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ADVANCED TECHNOLOGY REQUIREMENTS

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SYSTEM REQUIREMENTS WITH TECHNOLOGY IMPLICATIONS - I

- **LONG OPERATIONAL LIFE**
  - LONG LIFE COMPONENTS
  - REDUNDANCY
  - MAINTENANCE
- **UTILITY AND FLEXIBILITY**
  - MODULAR GROWTH
  - AMPLE POWER
  - UNRESTRICTED ORIENTATION
  - HIGH SPEED DATA PROCESSING
  - HIGH DATA RATE TRANSMISSION
  - FREQUENT DOCKING OPERATIONS
- **REDUCED DEPENDENCE ON GROUND**
  - LONG TERM STORAGE
  - RECLAMATION OF EXPENDABLES
  - ONBOARD CHECKOUT AND FAULT ISOLATION
  - ONBOARD GUIDANCE AND NAVIGATION

NASA HQ MF70-6070
5-25-70

Figure 1

The space station concepts and uses which have been discussed have a great number of implications with respect to the technology that will be required for this program. The unusually long life requirements impose a number of new considerations not only in terms of the design of basic components and systems redundancies, but also in the method of test qualification. Similarly, the necessity for safety dictates new approaches in developing manned systems for continuous operation where immediate return to Earth may no longer be feasible. It is also evident that in considering new advancements in technology, we must consider the impact of such systems on the crew efficiency.

SYSTEM REQUIREMENTS WITH TECHNOLOGY IMPLICATIONS - II

- **CREW EFFICIENCY**
  - COMPUTER ASSISTANCE
    - CHECKOUT FAULT ISOLATION
    - CAUTION AND WARNING
    - CORRECTIVE ACTION
  - MULTI-PURPOSE DISPLAYS
  - HABITABILITY IMPROVEMENTS
    - ATMOSPHERE
    - FOOD
    - CLOTHING
    - HYGIENE
    - WASTE MANAGEMENT
- **SAFETY**
  - MATERIALS
  - REDUNDANCY
  - WARNING
  - FAILURE CONSEQUENCES
  - ALTERNATE OPERATING MODES
  - HAZARD CONTAINMENT, AND CONTROL
- **COST AVOIDANCE**
  - SHUTTLE LOGISTICS
  - LONG LIFE SYSTEMS
  - MODULE COMMONALITY
  - REDUCED DEPENDENCE ON GROUND
  - REDUCED TESTING

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5-25-70

Figure 2

Other considerations which will impact the selection of advanced systems are their flexibility of application, their ability to operate in various gravitational fields, and their capability to operate in a manner so as to minimize ground support. A final consideration which will be of paramount importance in the selection of components will be to obtain reduced costs, both of initial development as well as for long term uses.

Subsequent discussion will summarize technological advancements which are being made in areas of applicability to the space station, with special emphasis on advantages which they offer in many of these critical dimensions.

MANAGEMENT AND TECHNICAL STRUCTURE

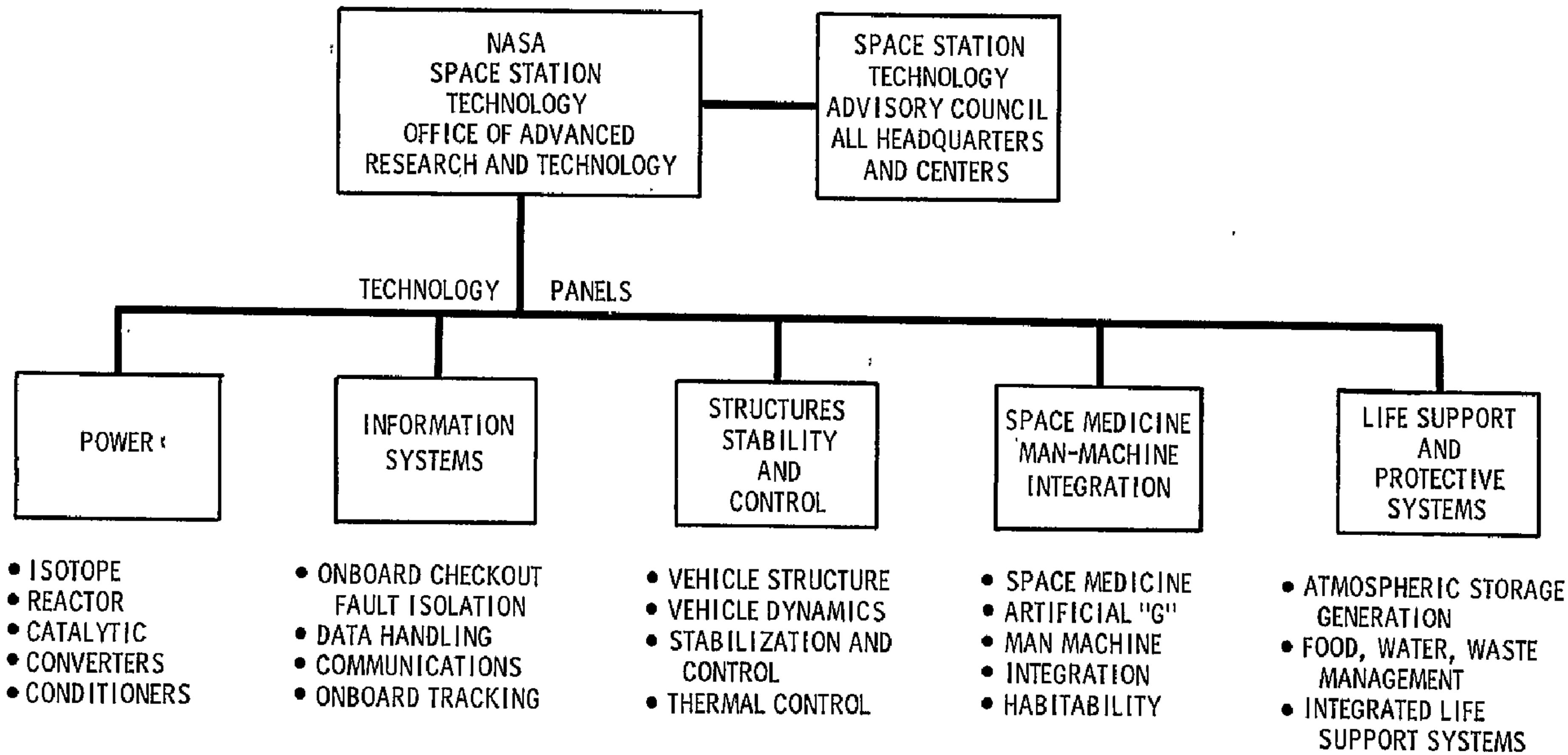

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Figure 3

The Management and Technical Structure of the NASA Advanced Technology Program for the Space Station is under the direction of the Office of Advanced Research and Technology. Five technology panels have been established, covering the areas of Electrical Power; Information Systems; Structures, Stability and Control; Space Medicine and Man-Machine Integration; and Life Support and Protective Systems. Each panel reviews the total research effort in its area of expertise and recommends additional work efforts to be accomplished. The Advisory Council reviews the overall program for balance of effort, areas being overlooked, and potential duplications.

NUCLEAR ELECTRIC POWER GENERATION SYSTEMS FOR SPACE APPLICATIONS

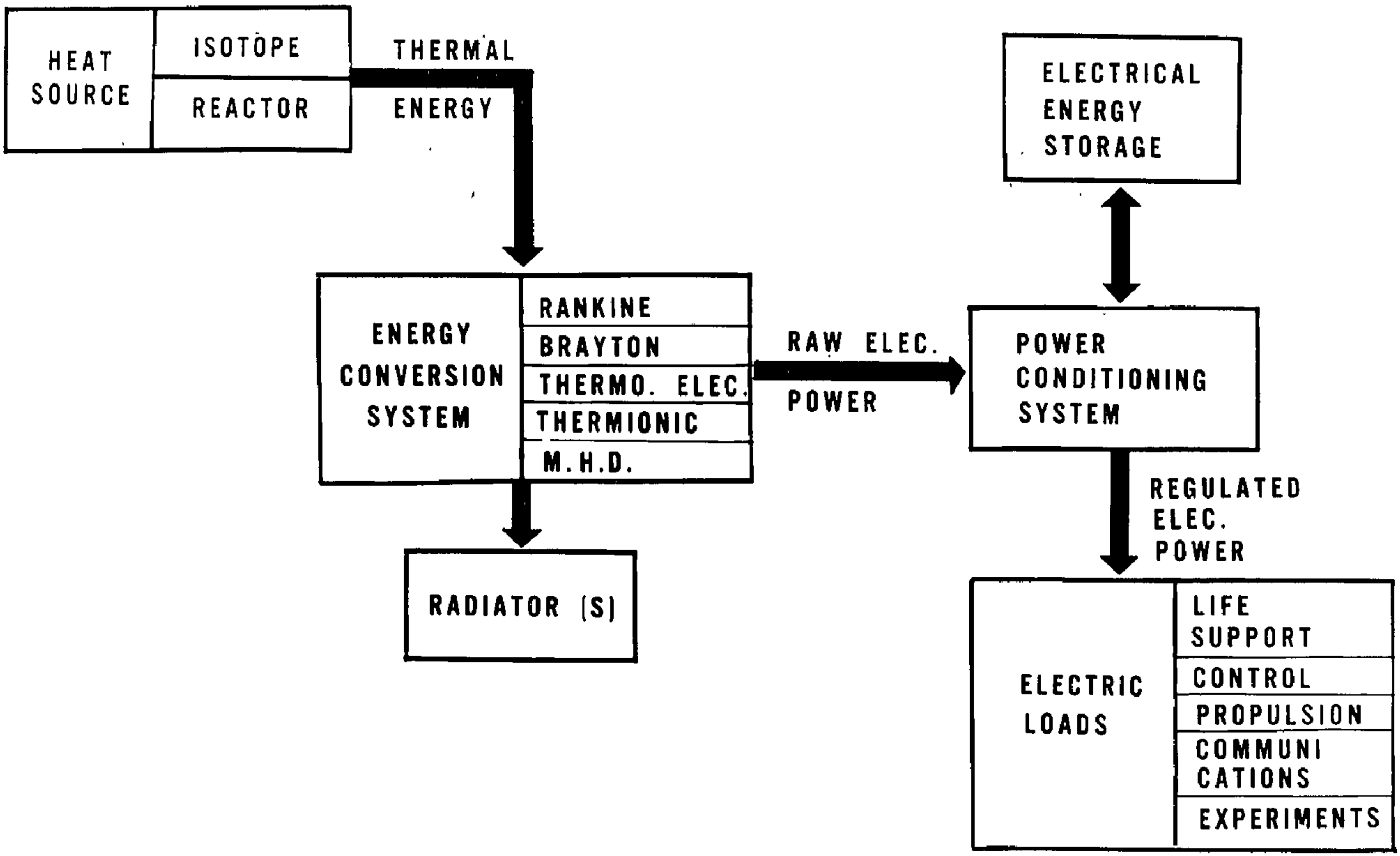

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Figure 4

One of the critical areas of subsystem development for the space station is the electrical power system. This chart indicates some of the major system elements which must be considered in selecting a nuclear electric power generation system. The thermal energy, from either isotope decay or reactor fission, can be converted into electrical power by a number of methods, five of which are identified here. The Rankine and Brayton are dynamic systems, employing a turbine to drive an alternator. The thermo-electric and thermionic systems are static converters and the magneto-hydrodynamic (MHD) system employs a conducting metal vapor. Overall system efficiencies range from four to thirty percent of the input thermal energy and all require radiators to dissipate waste heat. After leaving the conversion system, the electrical power then must be regulated, controlled, and distributed to the various loads and to the energy storage system.

TABLE I

NUCLEAR ELECTRIC SPACE POWER SYSTEM TECHNOLOGY FORECAST FOR MANNED APPLICATIONS

HEAT SOURCE	POTENTIAL FLIGHT READINESS	UNIT POWER KW	SYSTEM EFF. %
ISOTOPE-THERMO-ELECTRIC 1000°F AVG. HOT JUNCTION	1975 - 80	0.1 - 1	5
ISOTOPE - BRAYTON 1600°F TURBINE INLET	1975 - 80	2 - 12.5	25
SNAP-8 THERMO ELECTRIC 1200°F HOT JUNCTION	1980	25	4
SNAP - 8 HG RANKINE 1270°F TURBINE INLET	1980	35-50	9
SNAP-8 BRAYTON 1250°F TURBINE INLET	1980	100	20

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5-21-70

Figure 5

This table gives a forecast of five potential nuclear power systems of great interest for application in the 1975-80 time period. It is evident that the Brayton systems give high promise for applications to space station needs because of their availability at high power levels and high efficiencies.

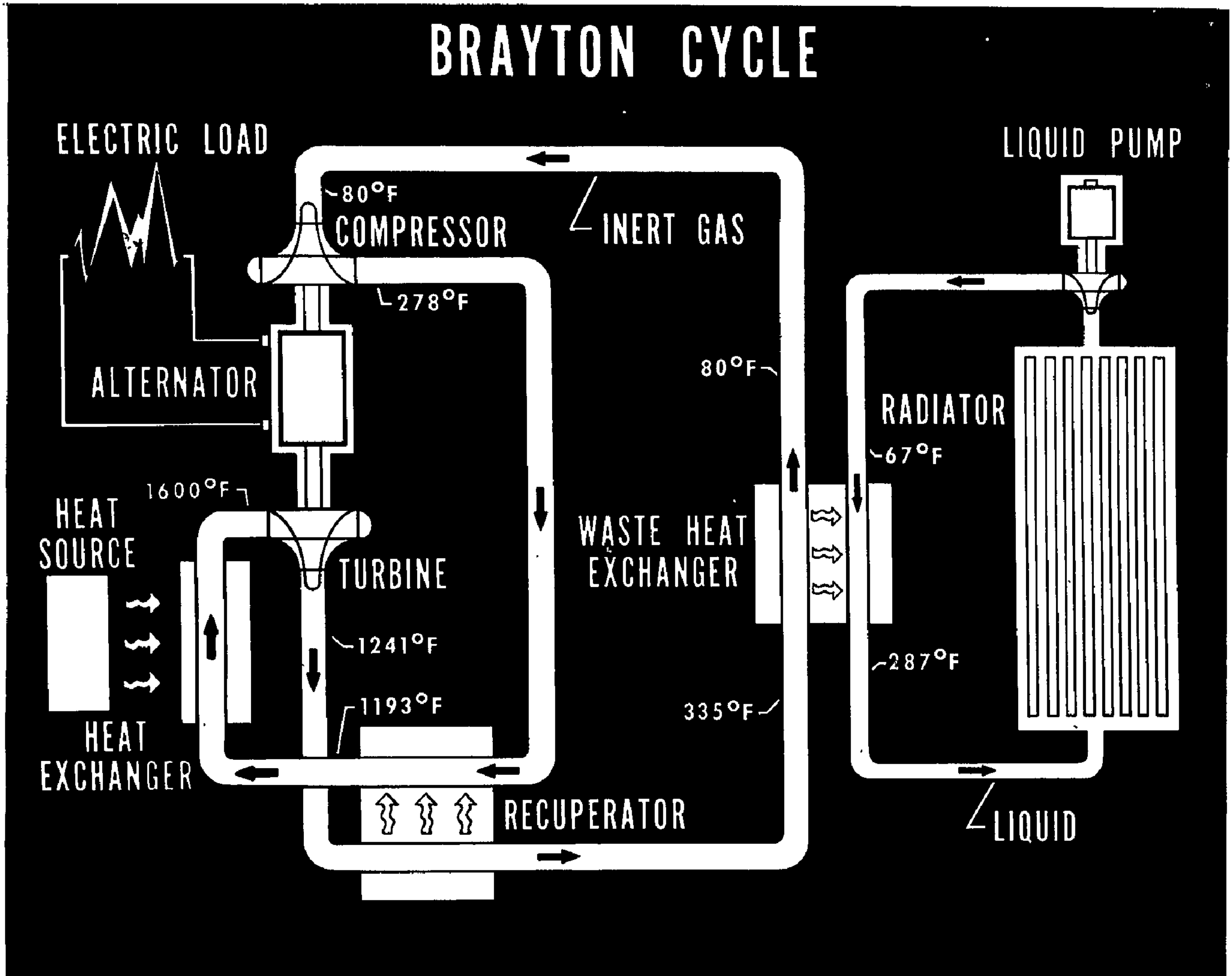

BRAYTON CYCLE
ELECTRIC LOAD
80°F
COMPRESSOR
INERT GAS
LIQUID PUMP
278°F
ALTERNATOR
80°F
RADIATOR
67°F
1600°F
HEAT SOURCE
WASTE HEAT EXCHANGER
TURBINE
1241°F
287°F
1193°F
335°F
HEAT EXCHANGER
RECUPERATOR
LIQUID

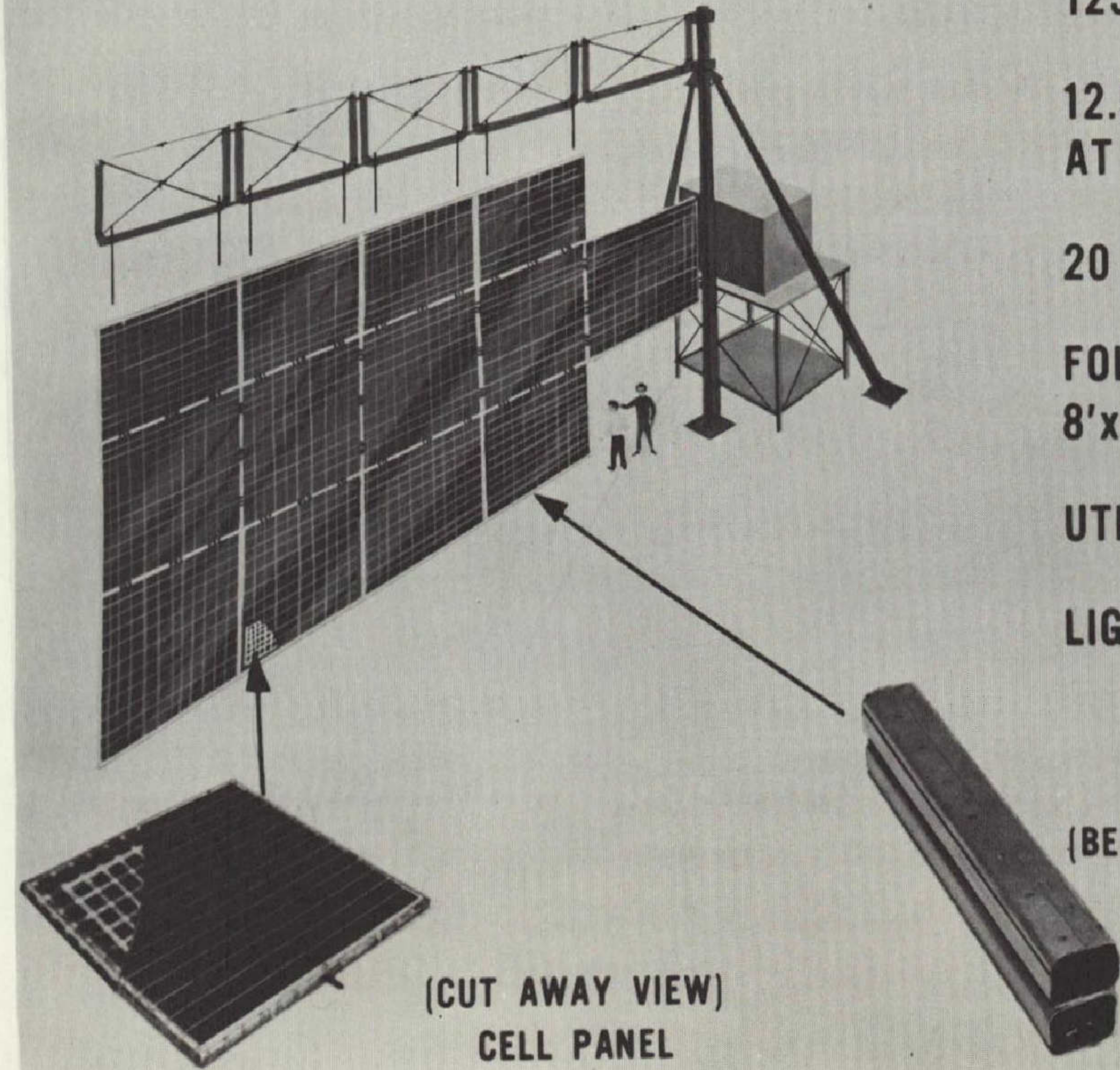
Figure 6

Because of the high potential offered by the Brayton conversion cycle, it warrants special attention. This cycle diagram indicates several of the attractive features of the system. First, there is no physical connection between the heat source and the conversion system, heating being transferred by radiation. Secondly, the working fluid is an inert gas, which reduces materials problems, and the gas does not go through a phase change during the cycle. In addition to these features, the rotating machinery can be used over a wide range of power and operating temperatures.

A complete Brayton Power Conversion System has been assembled and is undergoing testing at the NASA Lewis Research Center.

HIGH POWER FOLDING SOLAR CELL ARRAY

SIMULATED ZERO-G DEPLOYMENT



1250 FT^2 DEPLOYMENT TEST MODEL

12.5 KW OUTPUT IN 100% SUNLIGHT AT 1 A.U.

20 WATTS PER POUND

FOLDED INTO VOLUME OF LESS THAN 8'x13'x3½' FOR LAUNCH

UTILIZES LIGHTWEIGHT STRUCTURE

LIGHTWEIGHT SILICON SOLAR CELLS

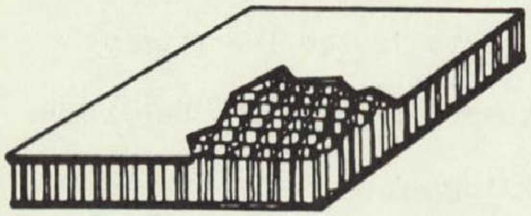
NASA RN 67-482
12-19-66

Figure 7

Although considerable progress is being made with large nuclear power systems, additional work is also underway on large solar arrays. This chart depicts a 120 square meter deployment test model for which the technology has been demonstrated in simulated zero gravity deployment tests in the laboratory. This array would produce 12.5 kilowatts in 100% sunlight condition and with its lightweight beryllium structure and silicon solar cells achieved an efficiency of 44 watts per kilogram.

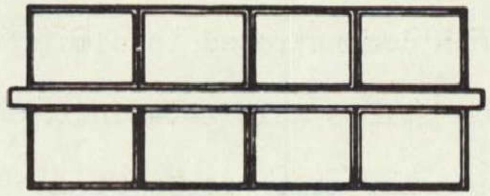
SOLAR ARRAY STRUCTURAL OPTIONS

SUBSTRATE



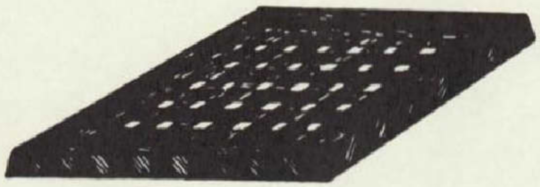
ALUMINUM
HONEYCOMB

STRUCTURE

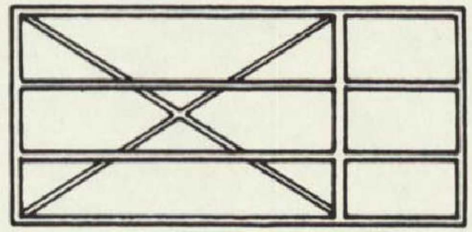


AL FRAME
AND BEAM

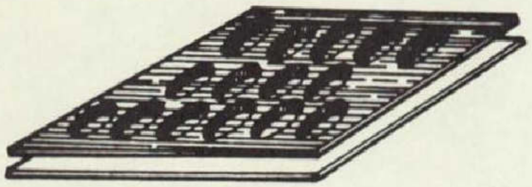
EXPERIMENTAL



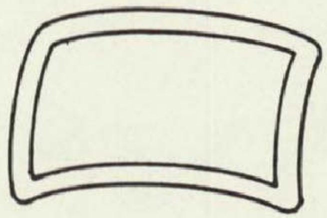
EPOXY
FIBER GLASS



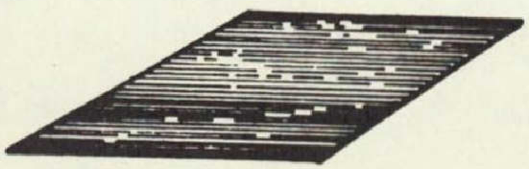
Be WINDOW
FRAME



ELECTROFORMED
ALUMINUM
HOLLOWCURE



CURVED Be
TORUS
FRAME



KAPTON
PLASTIC

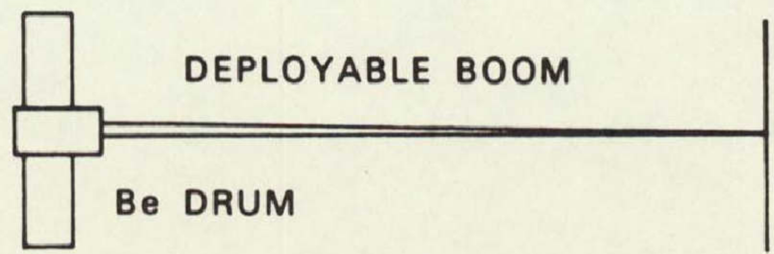


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Figure 8

The key to advancements in solar array technology are in new and more efficient structural designs and lightweight substrates on which the solar cells are attached. This chart illustrates several of the new approaches to these challenging problems.

250 FT^2 ROLL OUT SOLAR ARRAY

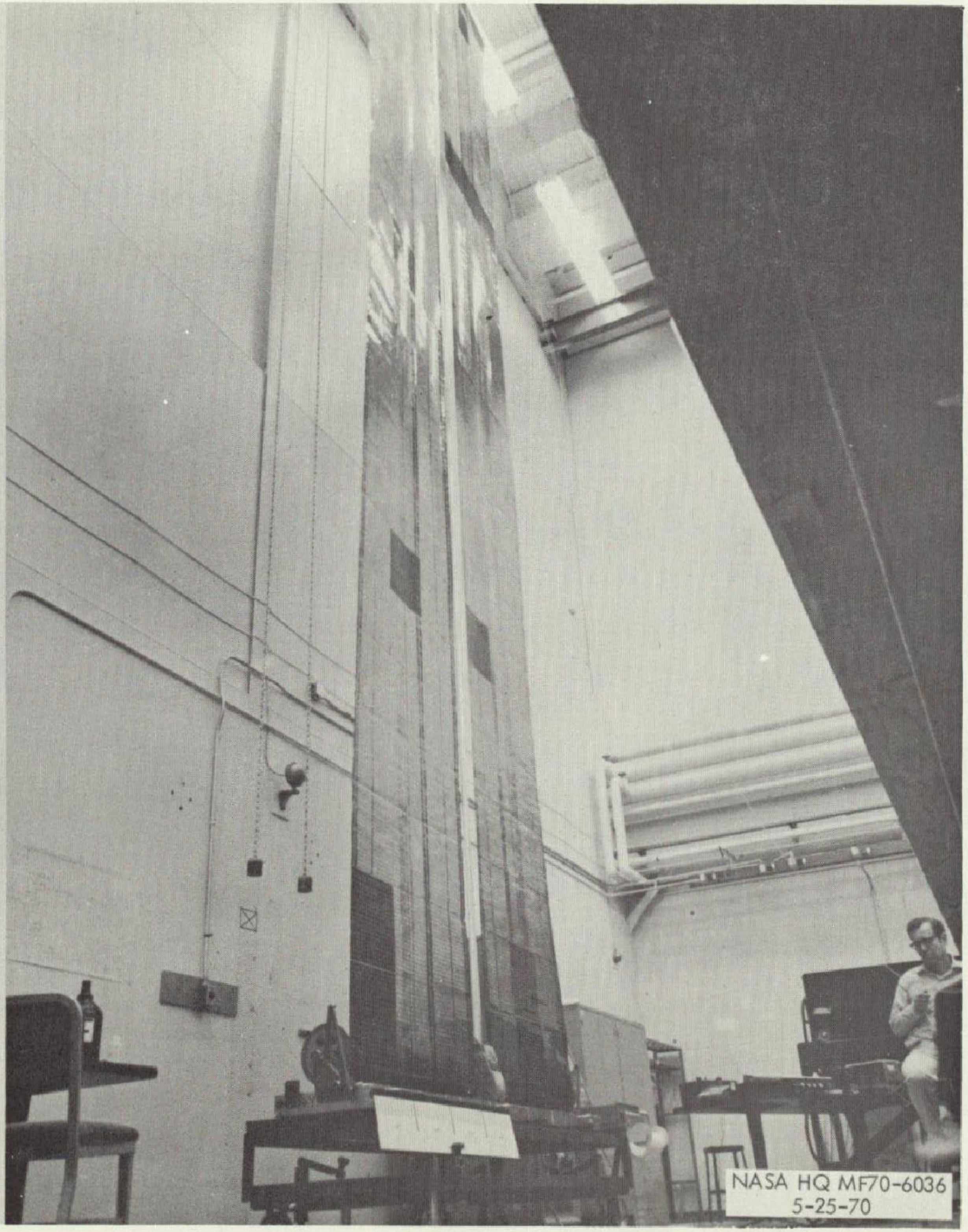
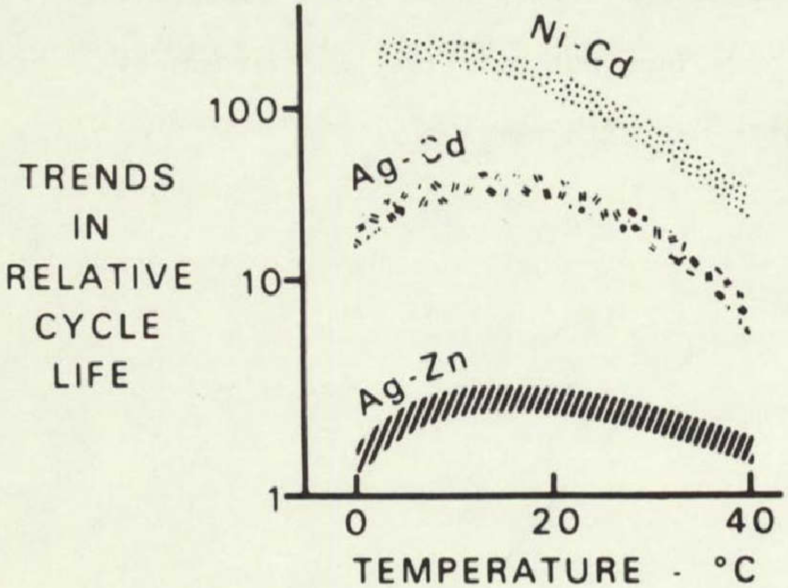
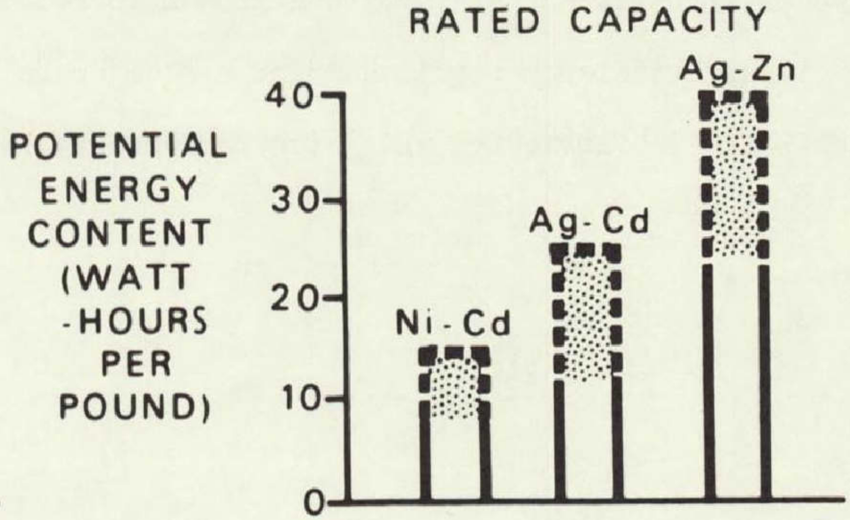


Figure 9

The rollout solar array is one attractive approach to reducing the stored volume while maintaining the high structural efficiency required. The system shown here is a rollout array 2.5 meters by 9 meters which has been fabricated and which produces 44 watts per kilogram.

RECHARGEABLE EARTH SATELLITE BATTERIES





CELL TYPE	SEPARATOR	MAJOR LIFE LIMITING PROBLEMS
NICKEL CADMIUM (Ni - Cd)	POLYPROPYLENE	a) LOSS OF WATER BY INTERNAL MIGRATION b) MIGRATION OF CADMIUM
SILVER CADMIUM (Ag - Cd)	POLYPROPYLENE/ CELLOPHANE	a) MIGRATION OF SILVER CAUSING SEPARATOR DEGRADATION
SILVER ZINC (Ag - Zn)	CELLOPHANE	a) GROWTH OF ZINC DENDRITES WITH CELL SHORTING

NASA HQ RN69-15928
(Rev. 1) 1-28-70

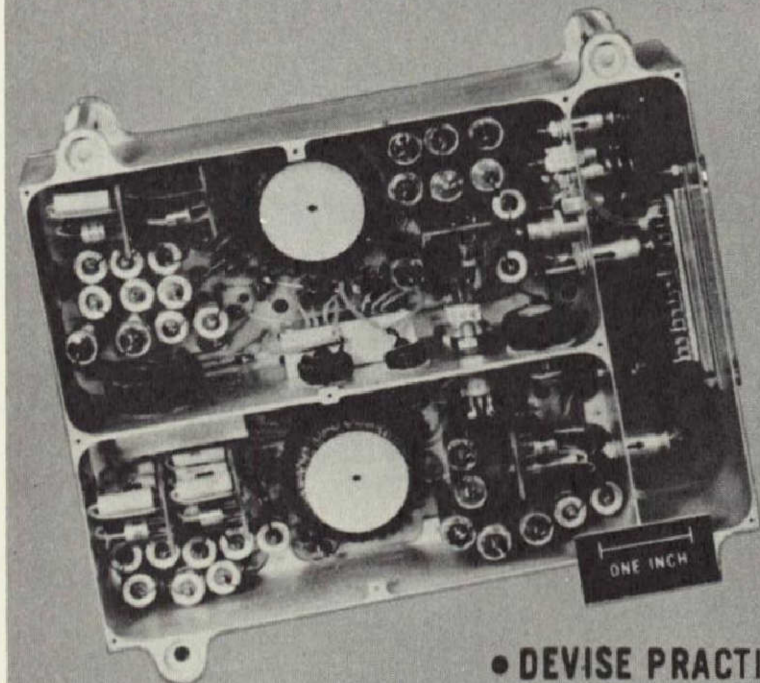
Figure 10

Chemical power, particularly rechargeable batteries, is an essential part of a solar power system in order to first activate the station and then to supply the power during the eclipse portions of the orbit. This chart illustrates the advantage in lifetime for nickel-cadmium cells; however, their low energy content makes them a less than desirable selection from this standpoint. Advancements in technology which could increase the lifetime of the higher energy content systems are highly desirable, present lifetimes being limited primarily by the major problems listed.

POWER CONVERSION ELECTRONICS

EXISTING DEFICIENCIES CAUSE:

- HIGH COST AND LOW RELIABILITY POWER SYSTEMS
- ENERGY WASTE AND THERMAL CONTROL PROBLEMS
- PERFORMANCE LIMITATIONS WHICH COULD RESTRICT FUTURE MISSION OPTIONS



TECHNOLOGY GOALS

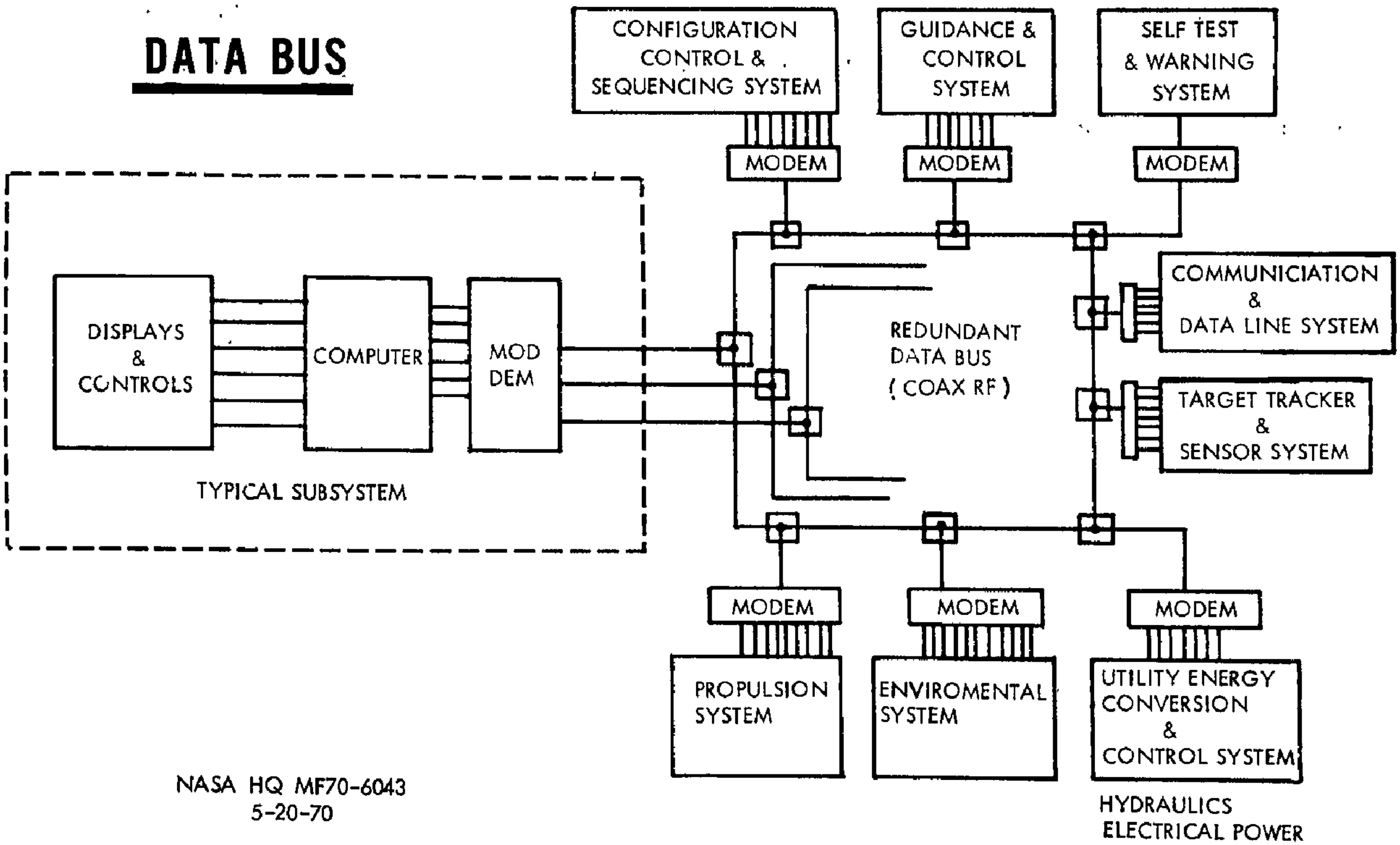
- DEVISE PRACTICAL MATHEMATICAL TOOLS FOR TRANSIENT ANALYSIS
- IMPROVE UNDERSTANDING OF NON-LINEAR CIRCUIT OPERATION
- DEVELOP NON-DESTRUCTIVE TESTS TO DETERMINE OFF DESIGN LIMITS
- IMPROVED POWER CONVERSION ELECTRONIC COMPONENTS
- DEVELOP STANDARD, MULTIPURPOSE MODULES

NASA RN69-807
12-18-68

Figure 11

Power conditioning equipment is perhaps the least advanced element of space power systems. Present equipment tends to be very costly, have low reliability, be wasteful of energy, produce thermal control problems and be limited in performance. An aggressive research program is underway to overcome these deficiencies.

DATA BUS

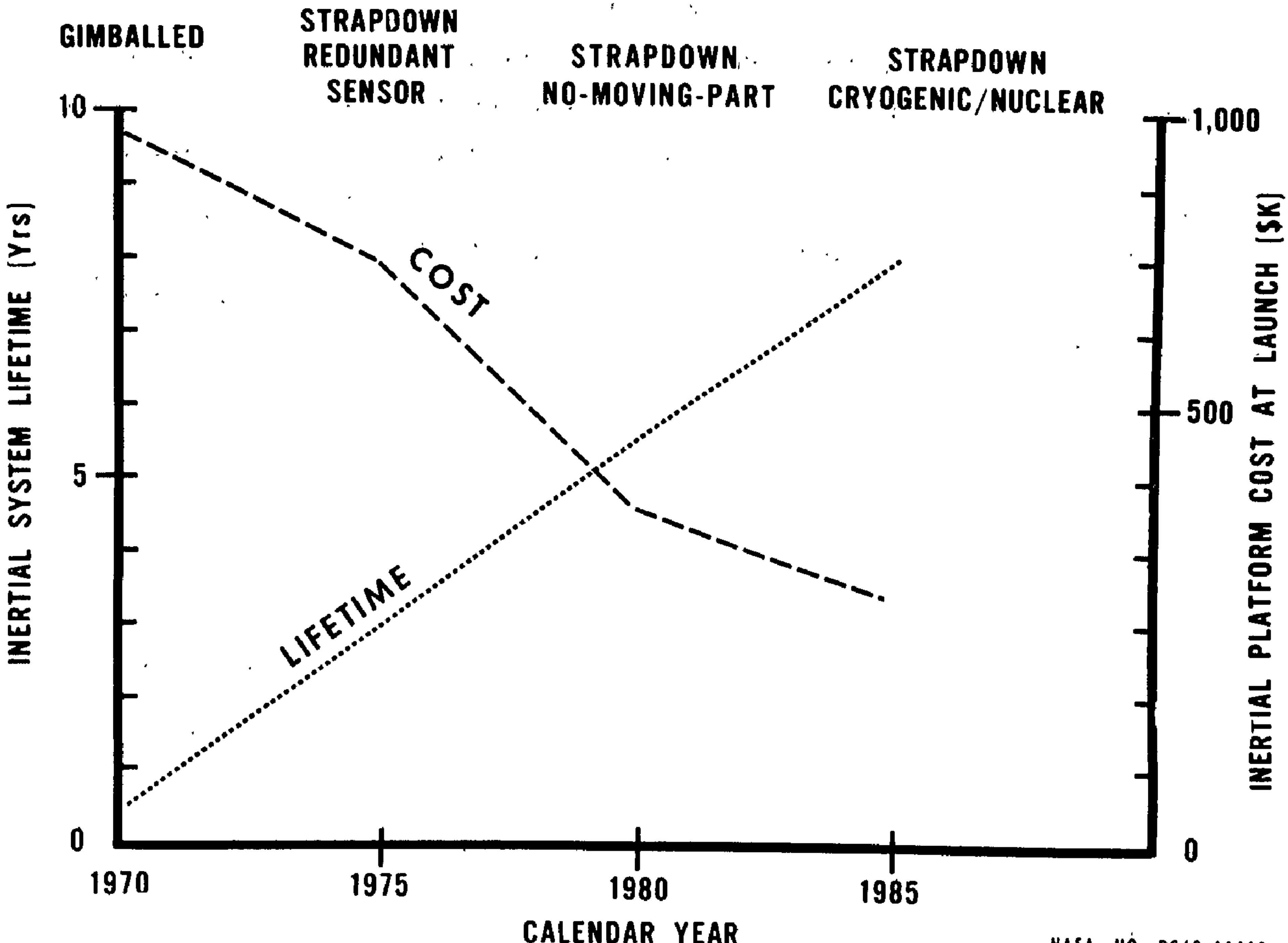


NASA HQ MF70-6043
5-20-70

Figure 12

Another primary subsystem of the space station which will have a major impact on its usefulness as a general purpose laboratory is the Information Management System. In order to interconnect all elements of the space station with a minimum of wiring, a data bus approach has been proposed. Such a bus would most likely involve a set of redundant cables, each of which would contain multiplexed information obtained from all of the connected elements. Modulator-demodulators at each terminal would provide the signal conditioning and decentralized computer systems would permit a maximum degree of flexibility and efficiency in status-monitoring, fault detection, and system growth.

INERTIAL GUIDANCE TECHNOLOGY

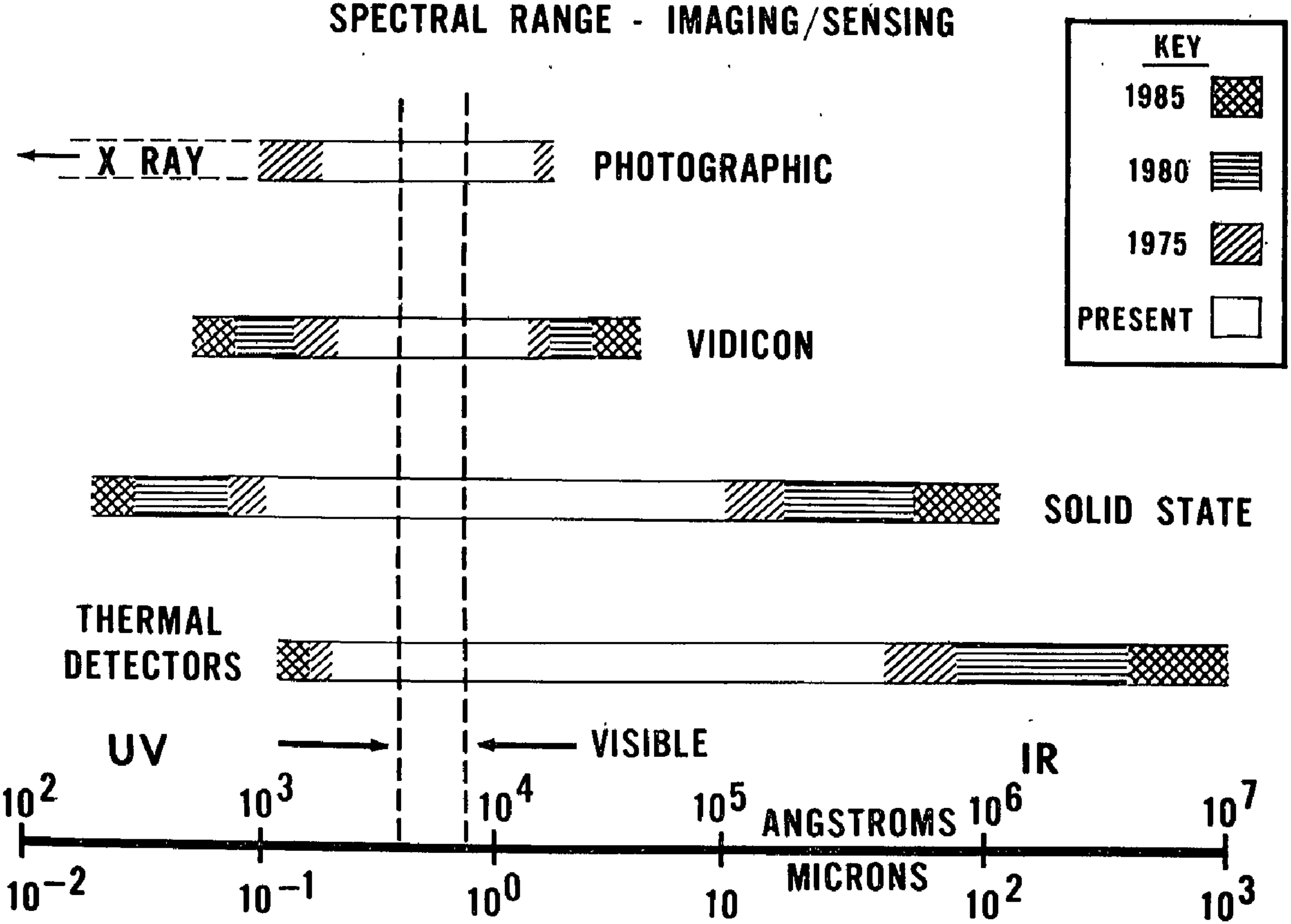


NASA HQ RC69-16460
5-23-69

Figure 13

Although guidance and navigation are not critical problems for the space station, considerable research is underway which promises to provide major improvements in both system life and costs. Trends shown here derive from the gimballed platforms of today to strapdown systems of increasing mechanical simplicity during the 1980's.

INSTRUMENTATION
TECHNOLOGY FORECAST
SPECTRAL RANGE - IMAGING/SENSING

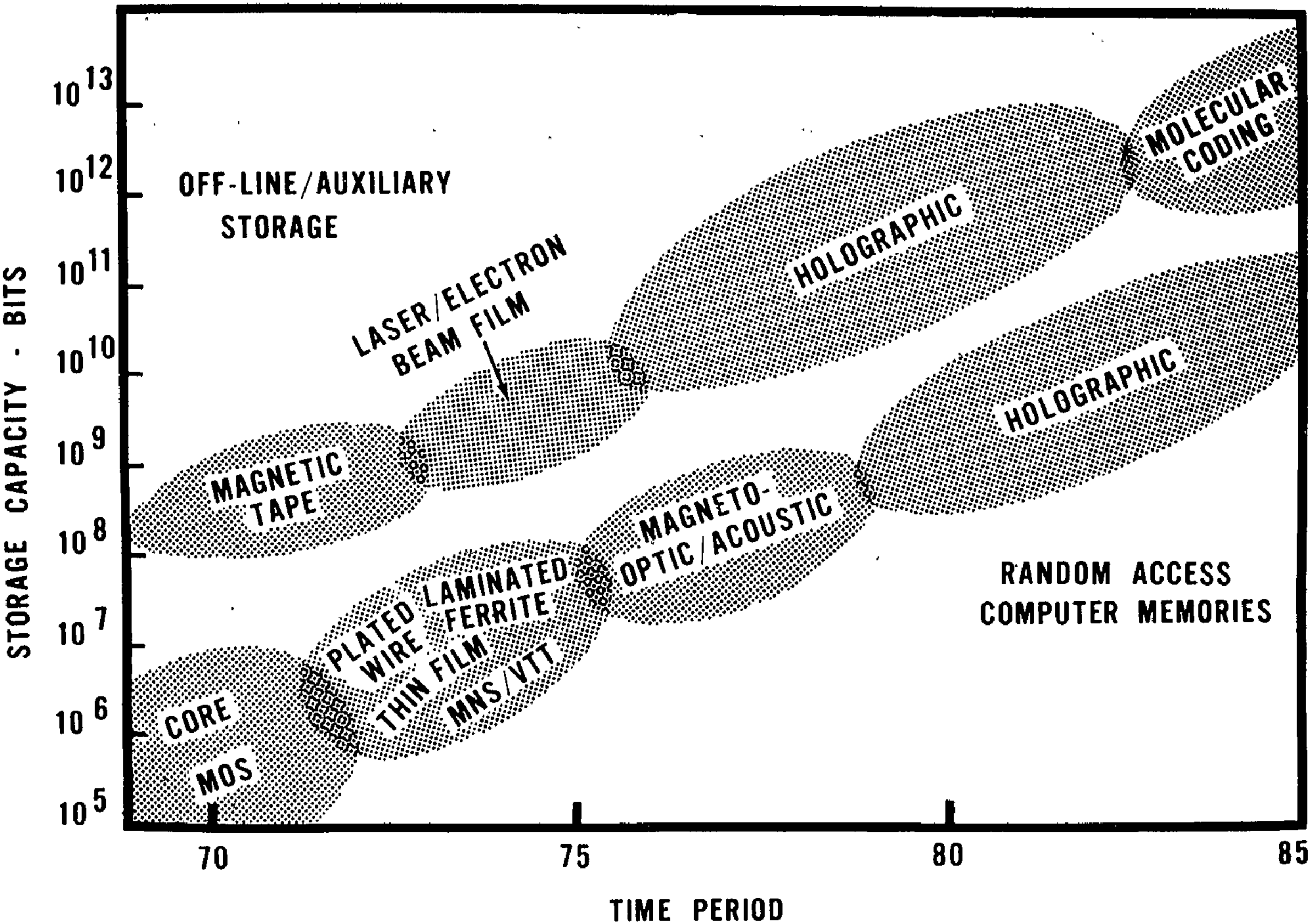


NASA HQ RC69-16463 5-23-69

Figure 14

Another area where spectacular progress can be foreseen is in the area of remote sensors. This forecast chart indicates that during the next 15-20 years, spectral ranges for all types of sensors can be expected to double by the development of new techniques. Similar advances can be expected in resolution, lifetime, storage capacity, and stability.

SPACECRAFT DATA STORAGE TECHNOLOGY TRENDS



NASA HQ RC69-16461 5-23-69

Figure 15

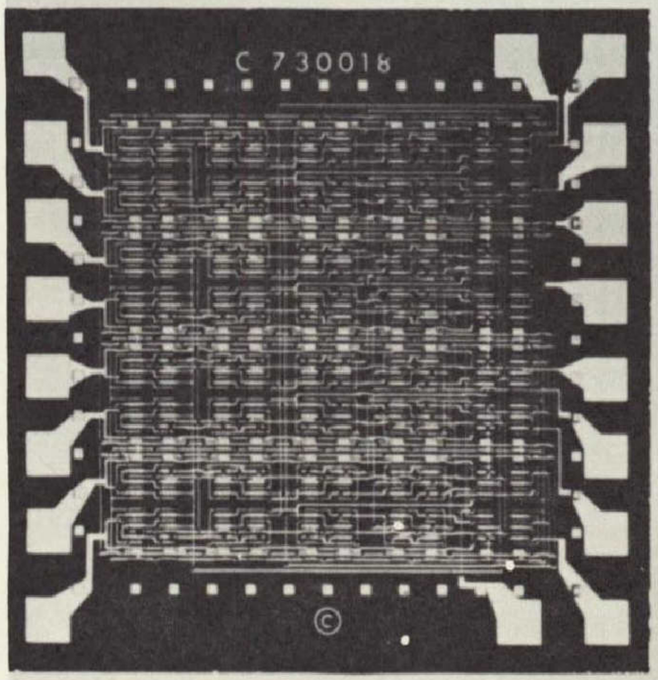
The technology trend in large capacity data storage systems also indicates a spectacular increase in capability. For random access computer memories, the evolution from today's core storage to eventual holographic techniques portends increases in storage capability from 10^6 to 10^{10} bits of data. Similar improvements in auxiliary storage from 10^8 bits for present day magnetic tape systems to 10^{12} bits or more by holographic techniques and genetic coding are envisioned. Since memory limitations are the major bottleneck in large scale data processing, these breakthroughs are of major importance for the handling of the large quantities of data which a multi-disciplinary space station may generate.

MULTICIRCUIT ARRAYS

40 x MAGNIFICATION

SINGLE-CIRCUIT SILICON DEVICE

PERFORMS 1 FUNCTION



40 x MAGNIFICATION

MULTI-CIRCUIT (LSI) DEVICE

PERFORMS 100 FUNCTIONS

- WITH 1/3 THE NUMBER OF PROCESS STEPS
- WITH 1/100 THE NUMBER OF HAND CONNECTIONS
- IN 1/10 THE WEIGHT AND VOLUME

NASA RE 67-1302
REV. 12-15-67

Figure 16

Improvements in micro-electronics continue to revolutionize the development of electronic components. The single-circuit silicon device shown on this chart is about .5 millimeter on a side. The multi-circuit large scale integrated (LSI) circuit devices, although only about two and one-half times as large can accomplish 100 functions. More important than the reduction in size and weight, however, are the reduction in processing steps to 1/3 and the number of hand connections to 1/100 those required with the use of single function chips.

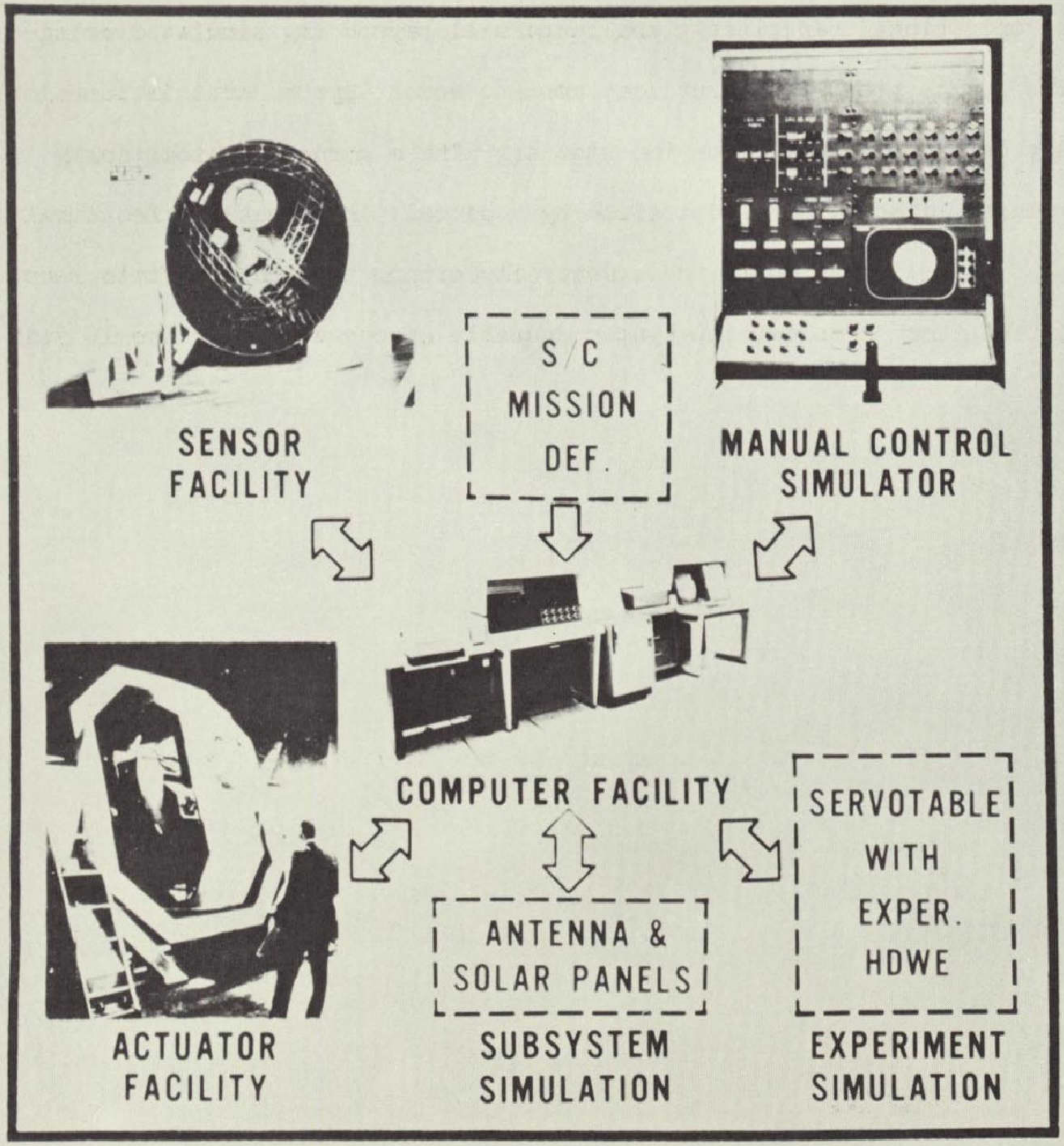
CONTROL MOMENT GYRO PROTOTYPE

NASA HQ RE67-15831 2-10-67

Figure 17

The dynamic control of the space station attitude poses a challenge well beyond any similar precision control accomplished to date. The Skylab program will utilize control moment gyros for this function and more advanced units are likely candidates for use on the station. These gyros are essentially a constant speed flywheel whose plane of rotation is controlled by a gimbal. Movement of the gimbal causes the momentum stored in the flywheel to act upon the spacecraft forcing the spacecraft to react. The main requirement for the space station is to develop systems capable of operating for the 10 year lifetime.

SPACE STATION/SPACE BASE SIMULATED CONTROL FUNCTIONS



- VEHICLE DYNAMICS AND MANEUVERS
- VEHICLE STABILITY
- EXPERIMENT POINTING
- CREW OPERATIONS
- SUBSYSTEM OPERATIONS

NASA RE70-766
12-29-69

Figure 18

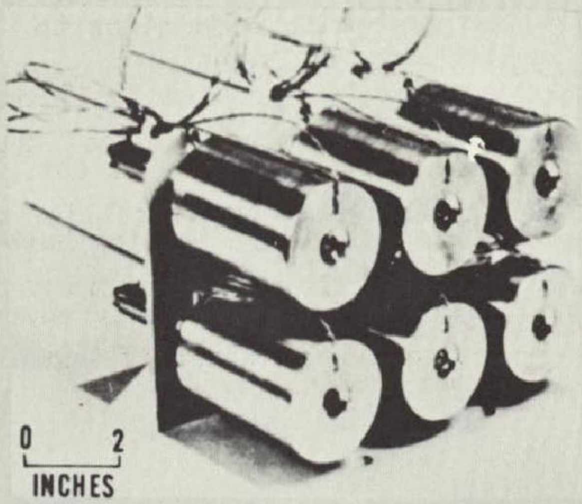
Control moment gyro arrangements, operational capability, and performance are being simulated using actual hardware as much as possible. The simulations include manual control inputs, experiment functions and related spacecraft subsystems. These are tied together with a computer which inputs vehicle dynamics, mission requirements, disturbances, and simulates the control computer. The results verify the control logic, accuracy of spacecraft attitude sensors, compatibility with experiment requirements, the opportunity to test other system monitoring equipment and the effect of manual control.

RESISTOJET TECHNOLOGY FOR MANNED SPACE STATIONS

AERODYNAMIC DRAG CANCELLATION & ATTITUDE CONTROL

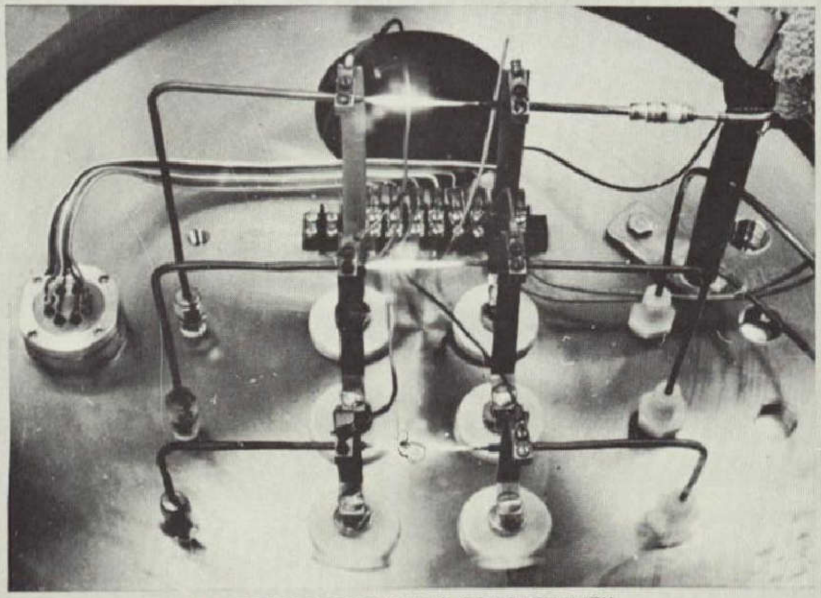
CURRENT STATUS

- ENDURANCE TEST COMPLETED



- 4 AMMONIA UNITS~8000 HRS.
- 2 HYDROGEN UNITS~6000 HRS.

- BIOWASTE THRUSTER RESEARCH INITIATED



- MATERIALS/BIOWASTES COMPATIBILITY
- INITIAL THRUSTER PERFORMANCE EVALUATION WITH WATER, CARBON DIOXIDE, & METHANE

CONTINUED THRUSTER & SUBSYSTEM COMPONENTS R & T

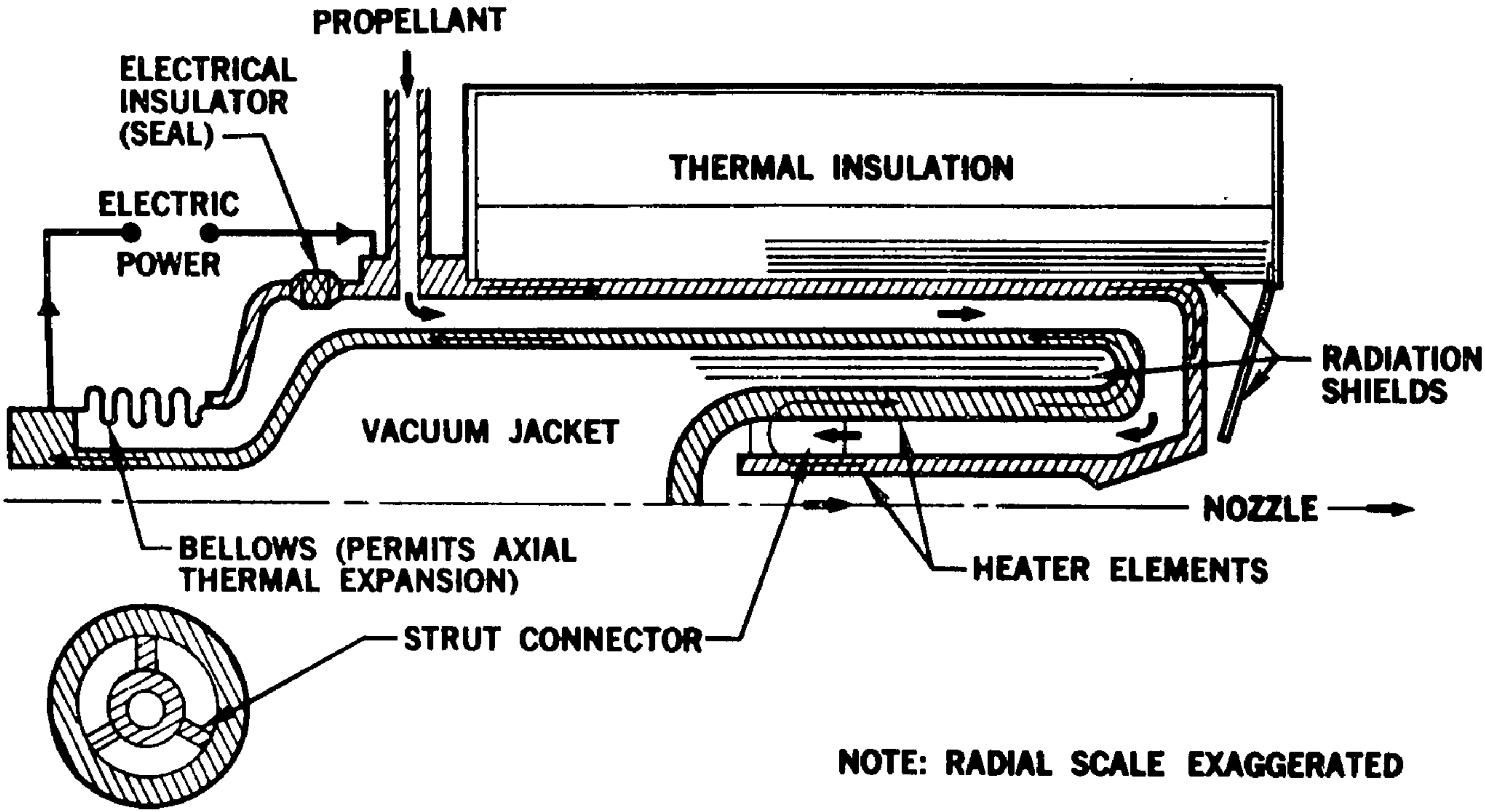
INTEGRATED LIFE SUPPORT/RESISTOJET SYSTEM INVESTIGATION

NASA RN70-901
2-5-70

Figure 19

A supplemental requirement with any control moment gyro stabilization system is some means to periodically unload the momentum accumulated. One attractive approach to this problem is through the use of resistojets, a device which utilizes waste materials from the space station as the reaction material in an electrically heated rocket. To date, substantial hours of testing have been accomplished using both ammonia and hydrogen, and research is underway to select materials suitable for construction of these thrusters which will withstand the induced problems of oxidation, carbonization, or material deposition.

EVACUATED RESISTOJET CONCEPT



NASA HQ MF70-6045
5-20-70

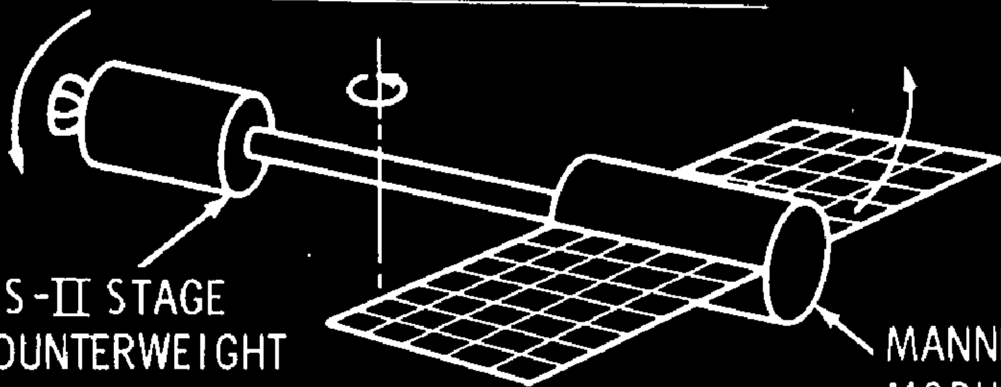
Figure 20

The resistojet itself is a relatively simple device in which the propellant is passed over a resistance-heated heat exchanger and through a nozzle to produce thrust. The 4.5 gram biowaste resistojet shown schematically here has overall dimensions of approximately 100 millimeters in length and 50 millimeters in diameter and requires approximately 200 watts of power.

SPACE STATION - SPACE BASE

ARTIFICIAL-GRAVITY DYNAMICS PROBLEMS

SPACE STATION CONCEPT



DYNAMIC BEHAVIOR DURING
ARTIFICIAL - G EVALUATIONS

DYNAMIC SCALE MODEL TESTS
FOR LARGE SYSTEMS

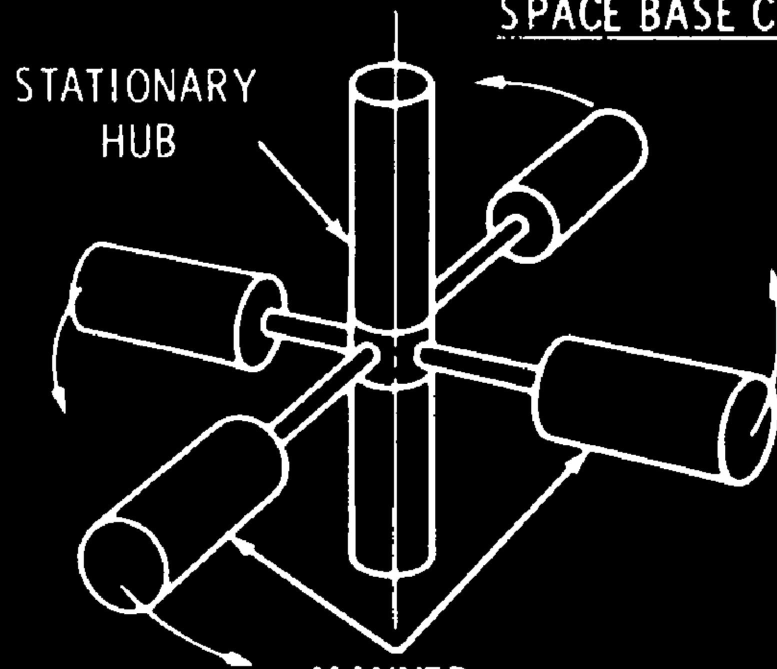
SPACE BASE CONCEPT

LONG - TERM ROTATIONAL STABILITY

MASS BALANCE DISTURBANCES

STRUCTURAL INTERACTIONS

DYNAMIC SIMULATION



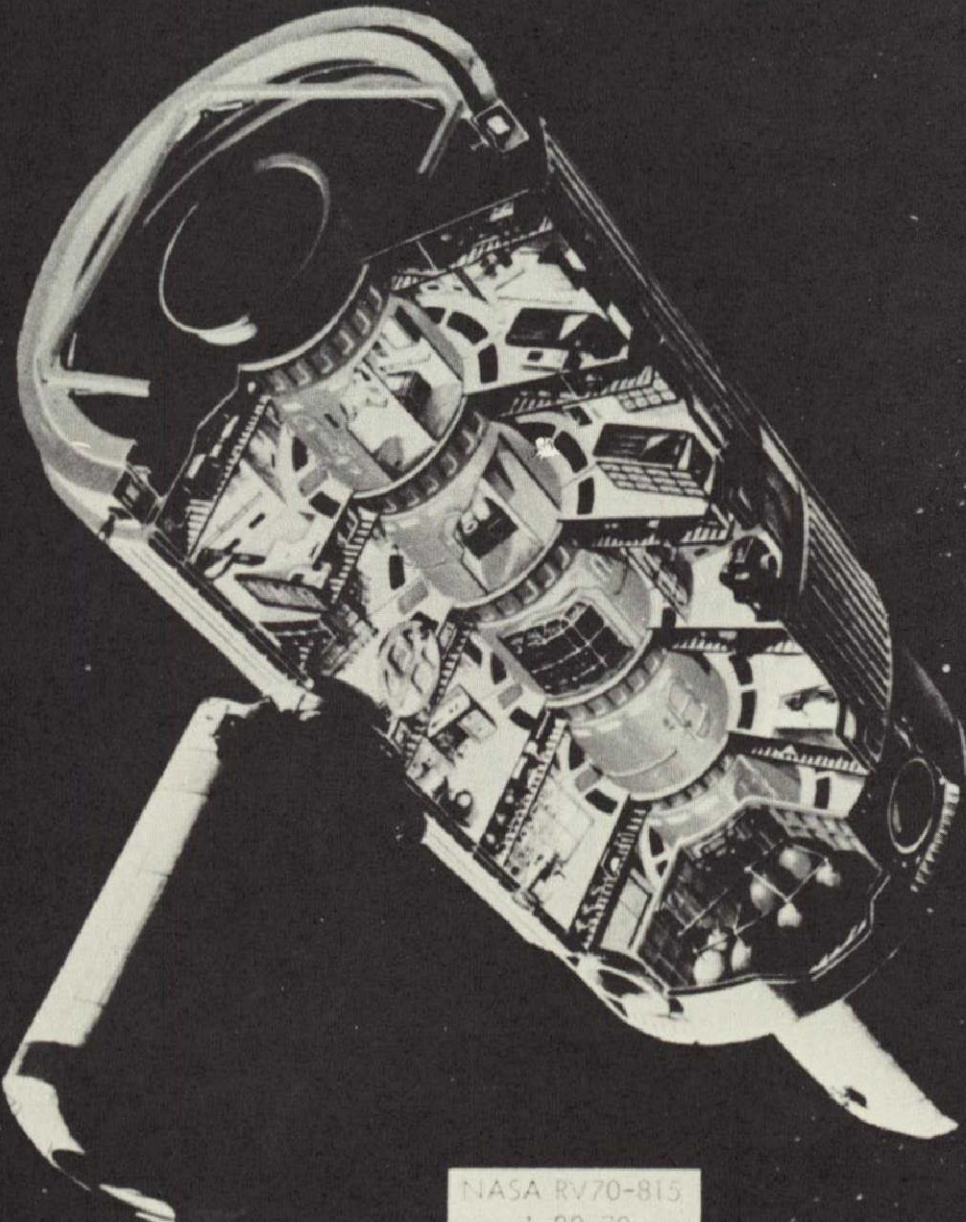
NASA RV70-804
1-14-70

Figure 21

The question of whether artificial gravity will be provided for long duration space flight has not been answered. It may be desirable either for astronaut performance enhancement or for physiological reasons, or for both.

The primary mode of operation being considered for the generation of intravehicular artificial gravity utilizes rotation of all or portions of the space vehicle. Because these systems involve large rotating modules connected with relatively long flexible members, dynamic response of the structure must be well defined so that stabilization and control systems can be properly designed. Dynamic scale model tests are presently being made on both space station and space base configurations.

SPACE STATION STRUCTURES AND ENVIRONMENTAL PROTECTION



PROBLEMS

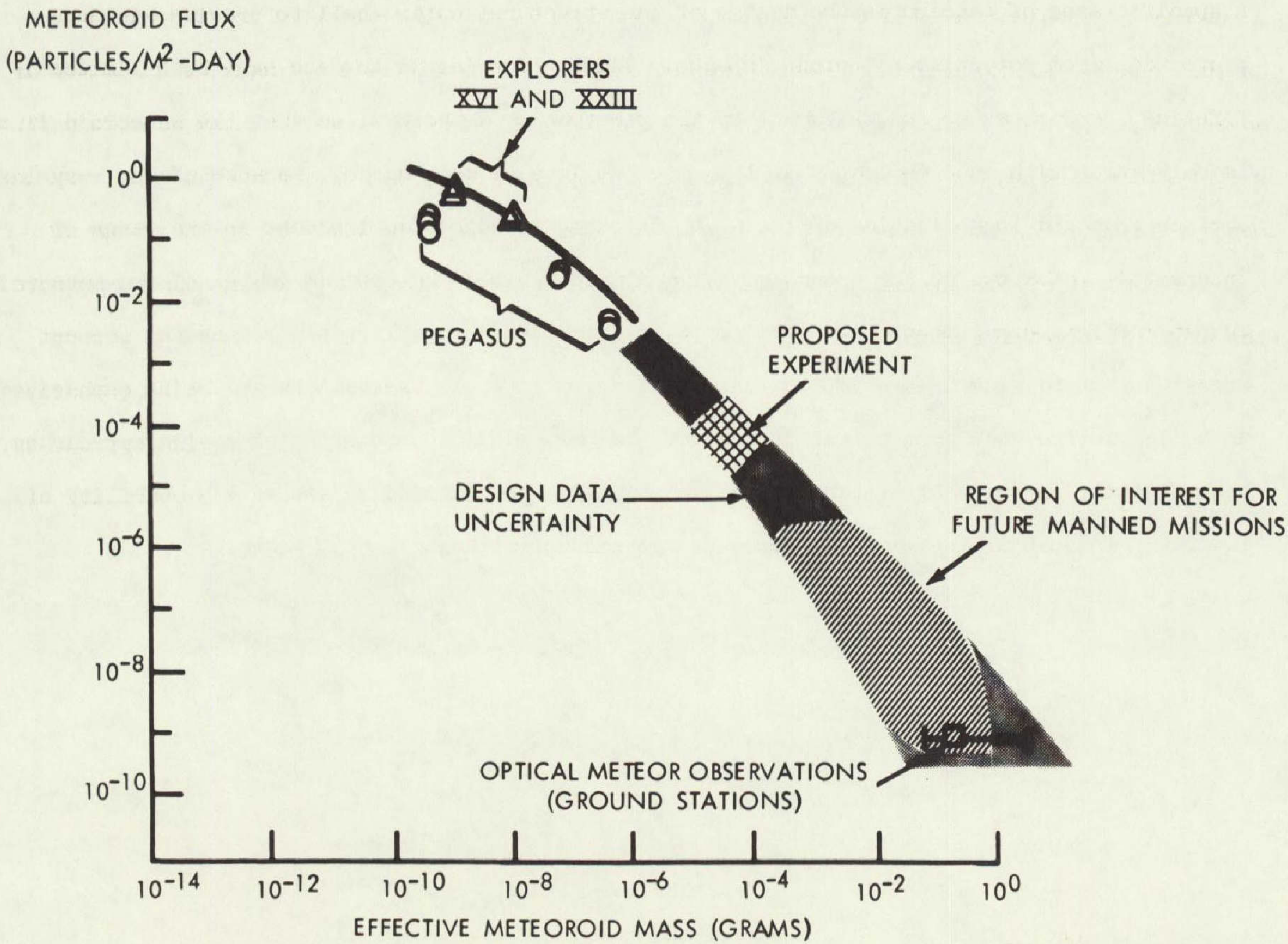
- LEAKAGE OF SEALS
- LEAK DETECTORS
- METEOROID PROTECTION
- DAMAGE EVALUATION
- REPAIR TECHNIQUES
- EXTERNAL RADIATORS
- THERMAL CONTROL COATINGS
- SURFACE CONTAMINATION
- THERMAL SCALE MODELING
- ARTIFICIAL GRAVITY DYNAMICS

NASA RV70-815
1-20-70

Figure 22

A summary of problems related to space station structures and environmental protection is shown in this chart. Although none of these problems appears insurmountable, research activities to advance the state of technology will produce significant dividends in terms of reduced launch weight, increased system lifetime, and mission safety, and decreased logistics resupply requirements. In general, these areas of concern are related to the structural integrity of the station and the control of the thermal environment, in addition to the dynamic considerations posed by the artificial gravity operation.

METEOROID DESIGN ENVIRONMENT (1970)



NASA RV70-805
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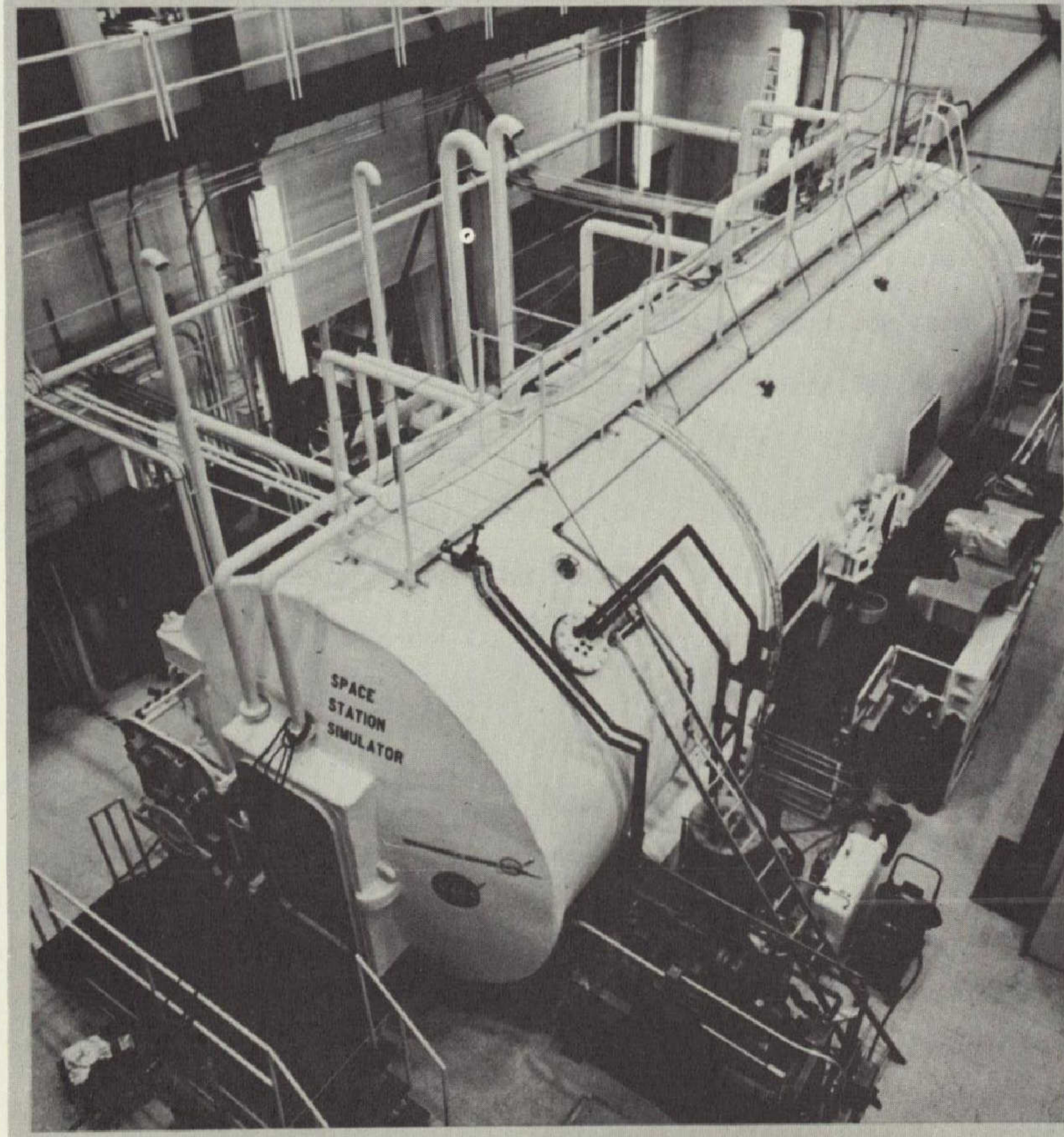
Figure 23

A specific area of concern is the design of the structural outer shell to provide adequate protection from potential meteoroid impacts. Flight experiments to date have been limited in lifetime, surface area, and thickness of the penetration detectors, so that the meteoroid flux is only known with some certainty in the upper regions of this curve. Because of the very large surface area and long lifetime of the space station, meteoroid environment in the range of interest is not known to the accuracy that would be desired for optimum design of the meteoroid bumper. Flight experiments have been proposed which would significantly reduce the present uncertainty, and ground observations using radar and optical observations are being emphasized to better define the lower end of the curve. In the meantime, conservative design approaches, though costly in terms of station launch weight, will be utilized to assure a probability of 0.9 of no meteoroid penetration of crew or systems compartments for 10 years.

90 DAY MANNED TEST

. . . ADVANCED OXYGEN & WATER REGENERATION TECHNOLOGY



FEATURING:

- 10 NEW SUB-SYSTEMS
- MICROBIOLOGY STUDIES
- CREW SELECTION TECHNIQUES
- RELIABILITY DATA
- MAINTENANCE EXPERIENCE
- LONGEST REGENERATIVE MANNED TEST

LANGLEY RESEARCH CENTER/MC DONNELL-DOUGLAS

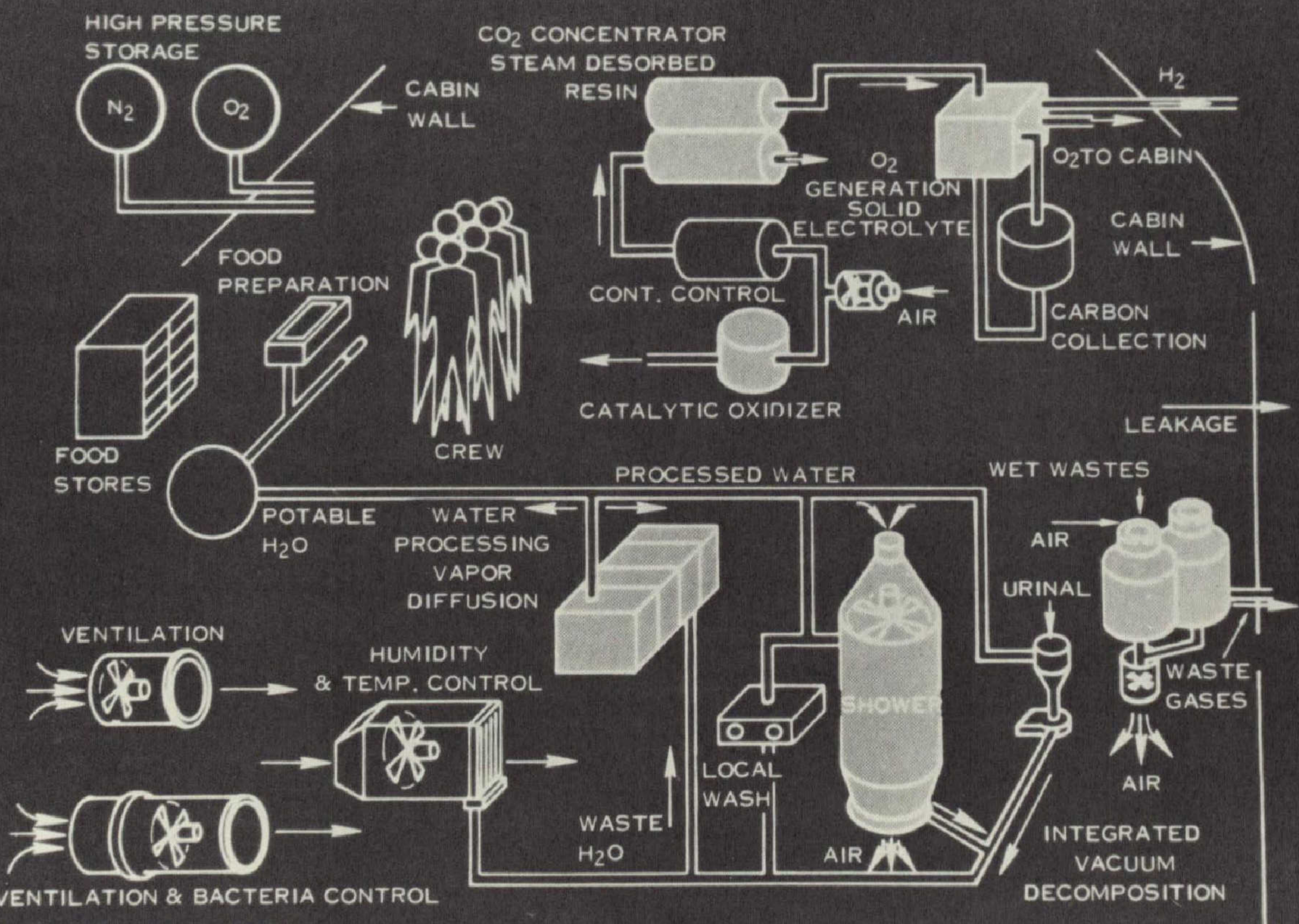
NASA RB70-716
12-5-69

Figure 24

One of the continuing goals of the space station program is to develop the technology for closed-loop regenerative life support systems which can be utilized in more advanced missions of the future. To date the longest simulation of a complete closed-loop system has been a 60-day mission; however, a 90-day simulation is to begin soon under the auspices of the NASA Langley Research Center by the McDonnell Douglas Astronautics Corporation at its Huntington Beach, California, facility. This new simulation run will include a water electrolysis unit for oxygen recovery, a vacuum distillation and vapor pyrolysis unit for water recovery, a water vapor electrolysis unit for humidity control, a flight-type atmospheric sensor utilizing a mass spectrometer to accurately measure the atmospheric constituents, and an advanced carbon dioxide removal unit. Four men will reside in this simulator continuously for the 90-day period and in addition to the subsystem testing, microbial, physiological, and behavioral investigations will be conducted.

ADVANCED INTEGRATED LIFE SUPPORT SYSTEM SCHEMATIC

. . . INCORPORATING NEW ADVANCED SUB-SYSTEMS



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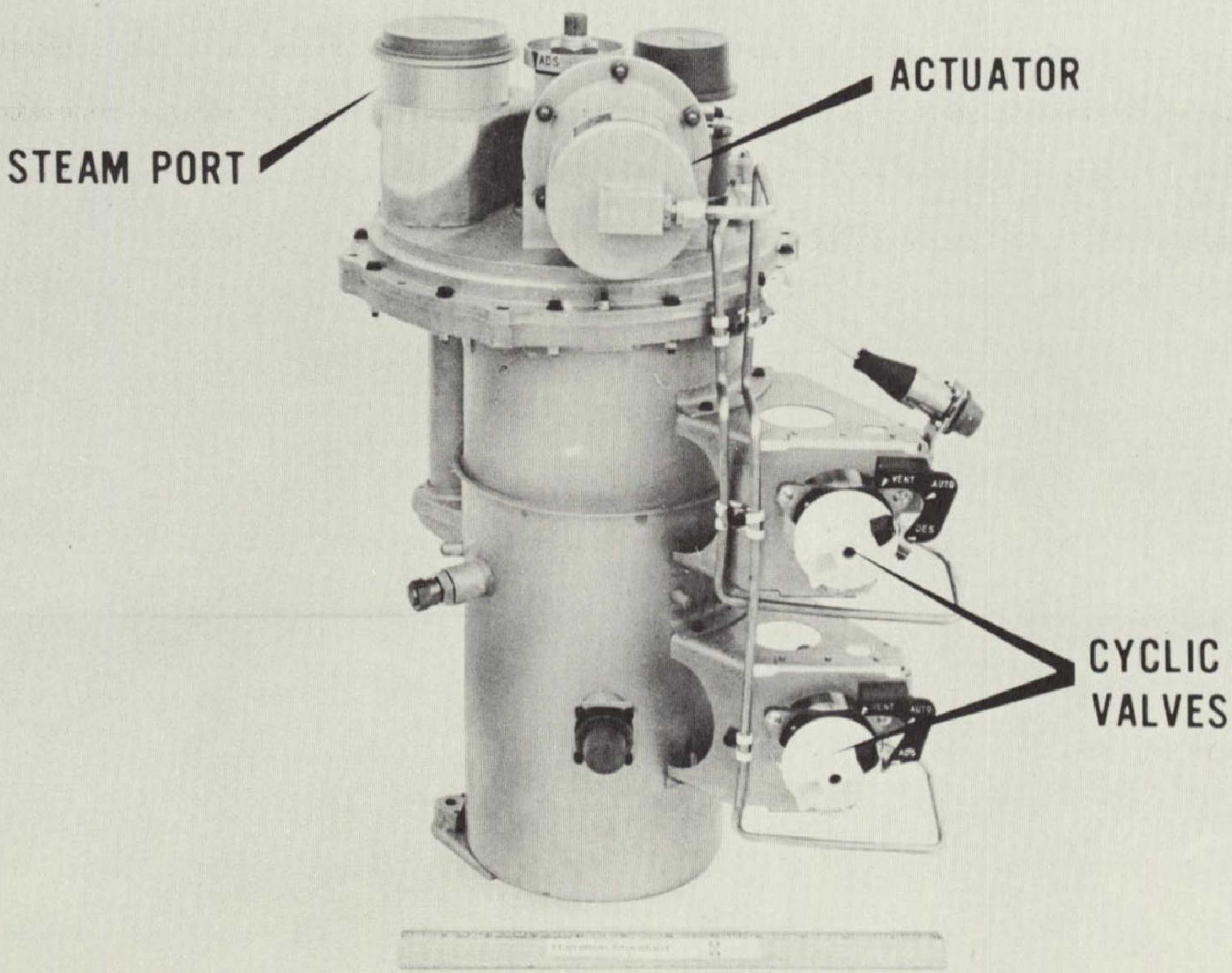
12-18-69

Figure 25

The next generation of an integrated life support system for which technology development is underway is illustrated on the attached schematic. This system has been designed to provide life support for a two-year mission without resupply, and incorporates such new subsystems as a steam desorbed resin carbon dioxide concentrator, a solid electrolyte oxygen generator, a catalytic oxidizer for control of atmospheric contaminants, a new wet waste management system, a zero gravity full-body shower, and a vapor diffusion water processing unit.

ADVANCED CARBON DIOXIDE CONCENTRATOR
STEAM DESORB AMINE POLYMER
FOR 90 DAY MANNED RUN



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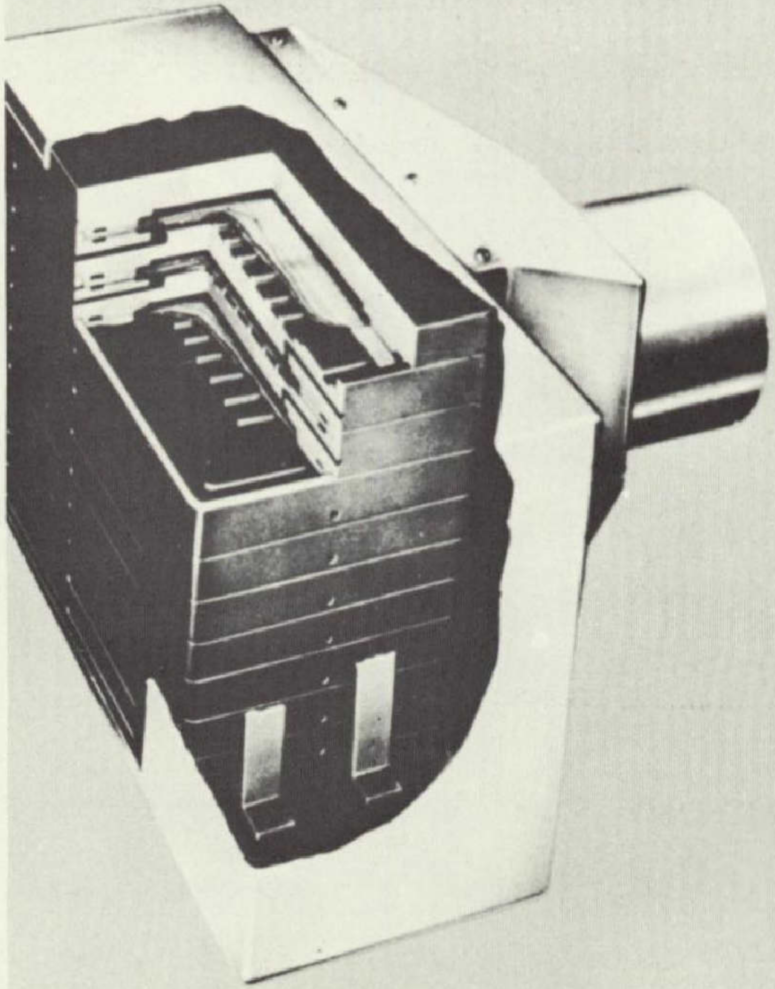
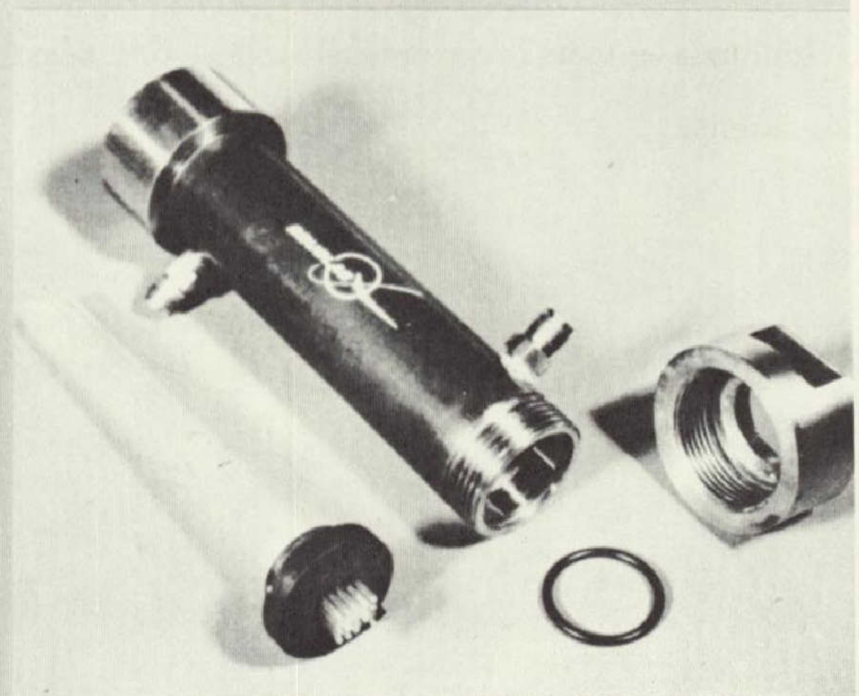
12-8-69

Figure 26

This is a photograph of the actual carbon dioxide concentrator which will be used in the 90-day simulation. Its working media is an amine polymer which adsorbs carbon dioxide from the atmosphere and which is periodically desorbed by a steam purge. A Sabatier system is then used for reduction of carbon dioxide to methane and water.

WATER AND OXYGEN RECLAMATION





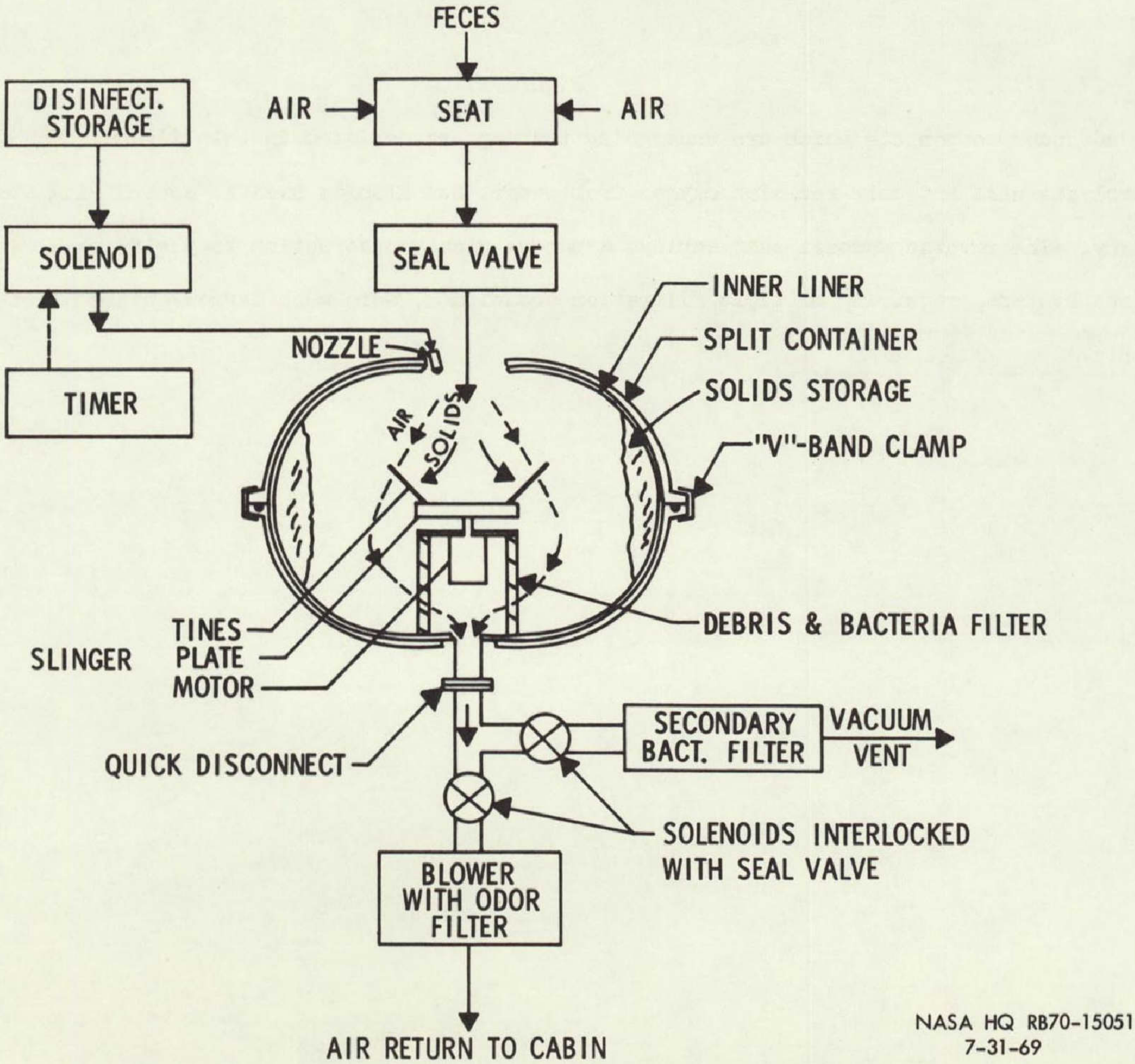
REVERSE OSMOSIS TEST CELL
TO RECLAIM WATER

NASA R69-997
1-31-69

WATER ELECTROLYSIS
TO OBTAIN OXYGEN

Figure 27

Other advanced components which are undergoing testing are depicted in this figure. The water electrolysis unit not only reclaims oxygen from water, but also is used in controlling atmospheric humidity. The reverse osmosis unit employs a porous glass construction to purify wash water. Previous systems, requiring multiple filtration techniques, were much larger and required expendable elements.



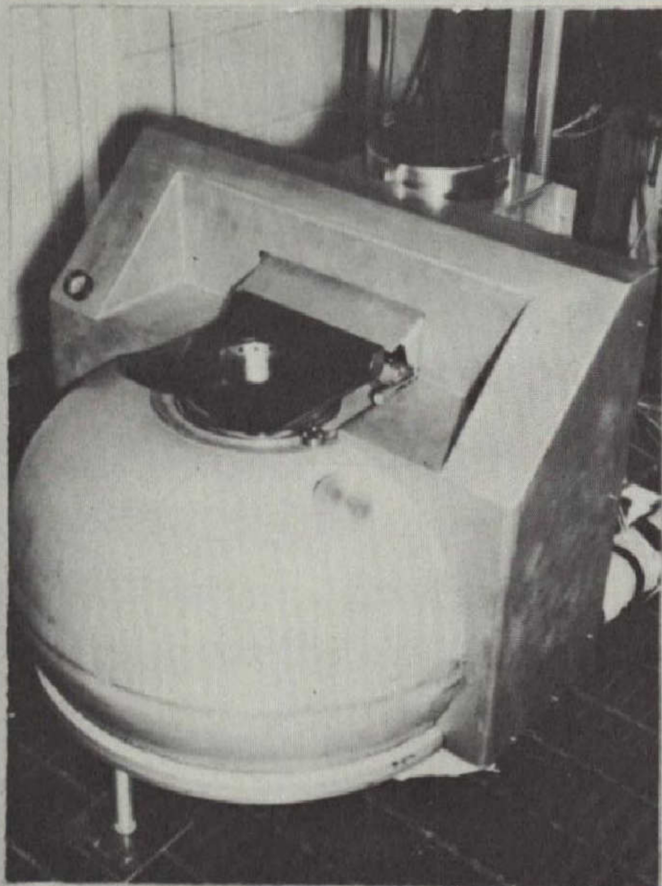
SYSTEM BLOCK DIAGRAM

Figure 28

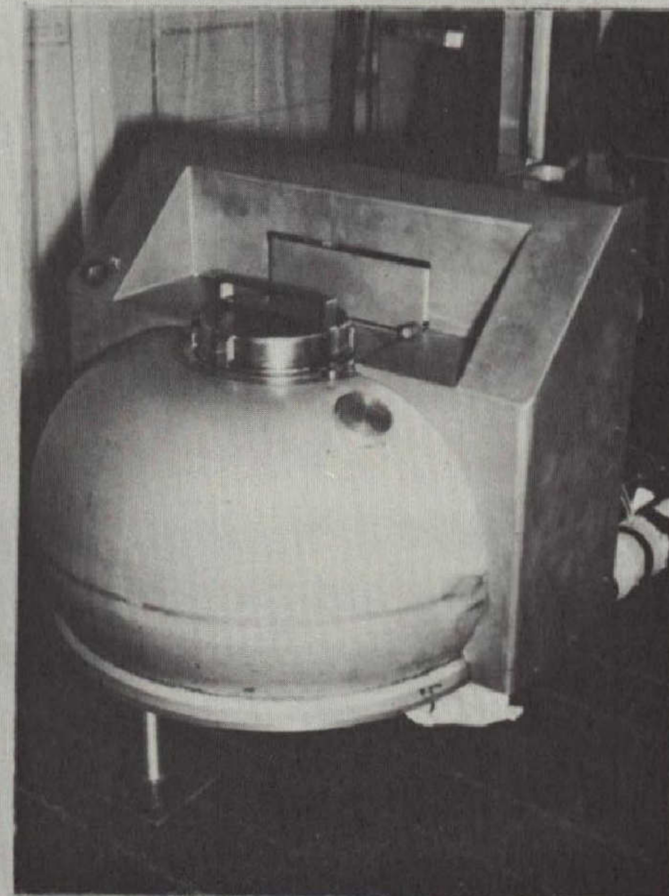
One of the most challenging problems related to man's living in space for extended periods has been the collection of human waste. This block diagram describes the system which will be used in the 90-day run and which has been designed to operate in a zero gravity environment. The slinger is used to break up the wastes and deposit them against the sides of the container. The system is then vacuum vented to dry the material and periodically the residue can be removed by opening the container and replacing the inner liner. This unit is designed to collect the waste from 4 men for 90 days.

ADVANCED SOLID WASTE MANAGEMENT SYSTEM

. . . UNDERGOING MICROBIOLOGICAL TESTS IN CLEAN ROOM



OPEN FOR USE



CLOSED FOR PROCESSING

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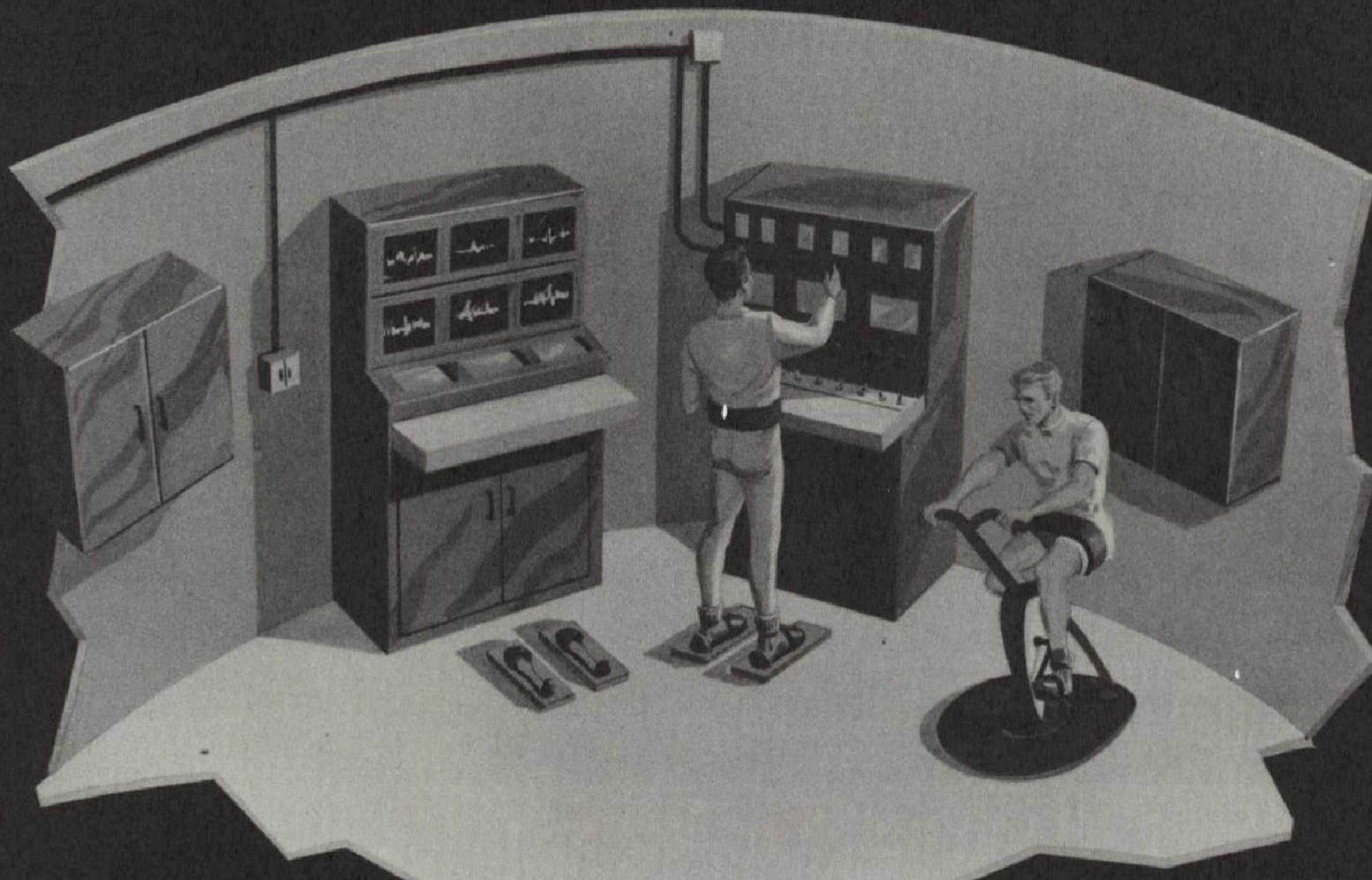
NASA RB70-743
12-18-69

Figure 29

These photographs of the fecal collection unit described on the previous chart show the system installed in a clean room at the NASA Langley Research Center where microbial and odor testing has been conducted.

IMBLMS

INTEGRATED MEDICAL/BEHAVORAL LABORATORY MEASUREMENT SYSTEM



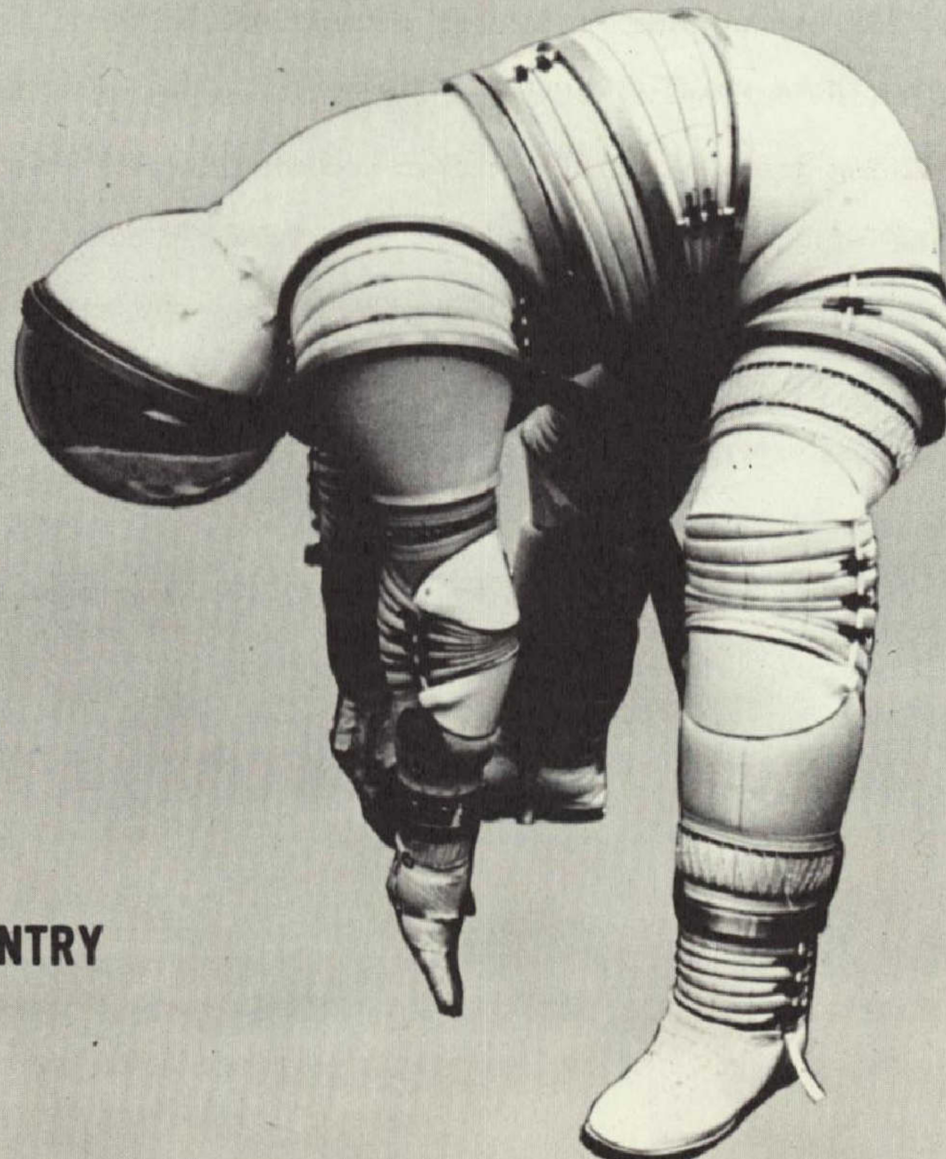
NASA HQ MM69-5745
6-27-69

Figure 30

The Integrated Medical and Behavioral Laboratory Measurement System is a highly flexible and sophisticated laboratory system designed to accommodate the presently planned experiments as well as those which could be anticipated in the future. It is basically a rack and module system which can be assembled into working consoles according to the requirements of the medical and behavioral experiments program and the space station. As a design goal, it will employ maximum commonality of measurement techniques as well as functional and structural elements. To date, two early prototype systems have been constructed by the General Electric and Lockheed Corporations and these systems are being evaluated at the NASA Manned Spacecraft Center. The system consists of five functional elements: (1) Physiological; (2) Behavioral; (3) Biochemical; (4) Microbiological; and (5) Data Management. Together they will accommodate all eight areas of investigation to which the behavioral and medical experiments program is directed.

ADVANCED HYBRID CONSTANT VOLUME SPACE SUIT

... INCREASED WAIST MOBILITY



- GREATER MOBILITY
- 50% REDUCTION OF TORQUES
- MULTIPLE SIZING
- NEUTRAL JOINT STABILITY
- QUICK-DON SINGLE AXIS WAIST ENTRY

MANNED SPACECRAFT CENTER

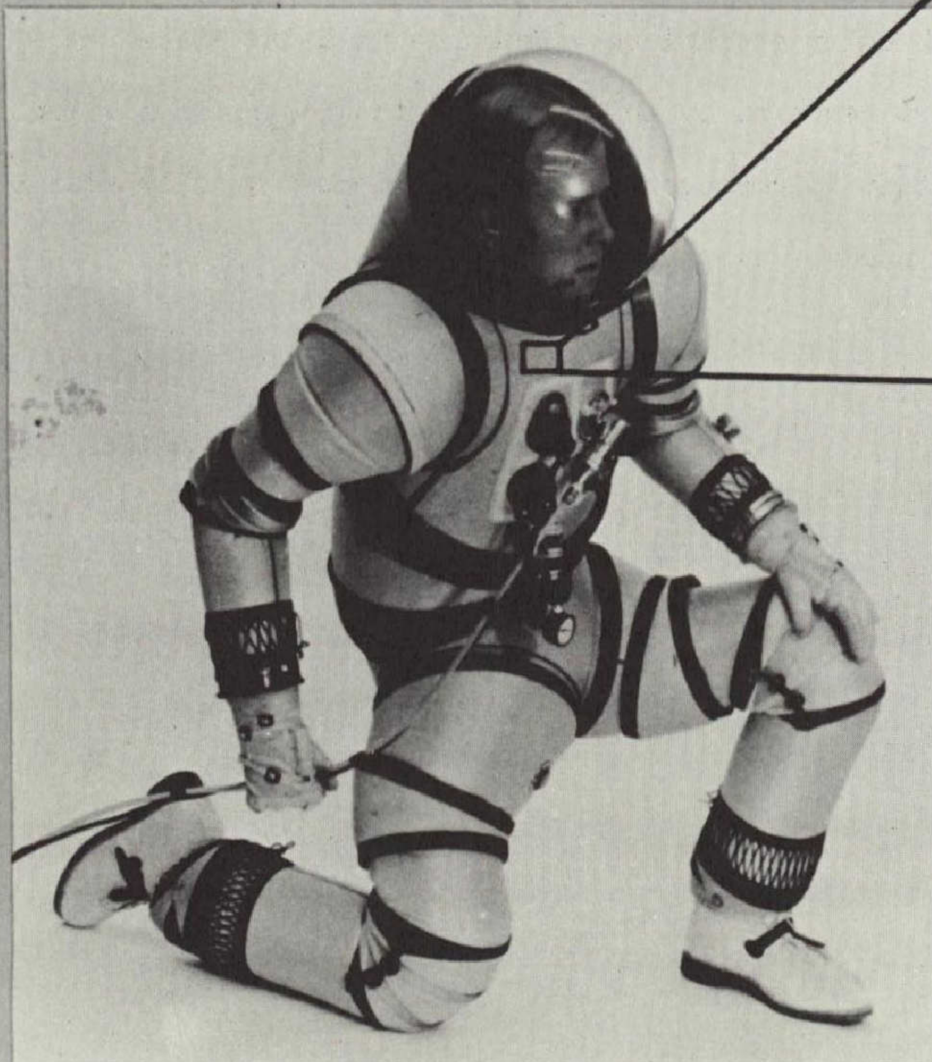
NASA RB70-701
11-14-69

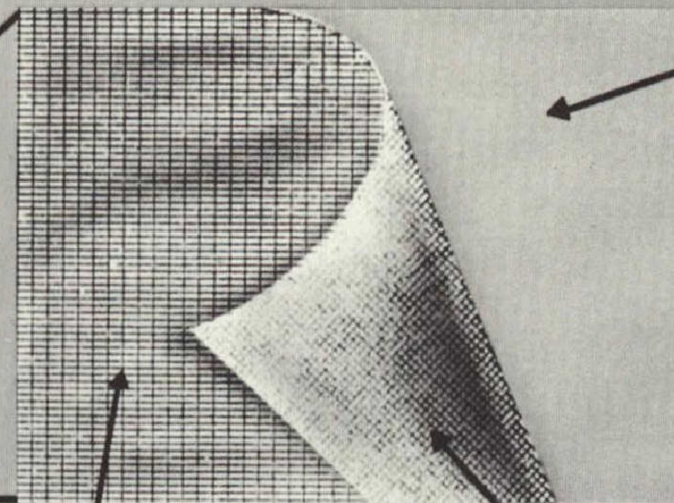
Figure 31

Although the space station and space transportation system designs will provide a shirtsleeve environment for the astronauts in most situations, continuing research work is desirable on improved space suits for contingency situations as well as extravehicular operations. Emphasis is being placed on obtaining greater mobility and in reducing the effort required by the astronaut to accomplish a given amount of work. This photograph illustrates a constant volume suit which can be donned quickly and which provides significant improvement over systems used previously.

ADVANCED COMPONENTS FOR SPACE SUITS

METAL FABRIC





- FLAME PROOF
- ONE LAYER-LESS BULK
  - ABRASION RESISTANCE
  - GAS RETENTION
- BONDING 50% STRONGER
- VARIETY OF CONSTRUCTION AND FASTENING TECHNIQUES

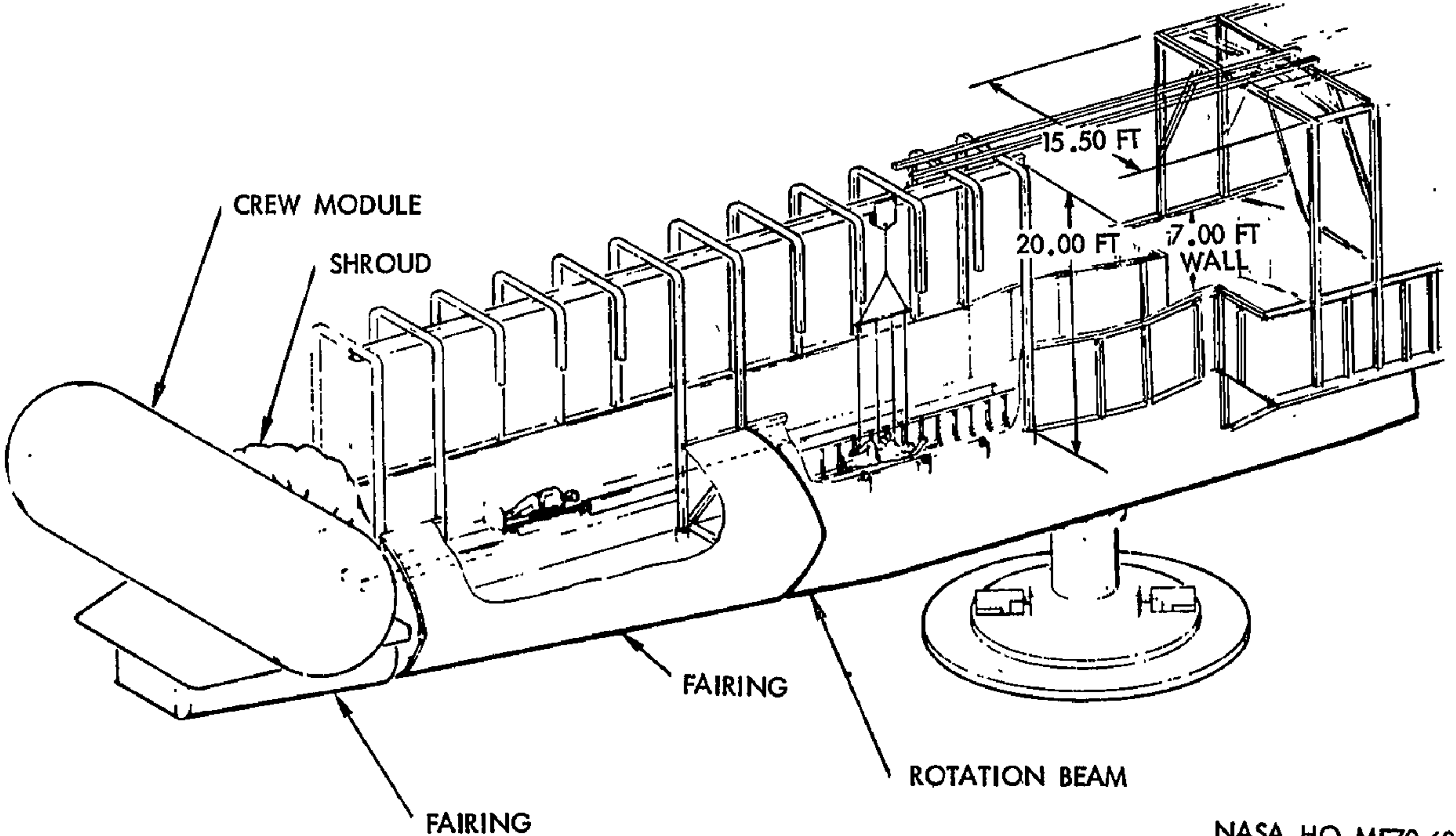
MANNED SPACECRAFT CENTER

NASA RB70-703
11-14-69

Figure 32

Related space suit research is directed toward improved materials providing longer life. This chart illustrates a suit utilizing a coated metal fabric which is flame proof, less bulky, and stronger than earlier systems.

CREW MODULE END OF ROTATIONAL FACILITY



NASA HQ MF70-6039
5-20-70

Figure 33

One of the most interesting questions with respect to manned habitation of an artificial gravity station is the effect of rotational rates and moment arms. A device is being used at the North American Rockwell facility at Downey, California, to explore some of these effects. The rotational facility has a variable radius from approximately 25 to 40 meters and can achieve rotational rates up to 12 revolutions per minute. The crew module at the end of the beam is approximately 3 meters in diameter by 12 meters in length, and can be inclined so as to keep the resultant gravity vector perpendicular to the floor.

TECHNOLOGY READINESS ESTIMATES

DATE TECHNOLOGY DESIRED

CURRENT EMPHASIS ADEQUATE

- CHEMICAL PROPULSION
- PASSIVE SHIELDING
- SOLAR ELECTRIC POWER
- STRAP DOWN INERTIAL GUIDANCE
- SPACE SUITS
- PORTABLE LIFE SUPPORT SYSTEMS
  BATTERIES

CONSIDERABLE EMPHASIS NEEDED

- ORBITAL ASSEMBLY AND OPERATIONAL TECHNIQUES
- ENVIRONMENTAL DATA
- ATTITUDE CONTROL $\leq 0.10^{0}$
- CONTAMINATION PROTECTION AND CONTROL

MORE EMPHASIS NEEDED

- 2 - 3 YEAR LIFE 50 K W. NUCLEAR POWER
- LIFE SUPPORT SYSTEMS (O_2, H_2O RECOVERY)
- POWER CONDITIONING SYSTEMS
- LARGE SCALE INTEGRATION
- INFORMATION MANAGEMENT
- REMOTE SENSORS

MAJOR EMPHASIS NEEDED

- MAN QUALIFICATION FOR 3 YEARS
- ARTIFICIAL G
- CLOSED LOOP LIFE SUPPORT
- SELF-ADAPTIVE ELECTRONICS

NASA HQ MF70-6145
5-27-70

Figure 34

This chart summarizes the relative states of readiness of technology to meet the space station requirements. Although there appear to be no insurmountable obstacles to the accomplishment of a space station program during the next decade, it is obvious that in a number of areas the potential payoff from further advancements in technology would be considerable.