium, as well as persistent increase in urinary excretion of nitrogen, amino acids, and 3-methylhistidine, demonstrate increased protein turnover in the muscles of space crew.

Significant muscle changes in animals have been demonstrated even during short-term space flight and appear to progress rapidly with exposure duration, especially in the antigravity muscles. Although it is assumed that results of animal experiments on muscle atrophy can be extrapolated to humans, quantitative assessment of human muscle atrophy has been difficult, because of variability in exercise and dietary regimens of crewmembers from mission to mission, and even within missions. The present scarcity of data on the effects of long-duration space flight on human musculature complicates any reliable or extensive assessment.

Attempts to understand muscle atrophy and remedial countermeasures have relied principally on human and animal research using experimental hypokinesia, the ground-based analog of weightlessness. Abundant information exists regarding alterations in specific cellular components and processes, but there is as yet no unifying hypothesis to account for the mechanisms of muscle atrophy in space. Nor have effective methods of treatment been devised to prevent or curtail the process.

Although the muscle atrophy experienced during space flight has not compromised the health or performance of crewmembers, it remains a significant biomedical problem for which solutions are needed, since muscle deconditioning may be assumed to progress unabated as flight times increase. Plans for Space Station demand increased attention and research in this area.

## MUSCLE PHYSIOLOGY

M-1. Measure the loss of strength of the extremity and trunk muscles utilizing isometric, concentric, and eccentric techniques. (Human Studies)

M-2. Identify optimal efficient methods of maintaining strength by evaluating isometric, concentric, and eccentric exercise programs. (Human Studies)

M-3. Demonstrate that muscle atrophy and decreased strength are associated with changes in the electromyographic potentials recorded from the major extremity and trunk muscles during various daily activities. (Human Studies)

M-4. Determine the degree of atrophy in the extremity and trunk muscles by (Human Studies):

CT scanning*
NMR

M-5. Histochemical analysis to determine rate of change of muscle fiber area, fiber type, glycolytic/oxidative enzyme concentrations of individual fibers, and degree of capillarity. (Animal Studies)

M-6. Ultrastructural analysis of Z-line widths, Z-line registry, mitochondrial volumes, and neuromuscular junction morphology, cytoskeletal structure, and myotendinous/fibrochondral junctions. (Animal Studies)

M-7. Determine by continuous EMG monitoring dimunition in activity of atrophying muscle quantitatively. (Animal Studies)

M-8. Develop countermeasures with use of variable-g centrifuge. (Animal Studies)

M-9. Determine efficacy of tetanic muscle stimulation in preventing atrophy, and relate to bone atrophy. (Animal Studies)

M-10. Identify the reduction in power output in the major muscle groups of the upper and lower extremities. (Human Studies)

M-11. Determine the most efficient methods of maintaining muscle power (this is necessary to provide the power required for emergency situations - to be differentiated from endurance). (Human Studies)

* This technology may not be available to fly on Space Station at IOC.

## MUSCLE PHYSIOLOGY (CONTINUED)

M-12. Identify abnormalities at the neuromuscular junction (NMJ) by performing single fiber EMG and repetitive stimulation studies. This can be related to ultrastructural changes of the NMJ in the animal studies. (Human Studies)

M-13. Determine the functional status of peripheral and central axons by evaluating alterations in the evoked response (amplitude, duration, and area under the curve) in the peripheral nervous system and the central pathways (by somatosensory conduction). This would help determine if axonal blockade occurs during prolonged space flight. (Human Studies)

M-14. Determine how load/activity signals are transduced to biochemical agent(s) which regulate muscle protein synthesis (initiation elongation). Quantify agent concentration in atrophying muscle. (Animal Studies)

M-15. Assay for deficiency of paracrine/autocrine polypeptide growth factors, prostaglandins, and diacylglycerol and polyphosphoinositols as possible transduction agents. (Animal Studies)

M-16. Determine changes in rates of myofibrillar protein degradation via lysosomal proteolysis, $Ca^{2+}$ activated proteases, ATP dependent ubiquitin pathway, and cytosolic alkaline proteases. (Animal Studies)

## RATIONALE FOR NEUROSCIENCE EXPERIMENTS

Past neurovestibular research has centered around space motion sickness, which may include symptoms such as depressed appetite, malaise, lethargy, gastrointestinal discomfort, nausea, and vomiting. This syndrome affects crew performance and productivity on Shuttle missions of short duration. However, as mission length increases this becomes a proportionately smaller problem. Space Station will enable neuroscientists to focus on the more generalized effects of microgravity on the musculoskeletal system.

Evolution of the central nervous system has been shaped by the Earth's gravitational field. For example, the central nervous system "programs" control movements and position of body parts. Those "programs" sense the position of body parts with respect to each other and the Earth's gravitational field; they move the limbs and the head against gravity. However, when gravity is no longer present, such "programs" are no longer appropriate and must be modified to compensate. The degree to which neurophysiological systems are able to adapt to microgravity and the reversibility of that adaptation process on return to Earth are problems which require answers for long-duration manned space flight.

Research conducted on Space Station will be crucial to understanding intricacies of the central nervous system, beyond the relation of space motion sickness to vestibular function.

## NEUROSCIENCE

NS-1. Determine the time course of structural and neurosensory changes underlying adaptation to microgravity.

Parallel human and animal experiments relating human performance and reflex changes to animal behavioral, reflex, unit response, neurochemical and structural changes.

NS-2. Determine how adaptation to microgravity can be facilitated (e.g., fractional g, pharmacology, biobehavioral, mechanical, training).

NS-3. Determine the necessary conditions for provoking space motion sickness early during flight and after prolonged periods in space.

NS-4. Determine the time course of structural and neurosensory changes underlying readaptation to 1-g (e.g., determine cause(s) of postflight ataxia/motion sickness).

NS-5. Determine measures to prevent deleterious effects of exposure to microgravity.

NS-6. Determine how readaptation to 1-g can be facilitated (e.g., g-exposure prior to return, pharmacology, etc.).

NS-7. Determine how deleterious effects of exposure to 0-g can be prevented (e.g., fractional g, pharmacology, etc.).

NS-8. Determine what levels of g are required to maintain a normally functioning (vestibular) system.

NS-9. Identify if there are critical periods in the development of the vestibular system (i.e., are there deficits if the system develops in microgravity).

NS-10. Study the central nervous system metabolism as influenced by microgravity and fractional g.

NS-11. Study the central nervous system neurotransmitter system responses to microgravity and fractional g.

## RATIONALE FOR PHARMACODYNAMICS EXPERIMENTS

The biological effect of a given dosage of a drug under any given condition is a function of the intrinsic activity of the agent and its concentration at the site of action. The onset, intensity, and duration of the pharmacological and therapeutic response produced by drugs depend upon the processes of absorption, distribution, metabolism, and elimination. Physiological and biochemical changes that occur during space flight may influence the pharmacodynamics and therapeutics of medications administered to crewmembers. It would be desirable to identify and characterize the effect of altered physiological conditions during space flight (e.g., organ blood flow and fluid redistribution) on the pharmacodynamics and disposition of drugs. Such studies will become increasingly important with the advent of space station program and long-duration space flights. Clinical drug monitoring in space has been a relatively neglected aspect of space medicine. Space Station research needs to focus on development and testing of simple sample collection methods and establishment of clinical pharmacokinetic profiles to provide information for successful future space medical operations.

## PHARMACODYNAMICS

PH-1. Evaluate the pharmacokinetics and availability of select representative drugs susceptible to physiological alterations.

PH-2. Identify and estimate relevant physiological changes that influence the pharmacodynamics of drugs.

PH-3. Develop, test, and establish reliable, noninvasive methods for kinetic evaluation and clinical drug monitoring in space.

PH-4. Establish physiologically based pharmacokinetic models for representative drug types with different kinetic characteristics.

PH-5. Evaluate therapeutic effectiveness of drugs and identify alternate routes of administration when applicable.

# RATIONALE FOR PLANT PHYSIOLOGY EXPERIMENTS

Gravity plays an important role in the development of plants. When investigators grew plants on a clinostat, they noted profound changes in the life cycle of the plants. Clinostatted plants formed multiple stems instead of single stems, and the appearance of flowers, growth of seed pods, and maturation of seeds was delayed. Total seed weight and numbers of pods produced were lower than normal. Soviet scientists recently reported a similar delay and abnormal seed production in plants grown aboard Salyut. This data emphasizes the important relationship between gravity and life on Earth and opens new areas of inquiry into the nature of life.

Scientists investigating gravity phenomena in plants are trying to identify mechanisms organisms use to perceive gravity and transmit this information to a site capable of processing it. These mechanisms are important to gravity's control over the form, function, and behavior of organisms.

Spacelab 1 research showed some significant behavior by plants in a microgravity environment. Dwarf sunflower seedlings were studied to resolve a question about the peculiar circular growth movement of plants called nutation. As plants grow on earth, their tips describe a circle around a central axis. It is not clear whether this circular movement depends on gravity or some other environmental stimulus. Results from Spacelab 1 were dramatic: nutation proceeded in microgravity, suggesting the response was programmed into the genetic code of the plant.

When chromosomal studies of root tips were conducted on sunflower and oat seedlings grown on the Space Shuttle, several chromosomal abnormalities were found and cell division was significantly depressed. This shows that the influence of gravity may extend even into genetic mechanisms of a cell.

These preliminary investigations have already yielded important results. We have learned about the fundamental behavior of important plant species, and also how to grow and maintain plants in space for short periods of time. However, these studies need to be expanded. The Space Station will provide a first opportunity for the U.S. to study plant development in the microgravity and radiation environment of space for a duration at least equal to that of complete seed-to-seed life cycle. Research on plant growth both on earth and in space will apply directly to the future development of controlled ecological life support systems for long-duration manned space flight and planetary habitation.

## PLANT PHYSIOLOGY

PL-1. Determine the role of gravity in control of development at the whole plant, organ, and cellular levels, including the use of variable g to manipulate and understand the thresholds.

PL-2. Determine the role of gravity in regulating metabolic and cellular processes in plants.

PL-3. Determine mechanisms of gravity sensing and transduction of this information into tropic and nastic responses, including the use of variable g to manipulate and understand the thresholds.

PL-4. Demonstrate a normal, productive life cycle capability in plants as potential atmosphere cleaners and food producers in CELSS (Controlled Ecological Life Support System).

## RATIONALE FOR PULMONARY FUNCTION EXPERIMENTS

It is generally accepted that gravity causes regional differences of ventilation, blood flow, gas exchange, alveolar size, intrapleural pressure, and parenchymal stress. Tests conducted in the laboratory (tilt table) and in aircraft to acquire data on the distributions of pulmonary ventilation and perfusion during weightless periods of up to 27 seconds suggest a virtual elimination of the topographical inequality of ventilation, blood flow, and lung volume when subjects are exposed to short periods of zero gravity.

Also, alterations in the distribution of body fluids during weightlessness are expected to alter pulmonary function. These marked alterations may not be deleterious to the astronauts, but it is important to obtain more information for the longer duration missions.

Space Station research on pulmonary function will include longitudinal studies of physiological parameters and perhaps periodic clinical evaluations of personnel, especially crewmembers exposed to special atmospheres, as in repeated extravehicular activities (EVAs).

## PULMONARY PHYSIOLOGY

P-1. Extend the data expected from Spacelab experimentation to longer term habitation in space. Find out if the expected loss of heterogeneity in ventilation perfusion ratio remains as a constant change as a function of time in space.

P-2. Develop a physiological model of gas exchange as a function of time in space.

P-3. Assess the interrelationships between pulmonary function changes, changes in gas exchange, and other phenomena such as space adaptation syndrome and the presence of subclinical bubbles in the pulmonary blood supply.

RATIONALE FOR RADIATION EFFECTS EXPERIMENTS

The Space Station is expected to operate in a $28.5^{0}$ orbit at an altitude of 240 to 270 nmi, where the major source of radiation will be the inner, geomagnetically trapped proton belt (Inner Van Allen belt). Most radiation from the belt will be received as the station passes through the South Atlantic Anomaly (a region where, because of an anomaly in the earth's magnetic field, the inner belt swells at lower altitudes). Other sources of space radiation -- galactic cosmic radiation and radiation from solar particle events -- will contribute little to the dose because of deflection by the geomagnetic field.

The geomagnetic field protects against most radiation from solar particle events; less than one percent of the free space dose penetrates to a $28.5^{0}$ orbit. Nonetheless, some very rare but very intense solar particle events more than 2000 rad. have been recorded in free space. Therefore, potential contribution to the total dose from anomalously large solar particle events must also be considered.

At operating altitude, the few virtually unshieldable, cosmic heavy particles would contribute little to the overall dose, but these heavy-charged particles are so energetic they can produce a densely ionized track through the entire body with consequent dead and damaged cells. The biological consequences of such mini-lesions are poorly understood, but recent evidence suggests they can be very effective in inducing cancer.

Exact information is not available about the relative biological effectiveness (RBE) of types of radiation to which Space Station crews will be exposed. Research is needed to assess precisely such risks in terms of dose-equivalents.

Background radiation on Space Station will probably set limits on total mission time for human crewmembers and be an increasingly important variable for long-term developmental experiments with animals and plants. After determining RBEs, it will be critical to conduct accurate dosimetry on the Space Station to obtain the total dose and percent contribution from each kind of radiation (protons, neutrons, and heavy ions). These data will be used to determine the allowable exposures to radiation by the crew and to promote an assessment of possible biological effects on other species.

Future space missions (e.g., polar orbiting station, sorties to geosynchronous orbit, lunar base, Mars Mission) will likely involve greater radiation doses and/or increased exposure to galactic cosmic ray heavy ions. The Space Station offers an opportunity to study the responses of crewmembers and experimental organisms to long-term, low dose rate exposures to the complex space radiation environment, an environment which cannot be feasibly duplicated on earth. Understanding the effect of exposure to this environment will contribute to our ability to conduct future high orbit and interplanetary missions safely.

## RADIATION EFFECTS

RA-1. Evaluate radiation within space vehicles as a function of long duration in space, vehicle construction materials, radiation type, and orbital altitude to GEO.

RA-2. Determine the risks of cancer, cataract, and nonstochastic effects from space radiation.

RA-3. With an appropriate understanding of the above objective, devise countermeasures. If none, improve risk assessment.

RA-4. Develop a measurement refinement of the current "passive" dosimetry, to include not only total absorbed dose, but also information on the contribution of high-LET particles and LET spectra.

RA-5. Develop "real time" active measurements with adequate onboard read out in which the devices identify the types of radiation, measure their energy spectra (in particular the Z component and velocity), and determine dose and radiation quality with time.

# RATIONALE FOR REPRODUCTION AND DEVELOPMENT EXPERIMENTS

The Space Station will provide the first significant opportunity to conduct comprehensive studies of reproduction and development in space. This biological field is currently undergoing dramatic changes partially due to major new scientific findings within related fields, including: genetic engineering, immunology, gene expression, embryology, endocrinology, evolution, behavior, and the neurosciences.

On Space Station, it will be possible to conduct somatic (changes within a lifetime) and transgenerational studies during chronic exposure to the space flight environment and, therefore, obtain the first data on space-adapted animals. These studies preclude the use of human subjects so specimens will be selected according to those unique characteristics of a species that increase the likelihood of satisfying multiple science objectives. It has been proposed therefore that mammals, birds, amphibia, and insects be studied through complete "egg-to-egg" life cycles. Studies should include mating, gestation, and postnatal development. Some studies require g levels down to $10^{-5}$-g, which will require carefully controlled conditions, even on Space Station.

Fundamental insights into reproduction and development that will clarify the response of living systems to the earth's environment may be obtained from such studies. The results appear to be essential for planning long-term space colonization. Such studies will also provide specimen models and baseline data for for commercial biotechnology objectives.

## REPRODUCTION AND DEVELOPMENT

RD-1. Study complete mammalian life cycle in space flight to determine effects on development using space-generated ova and sperm. If development is affected, perform sequential analysis to diagnose and attempt to reverse the effect.

RD-2. Study complete avian life cycle using these bipedal organisms free of indirect maternal influence to evaluate development of bone, organogenesis, vestibular mechanisms, and behavior.

RD-3. Study complete amphibian life cycle using those specimens with known gravity-sensitive eggs and evaluate metamorphosis and direct development.

RD-4. Conduct multi-generation development studies on insects and other invertebrates with large numbers per generation and established genetic lines to evaluate muscle maturation, exoskeleton, mutations, embryo viability, and fecundity.

RD-5. Study gravitational thresholds of developmental mechanisms using onboard variable-g centrifuge. Define gravity sensing mechanisms and effective countermeasures for adverse effects of long duration microgravity.

RD-6. Study gravitational influences on maturation and aging and role in life cycle regulation. Mutogenesis and tumorogenesis may be special problems in this area.

RD-7. Study readaptation to 1-g after development in microgravity in various specimens.

RD-8. Study wound-healing and regeneration effects during long duration space flight in various specimens.

RD-9. Study plant development.

## SECTION 2.0

This section contains lists of representative or reference experiments that correspond to the science objectives for each of the disciplines discussed in Section 1. These experiments were derived from the "Blue Book" and the "Green Book" and have been examined for applicability to the objectives by members of the science community and by JSC and ARC science management. Every effort was made to ensure that experiments listed represent important research activities for the IOC time frame for Space Station (i.e., within the first three years of operation).

This section also lists experiment hardware required to conduct all representative experiments identified by the science objectives for each discipline. Each piece of hardware was evaluated for general applicability to experiments within each discipline. Although certain items are "experiment specific," most would be applicable to a majority of the potential experiments within that discipline and are identified as "Life Science generic." Not all equipment items are of equal priority or equal likelihood of availability.

Experiment and hardware lists, like the science objectives, will undergo change as the actual experiment selection process for Space Station science is developed and proposals are solicited.

REPRESENTATIVE EXPERIMENTS FOR IOC

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| Discipline: Behavior and Performance Research | | |
| 1. Psychosocial support for extended space missions | B-1, 2 | Blue Bk |
| 2. Group interaction, compatibility, effectiveness | B-2 | Blue Bk |
| 3. Group problem solving evaluation and training | B-1, 2 | Blue Bk |

PROJECT EQUIPMENT LIST FOR IOC

| | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| <u>Discipline: Behavior and Performance</u> | | | | |
| Computer terminal | X | | X | |
| Video camera | | X | X | |
| Microphone | | X | X | |
| Video recorder | X | | X | |
| Video tapes | | X | X | |

REPRESENTATIVE EXPERIMENTS FOR IOC

| | | OBJECTIVE CODE | SOURCE |
|---|---|---|---|
| **Discipline: Calcium Homeostasis** | | | |
| 1. | Metabolic balance for calcium and other bone-related constituents | C-1, 3, 4 | Blue Bk |
| 2. | Bone density measurements | C-1, 2, 5 | Blue Bk |
| 3. | Measure of renal stone risk factors | C-3 | Blue Bk |
| 4. | Histopathogenesis of bone loss in microgravity | C-1 | Green Bk |
| 5. | Sex differences as a factor in bone loss from different skeletal sites | C-2 | Green Bk |
| 6. | Calcium absorption and homeostasis in microgravity | C-1 | Green Bk |
| 7. | Effect of microgravity on skeletal growth | C-1, 2, 6, 10 | Green Bk |
| 8. | Relationship between bone formation and bone resorption defects in microgravity | C-1, 2, 5, 6, 9, 10 | Green Bk |
| 9. | Effect of microgravity on bone cell growth: isolation of bone growth factor | C-17, 18 | Green Bk |

PROJECT EQUIPMENT LIST FOR IOC

| | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| <u>Discipline: Calcium Homeostasis</u> | | | | |
| Animal perfusion kit | | X | X | |
| Dynamic environment monitor system | X | | X | |
| 24-hr feces collection system | | X | X | |
| 24-hr urine collection system | | X | X | |
| Urine sample vials | | X | X | |
| Feces sample vials | | X | X | |
| Freeze-dryer | X | | X | |
| Bone densitometer | X | | X | |
| Passive dosimeter for operator | | X | X | |
| Urine slide preparation kit | | X | X | |
| Digital microscope | X | | X | |
| Osmometer | | X | | |
| G-control centrifuge | X | | X | |
| Rodent development module* | X | | X | |
| Incubator | X | | X | |
| Rhesus monkey habitat* | X | | X | |
| Rodent habitat module | | X | X | |
| Gamma counter | | X | X | |
| Liquid scintillation counter* | X | | X | |
| Small mass measurement device | X | | X | |
| X-ray equipment* | | X | X | |
| Bone mineral analyzer | | X | X | |
| Nonradioactive tracer kit* | | X | X | |
| Bone biopsy instruments | | X | X | |
| Fixation kit | | X | X | |
| Guillotine (rodent) | | X | X | |
| Hematology kit | | X | X | |
| Muscle biopsy instruments | | X | X | |
| Radioactive tracer kit* | | X | X | |
| Surgery/dissection kit | | X | X | |
| Veterinary kit | | X | X | |
| Refrigerated centrifuge | X | | X | |
| Freezer (-70$^{o}$C) | X | | X | |
| Freezer (-20$^{o}$C) | X | | X | |
| Multi-purpose work bench | X | | X | |
| Refrigerator (4$^{o}$C) | X | | X | |
| Cage cleaner | X | | X | |
| Rhesus monkey food* | | X | X | |
| Rhesus monkey water* | | X | X | |
| Rodent food | | X | X | |
| Rodent water | | X | X | |
| Hand wash facility | | | X | |
| Trash compactor | | | X | |
| CAT scanner* | | | | X |
| Biotelemetry system | X | | X | |
| Rhesus restraint* | X | | X | |
| Biotelemetry system | X | | X | |

* These items represent post-IOC growth scenarios or technologies that may not be ready at IOC.

## REPRESENTATIVE EXPERIMENTS FOR IOC

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| <u>Discipline: Cardiovascular System</u> | | |
| 1. Full assessment of the hemodynamic alteration | CS-1 | Blue Bk |
| 2. Dysrhythmia assessment | CS-4 | Blue Bk |
| 3. Effect of space flight on cardiovascular control in Rhesus monkey | | Green Bk |
| a. Neuroendocrine response with determination of regional blood flow | CS-1 | Green Bk |
| b. Hemodynamic responses to volume changes | CS-2 | Green Bk |
| c. Central and regional hemodynamic responses to adrenergenic stimulation and blockage | CS-2 | Green Bk |
| d. Cardiac and coronary response with and without chronotrophic stimulation | CS-2 | Green Bk |
| e. Comprehensive cardiac and peripheral vascular assessment | CS-2 | Green Bk |

## PROJECT EQUIPMENT LIST FOR IOC

| Discipline: Cardiovascular System | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| Freezer | X | | X | |
| 24-hr urine collection system | | X | | X |
| Refrigerated centrifuge | X | | X | |
| Body mass measuring device | X | | X | |
| Multi-purpose work bench | X | | X | |
| Lower body negative pressure device | X | | | X |
| Environmental monitor | | X | X | |
| Ultrasound imaging system | X | | | X |
| Multichannel strip chart recorder | X | | X | |
| Centrifugal hematology system | X | | | X |
| Display video monitor | X | | X | |
| Medical emergency life support kit | X | | X | |
| Urine sample vials | | X | | |
| Strip chart recorder paper | | X | | |
| Rhesus monkey habitat* | X | | X | |
| Blood gas analyzer | | X | X | |
| Blood pressure and flow equipment | | X | X | |
| Cardiac output equipment | | X | X | |
| Electrolyte analyzer | | X | X | |
| Gamma counter | | X | X | |
| Gas chromatograph | | | X | |
| Hematocrit centrifuge | X | | X | |
| Hematology analyzer | | X | X | |
| Implanted biotelemetry* | | | X | (X) |
| Compound microscope | | X | X | |
| Microtome | | X | X | |
| Cassette data recorder | | X | X | |
| Sonomicrometer | | X | X | |
| Biomedical recorder | X | | X | |
| Hematology kit | | X | X | |
| Histology kit | | X | X | |
| Muscle biopsy instruments | | X | X | |
| Radioactive tracer kit | | X | X | |
| Surgery/dissection kit | | X | X | |
| Veterinary kit | | X | X | |
| Laboratory centrifuge | X | | X | |
| Refrigerated centrifuge | X | | X | |
| Freezer (-70$^{o}$C) | X | | X | |
| Refrigerator (4$^{o}$C) | X | | X | |
| CAT scanner* | | | | |
| Mass spectrometer* | | X | | |
| Intravenous fluids* | | X | | |
| Biotelemetry system | X | | | |
| Rhesus restraint* | X | | | |
| Fluid infusion system* | | X | | |
| Experiment control computer | X | | | |
| Oscilloscope | X | | | |

* These items represent post-IOC growth scenarios or technologies that may not be ready at IOC.

PROJECT EQUIPMENT LIST FOR IOC

| | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| Discipline: Cardiovascular System (Cont'd) | | | | |
| Fixation kit | | X | X | |
| Video camera, recorder, supplies | | X | X | |
| Autoclave | X | | X | |
| Cage cleaner | X | | X | |
| Hand wash facility | X | | X | |
| Trash compactor | X | | X | |
| Rhesus monkey food* | | X | X | |
| Rhesus monkey water* | | X | X | |
| Dynamic environmental monitoring system | X | | X | |

* These items represent post-IOC growth scenarios or technologies that may not be ready at IOC.

REPRESENTATIVE EXPERIMENTS FOR IOC

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| Discipline: Endocrinology/Fluid Electrolytes | | |
| 1. Measurement of venous pressure and plasma volume early and long-duration effects of weightlessness | EN-1 | Blue Bk |
| 2. Circadian rhythm of plasma hormones and serum electrolytes during weightlessness | EN-2 | Blue Bk |
| 3. Effect of long-term space flight on hormonal regulation of fluid and electrolyte balance in rats | EN-1 | Green Bk |

PROJECT EQUIPMENT LIST FOR IOC

| Discipline: Endocrinology/ Fluid Electrolyte | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| Venous pressure disposables | | X | | |
| Venous pressure transducer | | X | | X |
| Venous pressure recorder display | | X | | X |
| Evans blue dye injection kit | | X | | |
| Blood collection reusables | | X | | X |
| Blood collection tubes | | X | | |
| Blood collection disposables | | X | | |
| Standard lab centrifuge | X | | X | |
| Spectrophotometer | | X | | X |
| Heparin lock kit | | X | | |
| Freezer | X | | X | |
| 24-hr urine collection system | | X | | X |
| Urine sample vials | | X | | |
| G-control centrifuge | X | | X | |
| Rodent habitat module | X | | X | |
| Rodent metabolic module* | X | | X | |
| Fixation kit | | X | X | |
| Guillotine | | X | X | |
| Hematology kit | | X | X | |
| Laboratory centrifuge | X | | X | |
| Freezer (-20$^{o}$C) | X | | X | |
| Multi-purpose work bench | X | | X | |
| Cage cleaner | X | | X | |
| Hand wash facility | X | | X | |
| Trash compactor | X | | X | |
| Rodent food | | X | X | |
| Rodent water | | X | X | |
| Veterinary kit | | X | X | |
| Fluid handling kit | | X | X | |
| Dynamic environment monitoring system | X | | X | |
| Experiment control computer | X | | X | |
| Surgery/dissection kit | | X | X | |

* These items represent post-IOC growth scenarios or technologies that may not be ready at IOC.

REPRESENTATIVE EXPERIMENTS FOR IOC

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| Discipline: Exercise Physiology | | |
| 1. Muscle adaptation and readaptation | EXP-1, 2 | Blue Bk |
| 2. Exercise program for space flight with the HMF | EXP-5 | Blue Bk |

PROJECT EQUIPMENT LIST FOR IOC

| | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| Discipline: Exercise Physiology** | | | | |
| Isokinetic measurement device | X | | | X |
| Surface EMG | | X | | X |
| EMG electrode kit | | X | | |
| Nerve conduction velocity tester | | X | | X |
| Nerve electrode kit | | X | | X |
| HRF terminal | X | | X | |
| Anaerobic exercise device | X | | X | |
| Treadmill | X | | X | |
| Bicycle ergometer | X | | X | |
| Versaclimber | X | | X | |
| Rowing machine | X | | X | |
| Heart rate monitor | X | | X | |

** All resources are cross utilized between HMF.

REPRESENTATIVE EXPERIMENTS FOR IOC

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| **Discipline: Hematology** | | |
| 1. Determine sequential change in red cell mass erythropoietin, reticulocytes, and ferritin | H-1 | Blue Bk |
| 2. Determine role of splenic sequestration on disease in the red cell mass | H-3 | Blue Bk |

PROJECT EQUIPMENT LIST FOR IOC

| | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| Discipline: Hematology | | | | |
| Red cell mass reagent kit | | X | | X |
| Blood collection reusables | | X | | X |
| Blood collection tubes | | X | | |
| Blood collection disposables | | X | | |
| Scintillation counter* | X | | | X |
| Reticulocyte smear kit | | X | | X |
| Digital microscope | X | | X | |
| Heparin lock kit | | X | | |
| Standard lab centrifuge | X | | X | |
| Fe59 isotope kit* | | X | | X |
| Cation exchange resin kit | | X | | X |
| Body mass measuring device | X | | X | |
| Evans blue dye injection kit | | X | | |
| Spectrophotometer | | X | X | |
| Red blood cell counter | X | | | X |
| Bicycle ergometer | X | | X | |
| Small mass measurement devices | X | | X | |
| Multi-purpose work bench | X | | X | |
| Hand washer | X | | X | |
| Trash compactor | X | | X | |
| Data system/experiment control computer | X | | X | |
| Refrigerator | X | | X | |
| Freezer | X | | X | |
| Refrigerated laboratory centrifuge | X | | X | |
| Hematology kit | | X | X | |
| Hematocrit centrifuge | X | | X | |
| Hematology analyzer | | X | X | |
| Blood gas analyzer | X | | X | |
| Fluid handling kit | | X | X | |

* These items represent post-IOC growth scenarios or technologies that may not be ready at IOC.

REPRESENTATIVE EXPERIMENTS FOR IOC

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| Discipline: Immunology | | |
| 1. Delayed type hypersensitivity | I-1 | Blue Bk |
| 2. Blast transformation/protein production | I-2 | Blue Bk |
| 3. Phenotyping of peripherally circulating blood cells | I-2 | Blue Bk |
| 4. Effect of space flight on susceptibility to bacterial and viral infections on return to earth | I-2 | Green Bk |
| 5. Effect of space flight on immune response to vaccines | I-2 | Green Bk |
| 6. Effect of space flight on immune response; mitogen response of leukocytes postflight | I-2 | Green Bk |

PROJECT EQUIPMENT LIST FOR IOC

| | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| <u>Discipline: Immunology</u> | | | | |
| Digital microscope | X | | X | |
| Inflight digitizer | X | | X | |
| Standard lab centrifuge | X | | X | |
| Radioisotopes* | | X | | X |
| Sample preparation device (fluid transfer) | | X | | X |
| Incubator | X | | X | |
| Contamination container | X | | X | |
| Flow cytometer | X | | X | |
| Blood collection disposables | | X | | |
| Blood collection reusables | | X | | X |
| Blood collection tubes | | X | | |
| Rodent habitat module | X | | X | |
| Cage cleaner | X | | X | |
| Hand wash facility | X | | X | |
| Rodent food | | X | X | |
| Rodent water | | X | X | |
| Radioactivity counter* | | X | | |
| G-control centrifuge | X | | X | X |

* These items represent post-IOC growth scenarios or technologies that may not be ready at IOC.

## REPRESENTATIVE EXPERIMENTS FOR IOC

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| **Discipline: Metabolic Regulation (Cell Biology)** | | |
| 1. Exocrine function and protein secretion in salivary glands as influenced by microgravity | MR-CB-1, 4 | Green Bk |
| 2. Mechanism of cellular receptor changes seen in microgravity as reflected by associated physiological changes | MR-CB-2 | Green Bk |
| 3. Energy utilization in eukaryotic and prokaryotic cells in microgravity | MR-CB-3 | Green Bk |

PROJECT EQUIPMENT LIST FOR IOC

| | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| <u>Discipline: Metabolic Regulation (Cell Biology)</u> | | | | |
| Rodent habitat module | X | | X | |
| Fluid handling kit | | X | X | |
| Guillotine | | X | X | |
| Surgery/dissection kit | | X | X | |
| Centrifuge, laboratory | X | | X | |
| Freezer (-70°C) | X | | X | |
| Freezer, cryo (-196°C) | X | | X | |
| Multi-purpose work bench | X | | X | |
| Cage cleaner | X | | X | |
| Hand wash facility | X | | X | |
| Trash compactor | X | | X | |
| Rodent restraint | | X | X | |
| Rodent food | | X | X | |
| Rodent water | | X | X | |
| Cell counter | | X | X | |
| Cell culture apparatus | X | | X | |
| Micro ultra centrifuge | X | | X | (X) |
| Glucose analyzer | | X | X | |
| Cell culture plate reader | | X | X | (X) |
| Small mass measurement device | X | | X | |
| Micro mass measurement device | X | | X | |
| Veterinary kit | | X | X | |
| G-control centrifuge | | X | X | |

REPRESENTATIVE EXPERIMENTS FOR IOC

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| Discipline: Microbiology | | |
| 1. Crewmember and space station microbial study | MI-1 | Blue Bk |

PROJECT EQUIPMENT LIST FOR IOC

| | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| Discipline: Microbiology | | | | |
| Reuter centrifugal sampler | | X | | X |
| D-sized batteries | | X | | |
| Trypticase soy agar strips | | X | | X |
| Incubator | X | | X | |
| Low power microscope | X | | X | |
| Photomicrographic set-up | | X | | X |
| Refrigerator ($4^{o}$C) | X | | X | |
| Sample swabs and sample tubes | | X | | X |
| Agar plates | | X | | X |
| Sterile loops | | X | | X |
| Millipore filters | | X | | X |
| Millipore filtration kit | | X | | X |

## REPRESENTATIVE EXPERIMENTS FOR IOC

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| **Discipline: Muscle Physiology** | | |
| 1. Measurement of inflight neuromuscular activity | M-1 | Blue Bk |
| 2. Measurement of neuromuscular potential output during flight | M-1, 3 | Blue Bk |
| 3. Determination of neuromuscular fatigability of muscles during flight | M-1, 3 | Blue Bk |
| 4. Muscle loss in rats in microgravity (histology-histochemistry) | M-5, 7 | Green Bk |
| 5. Muscle loss in rats in microgravity (electron microscope ultrastructure) | M-6 | Green Bk |
| 6. Muscle loss in rats in microgravity (electron microscope contractile properties) | M-7 | Green Bk |
| 7. Muscle loss in rats in microgravity (biochemistry) | M-8 | Green Bk |

PROJECT EQUIPMENT LIST FOR IOC

| | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| <u>Discipline: Muscle Physiology</u> | | | | |
| Surface EMG | | X | | X |
| EMG electrode kit | | X | | X |
| Force measurement device | | X | | X |
| Isokinetic measuring device | X | | | X |
| Goniometer and recorder | | X | | X |
| Accelerometer and recorder | | X | | X |
| Blood collection reusables | | X | | X |
| Blood collection tubes | | X | | |
| Blood collection disposables | | X | | |
| G-control centrifuge | X | | X | |
| Rodent habitat module | X | | X | |
| Implanted biotelemetry | (X) | | X | |
| Micro mass measure | X | | X | |
| Small mass measure | X | | X | |
| Biotelemetry system | X | | X | |
| Fixation kit | | X | X | |
| Muscle biopsy instruments | | X | X | |
| Animal perfusion kit | | X | X | |
| Freezer (-20$^{o}$C) | X | | X | |
| Freezer (-70$^{o}$C) | X | | X | |
| Freezer, cryo (-196$^{o}$C) | X | | X | |
| Multi-purpose work bench | X | | X | |
| Refrigerator (4$^{o}$C) | X | | X | |
| Experiment control computer | X | | X | |
| Freeze-dryer | X | | X | |
| Rodent food | | X | X | |
| Rodent water | | X | X | |
| Guillotine | | | X | |
| Handwash facility | | | X | |
| Cage cleaner | | | X | |
| Biomedical recorder | | | X | |
| Force transductor | | | | X |
| Muscle electro stimulator | | | | X |
| Veterinary kit | | X | X | |
| Surgery/dissection kit | | X | X | |
| Dynamic environmental monitoring kit | X | | X | |

REPRESENTATIVE EXPERIMENTS FOR IOC

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| Discipline: Neurosciences | | |
| 1. Vestibulo-visual and canalicular-otolith compensation | NS-1, 4 | Blue Bk |
| 2. SMS correlates | NS-3 | Blue Bk |
| 3. Study of structural changes in the vestibular labyrinth of rats in microgravity | NS-1 | Green Bk |
| 4. Determination of the nature and potential consequences of structural changes in central reflex vestibular pathways due to microgravity | NS-1 | Green Bk |
| 5. Determination of the effect of adaptation to microgravity on vestibular nerve activity | NS-1 | Green Bk |

PROJECT EQUIPMENT LIST FOR IOC

| | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| <u>Discipline: Neurosciences</u> | | | | |
| Rotator | X | | | X |
| Helmet assembly | | X | | X |
| Helmet interface box | | X | | X |
| Head restraint | | X | | X |
| EOG signal conditioner | | X | | X |
| SAS electrode kit | | X | | X |
| Computer for stimulus control | | X | | X |
| Recording minioscilloscope | | X | X | |
| Electrode impedance meter | | X | | X |
| Experiment control and display system | | X | | X |
| G-control centrifuge | X | | X | |
| Variable-g centrifuge (13') | X | | X | |
| Vestibular research facility | X | | X | |
| Rodent habitat module | X | | X | |
| Fixation kit | | X | X | |
| Guillotine | | X | X | |
| Surgery/dissection kit | | X | X | |
| Freezer (-20$^{\circ}$C) | X | | X | |
| Multi-purpose work bench | X | | X | |
| Cage cleaner | X | | X | |
| Hand wash facility | X | | X | |
| Trash compactor | X | | X | |
| Rodent food | | X | X | |
| Rodent water | | X | X | |
| Experiment control computer/data system | X | | X | |

## REPRESENTATIVE EXPERIMENTS FOR IOC

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| Discipline: Pharmacodynamics | | |
| 1. Drug pharmacokinetics in space and evaluation of modern noninvasive methods for clinical drug monitoring | PH-1, 2 | Blue Bk |

PROJECT EQUIPMENT LIST FOR IOC

| | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| <u>Discipline: Pharmacodynamics</u> | | | | |
| Blood collection reusables | | X | | X |
| Drug consumables kit | | X | | |
| Blood collection tubes | | X | | |
| Blood collection disposables | | X | | |
| Standard lab centrifuge | X | | X | |
| Freezer | X | | X | |
| Saliva collection unit | | X | | X |
| 24 hr urine collection system | | X | | X |
| Urine sample vials | | X | | |

REPRESENTATIVE EXPERIMENTS FOR IOC

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| Discipline: Plant Physiology/CELSS | | |
| 1. Optimization of plant nutrient and water supply systems | PL-1, 2 | Green Bk |
| 2. Optimization of plant support and orientation mechanisms for microgravity use | PL-1, 2 | Green Bk |
| 3. Role of microgravity in control of development at the organ and cellular level | PL-1, 2 | Green Bk |
| 4. Effect of microgravity on amyloplasts | PL-2, 3 | Green Bk |

BIOLOGICAL RESEARCH PROJECT EQUIPMENT LIST FOR IOC

| | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| Discipline: Plant Physiology/CELSS | | | | |
| G-control centrifuge (small) | X | | X | |
| Variable-g centrifuge (13') | X | | X | |
| Plant growth module | X | | X | |
| Plant habitat | X | | X | |
| Microscope, dissecting | | X | X | |
| Fixation kit | | X | X | |
| Plant harvesting kit | | X | X | |
| Seed planting kit | | X | X | |
| Surgery/dissection kit | | X | X | |
| Cryo freezer (-196$^{o}$C) | X | | X | |
| Multi-purpose work bench | X | | X | |
| Experiment control computer | X | | X | |
| Video camera, recorder, supplies | | X | X | |
| Autoclave | X | | X | |
| Hand wash facility | X | | X | |
| Trash compactor | X | | X | |
| Plant gas supplies | | X | X | |
| Plant nutrient supply | | X | X | |
| Media | | X | X | |
| Cell culture apparatus | X | | X | |
| Freezer (-20$^{o}$C) | X | | X | |
| Dynamic environment monitoring system | X | | X | |

## REPRESENTATIVE EXPERIMENTS FOR IOC

**Discipline: Pulmonary Physiology**

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| 1. Capability to study inert gas exchange as a function of time in space | P-1 | Blue Bk |
| 2. Evaluation of EVA work output and cardiovascular deconditioning | P-3 | Blue Bk |
| 3. Capability to evaluate EVA - bubble formation | P-3 | Blue Bk |
| 4. Measurement of standard pulmonary function | P-1 | Blue Bk |

PROJECT EQUIPMENT LIST FOR IOC

| | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| <u>Discipline: Pulmonary Physiology</u> | | | | |
| Gas analyzer/mass spectrometer | X | | X | |
| Cardiopulmonary analyzer flowmeter | X | | | X |
| Gas tanks/gas supplies | | X | | |
| Mask/regulator system | | X | | X |
| Body mass measuring device | X | | X | |
| Doppler recorder | X | | | X |
| Doppler expendables | | X | | |
| Blood collection reusables | | X | | X |
| Blood collection disposables | | X | | X |
| Blood collection tubes | | X | | |
| Standard lab centrifuge | X | | X | |
| Freezer | X | | X | |
| Bag-in-box | X | | | X |
| Electronics control assembly | X | | | X |
| Gas cylinder assembly | X | | | X |
| Alfe stowage kit | | X | | X |
| 31 calibration syringe | | X | | X |
| Personal rebreathing assembly | X | | | X |
| Spare $O_2$ experiment bag assembly | | X | | X |
| Spirometry assembly | | X | | X |
| Multichannel strip chart recorder | X | | X | |
| Physiological monitoring system | | X | X | |
| PMS accessories | | X | | |
| SCR paper | | X | | |
| Data tapes | | X | | |
| Batteries | | X | | |

REPRESENTATIVE EXPERIMENTS FOR IOC

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| Discipline: Radiation Effects | | |
| 1. Chromosomal aberration study | RA-2 | Blue Bk |
| 2. Dosimetry for all life sciences subjects | RA-4, 5 | Blue Bk |
| 3. Space dosimetry | RA-1 | Green Bk |
| 4. Effects of space radiation on hair follicles | RA-2 | Green Bk |
| 5. Effect of space radiation on spermatogenesis and intestinal villi | RA-2 | Green Bk |
| 6. Effect of space radiation on hematopoietic stem cells | RA-2 | Green Bk |
| 7. Alteration in length and number of synapses in CA-1 area of the hippocampus | RA-4 | Green Bk |
| 8. The response of the lungs to cosmic radiation | RA-2 | Green Bk |
| 9. Effect of space radiation on the retina | RA-2 | Green Bk |
| 10. Possible cataract formation/hazard during space flight | RA-2 | Green Bk |
| 11. Radiation damage to stem cells | RA-2 | Green Bk |

PROJECT EQUIPMENT LIST FOR IOC

| | RACK | STOWED | LS GENERIC | EXPERIMENT SPECIFIC |
|---|---|---|---|---|
| Discipline: Radiation Effects | | | | |
| Microdosimetric dosimeter | | X | | X |
| Proton and heavy ion spectrometer | | X | | X |
| TLD | | X | | X |
| TLD reader | X | | | X |
| Blood collection reusables | | X | | X |
| Blood collection disposables | | X | | |
| Blood collection tubes | | X | | |
| Standard lab centrifuge | X | | X | |
| Phycol and PBS consumables kits | | X | | |
| Cell handling accessories | | X | | X |
| Incubator (5% $CO_2$, 37$^{o}$C) | X | | X | |
| Chromosal slide prep device | | X | | X |
| Digital microscope | X | | X | |
| Microdosimetric dosimeter | | X | | X |
| Proton and heavy ion spectrometer | | X | | X |
| G-control centrifuge | X | | X | |
| Rhesus monkey habitat* | X | | X | |
| Rodent habitat module | X | | X | |
| BIOSTACK radiation detector | X | | X | |
| Radiation dosimeter (active) | | X | X | |
| Cage cleaner | X | | X | |
| Hand wash facility | X | | X | |
| Rhesus monkey food* | | X | X | |
| Rhesus monkey water* | | X | X | |
| Rodent food | | X | X | |
| Rodent water | | X | X | |
| Radiation dosimeter (passive) | | X | X | |
| Variable-G centrifuge (13') | | | | |
| Trash compactor | X | | X | |
| Dynamic environment monitoring system | X | | X | |
| Multi-purpose work bench | X | | X | |

* These items represent post-IOC growth scenarios or technologies that may not be ready at IOC.

# SECTION 3.0

This section presents the assumptions for outfitting the Life Sciences payload and mission scenarios. Next, experiment titles for each mission are listed according to discipline. Crew times are provided for each scenario on a week-by-week basis. The section concludes with the payload equipment list for Space Station. Specifications cited for each piece of equipment include depth, width, height, mass, and power; codes are included which identify the associated discipline.

## ASSUMPTIONS FOR OUTFITTING LIFE SCIENCES PAYLOAD

1. The initial operating configuration (IOC) will be phased and the station will be manned.

2. The research at IOC will emphasize support of "man in space."

3. A common set of science objectives will be developed and updated (i.e., the interim report "Red Book").

4. The investigations will be clearly tied to the objectives.

5. Human and animal research will be complementary. Basic research will also be conducted.

6. Each Center will develop experiment protocols (defined in the JSC "Blue Book" and ARC "Green Book").

7. Human and nonhuman research facilities are to be shared equally with respect to volume and crew time.

8. The logistics module and science module will be serviced every 90 days. Equipment changeout will be minimal in the IOC phase of Space Station 4 -- probably no more than 10% to 15% replacement every 90 days.

9. Six crewmembers will be on board the Space Station. One will be a life scientist devoting one half of his available time per day. The remaining crewmembers will each be available one-half day per week. This will yield 800 hours of crew time available for Life Sciences Research.

ASSUMPTIONS FOR OUTFITTING
LIFE SCIENCES PAYLOAD (CONTINUED)

10. Bioisolation for plants and animals will be at the habitat level.

11. The cost approximation will be $50K per kilogram (developed and flown).

## MISSION A SCENARIO

### ASSUMPTIONS FOR THE BIOLOGICAL RESEARCH PROJECT

- 6 Rhesus monkeys in the habitats
- All fluid samples returned to Earth for analysis

### ASSUMPTIONS FOR THE HUMAN RESEARCH PROJECT

- 6 crewmembers on Space Station; one will be a life scientist devoting one half of his available time per day
- Remaining 5 crewmembers will each be available one-half day per week
- Cross-utilization with exercise equipment on HMF

LIFE SCIENCES SPACE STATION
MISSION SCENARIO A

| | | OBJECTIVE CODE | SOURCE |
|---|---|---|---|
| I. | CALCIUM HOMESTASIS | | |
| | Longitudinal metabolic balance for calcium and other bone related constitutents | C-1,3,4 | Blue |
| | Bone density measurements | C-1,2,5 | Blue |
| | Measure of renal stone risk factors | C-3 | Blue |
| | Histopathogenesis of bone loss in microgravity | C-1 | Green |
| | Sex differences as a factor in bone loss from different skeletal sites | C-2 | Green |
| | Calcium absorption and homeostasis in microgravity | C-1 | Green |
| | Muscle adaptation and readaptation | EX-1,2 | Blue |
| | Measure of inflight neuromuscular activity | MS-1 | Blue |
| | Neuromuscular fatigability and metabolic potential of muscles | MS-1,3 | Blue |
| II. | CARDIOVASCULAR, PULMONARY, ENDOCRINOLOGY/ FLUID ELECTROLYTES | | |
| | Full assessment of the hemodynamic alteration | CS-1 | Blue |
| | Dysrhthymia assessment | CS-4 | Blue |
| | Effect of space flight on cardiovascular control in Rhesus monkey | CS-1 | Green |
| | 1. Neuroendocrine response with determination of regional blood flow | CS-1 | Green |
| | 2. Hemodynamic responses to volume changes | CS-2 | Green |
| | 3. Central and regional hemodynamic responses to adrenergenic stimulation and blockage | CS-2 | Green |
| | 4. Cardiac and coronary response with and without chronotrophic stimulation | CS-2 | Green |
| | 5. Comprehensive cardiac and peripheral vascular assessment | CS-2 | Green |

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| **II. CARDIOVASCULAR, PULMONARY, ENDOCRINOLOGY /FLUID ELECTROLYTES (Continued)** | | |
| Exercise program for space flight | EX-5 | Blue |
| Measurement of venous pressure and plasma volume early and long-duration effects of weightlessness | EN-1 | Blue |
| Circadian rhythm of plasma hormones and serum electrolytes during weightlessness | EN-2 | Blue |
| Capability to study inert gas exchange as function of time in space | P-1 | Blue |
| EVA work output and cardiovascular | P-3 | Blue |
| Measure of standard pulmonary function | P-1 | Blue |
| **III. RADIATION EFFECTS** | | |
| Space dosimetry | RA-1 | Green |
| Effect of space radiation on the retina | RA-2 | Green |
| Possible cataract formation/hazard during space flight | RA-2 | Green |
| Effect of space radiation on hair follicles | RA-2 | Green |
| Radiation damage to stem cells | RA-2 | Green |

## MISSION B SCENARIO

ASSUMPTIONS FOR THE BIOLOGICAL RESEARCH PROJECT

- 36 rats and 30 plants in the 12 habitats
- 24 rats and 20 plants in the 8 habitats on the centrifuge
- 6 test rats and 3 centrifuge rats sacrificed at 30, 60, and 90 days
  Blood serum, bones, muscle tissue, and relevant organs either frozen or preserved
  One hour of astronaut time for each rat sacrificed
- Plants collected at appropriate intervals
  One-half hour of astronaut time for each plant
- All samples returned to earth for analysis

ASSUMPTIONS FOR THE HUMAN RESEARCH PROJECT

- 6 crewmembers on Space Station; one will be a life scientist devoting one half of his available time per day
- Remaining 5 crewmembers will each be available one-half day per week
- Cross utilization with exercise equipment on HMF

LIFE SCIENCES SPACE STATION
MISSION SCENARIO B

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| **I. NEUROSCIENCES, BEHAVIOR, PHARMACOKINETICS** | | |
| Psychosocial support | B | Blue |
| Problem solving | B | Blue |
| Group interaction, compatibility and effectiveness | B | Blue |
| Vestibulo-visual and canalicular-otolith compensation | N-1,4 | Blue |
| SMS correlates | N-3 | Blue |
| Study of structural changes in the vestibular labyrinth of the rats in microgravity | NS-1 | Green |
| Determine the nature and potential consequences of structural changes in central reflex vestibular pathways due to microgravity | NS-1 | Green |
| Effect of adaptation to microgravity on vestibular nerve activity | NS-1 | Green |
| Drug pharmacokinetics in space and evaluation of modern noninvasive methods for clinical drug monitoring | Ph-1,2 | Blue |
| **II. BLOOD ALTERATIONS, RADIATION** | | |
| Chromosomal aberrations (radiation) | Ra-2 | Blue |
| Dosimetry for all Life Sciences subjects | Ra-4,5 | Blue |
| Space dosimetry | Ra-1 | Green |
| Effects of space radiation on hair follicles | Ra-2 | Green |
| Effect of space radiation on spermatogenesis and intestinal villi | Ra-2 | Green |
| Effect of space radiation on hematopoietic stem cells | Ra-2 | Green |
| Alteration in length and number of synapses in the CA-1 area of the hippocampus | Ra-4 | Green |

LIFE SCIENCES SPACE STATION
MISSION SCENARIO B

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| **II. BLOOD ALTERATIONS, RADIATION (Continued)** | | |
| The response of the lungs to cosmic radiation | Ra-2 | Green |
| Determine sequential change in red cell mass, erythropoietin, reticulocytes, and ferritin | Ra-4,5 | Blue |
| Determine role of splenic sequestration on disease in the red cell mass | | Blue |
| Delayed type hypersensitivity | | Blue |
| Cellular immune response, sequestration, and activation | | Blue |
| Effect of space flight on susceptibility to bacterial and viral infections on return to earth | I-2 | Green |
| Effect of space flight on immune response to vaccines | I-2 | Green |
| Effect of space flight on immune response; mitogen response of leukocytes postflight | I-2 | Green |
| **III. MICROBIOLOGY, METABOLIC REGULATION** | | |
| Crewmember and space station microbial study | MI-1 | Blue |
| Exocrine function and protein secretion in salivary glands as influenced by microgravity | MR-CB-1,4 | Green |
| Mechanism of cellular receptor changes seen in microgravity as reflected by associated physiological changes | MR-CB-2 | Green |
| Energy utilization in eukaryotic and prokaryotic cells in microgravity | MR-CB-3 | Green |

LIFE SCIENCES SPACE STATION
MISSION SCENARIO B

| | OBJECTIVE CODE | SOURCE |
|---|---|---|
| IV. PLANTS (CELSS) | | |
| Optimization of plant nutrient and water supply systems* | PL-1,2 | Green |
| Optimization of plant support and orientation mechanisms for microgravity use* | PL-1,2 | Green |
| Role of microgravity in control of development at the organ and cellular level | PL-1,2 | Green |
| Effect of microgravity on amyloplasts | PL-2,3 | Green |
| V. CALCIUM HOMEOSTASIS | | |
| Effect of microgravity on skeletal growth | C-1,2,6,10 | Green |
| Relationship between bone formation and bone resorption defects in microgravity | C-1,2,5,6,9, 10 | Green |
| Effect of microgravity on bone cell growth: isolation of bone growth factor | C-17,18 | Green |
| VI. MUSCLE PHYSIOLOGY | | |
| Muscle loss in rats in microgravity (histology-histochemistry) | M-5,7 | Green |
| Muscle loss in rats in microgravity (electron microscope ultrastructure) | M-6 | Green |
| Muscle loss in rats in microgravity (electron microscope contractile properties) | M-7 | Green |
| Muscle loss in rats in microgravity (biochemistry) | M-8 | Green |
| VII. ENDOCRINOLOGY/FLUID ELECTROLYTES | | |
| Effect of long-term space flight on hormonal regulation of fluid and electrolyte balance in rats | EN-1 | Green |

* These experiments will also be identified under the CELSS description.

PROJECTED CREW TIME
(hours per week)

MISSION A

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CALCIUM<br>MUSCLE<br>EXERCISE | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 | 27 |
| CARDIOVASCULAR | 25 | 17 | 29 | 21 | 16 | 30 | 33 | 21 | 16 | 17 | 29 | 17 | 30 |
| PULMONARY<br>NEUROSCIENCE<br>BEHAVIOR | 9 | | | | 9 | | | | 9 | | | | 9 |
| RADIOBIOLOGY | 3 | | | | | 1 | | | | | | 1 | 1 |
| HEMATOLOGY<br>IMMUNOLOGY | | | | | | | | | | | | | |
| MICROBIOLOGY | | | | | | | | | | | | | |
| PLANT*<br>METABOLISM<br>SERVICING/<br>HOUSEKEEPING | 22 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 22 |

*Times for plant experiments included in housekeeping

Times are listed (unless specified) for discipline groupings

PROJECTED CREW TIME
(hours per week)

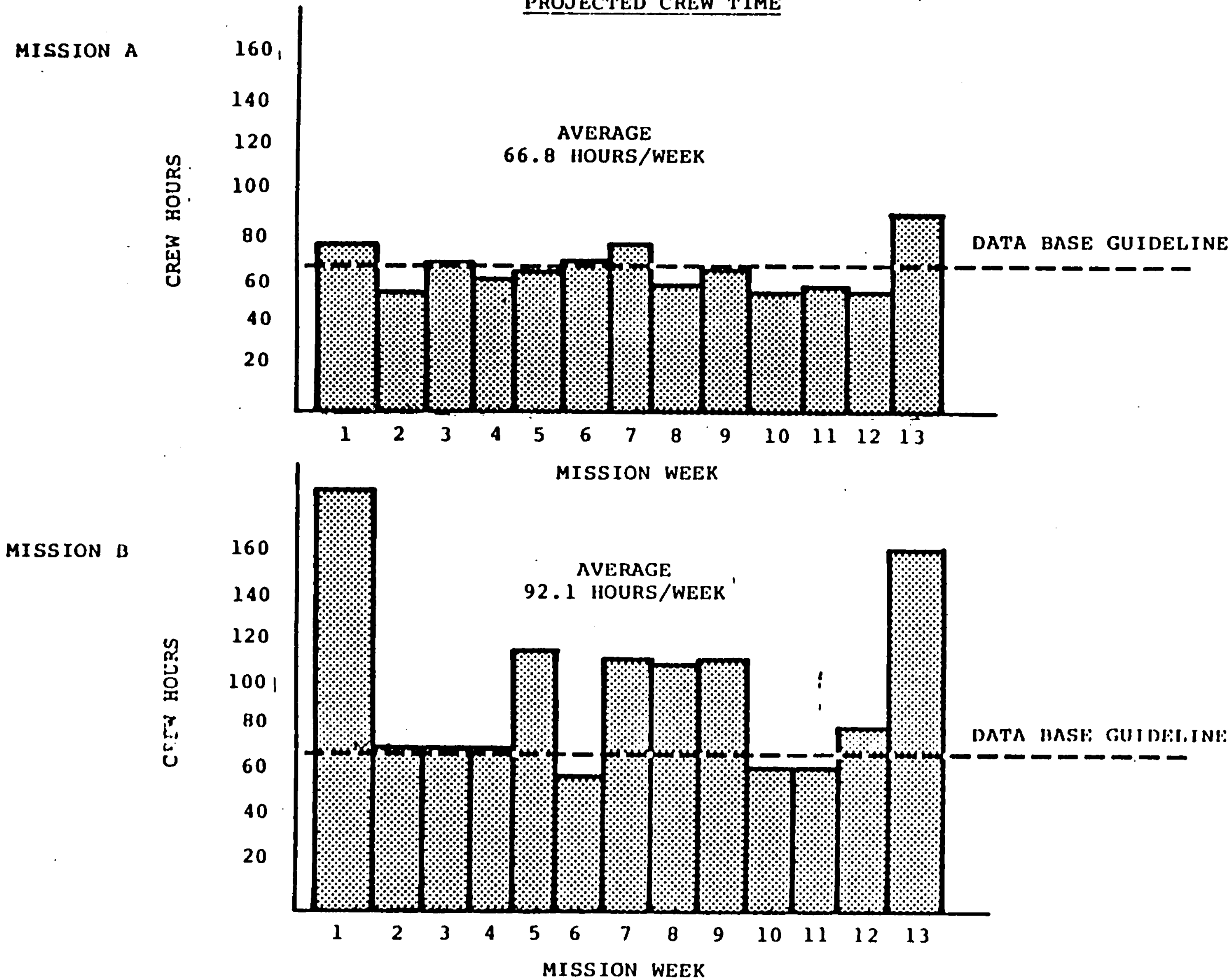
MISSION B

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CALCIUM MUSCLE EXERCISE | 13 | 19 | 19 | 19 | 19 | 7 | 40 | 52 | 19 | 7 | 7 | 19 | 49 |
| CARDIOVASCULAR PULMONARY NEUROSCIENCE BEHAVIOR | 111 | 10 | 10 | 10 | 46 | 10 | 10 | 10 | 46 | 10 | 10 | 10 | 46 |
| RADIOBIOLOGY HEMATOLOGY IMMUNOLOGY | 30 | 22 | 22 | 22 | 29 | 22 | 22 | 22 | 29 | 22 | 22 | 27 | 30 |
| MICROBIOLOGY | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| PLANT | 6 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 6 |
| METABOLISM | | | | | | | | | | | | | |
| SERVICING/ HOUSEKEEPING | 22 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 22 |

Times are listed (unless specified) for discipline groupings

LIFE SCIENCES SPACE STATION PAYLOAD

PROJECTED CREW TIME



LIFE SCIENCES SPACE STATION PROGRAM

# PRELIMINARY PAYLOAD EQUIPMENT LIST

# FOR

# SPACE STATION INITIAL OPERATING CONFIGURATION

AS OF:

APRIL 21, 1986

PREPARED BY:

AMES RESEARCH CENTER

AND

LYNDON B. JOHNSON SPACE CENTER

• REFERENCE DOCUMENT -- FOR PLANNING PURPOSES ONLY •

**Source (SOR)** NASA field installation providing requirements and equipment planning data

| | |
|---|---|
| A | Recommended Ames Research Center specific equipment requirements for non-human research. |
| C | Recommendation for common equipment to be used by multiple users. |
| J | Recommended Lyndon B. Johnson Space Center specific equipment requirements for human research. |

**MNT** Method of equipment mounting or storage within Space Station

| | |
|---|---|
| RE | Rack mounted experiment specific equipment |
| RG | Rack mounted general types of equipment that is more universal |
| RGC | Rack mounted general types of equipment that is common to most users |
| SE | Stowed experiment specific item that is not generated into trash |
| SG | Stowed general use item that is not generated into trash |
| SS | Stowed item that requires replacement |

**A/C** Equipment Candidates For Automation (Y = Recommended / N = Not Recommended)

*1 Upper case letter indicates the Ames Research Center as the data source
*2 Lower case letter indicates the Lyndon B. Johnson Space Center as the data source

| DISCIPLINE CODE | REPRESENTATIVE EXPERIMENTS *1 & 2 | DISCIPLINE TITLE |
|---|---|---|
| A | a,b,c | Calcium Homeostasis |
| B | d,e | Cardiovascular System |
| C | f,g,h | Muscle Physiology |
| D | i,j | Radiation Effects |
| E | k,l | Exercise Physiology |
| F | m,n | Endocrinology / Fluid Electrolytes |
| G | o,p,q | Behavioral Research |
| H | r,s | Hematology |
| I | t,u1,u2 | Immunology |
| J | v,w,x | Neuroscience |
| K | y,z | Pharmacokinetics |
| L | aa,ab,ac,ad,ah | Pulmonary Physiology |
| M | ai,aj | Microbioloby |

| EXPERIMENT Code | SOR | EXPERIMENT TITLE |
|---|---|---|
| ●●●●●●●●●●●● | ●●● | ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●● |

•1 Upper case letter indicates the Ames Research Center as the data source
•2 Lower case letter indicates the Lyndon B. Johnson Space Center as the data source

| Code | SOR | Experiment Title |
|---|---|---|
| a | J | Metabolic Balance For Calcium And OtherBone Related Constituents |
| b | J | Bone Density Measurements |
| c | J | Measurement Of Renal Stone Risk Factor |
| d | J | Full Assessment Of The Hemodynamic Alteration |
| e | J | Dysrhythmia Assessment |
| f | J | Measurement Of Inflight Neuromuscular Activity |
| g | J | Measurement Of Neuromuscular Potential Output |
| h | J | Neuromuscular Fatigability And Metabolic Potential Of Muscles During Space FLight |
| i | J | Chromosomal Abberation Study |
| j | J | Dosimetry For All Life Sciences Subjects |
| k | J | Muscle Adaptation And Readaptation |
| l | J | Exercise Program For Space Flight |
| m | J | Measurement Of Venous Pressure And Plasma Volume Early And Long-duration Effects Of Weightlessness |
| n/n | J | Circadian Rhythm Of Plasma Hormones And Serum Electrolytes During Weightlessness |
| o | J | Psychosocial Support |
| p | J | Group Interaction, Compatibility, Effectiveness |
| q | J | Group Problem-solving Evaluation And Training |

| EXPERIMENT Code | SOR | EXPERIMENT TITLE |
|---|---|---|
| ●●●●●●●●●●●● | ●●● | ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●● |

*1 Upper case letter indicates the Ames Research Center as the data source
*2 Lower case letter indicates the Lyndon B. Johnson Space Center as the data source

| | | |
|---|---|---|
| r | J | Determine Sequential Change In Red Cell Mass Erythropoieten, Reticlocytes, And Ferritin |
| s | J | Determine Role Of Splenic Sequestration On Disease In The Red Cell Mass |
| t | J | Delayed Type Hypersensitivity |
| u1 | J | Blast Transformation/Protein Production |
| u2 | J | Phenotyping Of Peripherally Circulating Blood Cells |
| v | J | Vestibulovisual Compensation |
| w | J | Canalicularotolith Compensation |
| x | J | SMS Correlates |
| y | J | Drug Pharmacokinetics In Space |
| z | J | Evaluation Of Modern Non-invasive Methods For ClinicalDrug Monitoring |
| aa | J | Capability To Study Inert Gas Exchange As A Function Of Time In Space |
| ab | J | Evaluate EVA Work Output |
| ac | J | Evaluate Cardiovascular Response |
| ad | J | Capability To Evaluate EVA Bubble Formation |
| ah | J | Measure Of Standard Pulmonary Function |
| ai | J | Crewmember Microbial Study |
| aj | J | Space Station Microbial Study |

PRELIMINARY PAYLOAD EQUIPMENT LIST FOR IOC (SECTION 1.0 MASTER EQUIPMENT LISTING) • AS OF APRIL 21, 1986 Prepared by ARC / JSC

| EQUIPMENT NAME | SOR | DISCIPLINE CODES | A/C | MNT | QTY Reqd | PAYLOAD TOTALS VOL cu m | MASS kg | POWER watts | ITEM CHARACTERISTICS DEPTH m | WIDTH m | HEIGHT m | MASS kg | POWER watts |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bio Specimen Holding Facility | A | | Y | RE | 4 | 3.840 | 600.00 | 1000.00 | 0.800 | 0.500 | 2.400 | 150.00 | 250.00 |
| Biostack Radiation Detector | A | | N | S | 1 | 0.008 | 5.00 | 0.00 | 0.200 | 0.200 | 0.200 | 5.00 | 0.00 |
| Biotelemetry System | A | | Y | RE | 2 | 0.060 | 60.00 | 100.00 | 0.300 | 0.500 | 0.200 | 30.00 | 50.00 |
| Blood Gas Analyzer | A | | Y | RE | 1 | 0.125 | 45.00 | 250.00 | 0.500 | 0.500 | 0.500 | 45.00 | 250.00 |
| Blood Pressure & Flow Instr. | A | | Y | RE | 1 | 0.030 | 10.00 | 50.00 | 0.300 | 0.500 | 0.200 | 10.00 | 50.00 |
| Cage Cleaning System | A | | Y | RE | 1 | 0.320 | 100.00 | 500.00 | 0.800 | 0.500 | 0.800 | 100.00 | 500.00 |
| Camera, 35 mm | A | | N | S | 1 | 0.010 | 1.50 | 0.00 | 0.200 | 0.200 | 0.250 | 1.50 | 0.00 |
| Camera, Polaroid | A | | N | S | 1 | 0.002 | 1.00 | 0.00 | 0.100 | 0.150 | 0.150 | 1.00 | 0.00 |
| Cardiac Output Instrumentation | A | | Y | RE | 1 | 0.080 | 10.00 | 75.80 | 0.400 | 0.500 | 0.400 | 10.00 | 75.80 |
| Centrifuge (6ft/VRF) | A | | N | RE | 1 | 3.840 | 250.00 | 100.00 | 0.800 | 2.000 | 2.400 | 250.00 | 100.00 |
| Centrifuge, Hematocrit | A | | N | S | 1 | 0.001 | 1.00 | 0.00 | 0.200 | 0.100 | 0.050 | 1.00 | 0.00 |
| Centrifuge, Refrigerated | C | B | Y | RGC | 1 | 0.200 | 40.00 | 450.00 | 0.800 | 0.500 | 0.500 | 40.00 | 450.00 |
| Centrifuge, Standard Lab | C | B,D,F,H,I,K,L | Y | RGC | 1 | 0.090 | 30.00 | 350.00 | 0.600 | 0.500 | 0.300 | 30.00 | 350.00 |
| Data System | C | | N | RGC | 1 | 0.320 | 40.00 | 200.00 | 0.800 | 0.500 | 0.800 | 40.00 | 200.00 |
| Dosimeter, Passive, Operator | C | A | Y | RGC | 1 | 0.090 | 5.00 | 0.00 | 0.600 | 0.500 | 0.300 | 5.00 | 0.00 |
| Dynamic Environl Meas. System | C | | Y | RGC | 1 | 0.075 | 40.00 | 20.00 | 0.500 | 0.500 | 0.300 | 40.00 | 20.00 |
| Film | A | | N | S | 5 | 0.125 | 10.00 | 0.00 | 0.500 | 0.500 | 0.100 | 2.00 | 0.00 |
| Fixation Kit/12 rats | A | | N | S | 2 | 0.240 | 40.00 | 0.00 | 0.600 | 0.500 | 0.400 | 20.00 | 0.00 |
| Fluid Handling Kit | A | | N | S | 1 | 0.016 | 5.00 | 0.00 | 0.400 | 0.200 | 0.200 | 5.00 | 0.00 |
| Freezer (-70°C, 30 liter) | A | | N | RE | 2 | 0.300 | 200.00 | 600.00 | 0.600 | 0.500 | 0.500 | 100.00 | 300.00 |
| Freezer, Cryogenic (-196°C) | C | | Y | RGC | 1 | 0.090 | 20.00 | 0.00 | 0.600 | 0.500 | 0.300 | 20.00 | 0.00 |
| Gas Chromatograph | A | | Y | RE | 1 | 0.200 | 25.00 | 100.00 | 0.800 | 0.500 | 0.500 | 25.00 | 100.00 |
| General Purpose Work Station | C | B | N | RGC | 1 | 1.920 | 350.00 | 500.00 | 0.800 | 1.000 | 2.400 | 350.00 | 500.00 |
| Guillotine | A | | N | S | 1 | 0.012 | 2.00 | 0.00 | 0.200 | 0.400 | 0.150 | 2.00 | 0.00 |
| Habitat, Plant | A | | Y | RE | 3 | 0.000 | 90.00 | 0.00 | | | | 30.00 | 0.00 |
| Habitat, Rat | A | | Y | RE | 6 | 0.000 | 180.00 | 0.00 | | | | 30.00 | 0.00 |
| Habitat, Squirrel Monkey | A | | Y | RE | 3 | 0.000 | 90.00 | 0.00 | | | | 30.00 | 0.00 |
| Hand Wash Facility | C | | N | RGC | 1 | 0.320 | 100.00 | 375.00 | 0.800 | 0.500 | 0.800 | 100.00 | 375.00 |
| Hematology Analyzer | A | | Y | RE | 1 | 0.075 | 20.00 | 150.00 | 0.500 | 0.500 | 0.300 | 20.00 | 150.00 |
| Hematology Kit/12 rats | A | | N | S | 3 | 0.072 | 30.00 | 0.00 | 0.400 | 0.200 | 0.300 | 10.00 | 0.00 |
| Histology Kit/12 rats | A | | N | S | 3 | 0.108 | 30.00 | 0.00 | 0.300 | 0.400 | 0.300 | 10.00 | 0.00 |
| Lab Centrifuge Head | A | | N | S | 1 | 0.009 | 5.00 | 0.00 | 0.300 | 0.300 | 0.100 | 5.00 | 0.00 |
| Mass Meas. Device, Micro | C | | Y | RGC | 1 | 0.075 | 15.00 | 15.00 | 0.500 | 0.500 | 0.300 | 15.00 | 15.00 |
| Mass Meas. Device, Small | C | A | Y | RGC | 1 | 0.075 | 15.00 | 15.00 | 0.500 | 0.500 | 0.300 | 15.00 | 15.00 |
| Mass Measure Calibration Kit | A | | N | S | 1 | 0.002 | 2.00 | 0.00 | 0.200 | 0.100 | 0.100 | 2.00 | 0.00 |

PRELIMINARY PAYLOAD EQUIPMENT LIST FOR IOC (SECTION 1.0 MASTER EQUIPMENT LISTING) • AS OF APRIL 21, 1986 Prepared by ARC / JSC

| EQUIPMENT NAME | SOR | DISCIPLINE CODES | A/C | MNT | QTY Reqd | PAYLOAD TOTALS VOL cu m | MASS kg | POWER volts | ITEM CHARACTERISTICS DEPTH m | WIDTH m | HEIGHT m | MASS kg | POWER volts |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mass Spectrometer | A | | Y | RE | 1 | 0.075 | 40.00 | 150.00 | 0.500 | 0.500 | 0.300 | 40.00 | 150.00 |
| Meter, pH/Specific Ion | A | | N | S | 1 | 0.008 | 3.00 | 5.00 | 0.200 | 0.200 | 0.200 | 3.00 | 5.00 |
| Microscope Video Interface | A | | N | S | 1 | 0.005 | 22.00 | 0.00 | 0.200 | 0.150 | 0.150 | 22.00 | 0.00 |
| Microscope, Compound | A | | N | S | 1 | 0.072 | 13.00 | 30.00 | 0.600 | 0.200 | 0.600 | 13.00 | 30.00 |
| Microscope, Digital | C | A,D,H,I | Y | RGC | 1 | 0.120 | 35.00 | 500.00 | 0.600 | 0.500 | 0.400 | 35.00 | 500.00 |
| Microscope, Dissecting | A | | N | S | 1 | 0.060 | 10.00 | 30.00 | 0.600 | 0.200 | 0.500 | 10.00 | 30.00 |
| Oscilloscope | C | | N | RGC | 1 | 0.030 | 14.00 | 100.00 | 0.300 | 0.500 | 0.200 | 14.00 | 100.00 |
| Plant Harvesting Kit | A | | N | S | 1 | 0.016 | 5.00 | 0.00 | 0.400 | 0.200 | 0.200 | 5.00 | 0.00 |
| Refrigerator (4°C, 30 liter) | A | | N | RE | 2 | 0.300 | 200.00 | 400.00 | 0.600 | 0.500 | 0.500 | 100.00 | 200.00 |
| SCR, Multichannel | C | B,L | N | RGC | 1 | 0.090 | 30.00 | 150.00 | 0.600 | 0.500 | 0.300 | 30.00 | 150.00 |
| Seed Planting Kit | A | | N | S | 1 | 0.016 | 5.00 | 0.00 | 0.400 | 0.200 | 0.200 | 5.00 | 0.00 |
| Spectrophotometer (UV/Vis) | A | | Y | RE | 1 | 0.090 | 40.00 | 300.00 | 0.600 | 0.500 | 0.300 | 40.00 | 300.00 |
| Surgery/Dissecting Kit | A | | N | S | 1 | 0.032 | 5.00 | 0.00 | 0.400 | 0.400 | 0.200 | 5.00 | 0.00 |
| Surgical Gloves, Box of 50 | A | | N | S | 10 | 0.015 | 1.00 | 0.00 | 0.100 | 0.150 | 0.100 | 0.10 | 0.00 |
| Surgical Gowns, Box of 25 | A | | N | S | 10 | 0.113 | 30.00 | 0.00 | 0.150 | 0.500 | 0.150 | 3.00 | 0.00 |
| Surgical Masks, Box of 25 | A | | N | S | 10 | 0.015 | 1.00 | 0.00 | 0.100 | 0.100 | 0.150 | 0.10 | 0.00 |
| Trash Compactor | C | | Y | RGC | 1 | 0.200 | 30.00 | 250.00 | 0.800 | 0.500 | 0.500 | 30.00 | 250.00 |
| Veterinary Kit/12 rats | A | | N | S | 2 | 0.032 | 10.00 | 0.00 | 0.400 | 0.200 | 0.200 | 5.00 | 0.00 |
| Veterinary Kit/3 Monkeys | A | | N | S | 1 | 0.016 | 5.00 | 0.00 | 0.400 | 0.200 | 0.200 | 5.00 | 0.00 |
| Video Cassettes, Box of 20 | A | | N | S | 5 | 0.188 | 25.00 | 0.00 | 0.500 | 0.500 | 0.150 | 5.00 | 0.00 |
| Video System | A | | N | RE | 4 | 0.600 | 180.00 | 600.00 | 0.600 | 0.500 | 0.500 | 45.00 | 150.00 |
| Wipes, Dry, Box | A | | N | S | 20 | 0.015 | 2.00 | 0.00 | 0.150 | 0.100 | 0.050 | 0.10 | 0.00 |
| Wipes, Wet, Box | A | | N | S | 20 | 0.030 | 2.00 | 0.00 | 0.150 | 0.100 | 0.100 | 0.10 | 0.00 |
| A L F E Stowage Kit | J | L | N | SE | 1 | 0.015 | 2.00 | 0.00 | 0.249 | 0.249 | 0.249 | 2.00 | 0.00 |
| Accelerometer and Recorder | J | C | Y | SE | 1 | 0.025 | 16.06 | 35.00 | 0.356 | 0.483 | 0.143 | 16.06 | 35.00 |
| Agar Plates | J | M | N | SE | 1116 | 0.103 | 50.62 | 0.00 | 0.076 | 0.076 | 0.016 | 0.05 | 0.00 |
| Bag Assembly, Expmt 02, Spare | J | L | N | SE | 1 | 0.004 | 2.99 | 0.00 | 0.432 | 0.102 | 0.102 | 2.99 | 0.00 |
| Bag-in-box | J | L | N | RE | 1 | 0.090 | 15.88 | 0.00 | 0.610 | 0.425 | 0.349 | 15.88 | 0.00 |
| Batteries | J | L | N | SS | 48 | 0.002 | 10.08 | 0.00 | 0.025 | 0.025 | 0.051 | 0.23 | 0.00 |
| Batteries, D-Cell | J | M | N | SS | 48 | 0.002 | 10.88 | 0.00 | 0.025 | 0.025 | 0.051 | 0.23 | 0.00 |
| Blood Collection Disposables | J | C,D,F,H,I,K,L | N | SS | 2160 | 0.027 | 122.45 | 0.00 | 0.013 | 0.013 | 0.076 | 0.06 | 0.00 |
| Blood Collection Reusables | J | C,D,F,H,I,K,L | N | SE | 1 | 0.028 | 1.36 | 0.00 | 0.305 | 0.305 | 0.305 | 1.36 | 0.00 |
| Calibration Syringe, 3 Liter | J | L | N | SE | 1 | 0.023 | 2.99 | 0.00 | 0.579 | 0.201 | 0.201 | 2.99 | 0.00 |
| Camera, Video | J | G | Y | SG | 1 | 0.003 | 2.00 | 50.00 | 0.305 | 0.076 | 0.114 | 2.00 | 50.00 |
| Cation Exchange Resin Kit | J | H | N | SE | 36 | 0.021 | 4.90 | 0.00 | 0.102 | 0.076 | 0.076 | 0.14 | 0.00 |

PRELIMINARY PAYLOAD EQUIPMENT LIST FOR IOC (SECTION 1.0 MASTER EQUIPMENT LISTING) • AS OF APRIL 21, 1986 • Prepared by ARC / JSC

| EQUIPMENT NAME | SOR | DISCIPLINE CODES | A/C | MNT | QTY Reqd | PAYLOAD TOTALS VOL cu m | PAYLOAD TOTALS MASS kg | POWER watts | ITEM CHARACTERISTICS DEPTH m | WIDTH m | HEIGHT m | MASS kg | POWER watts |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cell Handling Accessories | J | D | N | SE | 156 | 0.070 | 106.14 | 0.00 | 0.152 | 0.102 | 0.029 | 0.68 | 0.00 |
| Centrifugal Hematology System | J | B | Y | RE | 1 | 0.018 | 22.68 | 200.00 | 0.229 | 0.229 | 0.311 | 22.68 | 200.00 |
| Computer, Stimulus Control | J | J | Y | SE | 1 | 0.033 | 14.97 | 80.00 | 0.424 | 0.434 | 0.178 | 14.97 | 80.00 |
| Container, Contamination | J | I | N | RG | 1 | 0.243 | 54.43 | 0.00 | 0.762 | 0.483 | 0.660 | 54.43 | 0.00 |
| Counter, Red Blood Cell | J | H | Y | RE | 1 | 0.034 | 45.36 | 50.00 | 0.537 | 0.483 | 0.133 | 45.36 | 50.00 |
| Counter, Scintillation | J | H | Y | RE | 1 | 1.255 | 181.44 | 500.00 | 1.829 | 0.711 | 0.965 | 181.44 | 500.00 |
| Densitometer, Bone | J | A | Y | RE | 1 | 0.257 | 136.08 | 300.00 | 0.599 | 0.483 | 0.889 | 136.08 | 300.00 |
| Digitizer, Inflight | C | I | N | RGC | 1 | 0.179 | 11.33 | 500.00 | 0.609 | 0.483 | 0.609 | 11.33 | 500.00 |
| Display, Venous Press Recorder | J | F | N | SE | 1 | 0.004 | 2.27 | 25.00 | 0.305 | 0.051 | 0.229 | 2.27 | 25.00 |
| Display, Video Monitor | J | B | N | RG | 1 | 0.029 | 6.80 | 50.00 | 0.660 | 0.483 | 0.090 | 6.80 | 50.00 |
| Doppler Expendables | J | L | N | SE | 1 | 0.002 | 0.91 | 0.00 | 0.152 | 0.102 | 0.102 | 0.91 | 0.00 |
| Dosimeter, Microdosimetric | J | D | Y | SE | 1 | 0.015 | 54.43 | 0.00 | 0.076 | 0.483 | 0.400 | 54.43 | 0.00 |
| Drug Consumables Kit | J | K | N | SS | 1 | 0.002 | 0.00 | 0.00 | 0.102 | 0.102 | 0.152 | 0.00 | 0.00 |
| E M G, Surface | J | C,E | N | SE | 1 | 0.016 | 18.14 | 20.00 | 0.514 | 0.483 | 0.063 | 18.14 | 20.00 |
| Electrode Kit, E M G | J | C,E | N | SE | 180 | 0.017 | 12.14 | 0.00 | 0.203 | 0.076 | 0.006 | 0.07 | 0.00 |
| Electrode Kit, Nerve | J | E | N | SE | 180 | 0.017 | 13.60 | 0.00 | 0.203 | 0.076 | 0.006 | 0.08 | 0.00 |
| Electrode Kit, S A S | J | J | N | SE | 156 | 0.014 | 11.80 | 0.00 | 0.203 | 0.076 | 0.006 | 0.08 | 0.00 |
| Electronics Control Assembly | J | L | N | RE | 1 | 0.015 | 15.88 | 80.00 | 0.100 | 0.425 | 0.267 | 15.88 | 80.00 |
| Ergometer, Bicycle | J | E,H | N | RG | 1 | 0.120 | 13.61 | 10.00 | 0.400 | 0.500 | 0.599 | 13.61 | 10.00 |
| Evans Blue Dye Injection Kit | J | F,H | N | SS | 324 | 0.064 | 26.12 | 0.00 | 0.051 | 0.051 | 0.076 | 0.08 | 0.00 |
| Exercise Device, Anaerobic | J | E | N | RG | 1 | 0.165 | 21.46 | 105.00 | 0.762 | 0.610 | 0.356 | 21.46 | 105.00 |
| Expmt Control and Displays Sys. | J | J | N | SE | 1 | 0.062 | 11.34 | 120.00 | 0.508 | 0.483 | 0.254 | 11.34 | 120.00 |
| Feces Collection System, 24 Hr | J | A | Y | SS | 1 | 0.120 | 18.14 | 50.00 | 0.495 | 0.508 | 0.476 | 18.14 | 50.00 |
| Filter Kit, Millipore | J | M | N | SE | 1 | 0.028 | 0.23 | 0.00 | 0.305 | 0.305 | 0.305 | 0.23 | 0.00 |
| Filters, Millipore | J | M | N | SE | 72 | 0.003 | 0.32 | 0.00 | 0.076 | 0.076 | 0.006 | 0.00 | 0.00 |
| Flow Cytometer | J | I | Y | RE | 1 | 1.000 | 136.08 | 500.00 | 0.914 | 0.483 | 2.266 | 136.08 | 500.00 |
| Flowmeter, Cardiopul Analyzer | J | L | Y | RE | 1 | 0.268 | 42.00 | 9.00 | 0.584 | 0.483 | 0.950 | 42.00 | 9.00 |
| Force Measurement Device | J | C | Y | SE | 1 | 0.028 | 0.45 | 10.00 | 0.305 | 0.305 | 0.305 | 0.45 | 10.00 |
| Freeze Dryer | J | A | Y | RE | 1 | 0.067 | 19.34 | 140.00 | 0.483 | 0.305 | 0.457 | 19.34 | 140.00 |
| Freezer #1 | J | A,B | N | RG | 1 | 0.365 | 19.34 | 200.00 | 0.610 | 0.450 | 1.331 | 19.34 | 200.00 |
| Freezer #2 | J | F,K,L | N | RG | 1 | 0.365 | 19.34 | 200.00 | 0.610 | 0.450 | 1.331 | 19.34 | 200.00 |
| Gas Analyzer/Mass Spec | J | L | Y | RG | 1 | 0.100 | 34.93 | 50.00 | 0.584 | 0.483 | 0.356 | 34.93 | 50.00 |
| Gas Cylinder Assembly | J | L | N | RE | 1 | 0.092 | 42.00 | 0.00 | 0.610 | 0.425 | 0.356 | 42.00 | 0.00 |
| Gas Tanks/Gas Supplies | J | L | N | SS | 1 | 0.031 | 9.98 | 25.00 | 0.371 | 0.472 | 0.175 | 9.98 | 25.00 |
| Goniometer and Recorder | J | C | Y | SE | 1 | 0.002 | 1.81 | 25.00 | 0.102 | 0.102 | 0.152 | 1.81 | 25.00 |

| EQUIPMENT NAME | SOR | DISCIPLINE CODES | A/C | MNT | QTY Reqd | PAYLOAD TOTALS VOL cu m | PAYLOAD TOTALS MASS kg | POWER watts | ITEM CHARACTERISTICS DEPTH m | WIDTH m | HEIGHT m | MASS kg | POWER watts |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H R F Terminal | J | E | N | RG | 1 | 0.011 | 22.68 | 15.00 | 0.051 | 0.483 | 0.457 | 22.68 | 15.00 |
| Head Restraint | J | J | N | SE | 1 | 0.000 | 0.23 | 0.00 | 0.076 | 0.076 | 0.025 | 0.23 | 0.00 |
| Helmet Assembly | J | J | N | SE | 1 | 0.028 | 1.36 | 20.00 | 0.305 | 0.254 | 0.356 | 1.36 | 20.00 |
| Helmet Interface Box | J | J | Y | SE | 1 | 0.006 | 2.00 | 30.00 | 0.102 | 0.203 | 0.305 | 2.00 | 30.00 |
| Heparin Lock Kit | J | F,H | N | SS | 360 | 0.033 | 24.28 | 0.00 | 0.203 | 0.076 | 0.006 | 0.07 | 0.00 |
| Imaging System, Ultrasound | J | B | Y | RE | 1 | 0.179 | 90.72 | 600.00 | 0.609 | 0.483 | 0.609 | 90.72 | 600.00 |
| Incubator | J | I,M | N | RG | 1 | 0.142 | 27.22 | 100.00 | 0.632 | 0.483 | 0.464 | 27.22 | 100.00 |
| Incubator (5% CO2@37°C) | J | D | N | RG | 1 | 0.142 | 27.22 | 100.00 | 0.632 | 0.483 | 0.464 | 27.22 | 100.00 |
| Isokinetic Measurement Device | J | C,E | Y | RE | 1 | 0.017 | 7.98 | 0.00 | 0.305 | 0.254 | 0.222 | 7.98 | 0.00 |
| Isotope Kit, Fe59 | J | H | N | SE | 36 | 0.007 | 3.26 | 0.00 | 0.076 | 0.051 | 0.051 | 0.09 | 0.00 |
| L B N P Device | J | B | Y | RE | 1 | 0.293 | 19.05 | 55.00 | 0.762 | 0.483 | 0.795 | 19.05 | 55.00 |
| Life Support Kit, Med Emergency | J | B | N | RG | 1 | 0.026 | 13.61 | 100.00 | 0.610 | 0.483 | 0.089 | 13.61 | 100.00 |
| Mask/Regulator System | J | L | N | SE | 1 | 0.001 | 22.00 | 0.00 | 0.102 | 0.102 | 0.102 | 22.00 | 0.00 |
| Mass Meas. Device, Body | J | B,H,L | Y | RG | 1 | 0.067 | 34.02 | 15.00 | 1.029 | 0.083 | 0.795 | 34.02 | 15.00 |
| Meter, Electrode Impedance | J | J | Y | SE | 1 | 0.001 | 0.59 | 0.00 | 0.155 | 0.104 | 0.053 | 0.59 | 0.00 |
| Microphone | J | G | N | SG | 1 | 0.000 | 0.27 | 10.00 | 0.051 | 0.013 | 0.013 | 0.27 | 10.00 |
| Microscope, Low Power | J | M | Y | RG | 1 | 0.013 | 7.26 | 100.00 | 0.229 | 0.190 | 0.305 | 7.26 | 100.00 |
| Monitor System, Physiological | J | L | Y | SG | 1 | 0.001 | 0.91 | 100.00 | 0.051 | 0.102 | 0.119 | 0.91 | 100.00 |
| Monitor, Environmental | J | B | N | SG | 1 | 0.033 | 25.40 | 20.00 | 0.305 | 0.305 | 0.356 | 25.40 | 20.00 |
| Monitor, Heart Rate | J | E | Y | RG | 1 | 0.000 | 0.95 | 10.00 | 0.102 | 0.051 | 0.025 | 0.95 | 10.00 |
| Nerve Conduction Vel. Tester | J | E | N | SE | 1 | 0.002 | 2.84 | 25.00 | 0.102 | 0.483 | 0.044 | 2.84 | 25.00 |
| Oscilloscope, Mini Recording | C | J | N | SGC | 1 | 0.004 | 2.27 | 0.00 | 0.305 | 0.152 | 0.076 | 2.27 | 0.00 |
| Osometer | J | A | Y | SE | 1 | 0.017 | 5.44 | 20.00 | 0.254 | 0.356 | 0.185 | 5.44 | 20.00 |
| P M S Accessories | J | L | N | SS | 26 | 0.491 | 1.00 | 0.00 | 0.610 | 0.152 | 0.203 | 0.04 | 0.00 |
| Paper, S C R, Multichannel | J | B,L | N | SS | 32 | 0.245 | 57.60 | 0.00 | 0.330 | 0.152 | 0.152 | 1.80 | 0.00 |
| Personal Rebreathing Assembly | J | L | N | RE | 156 | 10.236 | 302.00 | 0.00 | 0.432 | 0.249 | 0.610 | 1.94 | 0.00 |
| Photomicrographic Set-up | J | M | N | SE | 1 | 0.001 | 0.91 | 100.00 | 0.076 | 0.152 | 0.051 | 0.91 | 100.00 |
| Phycol & P B S Consumables Kit | J | D | N | SS | 156 | 0.247 | 162.76 | 0.00 | 0.152 | 0.102 | 0.102 | 1.04 | 0.00 |
| Radioisotopes | J | I | N | SE | | 0.000 | 0.00 | 0.00 | | | | | |
| Reader T L D | J | D | Y | RE | 1 | 0.023 | 15.42 | 150.00 | 0.508 | 0.254 | 0.181 | 15.42 | 150.00 |
| Reagent Kit, Red Cell Mass | J | H | N | SE | 36 | 0.007 | 3.26 | 0.00 | 0.076 | 0.051 | 0.051 | 0.09 | 0.00 |
| Recorder, Doppler | J | L | Y | RE | 1 | 0.137 | 9.53 | 50.00 | 0.508 | 0.483 | 0.559 | 9.53 | 50.00 |
| Recorder, Video | J | G | Y | RG | 1 | 0.037 | 15.42 | 75.00 | 0.500 | 0.483 | 0.152 | 15.42 | 75.00 |
| Refrigerator (4°C) | J | M | N | RG | 1 | 0.171 | 34.93 | 200.00 | 0.574 | 0.424 | 0.701 | 34.93 | 200.00 |
| Reticulocyte Smear Kit | J | H | N | SE | 72 | 0.005 | 6.52 | 0.00 | 0.076 | 0.076 | 0.013 | 0.09 | 0.00 |

PRELIMINARY PAYLOAD EQUIPMENT LIST FOR IOC (SECTION 1.0 MASTER EQUIPMENT LISTING) • AS OF APRIL 21, 1986 • Prepared by ARC / JSC

| EQUIPMENT NAME | SOR | DISCIPLINE CODES | A/C | MNT | QTY Reqd | PAYLOAD TOTALS VOL cu m | PAYLOAD TOTALS MASS kg | PAYLOAD TOTALS POWER watts | ITEM CHARACTERISTICS DEPTH m | ITEM CHARACTERISTICS WIDTH m | ITEM CHARACTERISTICS HEIGHT m | ITEM CHARACTERISTICS MASS kg | ITEM CHARACTERISTICS POWER watts |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reuter Centrifugal Sampler | J | M | Y | SE | 1 | 0.005 | 1.45 | 50.00 | 0.203 | 0.152 | 0.152 | 1.45 | 50.00 |
| Rotator | J | J | Y | RE | 1 | 0.126 | 40.82 | 220.00 | 0.508 | 0.483 | 0.508 | 40.82 | 220.00 |
| Rowing Machine | J | E | N | RG | 1 | 0.220 | 17.24 | 0.00 | 1.219 | 0.711 | 0.254 | 17.24 | 0.00 |
| Saliva Collectioin Unit | J | K | N | SE | 528 | 0.026 | 11.98 | 0.00 | 0.025 | 0.025 | 0.076 | 0.02 | 0.00 |
| Sample Prep. Dev., Fluid X-fer | C | I | N | RGC | 1 | 0.179 | 11.33 | 150.00 | 0.609 | 0.483 | 0.609 | 11.33 | 150.00 |
| Sample Swabs and Sample Tubes | J | M | N | SE | 1080 | 0.053 | 24.50 | 0.00 | 0.025 | 0.025 | 0.076 | 0.02 | 0.00 |
| Signal Conditioner, E O G | J | J | Y | SE | 1 | 0.000 | 0.05 | 20.00 | 0.015 | 0.030 | 0.048 | 0.05 | 20.00 |
| Slide Prep Device, Chromosal | J | D | Y | SE | 1 | 0.003 | 3.27 | 0.00 | 0.368 | 0.211 | 0.044 | 3.27 | 0.00 |
| Slide Preparation Kit, Urine | J | A | N | SS | 1 | 0.000 | 0.73 | 0.00 | 0.152 | 0.076 | 0.032 | 0.73 | 0.00 |
| Spectrometer | J | F,H | Y | SE | 1 | 0.001 | 0.45 | 100.00 | 0.160 | 0.089 | 0.051 | 0.45 | 100.00 |
| Spectrometer,Proton/Heavy Ion | J | D | Y | SE | 1 | 0.008 | 9.07 | 100.00 | 0.127 | 0.483 | 0.133 | 9.07 | 100.00 |
| Spirometer Assembly | J | L | N | SE | 1 | 0.006 | 1.00 | 0.00 | 0.305 | 0.203 | 0.102 | 1.00 | 0.00 |
| Sterile Loops | J | M | N | SE | 1512 | 0.149 | 24.50 | 0.00 | 0.203 | 0.076 | 0.006 | 0.02 | 0.00 |
| Subject Restraint System | J | B | N | SE | 1 | 0.004 | 11.34 | 0.00 | 0.152 | 0.152 | 0.152 | 11.34 | 0.00 |
| T L D | J | D | N | SE | 24 | 0.001 | 0.64 | 0.00 | 0.076 | 0.051 | 0.006 | 0.03 | 0.00 |
| Tapes, Data | J | L | N | SS | 26 | 0.015 | 1.82 | 0.00 | 0.076 | 0.152 | 0.051 | 0.07 | 0.00 |
| Terminal, Computer | J | G | Y | RG | 1 | 0.112 | 9.07 | 100.00 | 0.508 | 0.483 | 0.457 | 9.07 | 100.00 |
| Transducer, Venous Pressure | J | F | N | SE | 1 | 0.000 | 0.68 | 0.00 | 0.102 | 0.051 | 0.051 | 0.68 | 0.00 |
| Treadmill | J | E | N | RG | 1 | 0.311 | 11.79 | 25.00 | 1.219 | 0.559 | 0.457 | 11.79 | 25.00 |
| Trypticase Soy Agar Strips | J | M | N | SE | 120 | 0.000 | 0.54 | 0.00 | 0.025 | 0.076 | 0.000 | 0.00 | 0.00 |
| Tubes, Blood Collection | J | C,D,F,H,I,K,L | N | SS | 1080 | 0.013 | 61.13 | 0.00 | 0.013 | 0.013 | 0.076 | 0.06 | 0.00 |
| Urine Collection System, 24 Hr | J | A,B,F,K | Y | SE | 1 | 0.138 | 18.14 | 50.00 | 0.566 | 0.476 | 0.513 | 18.14 | 50.00 |
| Venous Pressure Disposables | J | F | N | SS | 156 | 0.002 | 8.83 | 0.00 | 0.013 | 0.013 | 0.076 | 0.06 | 0.00 |
| Versaclimber | J | E | N | RG | 1 | 0.754 | 15.42 | 80.00 | 0.762 | 2.438 | 0.406 | 15.42 | 80.00 |
| Vials, Feces Sample | J | A | N | SS | 2160 | 0.026 | 122.26 | 0.00 | 0.013 | 0.013 | 0.076 | 0.06 | 0.00 |
| Vials, Urine Sample | J | A,B,F,K | N | SS | 2160 | 0.026 | 122.26 | 0.00 | 0.013 | 0.013 | 0.076 | 0.06 | 0.00 |
| Video Cassettes, Box | J | G | N | SG | 5 | 0.188 | 25.00 | 0.00 | 0.500 | 0.500 | 0.150 | 5.00 | 0.00 |
| •1, 2, 3, &4 Totals | | | | | | 39 | 6050 | 13190 | | | | | |

•1 Rack total adjusted to accommodate equipment panel heights.

•2 Mission consumables and expendables based on a 90 day mission.

•3 I O C = 2 Years

•4 All data P R E L I M I N A R Y - FOR REFERENCE ONLY

# SECTION 4.0

The fourth section includes a partial list of experiments to support disciplines not contained in mission A or mission B. Experiments in this mission may be conducted within the module or external to the module. Subsequent documents will address these experiments in greater detail. This is only a summary.

## OTHER POSSIBLE MISSION EXPERIMENTS

| | EXPERIMENTAL SITE | OBJECTIVE CODE | SOURCE |
|---|---|---|---|
| **I. BIOSPHERICS** | | | |
| 1. Biochemical contents of plant canopies | LSRF and/or Platform | BS-1 | Green |
| 2. Primary productivity in equatorial oceans | LSRF and/or Platform | BS-2 | Green |
| 3. Predictive modeling of disease transmission | LSRF and/or Platform | BS-3 | Green |
| **II. EXOBIOLOGY** | | | |
| 1. Collection and analysis of cosmic dust particles | Attached Payload | EX-1 | Green |
| 2. Study the formation, growth and interaction of dust grains and gases involved in solar system evolution | LSRF | EX-2 | Green |
| 3. Study the physical and chemical reaction of the biogenic elements in an artificial icy comet during exposure to space | Attached Payload | EX-3 | Green |
| 4. Study the survival of microbes in space | Platform | EX-5 | Green |
| **III. REPRODUCTION AND DEVELOPMENT** | | | |
| 1. Multiple generation studies of mammals in space | LSRF | RD-1 | Green |
| 2. Multiple generation reproduction in insects | Platform | RD-4 | Green |
| 3. Mammalian pregnancy, birth, and maturation | LSRF | RD-1 | Green |
| 4. Reproduction subsequent to space exposure | LSRF | RD-1 | Green |

# SECTION 5.0

Section 5.0 presents the Mission Requirements Data Base for mission 307. The information defines the Space Station resource (volume, power, crew time, etc.) envelope within which the actual science payload for Space Station will be contained. Because the hardware identified in this section is generally common to research activities within each discipline, the resource envelope defined by the reference payload should adequately meet Life Sciences needs on Space Station and will probably not change dramatically as the actual payload is developed.

NAME

| | |
|---|---|
| PAYLOAD ELEMENT NAME | LIFE SCIENCES LAB |
| LAST UPDATE | 022786 |
| COUNTRY OF ORIGIN | USA NASA OSSA (SAAX) |
| CONTACT | DR. MARVIN CHRISTENSEN<br>EBF<br>NASA/HQ<br>WASHINGTON, D.C. 20546 |
| PHONE NUMBER | FTS 453-1546 |
| STATUS | PLANNED |

FLIGHTS

FLIGHT SCHEDULE

| FLIGHT YEAR | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|---|---|---|
| EQUIPMENT UP | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EQUIPMENT DOWN | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OPERATIONAL DAYS | 365 | 365 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OTV FLIGHTS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| EARLY FLIGHTS | | | | | | | | | | |
| LATE RETURN | 2002 | | | | | | | | | |

OBJECTIVE

INITIALLY TO PERFORM THE FULL SPECTRUM OF LIFE SCIENCE RESEARCH INCLUDING HUMAN, ANIMAL AND PLANT. WHEN AN ANIMAL & PLANT VIVARIUM & LAB (SAAX302) IS ADDED, THIS PAYLOAD ELEMENT (SAAX307) WILL BECOME A HUMAN RESEARCH LAB (SAAX303). LIFE SCIENCES TECHNOLOGY DEVELOPMENT WILL BE INCLUDED IN THIS PAYLOAD ELEMENT. (TDMX2532 IS REDUNDANT TO THIS MISSION AND SAAX303).

DESCRIPTION

EQUIPMENT INCLUDES HUMAN PHYSIOLOGICAL MONITORING INSTRUMENTATION AS WELL AS PLANT AND ANIMAL GROWTH FACILITIES, ANALYTICAL INSTRUMENTS, STORAGE, WORKBENCHES, FREEZERS, DATA COLLECTION AND MANAGEMENT SYSTEMS, FLUID AND WASTE HANDLING SYSTEMS, ETC. THIS LAB BECOMES SAAX303 IN 1994, CONTINGENT ON LAUNCH OF SAAX302. IN THE EVENT THAT SAAX302 IS CANCELLED OR DELAYED SAAX307 WOULD OPERATE FOR 1994-2001 PERIOD AT 365 DAYS/YEAR. THE LAB MODULE MUST OPERATE AT AN ATMOSPHERE OF 14.7 PSI - 21% O2 FOR IOC AND BEYOND.

TYPE/SCALE

| | |
|---|---|
| TYPE NUMBER | 4 |
| IMPORTANCE OF SPACE STATION | 10 |
| NON-SERVICING OMV FLIGHTS (PER YEAR) | -0 |
| ADD RESOURCES | YES |
| RESOURCE REFERENCE | |

ORBIT

ANY ORBIT

SPECIAL CONSIDERATIONS (ORBIT):

POINTING/ORIENTATION

| | |
|---|---|
| HOURS | -0 |
| TRUTH SITES | |
| POINTING ACCURACY (ARC SEC) | -0.00 |
| POINTING KNOWLEDGE (ARC SEC) | -0.00 |
| FIELD OF VIEW (DEG) | -0.0 |
| POINTING STABILITY RATE (ARC SEC/SEC) | -0.000 |
| POINTING STABILITY (ARC SEC) | -0.000 |
| PLACEMENT (ARC SEC) | -0.000 |

SPECIAL CONSIDERATION (POINTING/ORIENTATION):

SAAX0308 INVOLVES POINTING TO EXTRASOLAR PARTICLE SOURCES.

POWER

*AC

| | | |
|---|---|---|
| OPERATING (KW) | NOMINAL | 4.00 |
| HOURS PER DAY (OPERATING) | | 11.00 |
| VOLTAGE | NOMINAL | 110.0 |
| FREQUENCY (HZ) | | 60.0 |
| PEAK (KW) | NOMINAL | 5.00 |
| HOURS PER DAY (PEAK) | | 1.00 |
| STANDBY POWER (KW) (NON OPERATIONAL PERIODS) | | 2.00 |

*DC

| | | |
|---|---|---|
| OPERATING (KW) | NOMINAL | 10.00 |
| HOURS PER DAY (OPERATING) | | 11.00 |
| VOLTAGE | NOMINAL | 28.0 |
| PEAK (KW) | NOMINAL | 15.00 |
| HOURS PER DAY (PEAK) | | 1.00 |
| STANDBY POWER (KW) (NON OPERATIONAL PERIODS) | | 6.00 |

SPECIAL CONSIDERATIONS (POWER):
STANDBY POWER MINIMUM MUST BE SUPPLIED FOR SPECIMEN AND SAMPLE SUPPORT, GAMMS, ETC. PRIOR TO LAUNCH/RETURN AND AFTER LANDING. 208 VAC IS ALSO ACCEPTABLE PROVIDED 110 VAC, 60 HZ IS AVAILABLE TO ALL RACKS.

THERMAL

*ACTIVE

| | | | | | |
|---|---|---|---|---|---|
| TEMPERATURE, DEG C | OPERATIONAL | MIN | 20.0 | MAX | 27.0 |
| | NON-OPERATIONAL | MIN | 20.0 | MAX | 30.0 |
| HEAT REJECTION, KW | OPERATIONAL | MIN | 15.00 | MAX | 21.00 |
| | NON-OPERATIONAL | MIN | 9.00 | MAX | 9.00 |

SPECIAL CONSIDERATIONS (THERMAL):
CRITICAL THERMAL CONTROL DONE WITHIN CAGE/RACKS. HEAT REJECTION REFLECTS EQUIPMENT PWR + 1 KW FOR EACH METABOLIC HEAT GENERATION

DATA/COMMUNICATIONS

ONBOARD DATA PROCESSING REQUIRED YES

DESCRIPTION:
ENVIRONMENTAL PARAMETERS, SPECIMEN STATUS, OBSERVATIONS & DATA ANALYSIS

ONBOARD STORAGE (MBIT) -0.00

STATION DATA REQUIRED:
TIME; ACCELERATION & RADIATION ENVIRONMENTS; HOUSEKEEPING & STATION OPERATIONS DATA; EPHEMERIS.

COMMUNICATION LINKS:

| FROM: STATION TO: GROUND | DIGITAL DATA | VIDEO DATA | VOICE |
|---|---|---|---|
| A. GENERATION RATE (KBPS) | 128.00 | 1300.00 | NA |
| B. DURATION (HOURS) | 24.00 | 4.00 | 24.00 |
| C. FREQUENCY (PER DAY) | 1.00 | 1.00 | 1.00 |
| D. DELIVERY TIME (HOURS) | 0.00 | 0.00 | 0.0 |
| E. SECURITY (YES/NO) | NO | NO | YES |
| F. RELIABILITY (%) | 2.00 | 2.00 | 2.00 |
| G. INTERACTIVE (YES/NO) | NO | YES | YES |

| FROM: GROUND TO: STATION | DIGITAL DATA | VIDEO DATA | VOICE |
|---|---|---|---|
| A. GENERATION RATE (KBPS) | 20.00 | 1300.00 | NA |
| B. DURATION (HOURS) | 24.00 | 4.00 | 24.00 |
| C. FREQUENCY (PER DAY) | 1.00 | 1.00 | 1.00 |
| D. DELIVERY TIME (HOURS) | 0.00 | 0.00 | 0.0 |
| E. SECURITY (YES/NO) | NO | NO | YES |
| F. RELIABILITY (%) | 2.00 | 2.00 | 2.00 |
| G. INTERACTIVE (YES/NO) | NO | YES | YES |

| FROM: STATION TO: SHUTTLE | DIGITAL DATA | VIDEO DATA | VOICE |
|---|---|---|---|
| A. GENERATION RATE (KBPS) | 20.00 | -0.00 | NA |
| B. DURATION (HOURS) | 2.00 | -0.00 | 0.50 |
| C. FREQUENCY (PER DAY) | 1.00 | -0.00 | 2.00 |
| D. DELIVERY TIME (HOURS) | 0.00 | -0.00 | 0.0 |
| E. SECURITY (YES/NO) | NO | | YES |
| F. RELIABILITY (%) | 2.00 | -0.00 | 2.00 |
| G. INTERACTIVE (YES/NO) | YES | | YES |

SAAX307

| | FROM: SHUTTLE<br>TO: STATION | DIGITAL DATA | VIDEO DATA | VOICE |
|---|---|---|---|---|
| | | ------- | ----- | ----- |
| A. | GENERATION RATE (KBPS) | 20.00 | -0.00 | NA |
| B. | DURATION (HOURS) | 2.00 | -0.00 | 0.50 |
| C. | FREQUENCY (PER DAY) | 1.00 | -0.00 | 2.00 |
| D. | DELIVERY TIME (HOURS) | 0.00 | -0.00 | 0.0 |
| E. | SECURITY (YES/NO) | NO | | YES |
| F. | RELIABILITY (%) | 2.00 | -0.00 | 2.00 |
| G. | INTERACTIVE (YES/NO) | YES | | YES |

COMMENT (DATA/COMMUNICATIONS):

390

EQUIPMENT

PRESSURIZED MODULE CODE 2

SHARED FACILITIES NONE

EQUIPMENT LOCATION LEGEND

1. INTERNAL/PRESSURIZED
2. EXTERNAL/ATTACHED/PRESSURIZED
3. EXTERNAL/ATTACHED/UNPRESSURIZED
4. FREE FLYER (REMOTE)

| | EQUIPMENT LOCATION 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| DIMENSIONS (M) | | | | |
| LENGTH | 9.75 | | | |
| WIDTH OR DIAMETER | 4.80 | | | |
| HEIGHT (OR BLANK) | | | | |
| VOLUME ( CU. M.) | 39.000 | | | |
| PKG. DIMENSION (M) | | | | |
| LENGTH | 9.75 | | | |
| WIDTH OR DIAMETER | 4.80 | | | |
| HEIGHT (OR BLANK) | | | | |
| PKG. VOL. (CU. M.) | 39.000 | | | |
| LAUNCH MASS (KG) | 8500.00 | | | |
| ACCEL. MAX (G) | .0000100 | | | |

EQUIPMENT LOCATION LEGEND

5. FREE FLYER (CONTACT-NAME-ORBITING)
6. 28.5 DEGREE PLATFORM
7. SUN SYNC/POLAR PLATFORM

| | EQUIPMENT LOCATION 5 | 6 | 7 |
|---|---|---|---|
| DIMENSIONS (M) | | | |
| LENGTH | | | |
| WIDTH OR DIAMETER | | | |
| HEIGHT (OR BLANK) | | | |
| VOLUME ( CU. M.) | | | |
| PKG. DIMENSION (M) | | | |
| LENGTH | | | |
| WIDTH OR DIAMETER | | | |
| HEIGHT (OR BLANK) | | | |
| PKG. VOL. (CU. M.) | | | |
| LAUNCH MASS (KG) | | | |
| ACCEL. MAX (G) | | | |

ATTACH POINTS 0

SET UP CODE:

HARDWARE DESCRIPTION:

COMBINED HUMAN AND NON-HUMAN LIFE SCIENCES RESEARCH EQUIPMENT. PAYLOAD ELEMENT CONVERTED IN 1994 TO SAAX0303- DEDICATED HUMAN RESEARCH FACILITY.

CREW
•INITIAL CONSTRUCTION/SET UP
TASK:
PERIOD (DAYS) -0.00
IVA TOTAL CREWTIME (MHR) -0.00
EVA PRODUCTIVE CREW TIME (MHR) -0.00

| | CI-SKILL-TYPE | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| CI SKILL LEVEL | TASK TRAINABLE | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | TECHNICIAN | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | PROFESSIONAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

•DAILY OPERATIONS
TASK:
EXPERIMENT MANIPULATIONS; SAMPLE PREPARATIONS; SAMPLE & DATA ANALYSIS
IVA CREW TIME PER DAY (MHR) 11.00

| | CD-SKILL-TYPE | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| CD SKILL LEVEL | TASK TRAINABLE | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| | TECHNICIAN | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | PROFESSIONAL | 0 | 1 | 0 | 0 | 0 | 0 | 0 |

•PERIODIC OPERATIONS NONE
•TEARDOWN AND STOW
TASK:
PERIOD (DAYS) -0
IVA TOTAL CREWTIME (MHR) -0.00
EVA PRODUCTIVE CREW TIME (MHR) -0.00

| | CS-SKILL-TYPE | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| CS SKILL LEVEL | TASK TRAINABLE | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | TECHNICIAN | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | PROFESSIONAL | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

COMMENTS (CREW):
FIVE TASK TRAINABLE CREW USED AS HUMAN SUBJECTS FOR LIMITED L.S. EXPERIMENTS.

SERVICING
INTERVAL (DAYS) 90
CONSUMABLES:
TYPE -
ANIMALS, PLANTS; SPECIMEN H2O, O2, FOOD, BLOOD SAMPLES, DATA TAPE, MED. SUPPLIES
WEIGHT (KG) 2500.00
RETURN (KG) 2500.00
VOLUME UP (CUBIC METERS) 5.000
VOLUME DOWN (CUBIC METERS) 5.000
POWER (KW) 2.000
HOURS FOR POWER 30.00
EVA HOURS PER SERVICE -0.00
TYPICAL TASKS (EVA) -
TBD
IVA HOURS PER SERVICE 60.00
LOCATION OF SERVICING LOCAL
TYPICAL TASKS (IVA) -
EXCHANGE SPECIMENS, SAMPLES, RECORDS, FOOD/H2O/O2/WASTE CONT & EQUIPMENT
SPECIAL CONSIDERATIONS (SERVICING):
REQUIRE THE FOLLOWING OF LOGISTICS MODULE: CONTINUOUS POWER DURING ASCENT(3KW), 4 M**3 VOL, ATMOSPHERIC TEMP +20-+25 DEG C, R.H.-40-60%, PRESSURE 14.7 PSI 21% O2, PARTICULATE SIZE <0.5 MICRON, VIBROACCOUSTICAL LEVEL 55DBA SHORTER & MORE FREQUENT SERVICING INTERVAL DESIRED(<90 DAYS)

CONFIGURATION CHANGES

| | | |
|---|---|---|
| INTERVAL (DAYS) | | 90 |
| CHANGE-OUT EQUIPMENT: | | |
| TYPE - | | |
| WEIGHT (KG) | | 850.000 |
| RETURN (KG) | | 850.00 |
| VOLUME UP (CUBIC METERS) | | 3.000 |
| VOLUME DOWN (CUBIC METERS) | | 3.000 |
| POWER (KW) | | -0.000 |
| HOURS FOR POWER | | -0.00 |
| EVA HOURS PER CHANGE | | -0.00 |
| TYPICAL TASKS (EVA) - TBD | | |
| IVA HOURS PER CHANGE | | -0.00 |
| LOCATION OF CHANGE | LOCAL | |
| TYPICAL TASKS (IVA) - TBD | | |

SPECIAL CONSIDERATIONS (CONFIG. CHANGES):

SPECIAL NOTES

CONTAMINATION-

CONTAMINATION AMONG HUMANS, PLANTS, AND ANIMALS MUST BE CONSIDERED.

STRUCTURES-

AIRLOCKS MUST ACCOMMODATE TRANSFERS OF MAJOR EQUIPMENT ITEMS. MODERATE SIZED 1 G CONTROL CENTRIFUGE MAY IMPACT STATION DYNAMICS.

MATERIALS-

RADIATION-

TRACER RADIOISOTOPES WILL BE USED DURING COURSE OF EXPERIMENTS.

SAFETY-

DEAD ANIMAL STORAGE PROVIDED BY USER, RADIOISOTOPE, CHEMICAL STORAGE

STORAGE-

OPTICAL WINDOW-

SCIENTIFIC AIRLOCK-

REQUIRED FOR EQUIPMENT TRANSFERS - TBD SIZE

TETHER-

VACUUM VENTING-

OVERBOARD VENTING REQUIRED FOR 2 VENTS (1 HIGH VAC, 1 LOW)

OTHER-

REQUIRE POST-LAUNCH ACCESS/CONTROL TO BE LESS THAN 2 HRS AFTER LAUNCH.
REQUIRE PRELAUNCH ACCESS LESS THAN 18 HOURS.

SECTION 6.0

This section alphabetically lists those participants in the various meetings and workshops who helped create of this document.

LIST OF PARTICIPANTS IN WORKSHOPS

AND

CONTRIBUTORS TO DOCUMENT

Christine Abbey/MATSCO-HQ
E. J. Ainsworth/University of Berkeley
Jeffrey Alberts/University of Indiana, Bloomington
Bobby R. Alford/Baylor College of Medicine
Sara Arnaud/NASA ARC
Roger Arno/NASA ARC
Maurice Averner/NASA HQ-ARC
Edward Balish/University of Wisconsin, Madison
Rodney Ballard/NASA ARC
June Benton/University of San Francisco
Henry Bielstein/NASA Headquarters
John Billingham/NASA ARC
C. Gunnar Blomqvist/University of Texas
Frank W. Booth/University of Texas Medical School
James A. Brass/NASA ARC
Lee R. Brown/University of Texas Dental Branch
Michael W. Bungo/NASA JSC
Christopher Cann/University of California, San Francisco
John B. Charles/NASA JSC
Marvin R. Christensen/NASA Headquarters
Nitza M. Cintron/NASA JSC
Robert Cleland/University of Washington, Seattle
G. K. Clemmons/University of California
A. A. Cogoli/Laboratorium fur Biochemie
Steven Corbin/MATSCO ARC
Merilee Corcoran/NASA ARC
Kent Cullers/NASA ARC
Fernando D'Amelio/ARC
Nancy Daunton/NASA ARC
Donald DeVincenzi/NASA Headquarters
Constantine B. Dolkas/NASA ARC

Stan Ellis/ARC
William Fedderson/JSC
Cesar D. Fermin/Baylor College of Medicine
Albert S. Fine/Veterans Administration Medical Center
James Fleming/Linus Pauling Institute
Robert Fowles/University of Utah
W. J. Frome/NAASA JSC
Charles Fuller/University of California, Davis
Drew Gaffney/NASA JSC
Reed M. Gardner/LDS Hospital
Joe Giannavario/General Electric Company
Herbert S. Ginoza/NASA ARC
John Greenleaf/NASA ARC
Lynn Griffiths/MATSCO-HQ
Richard A. Grindeland/NASA ARC
Edith Gustan/Boeing
Thora Halstead/NASA Headquarters
Milton Heinrich/Zero G Corporation
Michael F. Holick/MIT
D. J. Horrigan/NASA JSC
Millie Hughes-Fulford/NASA JSC
Carolyn L. Huntoon/NASA JSC
Phillip Hutchins/NASA JSC
P. C. Johnson/NASA JSC
David R. Jones/Brooks Air Force Base
Richard Keefe/Biospace, Inc.
Lanny Keil/NASA ARC
Herbert Kelly/McDonnell Douglas Astronautics Co.
Robert S. Kennedy/Exxex Corporation
Abraham Krikorian/SUNY-Stony Brook
Frank Kutyna/JSC
Robert Lange/University of Tennessee
James Lawless/NASA ARC
R. John Leigh/University Hospitals
Joel I. Leonard/MATSCO-HQ
John Lett/University of Colorado, Fort Collins
Barnett M. Levy/University of Texas Dental Branch

John Lintott/NASA JSC
Ralph J. Luciani/Kirkland Air Force Base
Joseph G. Lundholm/NASA GSFC
Robert MacElroy/NASA ARC
Richard Mains/Mains Associates
George Malacinski/University of Indiana
Adrian Mandel/NASA ARC
Chris McKay/NASA ARC
Maija Sue Mednicks/National Institute of Health
Richard T. Meehan/UTMB-Galveston
Edward Merek/NASA ARC
Roger Michaud/MATSCO JSC
LaDonna Miller/MATSCO-JSC
T. P. Moore/NASA JSC
Emily Morey-Holton/NASA ARC
Gary Musgrave/MATSCO-HQ
D. Stewart Nachtwey/NASA JSC
Anton Neff/University of Indiana
Micheal Nicor/University of Texas, Dallas
Doug O'Handley/NASA ARC
John F. Oro/University of Houston
J. Oyama/NASA ARC
Charles Y. C. Pak/University of Texas Southwestern Medical School
John C. Patterson/Brooks Air Force Base
David Penny/Cancer Center, School of Medicine and Dentistry
Tom Perry/NASA Headquarters
David Peterson/NASA ARC
Robert Phillips/NASA JSC
Del Philpott/NASA ARC
Duane Pierson/NASA JSC
Sam L. Pool/NASA JSC
Gary Primeaux/JSC
Paul Rambaut/NASA Headquarters
Mitch Rambler/NASA GSFC
Daryl Rasmussen/NASA ARC
Millard F. Reschke/NASA JSC
Robert Roberts/Baylor College of Medicine

Robert R. Rose/UTMB-Galveston
Muriel Ross/University of Michigan
John A. Rummell/MAP Systems
John Rummel/NASA ARC
Yvonne Russell/Russmark, Inc.
Patricia A. Santy/NASA JSC
Walter Sapp/University of Tuskegee
Richard Sauer/NASA JSC
Howard J. Schneider/NASA JSC
Victor S. Schneider/NASA JSC
Steven Schwartzkopf/NASA ARC
Tom Scott/University of North Carolina, Chapel Hill
Paul Sebesta/NASA ARC
Terry Secord/McDonnel Douglas
Charles Seeger/NASA ARC
Bette Siegel/MATSCO-HQ
Thomas Smith/NASA JSC
Gerald Sonnenfeld/University of Louisville
Kenneth Souza/NASA ARC
Dorothy Spangenberg/University of Virginia
Jill Tarter/NASA ARC
Gerrald R. Taylor/NASA JSC
David Tomko/NASA ARC
Edgar A. Tonna/Dental Center, New York University
J. M. Vanderploeg/JSC
Stephen Vatner/NASA ARC
Kris Vogelsong/NASA ARC
G. Donald Whedon/Shriners Hospital for Crippled Children
Ronald White/NASA Headquarters
Lynn Wiley/University of California, Davis
Mark Williams/MATSCO-ARC
Charles Winget/NASA ARC
Kathleen L. Wishner/Pasadena Diabetes and Endocrinology Medical Group
R. C. Wrigley/ NASA ARC
Donald Young/NASA ARC
Richard S. Young/Banks Committee

## SECTION 7.0

## REFERENCE LIST


A. The Federation of American Societies of Experimental Biology reports entitled, Research Opportunities In:

1. Cardiovascular Deconditioning (July 1983, NASA 3707)
2. Space Motion Sickness (July 1983, NASA 3708)
3. Bone Demineralization (April 1984, NASA 3795)
4. Muscle Atrophy (April 1984, NASA 3796)
5. Human Behavior and Performance (April 1985, NASA 3924)
6. The Loss of Red Blood Cell Mass in Space Flight (April 1985, NASA 3924

B. "The McDonnell-Douglas Report" - Space Station Life Sciences Research Facility Technology Assessments and Technology Development Plan Vol., I, II, III, (December 1983, MD 0743)

C. The JSC "Blue Book" Human Research Facility For Space Station IOC Science Requirements (Preliminary Draft, JSC (20799)

D. ARC "Green Book," Life Sciences Research Objectives and Representative Experiments for the Space Station. Biological Research Project - Preliminary Draft, 1986.

E. The Sinclair Report on Radiation (Preliminary Draft)

F. The Exobiology Program Plan

G. The Plant Gravitation Program Plan

H. The Space Biology Program Plan

I. The Fabricant Report on Life Sciences Experiments For a Space Station (1983)

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| NASA TM-89188 | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| Life Sciences Space Station Planning Document: A Reference Payload for the Life Sciences Research Facility | August 1986 |
| | 6. Performing Organization Code: EB |
| 7. Author(s) | 8. Performing Organization Report No. |
| | 10. Work Unit No. |
| 9. Performing Organization Name and Address: Life Sciences Division, NASA Office of Space Science and Applications, Washington, DC 20546 | 11. Contract or Grant No. |
| | 13. Type of Report and Period Covered: Technical Memorandum |
| 12. Sponsoring Agency Name and Address: National Aeronautics and Space Administration, Washington, DC 20546 | 14. Sponsoring Agency Code |

15. Supplementary Notes

16. Abstract


The Space Station, projected for construction in the early 1990s, will be an orbiting, low-gravity, permanently manned facility providing unprecedented opportunities for scientific research. Facilities for Life Sciences research will include a pressurized research laboratory, attached payloads, and platforms which will allow investigators to perform experiments in the crucial areas of Space Medicine, Space Biology, Exobiology, Biospherics and Controlled Ecological Life Support System (CELSS). These studies are designed to determine the consequences of long-term exposure to space conditions, with particular emphasis on assuring the permanent presence of humans in space. The applied and basic research to be performed, using humans, animals, and plants, will increase our understanding of the effects of the space environment on basic life processes. Facilities being planned for remote observations from platforms and attached payloads of biologically important elements and compounds in space and on other planets (Exobiology) will permit exploration of the relationship between the evolution of life and the universe. Space-based, global scale observations of terrestrial biology (Biospherics) will provide data critical for understanding and ultimately managing changes in the Earth's ecosystem. The life sciences community is encouraged to participate in the research potential the Space Station facilities will make possible.

This document provides the range and scope of typical life sciences experiments which could be performed within a pressurized laboratory module on Space Station.


| 17. Key Words (Suggested by Author(s)) | 18. Distribution Statement |
|---|---|
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