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EVOLUTION OF THE ASTRONAUT'S ROLE

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For additional background on this subject the reader is referred to Chapter 16 of "Foundations of Space Biology and Medicine" which is reproduced as an addendum at the end of this section.

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Historically, studies of man/machine interfaces have focused on proper allocation of system operating functions between man and machine. A typical approach has been to analyze task sequences to discover task components and allocate these functions to man or machine, depending upon which would be better at the particular task. Man is able to handle a variety of information processing tasks in which input (sensory) and output (motor) aspects vary widely. He is able to store and recall great amounts of information pertinent to system operation under both normal and emergency conditions. He is able to operate as a decision-maker through his capability to evaluate information and to distinguish between useful and unusable and irrelevant information. He can solicit additional information from the system when necessary, and can estimate probabilities. The human operator can respond to the unforeseen and operate at a level of complexity exceeding any reasonable amount of premission planning and programming of on-board automatic control equipment. So far, man is the only real-time system capable of accepting and operating on asynchronous and nonsequential input data.

Man's capabilities for sensing data have been studied longer and more thoroughly than any other aspect of his performance. Much information is available concerning the basic processes of seeing, hearing, and sensing motion. Significant aspects of man's sensory capabilities are shown. Such data are in substantial agreement in US and Soviet handbook compilations.

MAN'S ROLE IN SPACE

CAPABILITIES:

- O SENSOR
- O OBSERVER
- O DATA PROCESSOR
- O REPORTER
- O ACTUATOR
- O CONTROLLER

ATTRIBUTES:

- O REPLICATION
- O INTERCHANGEABILITY
- O PROGRAMMABLE
- O LEARNING

CHARACTERISTICS OF THE SENSES

PARAMETER	VISION	AUDITION	TASTE AND SMELL	TOUCH	VESTIBULAR
INDICATIONS FOR USE	1. SPATIAL ORIENTATION REQUIRED 2. SPATIAL SCANNING OR SEARCH REQUIRED 3. SIMULTANEOUS COMPARISONS REQUIRED 4. MULTIDIMENSIONAL MATERIAL PRESENTED 5. HIGH AMBIENT NOISE LEVELS	1. NONDIRECTIONAL WARNING OR EMERGENCY SIGNALS 2. SMALL TEMPORAL RELATIONS IMPORTANT 3. POOR AMBIENT LIGHTING 4. HIGH VIBRATION OR G-FORCES PRESENT	1. PARAMETER TO BE SENSED HAS CHARACTERISTIC SMELL OR TASTE 2. CHANGES ARE ABRUPT	1. CONDITIONS UNFAVORABLE FOR BOTH VISION AND AUDITION	1. GROSS SENSING OF ACCELERATION INFORMATION

The increase in the number and scope of Apollo and Skylab mission objectives is indicated by the growth in the number of stowed items. This growth reflects increase in crew size, duration of missions, and emphasis on scientific objectives as operational maturity evolves. An analysis of the information shows that growth is caused primarily by time-dependent operational items (e.g., food and film) and by increased emphasis on scientific and applications experiment activities.

The number of items increased, also the diversity and complexity of the items. The number of stowed items increased by a factor of 4, even when the items attributable to more crewmen and a longer mission were omitted.

The relationship of crew size, pressurized volume, and usable volume of each spacecraft is shown. The usable volume is defined as that within the pressure vessel not occupied by equipment and that can be used for temporary stowage, movement by the crewmen, or other functions that enhance habitability. The volumes increased noticeably from the first to the present spacecraft configurations. For the Mercury and Apollo command module spacecraft, the relationship of the pressurized volume to effective free volume reflects that most equipment was installed within the pressure vessel. Gemini and lunar module spacecraft had only the crew instrument panels and portions of the environmental control system installed within the pressure vessel. Estimates of the volumes for Soviet spacecraft indicate similar arrangements.

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SPACE CRAFT STOWAGE

	COMPARTMENTS NUMBER	VOLUME (m^3)	ITEMS STOWED
MERCURY	-	-	48
GEMINI	13	.42	196
APOLLO	25	2.12	1727
SKYLAB	241	19.36	10,160
ASTP	32	2.65	1965
SHUTTLE	55	4.44	1084
SPACE STATION	300	80.0	20,000

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HABITABILITY CONSIDERATIONS

SPACECRAFT	NO. CREWMEN	PRESSURIZED VOLUME,[1] m^3	EFFECTIVE SPACECRAFT INTERIOR FREE VOLUME,[1] m^3	HABITABLE VOLUME PER CREWMAN, m^3
MERCURY	1	1.42	0.71	0.71
VOSTOK	1	2.55	2.00	2.00
GEMINI	2	2.27	1.15	0.57
VOSKHOD	2 OR 3	4.85	3.68	1.84/1.23
APOLLO				
COMMAND MODULE	3	8.95	7.27	2.41
LUNAR MODULE	2	6.63	5.25	2.62
SOYUZ				
COMMAND MODULE	1 TO 3	4.81	3.96	3.96/1.32
ORBITAL MODULE	1 TO 3	6.22	4.53	4.53/1.51
SKYLAB				
COMMAND MODULE	3	8.95	7.24	2.41
ORBITAL ASSEMBLY TOTAL	3	351.06	316.06	105.35
SHUTTLE				
CREW CABIN	3 TO 7	70.3	35.6	11.8 TO 5.1
SPACELAB	4 TO 7	81	47.6	11.9 TO 6.8
'SPACE STATION'	8 TO 12	300 TO 400	200	25 TO 15

A pictorial of Spacelab and Shuttle habitable area is shown. A comparison of available space is shown in the table.

A comparison of habitable space for Skylab, Salyut, and projected Space Operation Center and Science and Applications Manned Space Platform.

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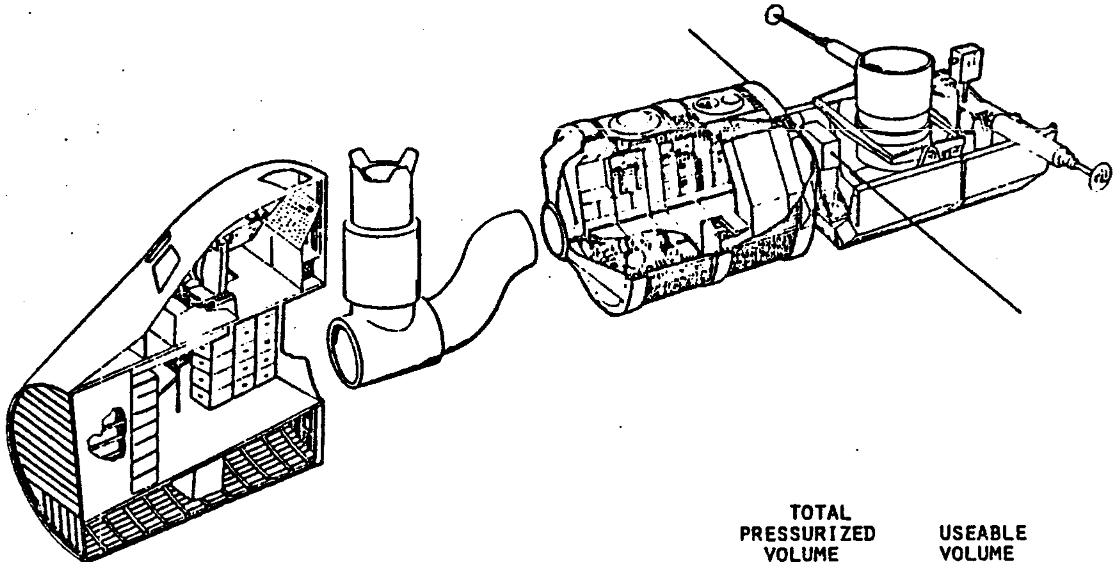
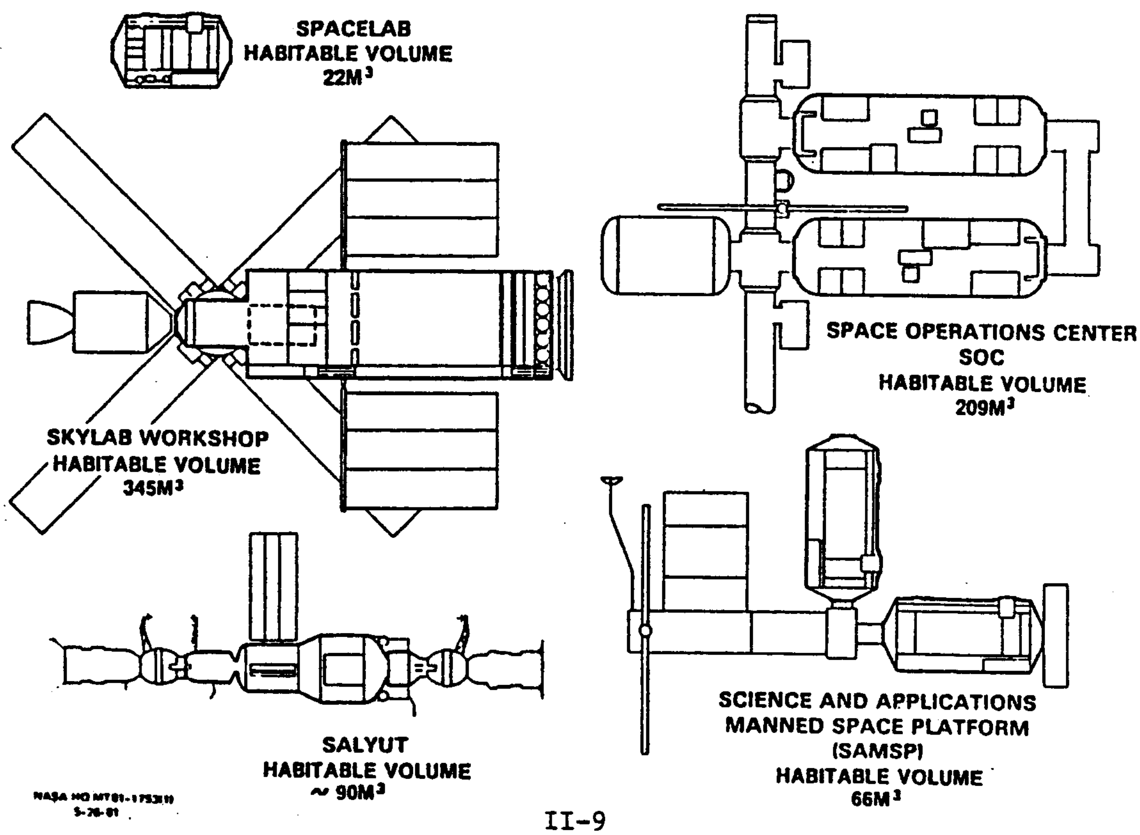
SPACE SHUTTLE
HABITABILITY CONSIDERATIONS



	TOTAL PRESSURIZED VOLUME M^3	(FT^3)	USEABLE VOLUME M^3	(FT^3)
ORBITER CREW CABIN	70.3	(2475)	35.6	(1250)
TRANSFER TUNNEL	8.6	(303)	8.6	(303)
SPACELAB				
LONG	72.4	(2570)	39.0	(1448)
	151.3	(5048)	73.2	(3001)

"SPACE STATIONS" — A PERSPECTIVE



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Shown are relationships of spacecraft volume, mission duration, and crew size to similar values for submersibles and aircraft. In all vehicles, the pressurized or conditioned volume of the vehicle increases as a function of both crew size and mission duration. Mission duration can be varied extensively for a given vehicle; however, for smaller vehicles, significant stresses may be placed on the crewmen.

An illustration of the weight and number of items related to on-board data management is shown.

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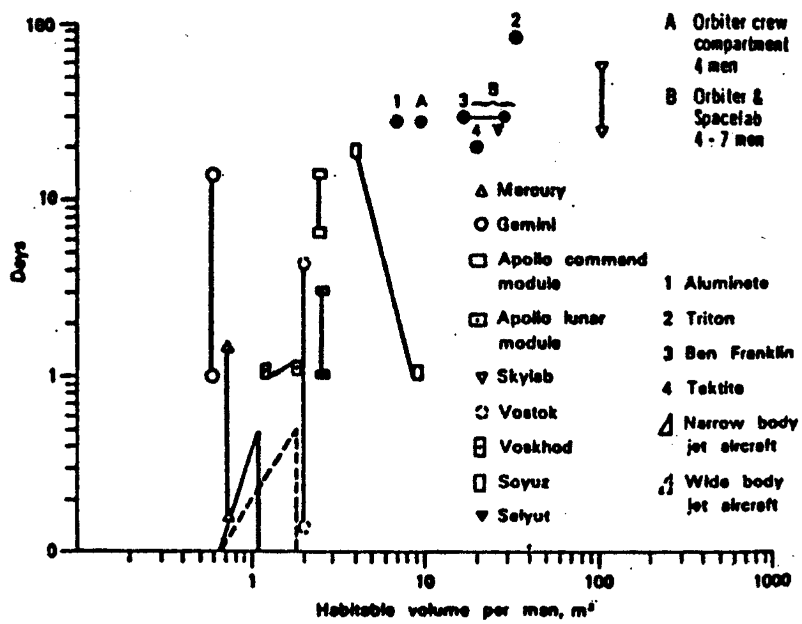
HABITABILITY CONSIDERATIONS



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ON BOARD DATA MANAGEMENT

	WEIGHT (kg)	NUMBER OF ITEMS
MERCURY	1.1	4
GEMINI	2.2	10
APOLLO	8.3	21
	13.0	34
SKYLAB	70.5	83
ASTP	18.6	34
SHUTTLE	28.6	37
SPACE STATION (1)	50.0	75

(1) ASSUMES: GROUND-TO-STATION DATAFAX.

The complexity, size, and number of display consoles in spacecraft have increased with more complicated missions and design commitment to the maximum effective use of crewmen.

The number of measurements required for each mission has grown from Mercury to Skylab. While the number has increased further from Shuttle to Space Station, the use of real-time control on-board and data base management from the ground will reduce the load on the crew and mission control substantially.

NASA-S-81-11057

STS-1 OPERATIONS

NORMAL FLIGHT

SYSTEMS CHECKOUTS/GO-NO GO's/FLIGHT TEST OBJECTIVES

ASCENT ABORTS		

• RTLS
• AOA
• ATO
• ROTA
• CONT
  • 2 SSME FAIL
  • 3 SSME FAIL
	• ORBIT 5 DE-ORBIT
	• CONTINGENCY LANDING SITE DE-ORBIT
		• DAY 2 ENTRY

SYSTEMS OPERATIONS

DDS ELEC OMS RCS ECLS APU HYD PBD MPS COMM

FAILURE CASES

ASC/ON-ORBIT/ENTRY	ASC/ON-ORBIT/ENTRY	ORBIT
• LOSS OF 1 FUEL CELL/ELECT BUSSES • LOSS OF 1 FREON LOOP • LOSS OF TOPPING EVAP • LOSS OF HIGH LOAD EVAP	• LOSS OF CABIN PRESSURE • LOSS OF 2 FUEL CELLS • LOSS OF 2 FREON LOOPS • LOSS OF 2 WATER LOOPS • LOSS OF BOTH EVAPS • LOSS OF BOTH CABIN FANS	• EVA TO CLOSE PBD's. • EMERGENCY D/O

ASC PCL - 106 PGS
ORB PCL - 104 PGS
ENT PCL - 106 PGS

MALF PROC - 688 PGS

NASA-S-81-2284

SPACECRAFT SYSTEM INFORMATION

PROGRAM	TOTAL MEASUREMENTS		DISPLAYED TO CREW		DISPLAYED TO MISSION CONTROL	
MERCURY	100		53		85	
GEMINI	225		75		202	
APOLLO						
CM	475	948	280	494	336	615
LM	473		214		279	
SKYLAB						
CM	521	2241	289	615	365	2034
OAM	1720		326		1669	
SHUTTLE	7831		2170		3826	
'SPACE STATION' (1)	10,000		4000		4000	

(1) ASSUMES REAL-TIME CONTROL ONBOARD, DATA BASE MANAGEMENT FROM THE GROUND

The technology of display and control components grew substantially more sophisticated from Project Mercury to the Gemini program, and this new technology was further refined for the Apollo and Skylab programs. Increased complexity of the displays and controls emphasizes the importance of crew functions on success of the mission; the emphasis is on finding the most efficient means to convey information to the crew.

Self Explanatory

NASA-S-81-2281

CREW DISPLAYS AND CONTROLS

	PANELS	WORK STATIONS	CONTROL DISPLAY ELEMENTS	COMPUTERS NUMBER/MODES
MERCURY	3	1	143	0
GEMINI	7	2	354	1
APOLLO ①	40	7	1374	4/50
SKYLAB ②	189	20	2980	4
SHUTTLE	97	9	2300	5/140
'SPACE STATION' ③	200	40	3000	8/200

1 - PRIMARY AND BACKUP IN CM AND LM

2 - CM PRIMARY AND BACKUP, TELESCOPE, WORKSHOP

3 - ASSUMES REAL TIME CONTROL ON BOARD, DATA BASE MANAGEMENT FROM THE GROUND

NASA-S-81-2282

CREW SOFTWARE INTERFACES

APOLLO

CM

- PROGRAMS 43
- VERBS 85
- NOUNS 92

LM

- PROGRAMS 31
- VERBS 78
- NOUNS 85

SHUTTLE

- DISPLAYS 75
- ITEM ENTRY 50
- OPERATIONAL SEQUENCES 9
- MAJOR MODES 16

- HARDWIRE MEMORY
- 3 REGISTER DISPLAY
- NAVIGATION, GUIDANCE & FLIGHT CONTROL

- READ WRITE ACCESS
  GENERAL MEMORY
  MASS MEMORY
- 3 ALPHANUMERIC & GRAPHIC DISPLAY CRT
- NAVIGATION, GUIDANCE, FLIGHT CONTROL & SYSTEMS MANAGEMENT
- REDUNDANCY MANAGEMENT

The following two charts summarize comments on various items that effected habitability and performance on the first four Shuttle flights.

Comments Continued

SUMMARY STS-1 THRU STS-4

TEMPERATURE:	CREW COMMENTS DECREASE FROM STS-1 TO STS-4 WTIH FEW COMMENTS ON STS-4
RELATIVE HUMIDITY:	CLOUDY WINDOWS (AROUND THE EDGES) AND CONDENSATION (FROM VENT DUCT) ON AFT WINDOWS ON STS-3. NO CONDENSATION ON WINDOWS, WHEN SHADES REMOVED, ON STS-4. BETTER THAN SKYLAB.
ODORS:	SOME BODY AND LAVATORY ODORS DETECTED, MOST ADDRESSABLE BY WASHING AND DEODORANT "STICK-UPS." SOME SLIGHT LAVATORY ODOR STILL DETECTABLE ON STS-4
SLEEP:	PRIMARY THRUSTERS (RCS) CAN INTERFER WITH SLEEP
WINDOWS:	EXTERNAL WHITE POWDERY SUBSTANCE ON WINDOWS 1 AND 6 ON STS-1--NONE THERE-AFTER THRU STS-4
TELEPRINTER:	USED LOTS OF PAPER ON STS-1 AND 3--NO COMMENTS ON STS-2 AND 4
COMMUNICATIONS:	WIRELESS WORKS GOOD. MOLDED EAR PIECES WORK PRETTY WELL--WITH SOME EAR SORENESS. THE CABIN FANS ARE RATHER NOISY.
DISPLAYS AND CONTROLS	SOME SWITCHES PROTRUDE PAST WICKETS AND WERE ACCIDENTALLY BUMPED ON STS-1 AND 2--NO COMMENTS ON SUCH THEREAFTER
	SOME CAUTION AND WARNING (ALARMS) DISCREPANCIES ON STS-4. PANEL LIGHTS VERY HOT

SUMMARY STS-1 THRU STS-4 CONTINUED

2

LAVATORY:	INCONVIENT AND A LITTLE DIFFICULT TO USE. WHILE SERVING ITS PURPOSE, CONSIDERABLE IMPROVEMENT IS DESIRABLE AND WARRENTED
STOWAGE:	MORE VOLUME FOR USED ARTICLES NEEDED. STS SHOULD HAVE A TRASH COMPACTOR
HYGIENE:	WASHCLOTHS AND TOWELS CREATE TRASH MANAGEMENT PROBLEM. SKYLAB HAD A WASHRAG SQUEEZER
FOOD:	GOOD. SANDWICHES AND PREPARED MEALS
WATER:	GOOD. CHILLED AND NO (OR MINIMAL) BUBBLES
TIMELINE:	QUES AND MULTIPLE ACTIVITIES SOMETIMES RESULT IN VERY BUSY PERIODS--SLACK AT OTHER TIMES. SOME TYPE OF ACTIVITIES "DISPLAY" SCOREBOARD DESIRABLE
WORKLOAD:	VERY HEAVY

The next two charts highlight comments from Shuttle flight 1 through 4 on items that could be changed to improve flight operations and habitability.

Comments Continued

"HIGHLIGHTS" STS-1 THRU STS-4

STS-1: MANY BITS OF DEBRIS (NUTS, BOLTS, AND PENCILS CAME OUT OF CRACKS AND CREVICES) FLOATED FREE IN THE SPACECRAFT UNTIL THEY ADHERED TO THE AIR CONTROL FANS' FILTERS. THE CREWS' HEADSET EARPHONES WERE FREQUENTLY JERKED OFF THEIR PROPER LOCATIONS ON THE USERS' EAR BY THE CONNECTING CABLES BECOMING TANGLED DURING ACTIVITIES. RESTOWAGE/REPACKAGING OF EQUIPMENT AND USED ARTICLES--AS COMPACTLY AS PRE-MISSION--WAS USUALLY NOT POSSIBLE. TRASH GENERATED BY THE TELEPRINTER PRINTOUT, FOOD WRAPPERS, ETC., WAS NOT EASY TO MANAGE. THE NOISE LEVEL IN THE SPACECRAFT WAS AROUND 67 DECIBELS. THE LAVATORY DID NOT WORK PROPERLY, AND IT WAS COLD THE FIRST SLEEP PERIOD.

STS-2: SOUND LEVELS ON-ORBIT WERE NOT BAD, EXCEPT FOR REACTION CONTROL SYSTEM ENGINE STARTUP--WHICH "SOUNDED LIKE A HOWITZER." SOME STOWAGE LOCKER DOORS WOULDN'T LINE UP TO ALLOW PROPER LATCHING. THE "WIRELESS" COMMUNICATION UNITS WERE VERY USEFUL. THE CABIN TEMPERATURE VARIED FROM DAY TO DAY, BUT NEITHER THE COOLEST OR WARMEST TEMPERATURES WERE UNCOMFORTABLE. AN UNPLEASANT ODOR WAS DETECTED AROUND THE LAVATORY. THE DRINKING WATER HAD GAS BUBBLES IN IT.

STS-3: THREE (3) OR FOUR (4) CAMERAS DID NOT WORK. THE LAVATORY DID NOT WORK PROPERLY. KLEENAX BECAME A LIMITED CONSUMABLE. THE TELEPRINTER SEEMS TO WASTE A LOT OF PAPER. A LOT OF MOTION (PHYSICAL ACTIVITIES) SHOULD BE MINIMIZED ON FIRST OR SECOND DAY. TOOLS MAY BE GOOD FOR CHANGING ENGINE RATHER THAN CHANGING OUT KEYBOARD. JET FIRING REVERBERATE THROUGH VEHICLE COULD AFFECT SLEEP. NO APPETITE FIRST COUPLE OF DAYS.

STS-4: CABIN "ILLUMINATION" IS NOT GOOD FOR PHOTOGRAPHIC PURPOSES. OVERHEAD LIGHTS WORTHLESS AROUND THE CENTER CONSOLE AREA AT NIGHT. ASTRONAUTS' HEAD COMES BETWEEN LIGHT AND OBJECT TO BE LOOKED AT--THE OVERHEAD LIGHTS ARE VERY HOT. THE CABIN FANS ARE THE NOISIEST--THE SILENCE WAS DEAFENING WHEN THEY WERE TURNED OFF. COMBINATION REFRIGERATOR/FREEZER VERY HELPFUL--MADE MANY ITEMS PALATABLE. THE LAVATORY IS A PROBLEM--IT WORKED THE WHOLE MISSION--JUST VERY INCONVIENT AND TIME CONSUMING.

These next two charts summarize Russian activities on Salyut 6. Particularly noteworthy is the fact that the crews contributed to six mission saving repairs.

The Russians have extensive human experience in space. Many of the capabilities of Salyut 6 require an active human involvement.

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RUSSIAN MANNED ACTIVITY ON SALYUT 6

- SALYUT 6 DESIGNED FOR CREW
  - ON BOARD MAINTENANCE AND MINOR REPAIRS
  - CARGO AND FUEL TRANSFER FROM MANNED AND UNMANNED SUPPLY VEHICLES
- CREWS HAVE SIGNIFICANTLY UPGRADED SALYUT 6 SINCE INITIAL OPERATION
  - NEW ITEMS INSTALLED
  - DOCKING HATCH CONFIGURATION CHANGED
  - ASSEMBLED RADIO TELESCOPE (KRT-10) AND DEPLOYED IT THROUGH REAR HATCH
- CREWS PERFORMED AT LEAST 6 MISSION SAVING REPAIRS
  - JETTISONED KRT-10 BY EVA AFTER ENTANGLEMENT WITH DOCKING TARGET
  - ISOLATED AND EMPTIED FAULTY FUEL TANK

NASA-S-82-07069

RUSSIAN MANNED ACTIVITY ON SALYUT 6

- SECOND GENERATION STATION, REPRESENTING NEW STAGE OF MANNED "COSMONAUTICS" - (REF: USSR NATIONAL PAPER, UNISPACE '82)
- EXTENDED DURATION HUMAN ACTIVITY IN SPACE
  - LYAKHOV AND RYUMIN, 175 DAYS IN ORBIT, DEVOTED
    - 1/3 TIME TO TECHNOLOGICAL WORK
    - 1/3 TIME TO EARTH OBSERVATIONS
- SALYUT 6 CAPABILITY REQUIRING MAN'S PRESENCE
  - MATERIALS PROCESSING
  - BIOSCIENCE
  - EARTH PHOTOGRAPHY
  - 1.5 METER OPTICAL TELESCOPE OBSERVATIONS
  - 10 METER RADIO TELESCOPE OPERATIONS

The lessons learned from Salyut 6 as viewed by the Russians. Besides effectively advancing space technology for the solution of scientific and economic problems, the Salyut serves in effective political roles in third world countries.

This chart provides a concise comparison between Russia and US human roles in space. Because of the difference emphasis in programs, the Russians have concentrated on the use of man in space and have more manned hours in space.

NASA-S-82-07067

RUSSIAN VIEW OF LESSONS LEARNED FROM SALYUT 6

- CONTINUOUS OPERATION OF ORBITAL COMPLEXES WITH REPLACEMENT CREWS REPRESENTS THE MOST EFFECTIVE AND PROFITABLE ADVANCE OF SPACE TECHNOLOGY FOR SOLUTION OF SCIENTIFIC AND ECONOMIC PROBLEMS
- THE EXTENDED MISSIONS PROVIDED UNIQUE EXPERIENCE OF REPAIR AND MAINTENANCE OPERATIONS UNDER SPACE FLIGHT CONDITIONS
  - DESIGN PHILOSOPHY OF MAINTAINABLE SPACE COMPONENTS WERE DEVELOPED
- JOINT INTERNATIONAL MANNED FLIGHTS IS A NEW DOMAIN OF THE SOCIALIST COUNTRIES COOPERATION
  - CURRENTLY BEING EXTENDED TO THIRD WORLD AND NATO COUNTRIES

NASA-S-82-07066

COMPARISONS BETWEEN RUSSIAN AND U.S. HUMAN ROLES IN SPACE

- RUSSIANS HAVE MANY MORE MANNED HOURS IN SPACE
  - 5 MAJOR "EXPEDITIONS" (95 TO 185 DAYS); 9 VISITING EXPEDITIONS AND 12 DELIVERY OPERATIONS AS OF MARCH 1981 FOR SALYUT 6
  - AFTER 3 SKYLAB MISSIONS (84 DAYS MAXIMUM), U.S. HAS CONCENTRATED ON SORTIES INTO SPACE
- RUSSIANS HAVE PERFORMED 3 EVA'S, PRESUMABLY ALL RELATED TO UNSCHEDULED REPAIRS
- U.S. EVA'S ON SKYLAB FOR SAME REASON. PROJECTED USE FOR SATELLITE SERVICING UNMATCHED AS YET BY RUSSIANS

Design implication for future manned operation in space should consider the listed items and their impact on productivity.

DESIGN IMPLICATIONS

O PRODUCTIVITY VS. MINIMAL REQUIREMENTS

EXAMPLES:

- O CABIN NOISE LEVELS
- O PERSPECTIVE DISPLAYS--ORBITAL GROUND TRACK
- O ANCILLARY EQUIPMENTS
  - MOTION PICTURE CAMERA
  - HAND CALCULATORS
- O HYGIENE
- O STOWAGE

ADDENDUM