D2

HUMAN FACTORS AND FUTURE SPACE TRANSPORTATION SYSTEMS

EDWARD A. GABRIS
AUGUST, 24, 1982

I am responsible for technology activities which relate to current and advanced space transportation systems.

These objectives are accomplished by system-level studies aimed at identifying and quantifying the value of technology advances by close contacts with centers of excellence both within and external to the agency including DoD and industry, and by the formulation of working groups to address specific issues.

D2

- NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

- OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

- TRANSPORTATION SYSTEMS OFFICE - EDWARD A. GABRIS, MANAGER

TRANSPORTATION SYSTEMS OFFICE

- PROVIDE SCOPE AND DIRECTION TO OAST'S SPACE TRANSPORTATION R&T PROGRAMS

  -- IDENTIFY HIGH PAY-OFF AND ENABLING TECHNOLOGY CATEGORIES
  -- PLAN AND ADVOCATE TECHNOLOGY DEVELOPMENT PROGRAMS

- PRINCIPLE INTERFACE BETWEEN RESEARCH AND TECHNOLOGY OFFICE AND SPACE TRANSPORTATION DEVELOPMENT OFFICE

The existence of the Shuttle and IUS, and to a lesser extent, the existence of the "standard" expendable launch vehicles has restructured the planning of missions such that most transportation needs will be within the capabilities of these systems. However, we are confident that the uses of space are sure to expand with attendant needs for new transportation vehicles, and these are likely to be principally justified on their economic impact. To accommodate this official picture of complacency with our more optimistic outlook, my office has created a vehicle model which plans a number of advanced vehicles in a time frame we feel is probable. This model allows us to identify the need for technology programs and to advocate and justify the allocation of resources to support them.

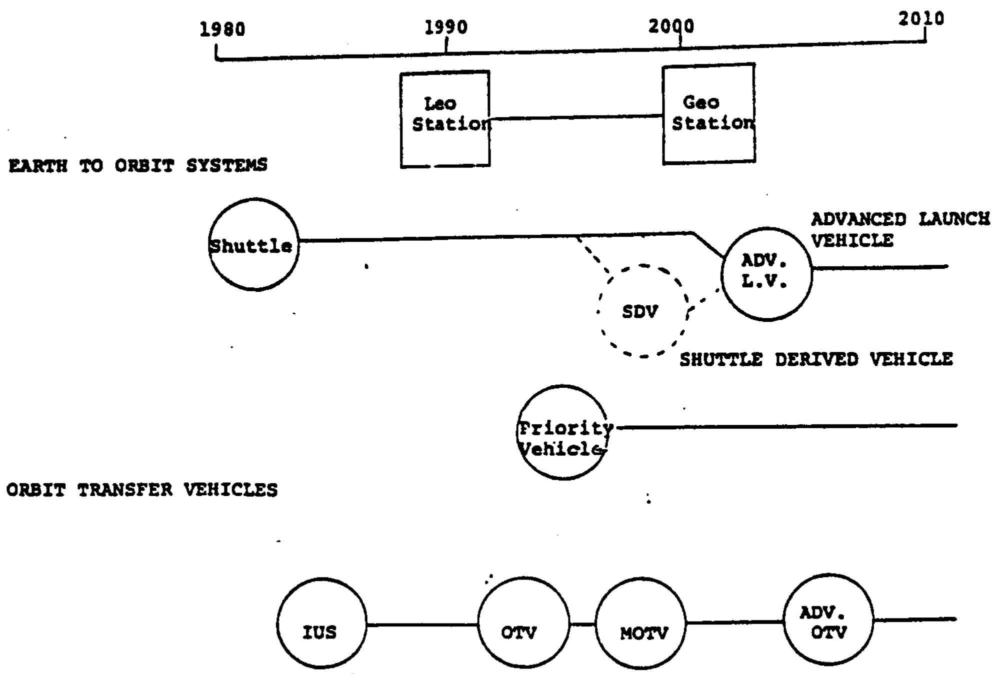
This vehicle model suggests that the Shuttle will be the standard transportation vehicle through the end of the century and that a replacement vehicle is unlikely to have an IOC prior to the 2005 time frame. This advanced vehicle will have lower payload costs, some growth in delivery capability, and will be totally reusable. Although not clearly indicated, the model does recognize the highly probable Shuttle improvement programs which will accommodate some performance growth, but which will more likely principally provide improvements in system reliability, turn-around time, and launch charges. The Shuttle-derived vehicle is a larger cargo vehicle capable of delivering 125 to 200 K lbs to LEO and is now viewed as less probable. Further this vehicle is not a significant technology driver. The priority vehicle is pursued as principally a military vehicle providing rapidness to space for military missions.

Upper stage requirements will initially be satisfied by the IUS and perhaps a Centaur. However, a true OTV will be required by the mid-1990s. This vehicle will be a high performance vehicle capable of delivering 15 to 20 K lbs to GEO and returning to LEO. It will have a high performance, cryogenic propulsion system, be recoverable and reusable utilizing aero-assist to return to a low-Earth orbit, and be space durable. The vehicle design will be sensitive to in-space maintenance and servicing needs. This vehicle will grow to support manned sortie missions to GEO in the late 1990s. An advanced OTV will occur when a breakthrough in propulsion occurs. This breakthrough system will require significantly less propellants, thereby reducing the principal cost of upper stage operation, the transportation of propellants from Earth to LEO.

WHAT IS THE FRAME OF REFERENCE?

- DEFINED MISSION REQUIREMENTS ARE COMPATIBLE WITH SHUTTLE/IUS CAPABILITIES
- HOWEVER, WE EXPECT AN EXPANDING AND VIGOROUS SPACE PROGRAM TO OCCUR
  - -- NATIONAL REQUIREMENTS WILL EXPAND
  - -- CURRENT VEHICLE SYSTEMS WILL REQUIRE REPLACEMENT
  - -- FOREIGN COMPETITION WILL BECOME KEENER
  - -- MAN WILL ASSUME "PERMANENCE" IN SPACE
  - -- ECONOMICS WILL BECOME THE KEY "FIGURE-OF-MERIT"
- THEREFORE, A VEHICLE MODEL HAS BEEN DEVELOPED TO PROJECT A FLEET CAPABILITY TO MEET THESE CHALLENGES - THIS IS THE FRAME OF REFERENCE WE USE TO GUIDE THE TRANSPORTATION TECHNOLOGY PROGRAM

SPACE TRANSPORTATION SYSTEMS SCENARIO



Man will play a critical role in the operation of these transportation systems: as a pilot, as a planner, as a servicer of missions, as an integrator of payloads, and as a critical element in the accomplishment of mission objectives. The allocation of technology resources to increase the effectivity of man's role will compete with other technology needs. Thus it is imperative that the important issues and the attendant technology deficiencies be identified.

Just considering in-space operations--there needs to be a systematic understanding of man's relationship to automation and robotic capability. Some would argue that man is not needed and that we can automate everything that needs to be accomplished and that automation is more cost-effective. I do not believe this. Man will play an important role in mission objective attainment.

TRANSPORTATION TECHNOLOGY FOCUS

- THE PROGRAM MUST FOCUS ON CRITICAL TRANSPORTATION SYSTEMS NEEDS
- ENHANCED SPACE TRANSPORTATION CAPABILITY (ETO, OTV, ON-ORBIT, PLANETARY)
- ENHANCED OPERATIONS IN SPACE
  - -- PAYLOAD DEPLOYMENT AND RETRIEVAL
  - -- SPACE STATION CONSTRUCTION, SERVICING, AND SUPPLY
  - -- OTV BASING (DEPLOYMENT, FUELING, RECOVERY, MAINTENANCE AND REPAIR)
- ENHANCED GROUND OPERATIONS
  - -- MISSION PLANNING
  - -- GROUND FLOW/LOGISTICS
- -- MAN'S ROLE WILL BE MORE THAN JUST A PILOT

MAN'S ROLE IN SPACE OPERATIONS

- THERE NEEDS TO BE A SYSTEMATIC, WIDELY-APPLIED TEHCNOLOGY BASE FOR ALLOCATING FUNCTIONS BETWEEN THE SPACE CREW AND CURRENT AUTOMATION AND ROBOTICS CAPABILITY
  - -- CREW STATION DEVELOPMENT
  - -- CREW TRAINING
  - -- MATCHING SYSTEM DESIGN TO HUMAN PERFORMANCE/RESPONSE
  - -- ON-ORBIT OPERATIONS
- THE OBJECTIVE IS TO ENHANCE MISSION CAPABILITY
- A METHODOLOGY IS NEEDED TO EVALUATE OPERATIONAL TASKS
  - -- TO DETERMINE MAN'S REQUIRED INVOLVEMENT VIS-A-VIS AUTOMATED, ROBOTIC, TELEOPERATOR OPPORTUNITIES
  - -- TO DETERMINE THE OPTIMUM MAN/HARDWARE MIX

This then is the opportunity--the promise of effective use of man is significant. Recognizing that the environment is hostile, much work needs to be done to understand the issues, the needs, and the opportunities. We need to understand the implication of man to define technology programs which will exploit these advantages.

OPPORTUNITY

- THE SPACE HUMAN FACTORS RESEARCH AND TECHNOLOGY PROGRAM HAS THE POTENTIAL
  - -- TO ENHANCE MAN'S EFFECTIVENESS IN SPACE
  - -- TO ENABLE BROADER AND MORE EXCITING MISSION SETS (SPACE BASE LABORATORIES, FACTORIES, REFURB GARAGES, ETC.)
  - -- TO HELP MAKE FUTURE SPACE SYSTEMS MORE AFFORDABLE

- TO EXPLOIT MAN'S CAPABILITIES TO PERFORM IN AN ALIEN ENVIRONMENT
  - -- ENVIRONMENTAL OBSTACLES MUST BE NEUTRALIZED
  - -- SYSTEMS DESIGNS MUST BE "HUMAN FACTOR CONFIGURED"

- HOWEVER, THE PROGRAM MUST BE SENSITIVE TO THE TECHNOLOGY TRANSFER ISSUES FOR APPLICATION TO FUTURE SYSTEMS
  - -- KNOW AND UNDERSTAND THE USERS NEEDS
  - -- PROMOTE CAPABILITIES - DEMONSTRATE UTILITY
  - -- PROCEED TO A POSITION OF OPERATIONS READINESS

SPACE STATION

RICHARD CARLISLE

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This chart offers a rationale for the Space Station Technology Steering Committee.

- Keyword is the desired level of technology for a Space Station. Skylab was a Space Station, although not designed for permanent presence in space. Space Shuttle is available for transportation.

- The task of the SSTSC, through the ten working groups, is to determine what the level of technology readiness is now and should be within the next few years to support a Space Station launch by the late 1980s.

- A half dozen year-long mission definition studies expected to get underway in the next month or two will provide configuration and mission concepts for a Space Station.

- Merging the technology evaluations of the SSTSC, the mission definitions and perspectives from outside advisory groups will permit NASA to formulate a program that would establish manned permanent occupancy of space.

INTRODUCTION

- SPACE STATION STEERING COMMITTEE (SSTSC) WAS FORMED TO PROVIDE GUIDANCE TO NASA IN DETERMINING THE READINESS OF TECHNOLOGIES NEEDED FOR A SPACE STATION.
- SSTSC INITIALLY FORMED NINE TECHNOLOGY WORKING GROUPS. A TENTH WORKING GROUP, DEALING WITH HUMAN CAPABILITY, HAS RECENTLY BEEN ADDED.
- HUMAN CAPABILITY INTERFACES WITH LIFE SCIENCES, LIFE SUPPORT AND SYSTEMS OPERATIONS: IT INCLUDES TRADITIONAL HUMAN FACTORS CONSIDERATIONS.
- THE OBJECTIVES OF HUMAN CAPABILITY "TECHNOLOGY" ARE TO KEEP THE CREW HEALTHY AND PRODUCTIVE, BOTH MENTALLY AND PHYSICALLY.

SPACE STATION TECHNOLOGY STEERING COMMITTEE
GOALS AND OBJECTIVES

GOALS:

PROVIDE BROAD AGENCY GUIDANCE IN THE INITIATION AND IMPLEMENTATION OF TECHNOLOGY DEVELOPMENT PROGRAMS TO SUPPORT AN AGENCY THRUST TO ESTABLISH MANNED PERMANENT OCCUPANCY OF SPACE.

OBJECTIVES:

1. ESTABLISH THE DESIRED LEVEL OF TECHNOLOGY TO BE USED IN THE INITIAL DESIGN AND OPERATION OF AN EVOLUTIONARY LONG LIFE SPACE STATION AND THE LONGER TERM TECHNOLOGY TO BE USED FOR LATER APPLICATION FOR IMPROVED CAPABILITIES. INITIAL TECHNOLOGY SHOULD BE AVAILABLE BY APPROXIMATELY 1986 TO SUPPORT A SPACE STATION LAUNCH AS EARLY AS 1990.
2. ASSESS THE LEVEL OF TECHNOLOGY FORECAST TO BE AVAILABLE FROM THAT PORTION OF THE CURRENT BASE R&T PROGRAM WHICH WILL BE APPLICABLE TO A SPACE STATION.
3. PLAN, RECOMMEND, AND MONITOR A PROGRAM TO MOVE THE CURRENT TECHNOLOGY PROGRAM TO THE LEVEL STATED IN NUMBER ONE ABOVE.
4. IDENTIFY, EVALUATE, AND RECOMMEND OPPORTUNITIES TO UTILIZE THE SPACE STATION AS AN R&T FACILITY.

- We do not yet have a specific mission defined or specific technology requirements identified. However, there are many functions and tasks which any Space Station must carry out.

- These ground rules have been carefully thought out and from them much guidance can be obtained as to broad technology requirements.

- Rather than go into interpreting each ground rule. I shall identify some key words and phrases that have important implications for human capability. Your expertise is needed to fully recognize and examine those implications.

- Second Bullet: 90 day Shuttle support cycle

- Third Bullet: Indefinite life; on-orbit maintenance

- Fourth Bullet: Evolutionary growth

- Fifth Bullet: Life cycle cost

- Interwoven with all technology needs and human capability considerations is a critical technology driver--the degree of on-board automation. What should be the role of the crew in a highly autonomous, complex station?

- The challenge to our human capability working group and to your members of the space human factors community is to begin to identify the full implications of these ground rules to build perspective on human function in relation to highly automated, even autonomous, systems; and to clarify what human roles could and should be in a permanent Space Station.

SPACE STATION TECHNOLOGY WORKING GROUP

GROUND RULES

REVISION A, APRIL 1982

- o SPACE STATION WILL BE IN LEO
- * o SPACE STATION WILL BE SUPPORTED BY THE SHUTTLE INITIALLY ON 90 DAY CYCLES
- * o SPACE STATION SHALL HAVE A DESIGN GOAL FOR INDEFINITE LIFE THROUGH ON- ORBIT MAINTENANCE
- o MODULAR-EVOLUTIONARY DESIGN THAT PERMITS GROWTH AND ACCEPTS NEW TECHNOLOGY
- o LIFE CYCLE COST (DEVELOPMENT, OPERATION, MAINTENANCE UTILIZATION) IS A TECHNOLOGY DRIVER
- o INITIAL PLANNING ASSUMES A PHASE C/D START BY OR BEFORE FY 1986 TO SUPPORT A FLIGHT AS EARLY AS 1990
- o INCLUDE TECHNOLOGY TO SUPPORT SPACE STATION MISSION OBJECTIVES BUT NOT THE TECHNOLOGY TO DEVELOP PAYLOADS
- o INCLUDE TECHNOLOGY TO INTERFACE WITH SPACE TRANSPORTATION SYSTEMS BUT NOT TECHNOLOGY TO DEVELOP NEW TRANSPORTATION VEHICLES
- o COMMUNICATIONS TO BE COMPATIBLE WITH TDRSS/TDAS, FREE-FLYERS, OTV'S AND SHUTTLE
- o PROVISION FOR NON-HAZARDOUS, PLANNED REENTRY
- o SYSTEM WILL BE A MANNED SYSTEM, THOUGH NOT NECESSARILY IN THE FIRST PHASE

* CHANGE BY REVISION A, APRIL 1982

FUTURE SPACE OPTIONS

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ADVANCED DEVELOPMENT
OFFICE OF SPACE FLIGHT
NASA HEADQUARTERS

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The first vugraph deals with the overall goal of the Office of Space Flight of establishing a permanent presence in space. In regards to that goal, we are dealing with the infrastructure of the elements that might be representative of a permanent presence in space which includes both manned and unmanned components. Unmanned low earth orbit operations are expected by 1990 with a goal of man in GEO operations by the year 2000.

This chart lists the required functions to support our goal. Although it is not an exclusive list, it includes the aggregation of payloads, maneuvering of satellites, low cost transfer to geostationary orbit including reusable orbital transfer vehicles, remote satellite servicing and upgrading propellant storage in orbit, and on-orbit assembly and checkout. In all of these areas, we see significant roles for man.

OVERALL GOAL

"ESTABLISH PERMANENT PRESENCE IN SPACE"

- INFRASTRUCTURE OF ELEMENTS
- MANNED AND UNMANNED COMPONENTS
  - IN LOW ORBIT BY 1990
  - MANNED IN GEO BY 2000

REQUIRED FUNCTIONS

- AGGREGATION OF PAYLOADS
- MANEUVERING OF SATELLITES
- LOW-COST TRANSFER TO GEO
- REMOTE SATELLITE SERVICING/UPGRADING
- PROPELLANT STORAGE IN ORBIT
- ON-ORBIT ASSEMBLY/CHECKOUT

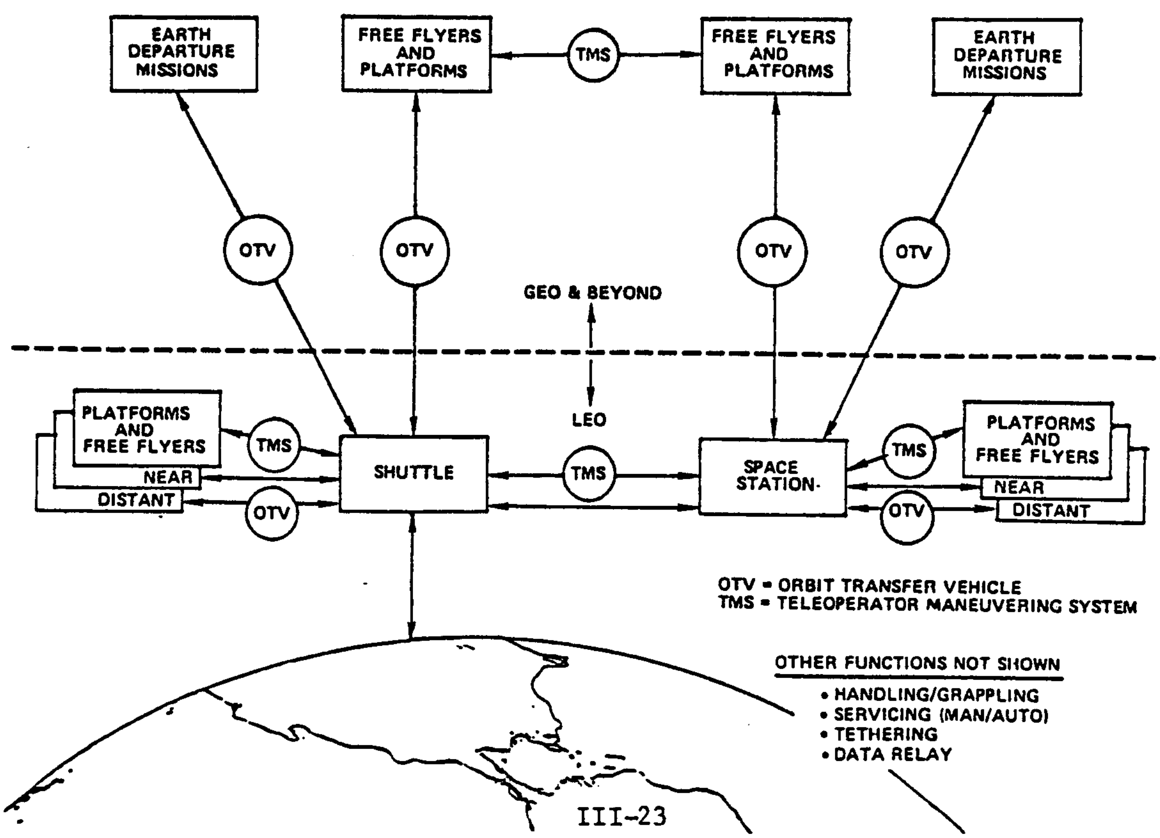
The major elements which are required to support our goal are listed on this third vugraph and include transportation, orbital services, unmanned platforms, and manned facilities. We see significant roles for man in operations of orbital transfer vehicles, in local maneuver of vehicles, and in refueling and servicing of those systems. Man's role in orbital services includes docking, grappling, handling, and module change mechanisms. This role includes both manned EVA, as well as man in the loop either directly or automated with man supervising. On free-flyers and tethered satellites where we are looking at "man in the loop" supervision, we see significant roles for: manned facilities for LEO Space Stations, GEO sortie hangers, and eventually crew capsules with OTVs that would imply geostationary operations.

The elements of the space infrastructure are shown in this vugraph. Indicated are both Shuttle-based operations and Space Station based operations serving a wide variety of potential systems such as platform free-flyers, geostationary operations, and earth departure missions out of earth orbit. Implication of man's role in operations are prevalent throughout all of these infrastructures.

REQUIRED ELEMENTS

TRANSPORTATION	ORBITAL TRANSFER VEHICLES "LOCAL" MANEUVERING VEHICLES
ORBITAL SERVICES	DOCKING/GRAPPLING/HANDLING MODULE CHANGEOUT MECHANISMS
UNMANNED PLATFORMS	FREE-FLYERS AND TETHERED LEO AND GEO
MANNED FACILITIES	LEO SPACE STATION GEO SORTIE HANGAR CREW CAPSULE FOR OTV

ELEMENTS OF SPACE INFRASTRUCTURE



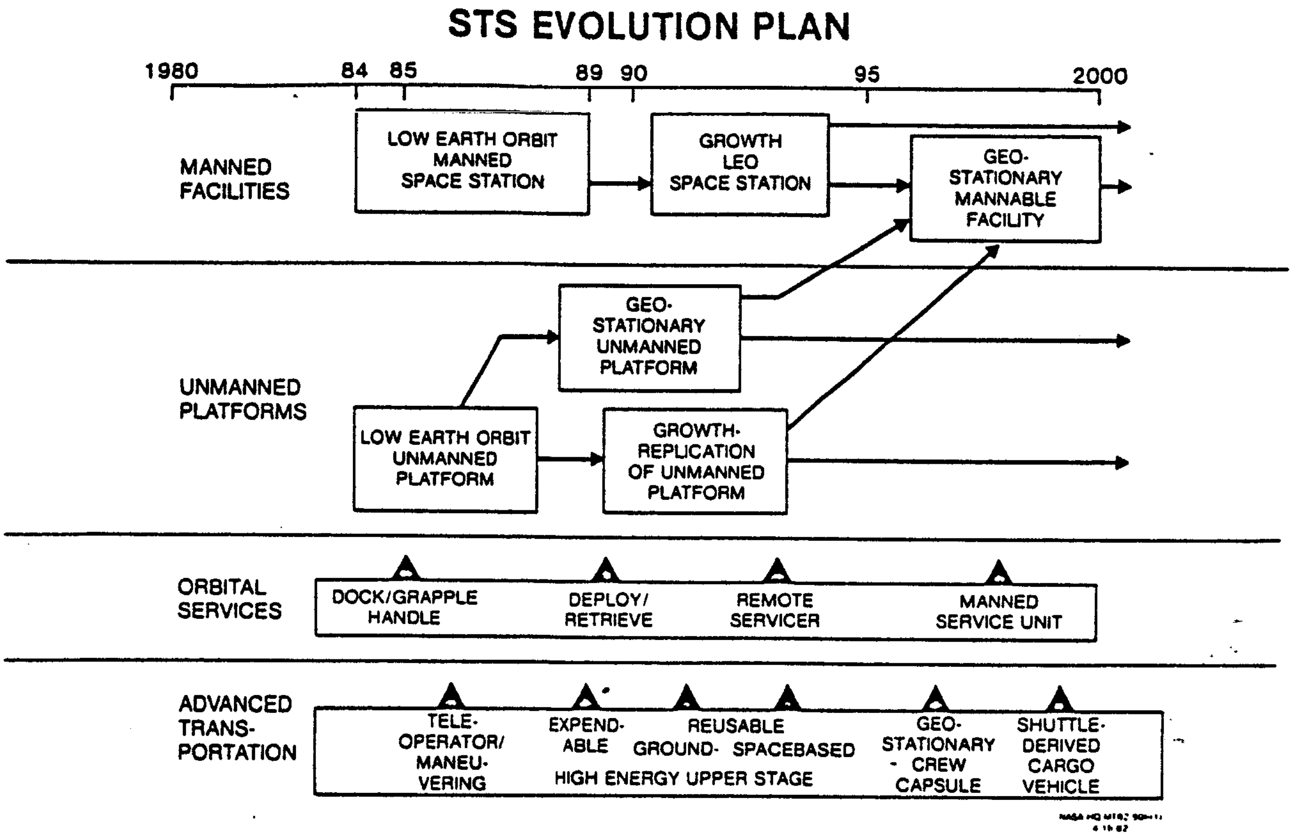
The four major thrusts of the STS evolution plan are illustrated in the chart. From the Office of Space Flight standpoint, we see man's involvement in all of these systems including everything from manned EVAs to man in the supervisory mode where there are automation or robotics capabilities applied to our space systems. There are vital roles for man in all of these thrusts.

Manned facilities require both manned EVA involvement, as well as remote manned systems such as highly dexterous manipulator systems.

Unmanned platforms require man for Shuttle servicing and eventually station servicing.

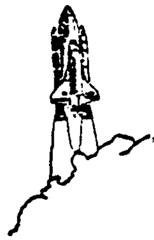
Orbital services includes both manned and unmanned activities for a docking and grappling capability to deploy and retrieve an advanced and remote servicer that is either a teleoperator system or a man in a supervisory mode system. A direct man in the loop type involvement includes the manned servicing unit which is shown in between the year 1995 and 2000.

Advanced transportation requires teleoperator maneuvering vehicles first with man directly in the loop and eventually in a manned supervisory role. We see the high energy upper stages requiring support of man initially to provide refurbishment for orbitally based upper stages. The geostationary crew capsule obviously needs man involvement and man will also play a role in the Shuttle derived cargo vehicle.



STS EVOLUTION PLAN
1980
84
85
89
90
95
2000
MANNED FACILITIES
LOW EARTH ORBIT MANNED SPACE STATION
GROWTH LEO SPACE STATION
GEO-STATIONARY MANNABLE FACILITY
UNMANNED PLATFORMS
GEO-STATIONARY UNMANNED PLATFORM
LOW EARTH ORBIT UNMANNED PLATFORM
GROWTH-REPLICATION OF UNMANNED PLATFORM
ORBITAL SERVICES
DOCK/GRAPPLE HANDLE
DEPLOY/RETRIEVE
REMOTE SERVICER
MANNED SERVICE UNIT
ADVANCED TRANS-PORTATION
TELE-OPERATOR/MANEU-VERING
EXPEND-ABLE
REUSABLE
GROUND-
SPACEBASED
HIGH ENERGY UPPER STAGE
GEO-STATIONARY - CREW CAPSULE
SHUTTLE-DERIVED CARGO VEHICLE

NEEDS FOR MAN IN SPACE



Jesco von Puttkamer
Advanced Planning
Office of Space Flight
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After the successful conclusion of its orbital flight test program, the Space Shuttle is in the process of establishing operational capability of routine flights to and from low Earth orbits. As the next logical step in America's space program, NASA is now turning to the development of our permanent presence in space.

This program will have to include a manned space station with an evolutionary capability that allows us to go from a modest-to-moderate initial step to more ambitious phases lateron as man's growing permanent presence in space increasingly provides all elements necessary for safe, productive, comfortable human living conditions.

Manned space programs of the past, especially Skylab, have yielded a great amount of new information on the utility of man in space. In many cases, what were rather speculative guesses about man's potential contributions have been supported and corroborated by real flight experience. In other areas, the actual performance and capabilities of the crews have far exceeded preflight expectations. It is the purpose of this study to present some summary conclusions on the human role in space in light of past experience, and to examine man's future needs as we move toward permanent presence in space which will impose requirements on man/machine function allocations, crew systems, human factors, habitation comforts and manned/teleoperated/automated operations an order of magnitude beyond the state-of-the-art of past and present programs such as Skylab and Shuttle/Spacelab.

In order to accomplish this purpose and to suggest some important issues that remain for future study, the presentation addresses a number of questions which are listed on the chart.

The human role in space seems to fall naturally into two categories: (1) the utilization of man in space with his unique attributes and capabilities, but also relative frailties and survival needs, in order to serve practical national and global interests; and (2) the existence ("being there") of man in space for humanistic reasons.

As shown on the facing chart, man's purpose in space, in a very direct, materialistic sense, comprises primarily utilitarian roles aimed at (a) understanding man himself through a variety of empirical investigations, and (b) utilizing man in scientific, military and economic/industrial operations. In the latter aspect, automation or remote control also have a distinct potential role. The division of manned and automated operations is a function of the technology at the time and its economy. While the relative emphasis between the two has naturally shifted with time, there has always been a balance. This will continue to be so: such balance will also establish itself in space, driven by technological "can do" on one side and the desire for economy in doing it on the other side.

QUESTIONS ADDRESSED

- What is the rationale for Man in Space ?
- What is the evolution of Man in Space ?
- What have we learned from past manned missions ?
- What are the pertinent general human qualities / capabilities ?
- What manned systems are we presently planning for the future ?
- What are the major human factors issues of future manned systems ?
- How can future space systems be optimized for man ?
- What unknowns / issues / questions remain for study ?

(#1 of 2)

REASONS FOR MAN IN SPACE

- UTILITARIAN
  - UNDERSTANDING MAN (for potential utilization)
    - Behavior of man in space
    - Applied science experiments
    - Advanced Technology experiments
    - Demonstration - Proof of concept
  - UTILIZATION OF MAN
    - Scientific
    - Military
    - Economic/Industrial

(cont'd)

There is also a humanistic role of man in space which derives basically from his idealistic needs, desires and aspirations. This is because humans are intellectual, social and ethical beings. Some of these needs may be less tangible than his utilitarian functions and may be open to ideological argument regarding their relative merits and priorities, but they are nevertheless real and important attributes of man's well-being and quality of life.

With the establishment of permanent presence in space, political factors, particularly at the international level, are of major import. This is demonstrated by the USSR Salyut space station program which by now has logged twice as many total manhours in space as the entire US manned space program. While social factors of the space program may be assumed a primary influence in the world, it is probably more realistic to recognize the political estimate of this social influence as the chief factor.

With permanent presence in space, the concept of international participation - always a key element of NASA's charter - will be expanded to include physical participation by foreign personnel. The image of probing exploration by man, strong technological development and peaceful applications elicits great prestige value while at the same time carrying an awareness that such technology is on hand to apply to national security.

Human ethics include intellectual, moral, spiritual and other factors. Curiosity, love of adventure, search for truth, goodness, justice, wisdom and beauty, belief in higher goals, etc., are recognized manifestations of human ethics. Some sociological/ethical needs of man which his presence in space may help to fulfill are listed.

In a long-range view, man's increasing capability in space can be seen to advance in three major phases: (1) Easy access to and return from space; (2) permanent presence in low Earth orbit; and (3) limited self-sufficiency of man in space.

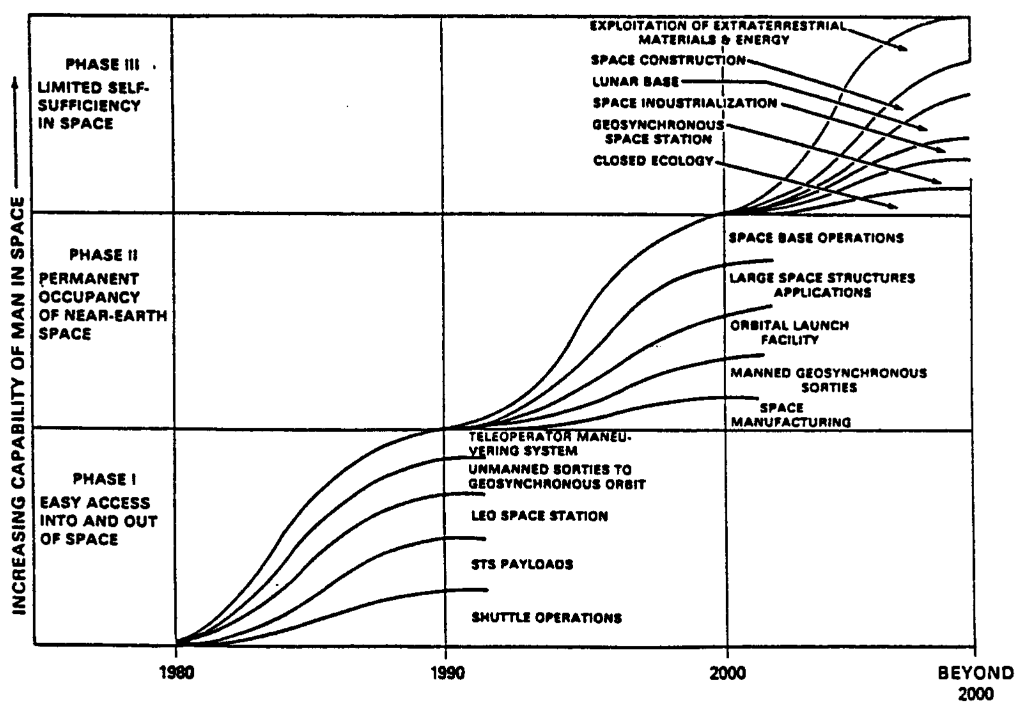
The development of the Space Shuttle for transportation and of an initial space station for orbital habitation are the main elements of the infrastructure of Phase I, to be accomplished by the end of this decade. But permanent manned presence requires more than this: an orbital operations capability of a scale large enough to respond adequately to the projected socio-economic needs of the 90s. In particular, Phase II will add the capability of manned access to geostationary orbit and the operational deployment of large space structures.

To become more autonomous in space, man will continue to develop closed-cycle life support systems and larger-scale industrial applications in space which, in Phase III, should lead to closed ecological systems (including space-grown food), space construction, space industrialization, and access to extra-terrestrial materials.

REASONS FOR MAN IN SPACE (cont'd) (#2 of 2)

- HUMANISTIC
  - POLITICAL
    - -- Means for political pressure (diplomatic tool)
    - -- Propaganda
    - -- International prestige
    - -- War surrogate
  - SOCIOLOGICAL/ETHICAL
    - -- Presence: National identity
      - Inspiration and morale
        - · social-economic value
        - · vicariousness (sense of participation)
        - · new information ("gee whizz")
        - · dollar value
    - -- Exploration: Education
      - Curiosity and love of adventure
      - Search for truth
      - Belief in higher goals
    - -- Settlement: Physical and mental growth
      - New future options

MAN'S PROGRESS IN SPACE



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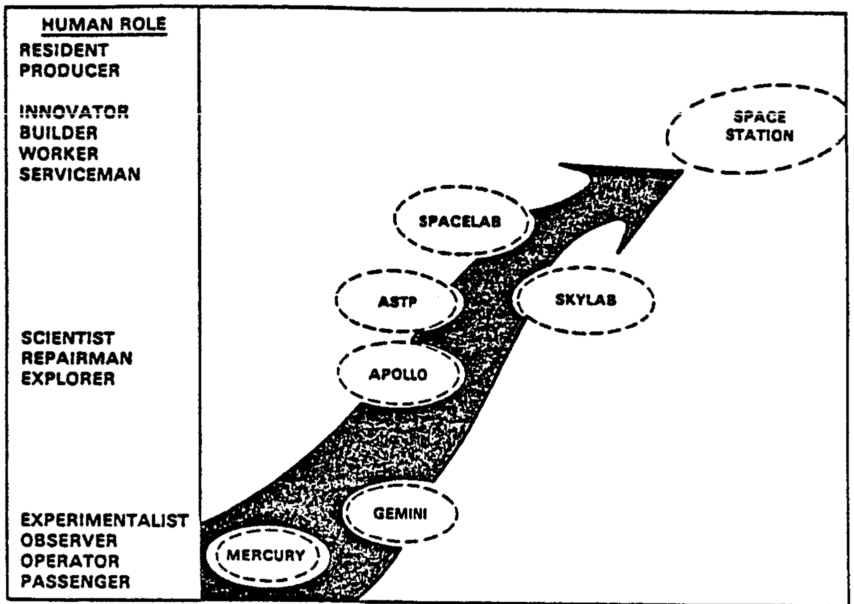
The progress of the human function in orbital programs leading to permanent presence in space is shown. Also listed are the total manhours in space accumulated by astronaut crews in each of the five major US programs of the past, as well as the times spent on extravehicular activities (EVA). With permanent presence in space, the manhour count for STS/Space Station becomes indefinite.

The objectives of the Apollo missions would have been impossible or inordinately expensive and time-consuming to achieve with an unmanned vehicle.

An examination of manned flights during the Apollo Program yields a number of unique capabilities and attributes exhibited by man which are relevant to future developments. These are listed.

Not listed are other benefits of Apollo because of manned involvement which, although very real, are difficult to measure. There is no question that landing man on the moon demonstrated to the world our national strength, unity, and technical competence. In these respects, Apollo was strongly motivated by humanistic objectives.

EVOLUTION OF MAN'S ROLE IN SPACE



DURATION IN SPACE	HOURS	DAYS		WEEKS	MONTHS	
	MERCURY	GEMINI	APOLLO	SKYLAB	ASTP	SPACE STATION
TOTAL MANHOURS	54	1940	7560	12,351	652	INDEFINITE
EVA MANHOURS		12	168	82		INDEFINITE

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MAN's CAPABILITIES IN SPACE

THE APOLLO EXPERIENCE

- RAPID RESPONSE TO EMERGENCIES
  - e.g., Lunar touchdown, Apollo 11
    Lightning strike, Apollo 12
- SELF-CONTAINED OPERATION IN ABSENCE OF COMMUNICATION WITH GROUND
  - e.g., Major maneuvers behind Moon
- RAPID SENSING, REACTION, AND VEHICLE CONTROL
  - e.g., Lunar Orbit Rendezvous (LOR) decision
- ENHANCEMENT OF INSTRUMENT FLEXIBILITY
  - e.g., In-flight EVA for film retrieval
- REDUCTION OF AUTOMATION COMPLEXITY IN MULTI-PURPOSE MISSIONS
  - e.g., Lunar surface sampling
- EQUIPMENT REPAIR AND IMPROVISATION
  - e.g., Lunar Rover fender repair
    Air filter, Apollo 13
- INVESTIGATION AND EXPLORATION
  - e.g., 33 km in 3 days, Apollo 17 (vs. 10.25 km in 10½ months, Lunokhod-1

After the conclusion of the Apollo Program, a number of questions regarding man's capabilities in space remained open which the Apollo missions, due to their limitations in duration, scope and equipment, as well as relative inflexibility, could not answer. These questions, listed on Chart 8, before Skylab could only be answered tentatively by studies, analyses and extrapolations of data available from previous manned space programs.

The three Skylab missions, accumulating a total of 171 manned days, answered these questions in the affirmative, as shown on the next three charts. Thus, they provided building blocks for future space programs.

Skylab was the first manned space program where man's functions were manifold and the spacecraft more than a vehicle for transporting him to his work.

The chart lists experiential examples of man's capabilities as (a) Scientific Observer where his observations and judgment made it possible to obtain data that could not otherwise have been recorded (e.g., descriptions of Comet Kohoutek); (b) Operator with the ability to make real-time changes in planning, objectives, film and data management; and (c) Engineer/Technician performing planned and unplanned repairs and maintenance on both the spacecraft and the experiments.

MAN'S CAPABILITIES IN SPACE

QUESTIONS ASKED BEFORE SKYLAB

- Can man function effectively in space over long periods of time?
- Are there worthwhile experiments, tasks, and services which can only be accomplished through manned operations?
- Will the worthwhile services man can perform in space compensate for the added complexity required to put him there?

MAN'S CAPABILITIES IN SPACE

THE SKYLAB EXPERIENCE

- SCIENTIFIC OBSERVER
  - Apollo Telescope Mount
  - Comet Kohoutek
  - Earth Observations
  - Zero-Gravity Flammability
  - Materials Processing in Space
  - Barium Plasma Observations
  - Earth Laser Beacon
  - Student Experiments
  - Science Demonstrations (TV)
- OPERATOR
  - Real-Time Planning
  - Film Management
  - Experiment Pointing
  - Data Management
  - Scientific Airlock Operations
  - Extravehicular Activities
- ENGINEER/TECHNICIAN
  - Unplanned Repairs and Maintenance (in-flight supply of parts and development of procedures)
  - Planned Repairs and Maintenance (use of spares, trained procedures)

An example for major unplanned repair on Skylab is given.

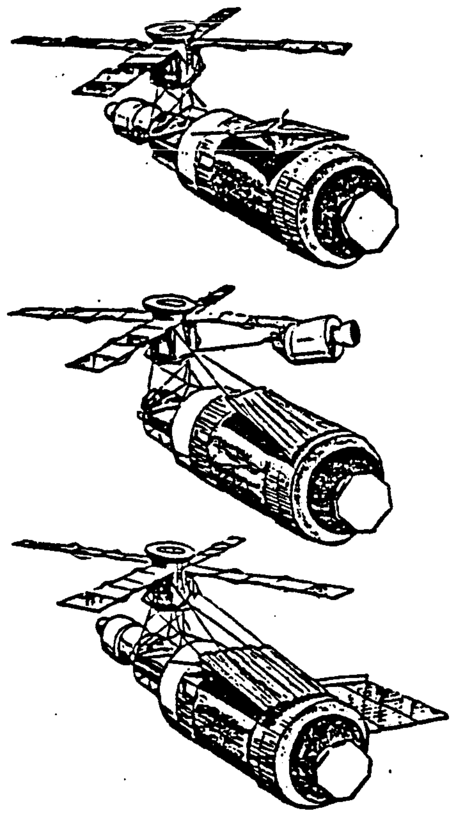
During the Skylab SL-1 launch, the micrometeorite shield was lost, one of the Solar Array System wings was ripped off, and the second SAS wing was jammed shut. The micrometeorite shield not only provided protection against micrometeorites but also provided thermal protection for the Orbital Workshop (OWS) to maintain habitable temperatures.

Three "thermal fixes" were developed within 10 days from the mishap, shown on the chart. All three were flown into space; the JSC-developed Parasol was deployed during SL-2, the MSFC-developed Twin-Pole Sail during SL-3. A third device, the JSC "Stand-up EVA (SEVA)" Sail, remained in reserve and was not deployed. The presence of man made the deployment of these fixes and of the jammed SAS wing possible and thus led to the successful recovery of Skylab, a $2½ billion program.

The Skylab Program proved that man does add extra dimensions to the overall success of certain types of space missions.

Listed on Chart 11 are some of the more important answers furnished by Skylab and its crews to the understanding of the human role in space.

SKYLAB OWS SUNSHADE SCHEMES



JSC PARASOL

JSC SEVA SAIL

MSFC TWIN-POLE AWNING

MAN'S CAPABILITIES IN SPACE

ANSWERS FURNISHED BY SKYLAB

- Man can live and do useful work over extended periods in space (less than 12 man-hours were lost due to motion sensitivity out of 200 man-hours of work);
- A single man can perform many tasks in space originally planned for two;
- Man can move large and massive objects with precision;
- Interchange of information between crew and ground-based scientists enhances experiments, specifically during solar events;
- Crew judgment and knowledge of hardware and experiment objective aid the success of materials processing and other experiments;
- Crew's ability to restore experiments to their original data gathering capability and to operate experiments in degraded mode to gather useful data contributes significantly to mission success.

The next three charts attempt to extract some general observations on man's qualities and capabilities from the experience of past manned space programs.

There is no adequate substitute for man as a general sensor, manipulator, evaluator and investigator now or in the foreseeable future. Man is essential to research, development, initial operations, assembly and troubleshooting of large and complex systems, or a combination of these.

These functions, for which he is uniquely suited, increase considerably our options to explore and use space. Conversely, if man is eliminated from space missions, these options will be reduced significantly.

Man's characteristics as a sensor of visual, auditory, olfactory and tactile information, and as a computer capable of conceptual thinking, interpretive thinking, memory and adaptive and inductive reasoning combine to provide him with powerful abilities which set him apart from (current) machines. Some of these are discussed on Chart 13.

HUMAN FUNCTIONS IN SPACE

- SENSOR
  - more flexible than instruments
  - can select data, systematize and recognize patterns
- MANIPULATOR
  - performs similar to technician or laboratory assistant on ground
  - can overcome or bypass equipment failures in preplanned activities
  - could be done by robotics but would be difficult and would introduce possibility of equipment malfunction
- EVALUATOR
  - controlls what he perceives as sensor and how he reacts as manipulator
- INVESTIGATOR
  - responds creatively to unexpected situations
  - acts as scientist, research, etc.

(#1 of 2)

HUMAN CAPABILITIES

In general, man —

- is able to recognize and use information redundance (patterns) in the real world to simplify complex situations;
- has a high tolerance, i.e., can "live with" ambiguity, uncertainty and vagueness;
- can interprete an input signal accurately even when subject to distraction, high noise level or message gaps;
- has very low absolute thresholds and difference thresholds for vision, audition, and the tactile sense;
- has an excellent long-term memory for related events;
- is a selecting mechanism.

(cont'd)

As an evaluator, investigator and manipulator, man moves from the passive role of sensor to active involvement with his environment.

His characteristics as a communicator with the abilities of command execution and interpretive translation, as an adaptive servomechanism and as a physical manipulator with high dexterity in translational and rotational degrees of freedom combine with sensory and mental processes to provide man with the capacity to function with a high degree of self-reliance.

Some examples are discussed on the chart.

What will be required of future orbital systems, subsystems and operations to support man's permanent presence in space can be reduced to three simple statements.

The achievement of these requirements, however, will be anything but simple. In many instances, it requires considerable advances and quantum leaps in the state of the art of orbital habitation technology, crew comfort and safety, operational effectiveness and reliability, and man/machine interactions.

HUMAN CAPABILITIES (cont'd)

In general, man —

- can develop high flexibility for task performance;
- has the ability to improvise and exercise judgment based on long-term memory and recall;
- performs well under transient stress and overload;
- can make inductive decisions in novel situations and has the ability to generalize;
- can modify his performance as a function of experience and can "learn" as well as "learn to learn";
- can override his own actions if needed;
- is reasonable reliable and can add overall reliability to systems performance.

BASIC REQUIREMENTS FOR FUTURE MANNED PRESENCE IN SPACE

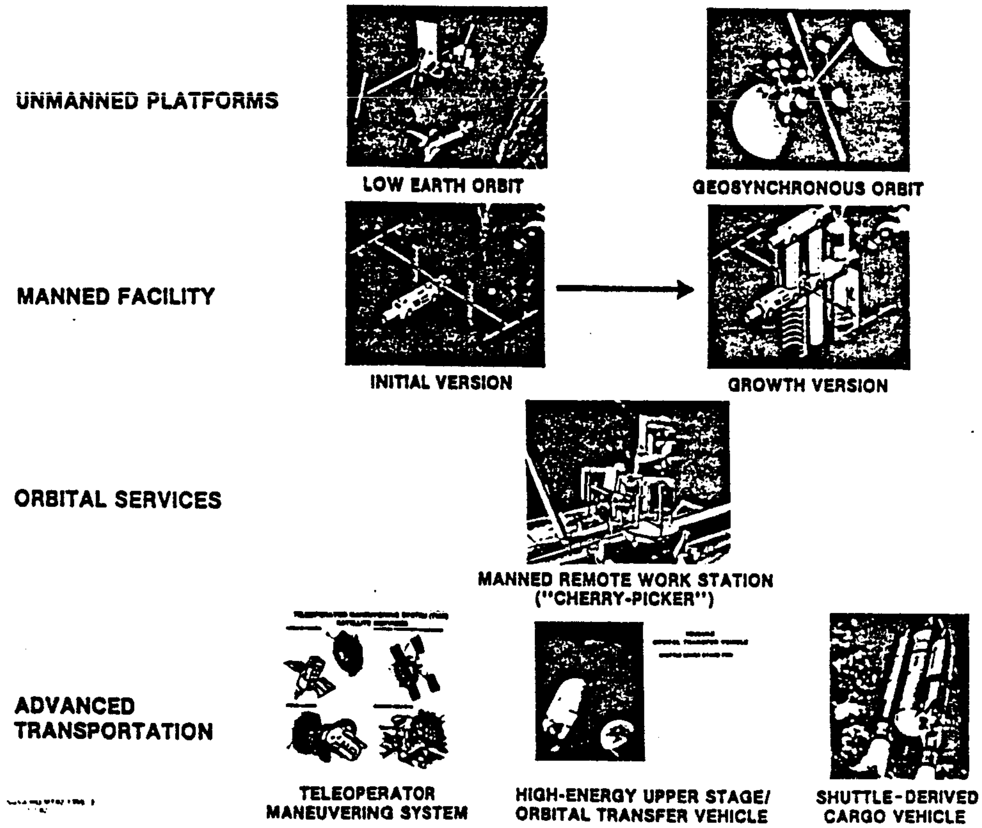
- GO INTO SPACE AND RETURN AT WILL WITH FULL SAFETY AND ADEQUATE SUPPORT EQUIPMENT
- STAY IN SPACE IN ROUTINE MANNER FOR LONG PERIOD
- PERFORM COMPLEX TASKS IN SPACE JUST AS ON GROUND.

Depicted are key future systems required to achieve permanent presence in space that are currently in the conceptual stage under study.

They involve unmanned space platforms in low and geostationary Earth orbit, manned space station, satellite services equipment, and advanced transportation including a Teleoperator Maneuvering System (TMS) for operations remote from Shuttle and Space Station, and a reusable Orbital Transfer Vehicle (OTV) for sorties to geostationary orbit, initially unmanned and later manned.

Future systems shown on the preceding chart will involve the human in a number of definable aspects, summarized on the chart and discussed in more detail on the following three charts.

SPACE TRANSPORTATION SYSTEM
ADVANCED PROGRAMS



MAJOR ASPECTS OF MAN'S ROLE IN FUTURE SYSTEMS

- CREW SYSTEMS
- HABITABILITY
- SATELLITE/SPACECRAFT SERVICING AND REPAIR
- SPACE ASSEMBLY AND CONSTRUCTION
- OBSERVATIONS, EXPERIMENTS, AND EVALUATIONS
- BIOMEDICAL REQUIREMENTS

The chart lists major issues and technologies that future systems will encompass in the areas of Crew Systems and Habitability. Particularly in the latter area, there is need for considerable advancement in the state of the art beyond current technologies. To sustain permanent presence in space, current Orbiter-era habitability is inadequate.

Man's roles in future space systems are listed in the areas of Satellite/Spacecraft Servicing and Repair and Space Assembly and Construction.

Here, too, new developments will pace the gradual achievement of permanent manned presence in its true meaning.

MAJOR ASPECTS OF MAN'S ROLE IN FUTURE SYSTEMS

- CREW SYSTEMS
  - CREW STATION DESIGN (IVA)
  - EVA PRESSURE SUIT
  - EVA WORK STATION DESIGN
    - Cherrypicker (open/closed cab)
    - Positioning, Mobility, and Handling Aids
    - Standardized and Specialized Tools
  - MANNED MANEUVERING UNIT (MMU)
  - TELEOPERATOR MANEUVERING SYSTEM (TMS)
  - MANEUVERABLE TELEVISION (MTV)
- HABITABILITY
  - SPACE SHUTTLE ORBITER
  - SPACE STATION
  - CREW SIZE vs. FLIGHT DURATION
  - CREW SIZE vs. CREW EFFICIENCY vs. VOLUME PER PERSON

MAJOR ASPECTS OF MAN'S ROLE IN FUTURE SYSTEMS

(cont'd)

- SATELLITE/SPACECRAFT SERVICING AND REPAIR
  - PROPELLANT TRANSFER
  - MODULE EXCHANGE
  - MODULAR UPGRADE
  - CHECKOUT AND CONTROL
  - SPACECRAFT DESIGN
    - Modularity
    - Accessibility
    - Standardized Hardware (connectors, fasteners, etc.)
  - ORBITAL LAUNCH OPERATIONS
- SPACE ASSEMBLY AND CONSTRUCTION
  - ASSEMBLY AIDS
  - CONSTRUCTION FIXTURES
  - ALIGNMENT VERIFICATION
  - "LOCAL" TRANSPORTATION

The chart shows where man's roles will be in future space systems in the areas of Observations, Experiments, and Evaluations, and Biomedics.

To achieve permanent manned presence in space it is not sufficient to consider man merely as another subsystem, added to a spacecraft that has largely been designed on the basis of specifications derived from original program "requirements". Future systems need to be increasingly optimized for man.

In considering man's capabilities and needs from past manned programs, we can already identify a number of "hard" musts that routine operations by man in space in future years will impose. This chart lists some of these requirements for man-tending where man performs orbital servicing, repair, maintenance and upgrading on unmanned orbital systems in the course of intermittent Shuttle visits.

MAJOR ASPECTS OF MAN'S ROLE IN FUTURE SYSTEMS
(cont'd)

- OBSERVATIONS, EXPERIMENTS, AND EVALUATIONS
  - MANNED FACILITY vs. UNMANNED PLATFORM
    - Visual Perception and Cognition
    - Knowledge and Intellect
    - Physical Dexterity and Mobility
  - ENGINEERING RECORD/PHOTO DOCUMENTATION
  - METEOROLOGY
  - OCEANOGRAPHY
  - GEOLOGY
  - PHYSIOLOGY
  - PSYCHOLOGY, etc.
- BIOMEDICAL REQUIREMENTS
  - ANTHROPOMETRICS/ERGONOMICS
  - PSYCHOMETRICS
  - MOTION SENSITIVITY
  - CARDIOVASCULAR DECONDITIONING
  - OSTEOPORESIS (BONE DEMINERALIZATION)
  - RADIATION EXPOSURE

FUTURE SYSTEMS NEED TO BE OPTIMIZED FOR MANNED OPERATIONS (#1 of 2)

MAN-TENDING (ORBITAL SERVICING, REPAIR, MAINTENANCE, AND UPGRADING)

- Consider EVA a normal means of man-tending and a "natural" way of life
- Provide proper procedures, tools, equipment, mobility & positioning aids for crew usage
- Design systems to facilitate in-flight man-tending –
  - --- provide adequate accessibility, work space, and work clearance,
  - --- provide worksite, repair bench or equivalent (IVA & EVA) equipped with adequate restraints for crewman, tools, and equipment,
  - --- provide effective containment of hardware components (nuts, bolts, washers, etc. by means of boxes, bungee cords, etc.
- Promote standardization of mobility & positioning aids, tools, fasteners, joints, connectors couplings, etc., and limit their number and variety
- Provide high-fidelity man-tending training simulator and adequate crew training.

(cont'd)

Some basic requirements for the development of permanently manned orbital systems in the future are listed on Chart 22.

In the increasing optimization of orbital habitation systems, the need for human comfort, well-being and quality of life must become a firm requirement as real as the more traditional requirements of cost effectiveness and performance. Adequate human engineering standards, not existing now, must be developed before final design. It thus may become desirable, even necessary increasingly to include the thinking of skilled architects in the design approaches.

Numerous questions still remain to be answered. New questions have joined old ones as we have penetrated deeper into the area of the human role in space.

More in-depth studies and analyses are necessary to answer these questions, supported by ground-based laboratory and simulator experiments and Shuttle-based technology R&D in human factors.

Some of the major questions are listed on Chart 23. They will be the subject of a specific study activity being planned by the Office of Space Flight and Marshall Space Flight Center at present.

FUTURE SYSTEMS NEED TO BE OPTIMIZED FOR MANNED OPERATIONS (#2 of 2)

PERMANENTLY MANNED (ORBITAL HABITATION)

- Develop improved human engineering standards before final design
- Use Skylab experience wherever applicable
- Fundamental habitability should be built-in, not added on
- Separate on-board functions - work, eating, sleeping - so as to avoid noise, light, physical interference
- Provide for off-duty activities including exercise and looking out the window
- Provide for personal privacy
- With increasing flight duration provide increasing personal comfort.

MAN'S ROLE IN SPACE

QUESTIONS REMAINING

- What are man's basic, unique capabilities for future space activities, and what are his limitations?
- Which of the activities within presently planned space projects and missions should preferrably be carried out by humans, and what are the required skills to be developed?
- What impacts has human presence in space on the requirements for spacecraft design, equipment, power, logistics, and habitation?
- What are the economics of human space activities?
- What technology advancements will enhance human productivity in space?
- How can the available data and information on human potentials in space be made available to project managers in a manageable and practical form?
- What new data and information is needed for efficient future planning for man's role in space?

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

MAJOR LARRY J. GLASS
MAJOR RUDY R. FEDERMAN

Self Explanatory

Self Explanatory

PURPOSE

PROVIDE AN OVERVIEW OF THE AF MANNED SPACE-FLIGHT ENGINEER (MSE) PROGRAM

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

OBJECTIVE

- CHARTER / MISSION
- PROGRAM DESCRIPTION
- MSE ACTIVITIES
- FUTURE ACTIVITIES

Comments:

What can the Space Shuttle do relative to supporting the military role in space?

The Manned Spaceflight Engineer has many duties while assigned to a Program Office. However, his knowledge of the orbiter, mission requirements, etc., will ensure that the utility of the Shuttle is:

- Understood
- Enhanced when required
- Exploited
- Supported.

Self Explanatory

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

CHARTER

- INSURE THAT THE MILITARY UTILITY OF THE SHUTTLE, AND ITS CREW, IS:
  - UNDERSTOOD
  - ENHANCED WHERE REQUIRED
  - EXPLOITED
  - SUPPORTED

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

MISSION

- CONDUCT MSE PROGRAM
  - SELECT MSES
  - TRAIN MSES
  - PROVIDE MSES TO WORK IN PROGRAM OFFICES
  - SUPPORT MSES AND THEIR PROGRAMS
- EXPLOIT THE MILITARY UTILITY OF THE SHUTTLE
  - DEVELOP CAPABILITIES
  - DISSEMINATE INFORMATION

Self Explanatory

Self Explanatory

AF MSE PROGRAM CONCEPT

- DEVELOP AND USE DOD EXPERTISE
  - SHUTTLE
    - — INTERFACES
    - — IMPLICATIONS
  - MAN / PAYLOAD INTERACTIONS
    - — MAXIMUM SYSTEM EFFECTIVENESS
- RECOGNIZE AND USE NASA EXPERTISE AND SERVICES
  - SHUTTLE VEHICLE
  - SHUTTLE CREW (CMDR, PILOT, MS)
  - PAST MANNED SPACEFLIGHT EXPERIENCE
- OPERATIONAL SECURITY PHILOSOPHY

AIR FORCE MANNED SPACEFLIGHT ENGINEER PROGRAM

OPERATIONAL APPROACH

- MANAGEMENT ORGANIZATION UNDER SPACE DIVISION. DEPUTY COMMANDER FOR SPACE OPERATIONS (SD/YOM)
  - — JOINT SD / SAFSP PROGRAM
- USE TEST PROGRAM EXPERIENCE
- SELECT HIGHLY QUALIFIED TECHNICAL OFFICERS
  - — TRAIN TO UNDERSTAND INHERENT CAPABILITIES OF SHUTTLE AND ITS CREW
  - — USE AS <u>DEVELOPMENT ENGINEERS</u> IN PROGRAM OFFICES
  - — PROVIDE POOL FOR MISSION SPECIFIC SUPPORT
- MISSION SPECIFIC ACTIVITIES FUNDED BY USERS

Self Explanatory

The MSE training/utilization flow can be divided into three basic phases.

I - MSE selected and given basic qualification training while being assigned to a Program Office.

II - MSE(s) selected and designated as Flight MSE(s) are given flight specific training and begin integrated training with NASA astronauts.

III - MSE supports actual flight. Note that MSE(s) will have ground responsibilities as well as space flight responsibilities. Therefore, MSEs not selected to support a mission as a flight MSE can be utilized as ground specialists.

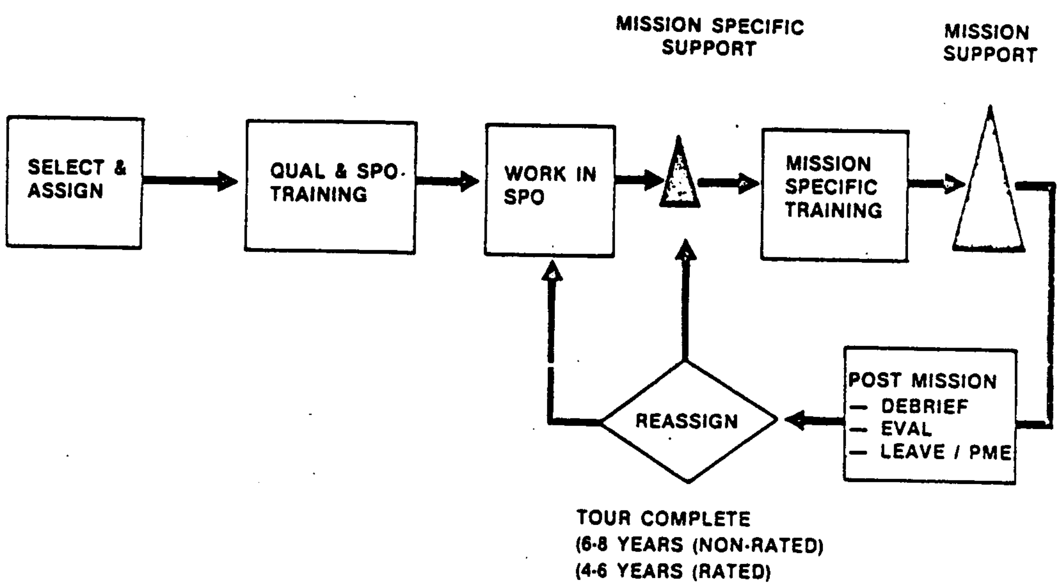
AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

PROGRAM DESCRIPTION

- FOUR PHASES
  - SELECTION
  - TRAINING
  - PROGRAM OFFICE DUTIES
  - POTENTIAL FLIGHT ACTIVITIES

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

MSE UTILIZATION PLAN



Self Explanatory

It is our (Space Division) hope to have this training program as an official Air Force school. Work is ongoing currently to get this accomplished.

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

FY 83 MSE CADRE

- NUMBER TO BE SELECTED
  - FOURTEEN MSES
- SCHEDULE MILESTONES

— MAY 82	— CALL FOR VOLUNTEERS BY AFMPC
— MAY - JUL 82	— APPLICATION PERIOD
— AUG - SEP 82	— SELECTION BOARD
— OCT 82	— BOARD RESULTS
— JAN 83	— SELECTEES REPORT TO SPACE DIVISION

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

TRAINING

- QUALIFICATION PROGRAM
  - INITIAL TRAINING ON SHUTTLE CAPABILITIES AND HUMAN FACTORS
- CONTINUING EDUCATION

Self Explanatory

Specific Program Office responsibilities are numerous for the MSE(s).

AF MSE PROGRAM QUALIFICATION PROGRAM

- OBJECTIVE
  - UNDERSTAND
    - SHUTTLE DESIGN AND CAPABILITIES
    - MANNED SPACEFLIGHT DESIGN AND CAPABILITIES
    - SHUTTLE PAYLOAD INTERFACE
    - MANNED SPACEFLIGHT ACTIVITIES
    - PAYLOAD DESIGN
    - PAYLOAD INTEGRATION

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

PROGRAM OFFICE DUTIES

- WORK AS DEVELOPMENT ENGINEERS
- IDENTIFY BENEFICIAL USES OF CREWS
- SUPPORT LAUNCH SYSTEM INTEGRATION AND OPERATIONS TEAM
- MANAGE MANNED SPACEFLIGHT ACTIVITIES
  - PREPARE TIMELINES
  - IDENTIFY CREW MEMBER ACTIVITIES
  - PREPARE PLANS FOR
    - PROCEDURE DEVELOPMENT AND VALIDATION
    - CREW TRAINING
    - FACILITY & EQUIPMENT REQUIREMENTS

Self Explanatory

Self Explanatory

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

POTENTIAL FLIGHT ACTIVITIES

REPORT AND ADVISE IN GO / NO-GO DECISION

PERFORM PAYLOAD CHECKOUT

CONDUCT EXPERIMENTS

ACT AS FLIGHT SECURITY ADVISOR

INSPECTION (CLOSEOUT PHOTOS, DAMAGE ASSESSMENT, GO / NO-GO INPUT)

MINOR REPAIR AND CONTINGENCY FUNCTIONS

REMOVE COVERS

IN-BAY CONTAMINATION EVALUATION AND CLEAN SURFACES

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

FUTURE ACTIVITIES

- SELECTION OF MSES
  - BOARD CONVENES-30 AUG 82
  - SELECTIONS ANNOUNCED MID-OCT 82
- ALLOCATION OF MSES
  - BASED ON MISSION MODEL
- TRAINING OF MSES
  - BEGINS 17 JAN 83

Self Explanatory

These are items considered to be a small shopping list of items which concern us (the military) relative to man's role in space.

We must stress here that in order to properly address these items of concern, we must establish and maintain with NASA and other payload communities a cooperative learning effort.

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

SUMMARY

- PROGRAM UNDERWAY
- MSES ON-SITE MID JAN 83

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

KEY ISSUES

- EXTENSION OF MAN TO THE JOB
- SPACECRAFT DESIGN
- SERVICING, REPAIR, ASSEMBLY OF SPACECRAFT
- EXPERIMENTS / EVALUATIONS
- BIOTECHNOLOGY

- We must fully integrate man into the space environment. We must make it easy for the payload community to integrate into the Shuttle. One way to do this is through the Orbital Payload Work Station.
- We must explore all requirements and constraints for an EVA Work Station. Also, EVA must be a nominal mission event, not just contingency. EVA can be profitable!
- Further work must be done in space suit technology. The effort given to the 8 psi suit is good.
- Teleoperator/Robotics requires us to blend man and machine in any given mission.
  (Same discussion relative to the remaining items.)

Efficient spacecraft design requires us to consider many areas where improvement is required.

(1) We must get standardized. A helpful tool would be a very definitive payload/Shuttle handbook.

(2) The MSE can help from program inception to design the payload with the Shuttle vehicle requirements considered. The payload can be designed modularly and such that it can be accessible. Again, EVA or teleoperator robotics is being considered during development.

(3) Engineering design has to consider fuel (consumable) servicing requirements/ methodology.

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

EXTENSION OF MAN TO THE JOB

- ORBITAL PAYLOAD WORK STATION (OPWS)
  - DIGITIZED TV
- EVA WORKSTATION
  - STANDARDIZED TOOLS / INTERFACES
  - TORQUE COMPENSATING TOOL
- SPACESUIT
- TELEOPERATOR / ROBOTICS
- MANNED MANEUVERING UNIT (MMU)
- REMOTE SERVICER / MANEUVERABLE TV
- HANDLING POSITIONING AID (HPA)

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

SPACECRAFT DESIGN

- DESIGN HANDBOOK
- DESIGN PHILOSOPHY
  - MODULARITY
  - ACCESSABILITY
- IMPLEMENTING TECHNOLOGY
  - STANDARDIZED
    - CONNECTORS
    - FASTENERS
    - JOINTS / COUPLINGS
- FUEL TRANSFER EQUIPMENT

Self Explanatory

In order to perform the mission right the first time, we must consider the characterization of man and the platform.

- Platform: Quantify the orbit
  Contaminants problems
  Thermal considerations, etc.

- Man: Quantify the individual
  Select crew for mission based on known data relative to the man and his ability to do the task
  -- Visual perception/cognition
  -- Knowledge intellect
  -- Physical dexterity and mobility.

Engineering record keeping and photo documentation to date has been relatively immature and not suitable engineering data. (Good data is important in the remaining items on the slide.)

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

SERVICING, REPAIR, ASSEMBLY OF SPACECRAFT

- FUEL TRANSFER
- MODULAR UPGRADE
- ACCESSABILITY
  - TO SPACECRAFT
  - TO MODULES / COMPONENTS
  - FOR CHECKOUT

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

EXPERIMENTS / EVALUATIONS

- CHARACTERIZATION OF PLATFORM
- CHARACTERIZATION OF MAN
  - VISUAL PERCEPTION & COGNITION
  - KNOWLEDGE & INTELLECT
  - PHYSICAL DEXTERITY & MOBILITY
- ENGINEERING RECORD / PHOTO DOCUMENTATION
- METEOROLOGICAL
- OCEANOGRAPHIC
- GEOLOGICAL
- PHYSIOLOGICAL
- PSYCHOLOGICAL

Much work needs to be done in quantifying man.

- Ergonomics--how much work can a human do while under certain mission constraints. Body efficiency ratings.
- Psycometrics
  - Impact on crew on long missions
  - Crew member compatibility
  - How do we pick the right crew to insure mission success?
- Space sickness--do not understand
  - Impact on mission success
- Problems associated with
  - Cardiovascular deconditioning (related to space sickness?)
  - Bone demineralization
  - Radiation exposure, etc.

The Air Force is seeking help from the Brooks Air Force Base Aeromedical Center to assist in quantifying man in each of these areas and others.

AIR FORCE MANNED SPACEFLIGHT ENGINEER (MSE) PROGRAM

BIOTECHNOLOGY

- ERGONOMICS
- PSYCHOMETRICS
- SPACE SICKNESS
- CARDIOVASCULAR DECONDITIONING
- BONE DEMINERALIZATION
- RADIATION EXPOSURE