SPACE STATION EVA SYSTEM EVOLUTION STUDY

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CONTRIBUTORS: MDSSC-SSD
H. G. Slade
L. N. Panzarella
D. E. Anderson

LESC
C. Simonds, PHD

M. N. Rouen, NASA/JSC-EC3
Task Monitor

H. G. Slade, MDSSC-SSD
Study Manager

SPACE STATION FREEDOM
EVA SYSTEMS
EVOLUTION STUDY

ABSTRACT

Evaluation of Space Station Freedom support of manned exploration is in progress to identify SSF EVA system evolution requirements and capabilities. The output from these studies will provide data to support the preliminary design process to ensure that Space Station EVA system requirements for future missions (including the Transportation Node) are adequately considered and reflected. The study considers SSF support of future missions and the EVA system baseline to determine adequacy of EVA requirements and capabilities, and to identify additional requirements, capabilities, and necessary technology upgrades.

EVA demands levied by formal requirements and indicated by evolution mission scenarios are high for the out-years of Space Station Freedom. An EVA system designed to meet the baseline requirements can easily evolve to meet evolution demands with few exceptions. Results to date indicate that upgrades or modifications to the EVA system may be necessary to meet all forseeable hangar induced EVA environments. Work continues to quantify the EVA capability in this regard. Evolution mission scenarios with EVA in and around unshielded nuclear propulsion engines are inconsistent with anthropomorphic EVA capabilities.

NEW/UNIQUE REQUIREMENTS IMPLIED IN EVOLUTION STATION SCENARIOS

The results of this study indicate new or unique requirements above and beyond the baseline requirements implied in the evolution space station scenarios.

EVA RESOURCE DEMAND

The demand for EVA resource continues to be high and may exceed current baseline growth requirements of 3000 man-hours per year (250 EVAs per year).

EVA ENVIRONMENT

The evolution of Space Transfer Vehicles include upgrading the propulsion systems to nuclear propulsion engines. The impact on the EVA environment assuming the unshielded engines was assessed. This study concludes that EVA environments associated with unshielded NTR engines is incompatable with anthropomorphic EVA capabilities.

Thermal environments associated with STV servicing and transportation node hangars are more severe than typical SSF truss EVAs. Full duration EVAs in these thermal environments with the present SSF EMU baseline may not be possible without supplemental cooling.

QUARANTINE

Biological quarantine issues associated with SSF EVA must consider both inbound and outbound vehicle biological contamination.

CONTAMINATION DETECTION AND REMOVAL AT EVA WORKSITES

The EMU suit materials are proving to be fairly compatable with space vacuum exposures to contaminants associated with fuel and coolant system spills. The EVA System provides adequate means for contaminant removal from exposed EVA crewmembers prior to ingressing the airlock. The EVA System does not address cleanup of worksites, or space station or STV external hardware contaminated as a result of a spill.
This contingency should be investigated further to address if natural sublimation of spill fluids is adequate to support transportation node operations or if methods of enhanced sublimation are required to cleanup worksite spills.

HANDLING OF EVA CREW OPERATIONS DATA

EVA crewmembers will need access to a high quantity of EVA operational data in order to support the myriad space station and STV processing activity. The ability to support data access and transmission decreases with the implementation of UHF space-to-space communications with EVA personnel. Other means of data access, transmission, and display, other than crew worn cuff checklists, must be implemented to retain this EVA crew support data interface.

STUDY ACTIVITY

- Evaluation of EVA System Requirements for Transportation Node
  - EVA Resource Demand
  - Environment
    - Ionizing Radiation
      - South Atlantic Anomaly (SAA)
      - Nuclear Powered Engine Reactors
    - Thermal Environments
  - Quarantine
  - Contamination Detection and Removal
  - EVA Operations Data Handling

EVA DEMAND

- EVA resource required to support Transportation Node assessed
  - SSF Maintenance and Contingencies
  - User Support
  - LTV Refurbishment and Processing
  - MTV Assembly

- EVA demand for SSF outyears anticipated to be high
  - Peak resource requirements are consistent with peak transportation node activity
  - EVA demand without transportation node is also significant

- EVA demand requires routine EVA capability even with robotics
  - EVA and telerobotics must be balanced
    - Diving industry experience with robotics
      - Currently 30% task off-loading with robotics
      - 40% plateau projected for cost effective operations

- EVA system built to Phase C/D requirements best approach for meeting demand with LEO operational constraints
  - New SSF EMU - no prebreathe, low IV overhead, low volume regenerable
  - Two airlocks with automated service and performance checkout

ESTIMATE OF ANNUAL EVA RESOURCES

An assessment of EVA resources required to support the evolutionary scenario of space station as a manned exploration transportation role was conducted to establish the adequacy of the baseline.

The assessment considered the EVA resource requirement necessary to support space station maintenance, space station contingency operations, space station payload users, and manned exploration STV refurbishment and assembly activity.

This study assumed that SSF contingencies and user support were consistent with pre-scrub EVA resource allocations as defined in SSP 30000. EVA resource for SSF maintenance was based on post-scrub configuration estimates from the maintenance data base. Actual EVA requirements for SSF maintenance are assumed to be larger than these estimated due to SSF add-backs and expected growth beyond assembly complete.

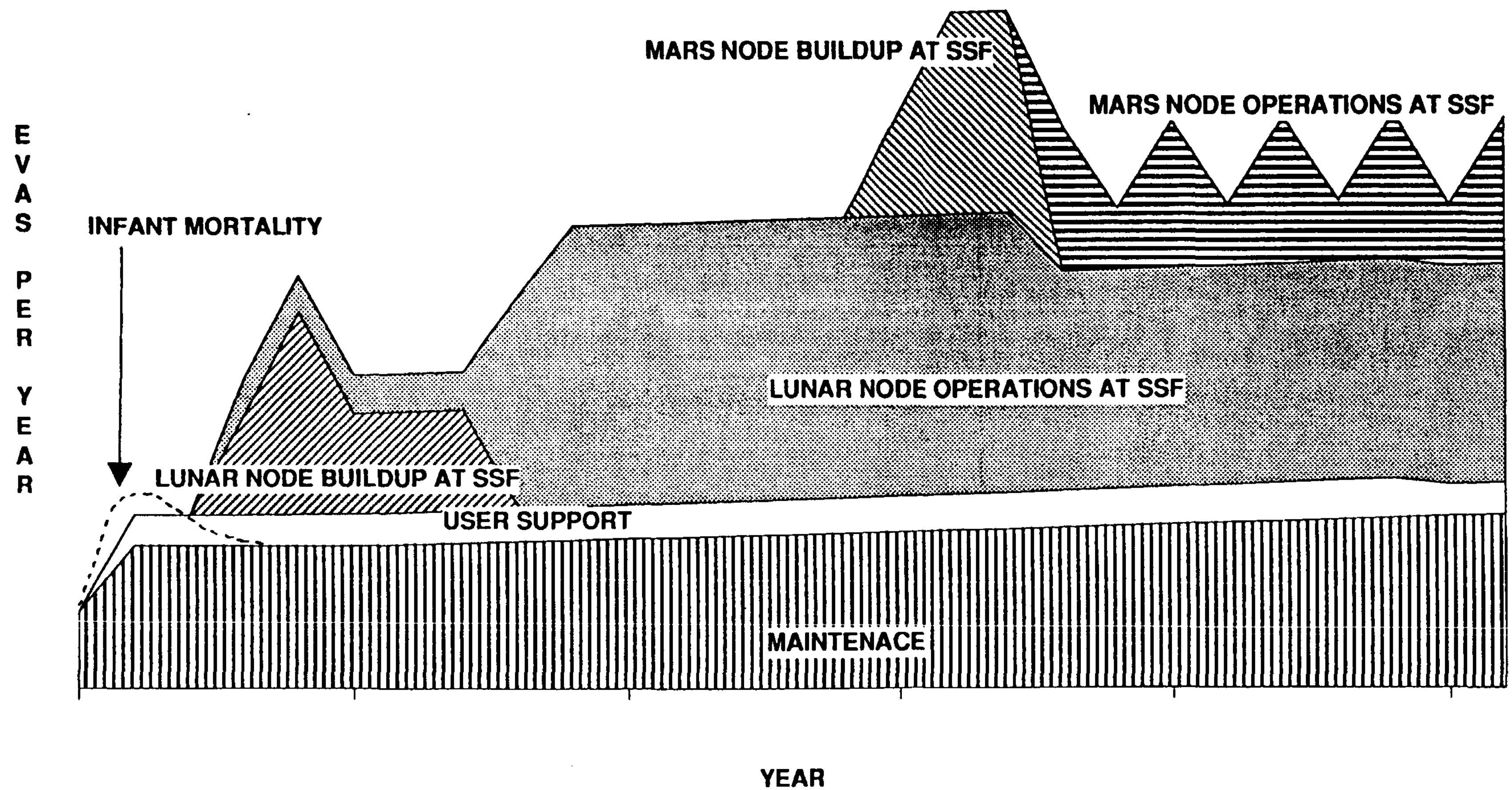
Data for EVA resource requirements for on-orbit STV processing was derived from on-going MDSSC-KSC studies (Ref's 9,10, and 22) concerning on-orbit refurbishment and assembly of Lunar Transfer Vehicles and Mass Transfer Vehicles respectively. STV mission loading was based on the OEXP presentation on Manned Exploration to contractors (Ref 5).

The results show that current EVA resource growth requirements of 3000 man hours may be insufficient even with robotics off-loading and assisting manned EVA tasks. Figure 6 shows an expected profile of EVA resource demand with time. Peak resource requirements are consistent with peak transportation node activity. SSF EVA resource requirement minus the transportation node are not insignificant.

ESTIMATE OF ANNUAL EVA DEMAND

	EVA Man Hours post-AC
SSF Maintenance • Post-scrub configuration • Add-backs will increase EVA demand • Growth expected beyond AC configuration	> 702
SSF Contingencies • Pre-scrub EVA resource allocation	104
User Support • Pre-scrub EVA resource allocation	280
LTV Refurbishment and Processing • On-Orbit Assembly/Servicing Task Definition Study — MDSSC-KSC, Nov 89 • > 1100 man hours per vehicle • Robotics off-loading not assessed	> 2200-3300
MTV Assembly • On-Orbit Assembly/Servicing Task Definition Study — MDSSC-KSC, Nov 89 • 432 man-hours per vehicle • Robotics off-loading for fueling	432
Total	> 3718 - 4386

FIGURE 6: AMOUNT OF REQUIRED EVA



SOUTH ATLANTIC ANOMALY

The South Atlantic Anomaly (SAA) is an area of Low Earth Orbit (LEO) that contains higher levels of radiation than the surrounding atmoshpere. The SAA is located over the South Atlantic ocean and extends over certain areas of South America, specifically parts of Brazil, and Argentina, and covers Uruguay entirely. The SAA is somewhat fixed with respect to ground coordinates (latitide and longitude). The area and geometry (shape) of the SAA varies with altitude. The area of the SAA is greater at higher altitudes than at lower altitudes. Figure 7 defines the SAA geometry and approximate locations (Ref 11).

For a portion of each day, Space Station will encounter the SAA on consecutive orbits for only a portion of those orbits. As the area of the SAA increases with altitude, so does the number of consecutive orbits that pass through the SAA, the portion of each day containing those orbits, and the total SAA exposure time. In other words, the time each day available to perform EVA free of SAA exposure decreases at higher altitudes. It is highly desirable, and also a requirement, to minimize crew exposure to the SAA on a routine basis in order to minimize any increased health risk due to cumulative exposure. Space Station encounters with the SAA occur at earlier times each subsequent day for the entire range of Space Station orbital altitudes. This presents additional challenges to EVA scheduling, when Space Station operations are divided into two equal working shifts per day.

A preliminary study was performed to determine how Space Station EVA scheduling would be affected by the SAA. The study was based on the assumption that Space Station would orbit the earth at a constant altitude in a 28.5 degree orbital inclination. The two orbital altitudes chosen for this study were 175 and 225 nautical miles. A computer program was used to simulate two Space Station orbital scenarios in order to relate the time of day (24 hour time period) with the location (latitude and longitude ground coordinates) of the station and the SAA. The program generated a 30 day orbital profile that provided a statistical base of data regarding the time and duration of SAA encounters (Ref 12).

The results of this analysis are graphically represented in Figure 8. Specifically they are:

1. The duration of consecutive orbital passes through the SAA increases with orbital altitude.

2. On the average, the time of the consecutive orbit passes through the SAA precesses approximately 30 minutes earlier each subsequent day (precession times varies slightly from day to day). Precession time varies with orbital altitude.

3. In the long term, routine EVAs will have to be performed in alternating shifts in order to avoid the SAA passes.

4. EVA (based on two 12 hour working shifts) flexibility increases when orbital altitude decreases due to the reduced SAA exposure time and vica versa.

RADIATION PROTECTION OF ASTRONAUT IN SSF EMU

The following sections address radiation protection of an astronaut in a Space Station Freedom EMU.

The starting point for the data and analyses presented here is the definition of key issues and limiting assumptions for radiation protection of an EVA astronaut. The underlying issues are whether current EMU designs are adequate for: 1) the large number of mission critical EVA's required for servicing lunar and Mars bound vehicles, and 2) work with nuclear powered vehicles.

The data presented is based on analysis of calculations and data presented in a broader work entitled "Candidate Space Station EVA Space Suit Radiation Analysis Final Report" (CTSD-SS-241) by Kosmo, Nachtway, and Hardy (Ref 15). For data related to nuclear powered vehicles data was derived for reactor concepts based on a report to the Space Station Evolution group by Texas A&M and NASA Lewis Research Center (Ref 16).

Data was evaluated against a limiting set of assumptions concerning several exposure factors, such as duration, frequency, location, and type of protection. The key assumptions on which the calculations are based can be summarized as follows:

1) Maximum plausible amount of EVA per individual based on the recommendation of former astronaut Joseph P. Kerwin, MD:

   - 2 EVA's, 6 hrs/wk for 1.5 years (936 hrs/lifetime)
   - 2 EVA's, 6 hrs/wk for 1 year continuous orbit (624 hrs/lifetime)

2) Maximum permissible amount of EVA per individual (per SSP 30000):

   - 3 EVA's, 6 hrs/wk for 1.5 years (1404 hrs/lifetime)
   - 3 EVA's, 6 hrs/wk for 1 year continuous orbit (936 hrs/lifetime)

3) Space Station Freedom (no polar or GEO platform) location factors which match source calculations:

- 28.5° inclination
- 400-500 km (216-270 nm) altitude

4) Protection due to EMU configuration:

- Mark III standard design
- Mark III with radiation/meteoroid protection
- AX-5 standard design
- AX-5 with radiation protection

The calculation results presented for radiation exposure were weighed against standards outlined in the National Council on Radiation Protection and Measurements Recommendation to NASA. Their limits are set based on a radiation dosage that will add a 3% additional cancer mortality risk over an astronaut's career. For reference, this amount of increase in dosage increases the astronaut cancer mortality risk from the current public-wide average of 17% to 20%.

DISCUSSION OF RADIATION RESULTS

- <u>Nominal EVA Doses</u>

The results of this study are summarized in Table IV. It shows annual and lifetime doses for various EVA frequency scenarios corresponding to the assumptions discussed above. Protection cases listed are for baseline space station and a typical EVA space suit assembly (SSA), both with and without added radiation protection. Due to similarity in AX-5 and Mark III results, only AX-5 results are listed.

The lifetime limits are not approached with worst case results in any of the scenarios evaluated. Therefore, radiation protection is not needed. The annual limits were only exceeded for the worst case based on continuous EVA operations by the same person for a year in the highest orbit and deliberately running all 3 EVA's per week in the South Atlantic Anomaly (SAA). In this situation and others involving the SSA, it was found that a radiation protection garment offers no significant reduction in dose. Other study observations were that the AX-5 offered no significant improvement over the Mark-III hybrid SSA.

Other considerations are that operations requiring a significant number of SAA passes will not be possible, since OSHA requires that all reasonable precautions must be taken to minimize radiation. The OSHA requirements and reasonable operation planning would reduce EVA's in the SAA to a small fraction of the total. Study results and summarized data do not directly address the effects of solar storm effects on radiation levels. However, in low equatorial orbits, such as considered in this study, it is known that solar storm induced radiation builds up very slowly. In place procedures for monitoring solar activity and radiation at SSF during EVA will give ample warning in the unlikely event that an unacceptable radiation level was about to develop.

A key conclusion derived from the data presented is that no scars are required to provide protection for SAA operations. The baseline design for suits and EVA scenarios is adequate in most cases because crew durability limits are lower than radiation limits. Also U.S. Federal statutes require acceptable operation hits to avoid radiation exposure in the work place, that is, a minimum number of EVA's in SAA.

- <u>Effect of Reactors on EVA Doses</u>

All low mass shielding schemes for SP-100 reactors involve shadow shields. The shields only allow protection in a cone with a half angle of about 15° as shown in the attached illustration (Figure 11). This amounts to only 15% of the region surrounding the reactor as being safe. Even brief exposure in the other 98% of the volume around the reactor is lethal. This means that with the shadow shield protection method there can be absolutely no tolerance for failures in attitude control. Portable shielding also provides only highly directional protection with the same lethal consequences for loss of attitude control. As concluded in the previous section, radiation protection from a micrometeoroid garment offers no significant improvement.

The conclusion is that EVA around reactors is effectively impossible. For nuclear powered vehicles robotic separation of reactors and radioactive parts from non-radioactive parts will be required. Non-radioactive parts could then be transferred to EVA orbit.

ENVIRONMENT

- Ability of SSF EMU to meet anticipated radiation and thermal environments was assessed

- LEO Radiation
  - LEO exposure assessed against permissible and likely crew annual and lifetime EVA duty with plausable suit configurations
  - Conclusions
    - Suits adequate for assumed lifetime limits with annual limits exceeded only by worst on worst case
    - Federal statutes require routine EVA operationsd avoid SAA
      - Results in decreased EVA operational flexibility

- Radioactive reactors associated with Nuclear Powered Vehicles
  - All low mass shielding schemes involve shadow shields
  - Brief exposure to unshielded zones with anthropomorphic suit concepts is lethal
  - Conclusion
    - Failure tolerance of EVA near partially shielded reactors is unacceptably low

EVA RADIATION PROTECTION AT SPACE STATION FREEDOM

TABLE IV - EMU RADIATION DOSAGE SUMMARY

DATA SHOWN AS PECENT OF MAXIMUM ALLOWABLE

	ANNUAL - 3 EVAs/WEEK AT 500 KM ORBIT		LIFETIME - 2 EVAs/WEEK 18 MOS. ON-ORBIT TIME	
	NONE IN SAA	ALL IN SAA	NONE IN SAA	ALL IN SAA
MK-III	28.4%	102.9%	8.9%	13.9%
w/ Radiation Protection	27.4%	97.1%	8.9%	13.1%
AX-5	27.9%	101%	8.9%	13.6%
w/ Radiation Protection	15.9%	91.8%	8.9%	12.4%

SAA = SOUTH ATLANTIC ANOMALY

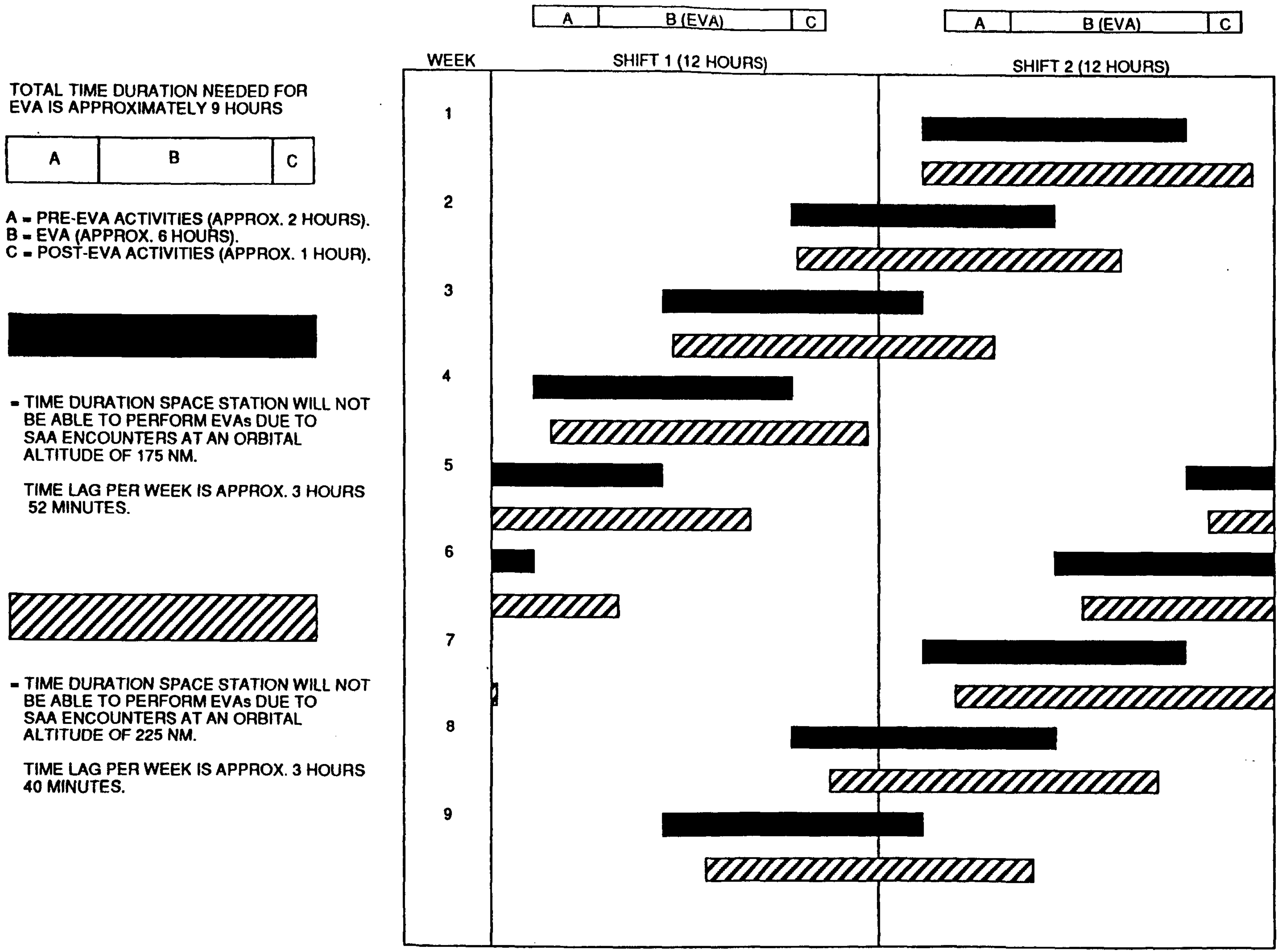


FIGURE 8 : SOUTH ATLANTIC ANOMALY V.S. SS EVA SCHEDULING

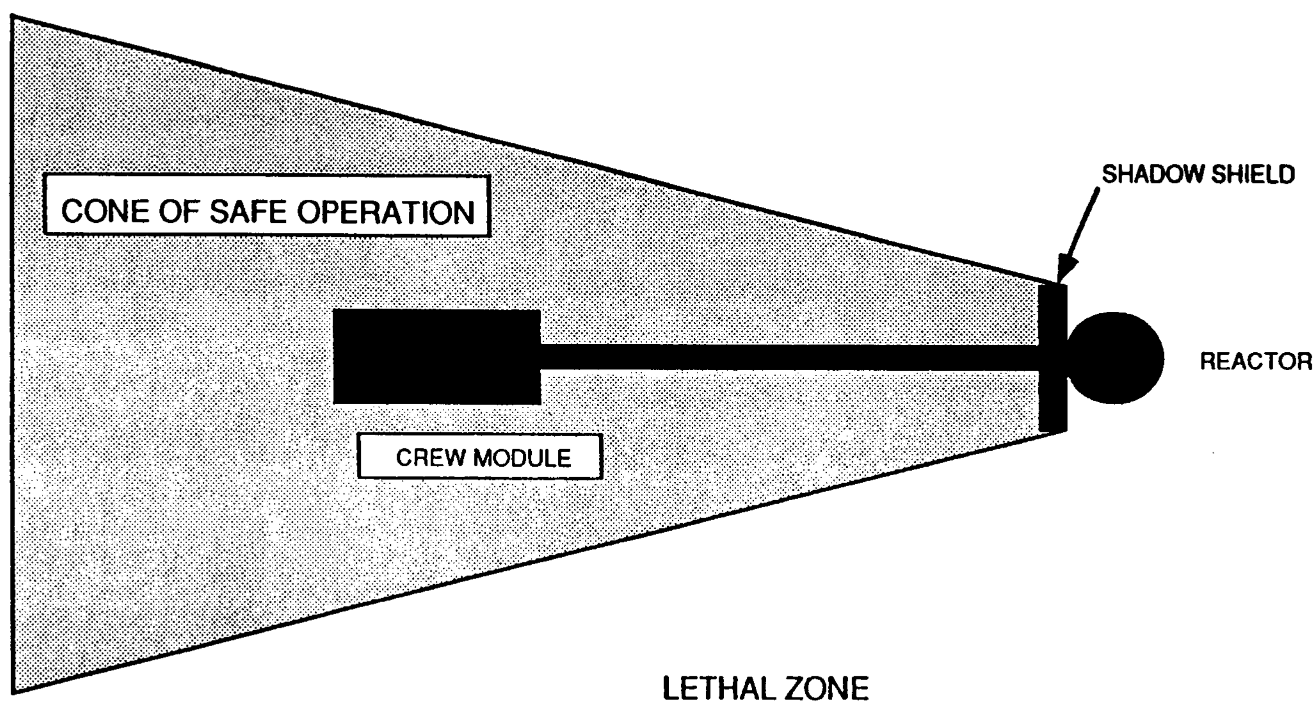


FIGURE 11: SAFE OPERATION IN SHADOW ZONE

EMU THERMAL PERFORMANCE

The Space Station EMU baseline uses a radiator in conjunction with a wax phase-change thermal storage material to reject EMU waste heat. Its performance is significantly effected by the thermal environments at EVA worksite locations. An analysis of LEO transportation node thermal environments and related EMU heat rejection estimates was conducted to determine the EVA thermal requirements for the evolutionary growth Space Station. At this time, evolutionary growth primarily refers to a LEO transportation node supporting a lunar outpost. The adequacy of the baseline EMU thermal performance in these environments was also assessed.

Approach

In this work new thermal analysis results for LEO are combined with prior analyses to compare thermal environments for a variety of Space Station Freedom (SSF) locations. A major part of this effort involved casting the results of prior SSF thermal studies into new formats allowing one-to-one comparisons of new and previous results. The final product of this effort is the comparison of exterior Space Suit Assembly (SSA) temperatures and EMU heat losses at the various SSF and LEO locations.

The solar and emmissive flux data versus orbital position was compiled from previous and new analyses for beta angles of 0 and 52 degees. Since the exact orientation of the EMU at any location is not known, the average flux for each location was calculated. Instantaneous and time averaged adiabatic equilibrium temperatures for EMU SSA material (beta cloth) were determined at each location. Based on estimates of suit insulation performance, suit and radiator areas,and radiator surface properties, instantaneous and time averaged suit and radiator heat leaks were calculated. Calculated heat leaks were then summed and compared to the nominal EMU design estimate of 941 BTU/hr.

A summary of thermal environments that have been evaluated is listed in Table II.

TABLE II - THERMAL ENVIRONMENT EVALUATED

STS ORBITER NOT PRESENT

LOC #	DESCRIPTION	TYPE OF AVERAGE	LESC SOURCE MEMO	MEMO ITEM #
1)	Forward of Nodes 3&4, in plane	cube average	25,520	D-1
2)	Between Modules, in plane	cube average	25,520	D-2
3)	Between JEM & ESA, in plane	cube average	25,520	D-3
4)	Next to HAL-Lab, in plane	cube average	25,520	D-4
5)	Near Node 1 next to Airlock	cube average	25,520	D-5
6)	Below U.S. Hab Module, next to PLM	cube average	25,520	D-6
7)	Above Airlock	cube average	25,520	D-7
8)	Outside Hyper. Airlock Hatch, in plane	cube average	25,520	D-8
9)	Aft of Truss	cube average	25,520	B
10)	Below Truss	cube average	25,520	B
11)	<u>Nominal Case</u> Below Lab Module	EMU flux	26,696	A
12)	<u>Cold Case</u> above ESA	EMU flux	26,696	B
13)	Solar Panel	EMU flux	25,520	C-3
14)	<u>Hot Case</u> Solar Panel	cube average	CTSD-0179	
15)	Hangar, open door	cube average	25,520	C-1
16)	Hangar, open door	cube average	25,520	C-2
17)	Hangar, closed door	cube average	this study	
18)	Hangar, open door	cube average	this study	

ORBITER PRESENT

LOC #	DESCRIPTION	TYPE OF AVERAGE	LESC SOURCE MEMO
1)	Orbiter Belly, near black tiles (possiblly analogy to near LTV Aerobrake)	cube average	25,926
2)	Between U.S. Lab, U.S. Hab, and Nodes 1&2	cube average	25,926
3)	Between JEM-ESA modules	cube average	25,926
4)	Above U.S. Lab module	cube average	25,926
5)	Above Node 1	cube average	25,926
6)	Below Node 1	cube average	25,926
7)	Outside of module cluster near ESA	cube average	25,926
8)	Near Outside Hyperbaric Airlock Hatch	cube average	25,926
9)	Btwn. Orb. Starboard Bay Door and Node 3	cube average	25,926
10)	Orbiter windshield	cube average	25,926
11)	Docking Mast inside payload Bay	cube average	25,926

Results

The summed heat leaks for each environment location was compared to the baseline EMU design estimate of 941 BTU/hr. Heat leaks greater than 941 BTU/hr indicated that the baseline EMU would support a full duration EVA at that location. Heat leaks significantly less (< 850 BTU/hr) indicate that the ability to support a full duration EVA at that location would be compromised unless supplemental cooling was provided.

A list of HOT environments where full duration EVAs would not be ensured is given in Table III.
Of these locations, the hangar, orbiter belly, and between module cases are analogous to transportation node locations of the LTV hangar, an STV aerobrake, and STV modules at a SSF. Actual EVA performance in these locations is unknown since radiator performance is orientation dependent.

Conclusions

Some of the Hot environments evaluated are analogous to major servicing functions at the SSF transportation node. These would include EVA in an LTV hangar, EVA in front of the STV aerobrake tiles, and EVA around the STV module clusters.

Therefore, the following key conclusions are drawn from an evaluation of the summarized thermal environments:

1. Standard duration EVAs for Evolutionary Growth will require more performance from the EMU than from the "Nominal" baseline.

2. Supplemental cooling may be required if mission profile requires long operations in these environments.

HOT ENVIRONMENTS

(TABLE III - HEAT LEAK OF < 850 BTU/HOUR)

Heat Leak BTU/hr	LOC. #	Orbiter Present?	Beta Angle	Name
313	13	No	52	Solar Panel
460	14	No	52	Solar Panel
493	13	No	0	Solar Panel
698	18	No	52	Hangar
709	16	No	0	Hangar
755	1	Yes	0	Orbiter Belly, near black tiles
784	17	No	0	Hangar
791	17	No	52	Hangar
818	18	No	0	Hangar
830	2	No	0	Between U.S. Lab, U.S. Hab, and Nodes 1&2, in plane of raft
831	6	Yes	52	Below U.S. Lab next to PLM
842	2	No	52	Between U.S. Lab, U.S. Hab, and Nodes 1&2, in plane of raft
844	6	No	52	Below U.S. Hab next to PLM
847	2	Yes	52	Between U.S. Lab, U.S. Hab, and Nodes 1&2, in plane of raft

ENVIRONMENT (continued)

- EMU thermal performance assessed against environments analogous to evolution SSF EVA sites

- Approach
  - Flux data from previous and new SSF environment analyses was compiled for analogous EVA sites
  - EMU heat leaks calculated and compared to nominal design case

- Conclusion
  - Hottest environments analogous to major servicing functions
    - Hangar
    - Black aerobrake materials
    - Between modules

  - Standard duration EVAs for evolutionary growth will require more performance from EMU than the baseline nominal case

EVA BIOLOGICAL QUARANTINE ISSUES

- Current Policy and Policy Needs

The current NASA policy is well defined for outbound probes to planets, asteroids and comets under the Planetary Protection Policy. The procedure prescribed by this policy require reducing the biological load on the spacecraft below an amount that can be expected to reproduce.

The NASA policy is not well defined, however, for material returning from planets, asteroids or comets. Since Viking probes did not totally resolve the issue of whether or not there is life on Mars, future missions to Mars are likely to force a policy statement. Although the consensus of Viking researchers is that life has never existed on Mars, that is not good enough proof to avoid a quarantine. Government policy in this area reflects the lack of understanding of the problem by the public at large. For example, the science fiction movie "Andromeda Strain", despite its lack of real life credibility, probably accurately reflects current public understanding.

At any rate, consideration should be given to several aspects of Mars life or Mars "bugs". If Mars life exists, these bugs would already have been exposed to oxidants in the Mars soil as strong as hydrogen peroxide. Their survival of such strong oxidants would presumably make them resistant to many known types of sterilization. Mars life could also exist as tough spore-like phases capable of surviving hard vacuum outside a returning spacecraft. Heat sterilization would be a certain method of killing any life. Exposure to 200°C for a few minutes breaks down complex molecules like DNA required for replication. Heat sterilization would almost certainly be an acceptable sterilization procedure.

The conclusion is that some requirements will have to be set for biological quarantine for missions to and from planets, particularly Mars.

- Outbound Missions from Space Station

Both manned and unmanned Mars missions and other planetary probes may require concern with biological cleanliness and sterilization of hardware. Sublimator water vapor and other vented gases must be demonstrated to be sterile. Venting EMU designs using sublimators or hollow fiber membranes pose the problem of releasing unacceptable biological loads. All unmanned planetary probes assembled at the Space Station will have to conform to the current Planetary Protection Policy.

- <u>Mars Rover/Sample Return (MR/SR) Quarantine</u>

Unmanned return to SSF of Mars Rover recovered samples has been thought through in some detail. A report issued March 31, 1988 under NASA contract NAS 9-17878 entitled "Mars Rover Sample Return Mission Requirements Affecting Space Station" addresses the quarantine issues. The MR/SR would require Mars samples kept at less than -40°C. Weight constraints on the Mars-Earth return vehicle would imply that sample canisters be removed from the return vehicle at or near SSF. The SSF is not the preferred location for a sample return drop-off. The preferred approach is direct entry of the MR/SR vehicle with air snatch of the canister, possibly by rendezvous in orbit. Such a drop-off may involve the Shuttle RMS. If SSF is involved, then a preferred approach is a hatch mounted unit with airlocks similar to those on JEM. In that case the canister transfer would involve the following steps:

1) Capture and dock of return vehicle

2) Stowage of return vehicle in on orbit stowage canister and ASE for return to Earth in Shuttle Payload Bay

3) Extraction of return canister from return vehicle

4) Transfer canister to airlock for processing

5) Transfer canister and enclosing airlock to Shuttle Payload Bay for deorbit

- <u>Manned Mars Return Quarantine</u>

Manned missions to Mars are less likely to involve concern with biological isolation than the MR/SR. Quarantine of the crew for 8-12 months during the return trip should be adequate.

BIOLOGICAL QUARANTINE

- Summary
  - Biological quarantine policy will be the basis for some requirements for EVA for missions to and from planets such as:
    - Outbound missions assembled at space station.
    - Unmanned sample return (Mars Rover/Sample Return)
    - Manned Mars mission
- Conclusions
  - Biological quarantine is a relatively minor issue
    - Most planetary missions do not integrate into SSF
  - Quarantine of inbound manned Mars mission will be completed in transit from Mars to Earth.
  - Analysis of specific mission requirements and vehicle configuration necessary to any quarantine requirements
  - If quarantine deemed necessary at SSF, limiting biological load on outbound vehicles may result in the following impacts
    - Venting EMU systems may have to shut down
    - Overgloves may be necessary

ASSESSMENT OF CONTAMINATION DETECTION AND REMOVAL

In order to ensure the safe assembly and maintenance of future space vehicles, possible contaminants had to be identified and then researched. The facing page lists possible places these contaminants may be found. It was then necessary to research how these contaminants could affect a worksite, particularly EVA crewmembers. A decontamination station is presently being developed for the Space Station airlock. It is relocatable, though not portable. A smaller and more portable station would have to be developed for assembly and maintenance work done on the Station truss extension.

Before future assembly and maintenance can be done safely, more research must be completed in the following areas:

- Spill clean-up time
- How will the worksite be cleaned? EVA? Sublimation
- Are there some materials that cannot be cleaned from a worksite?

RESULTS

The following page lists some of the possible contaminants and the associated vehicles. Tests are presently being conducted to determine what each will do to certain materials should a spill result.

Materials from the EMU was tested at White Sands Test Facility (Ref 21) for compatibility with different "contaminants" including water. Of significant result is the impact monomethylhydrazine had on the suit MLI, as noted below. However, recent tests have shown that a new material has been developed that can withstand the corrosive property of monomethylhydrazine. A coating possible of eliminating helmet cracking is also being tested.

At last look, the decontamination station was bolted to the outside of the airlock, thereby making it relocatable but not necessarily portable. It could accommodate two crewmembers at once, operating simultaneously. The unit includes IR lamps that heat an area which increase sublimation rates of the contaminants, two portable contamination detectors, and PFRs for two crewmembers. Testing showed that exposure to one solar constant increased evaporation 5-10 times over ambient level of radiation. Therefore, the provided heat lamps will play a significant role in worksite cleanup. Other decontamination concepts include brushing of particles, direct contact heaters and neutralizing or catalytic agents.

CONTAMINATION DETECTION AND REMOVAL

- Compatability of EMU materials with known SSF hazardous contaminants was assessed
  - Data from previous and on-going materials testing at WSTF was reviewed
    - Test contaminants include ammonia, dinitrogen tetroxide, hydrazine, and monomethyl hydrazine
  - Results
    - modifications necessary to previous suit design to protect suit insulation layers and helmet visor from damage
    - Testing with modifications indicate no degradation

- Baseline EVAS Portable Decontamination and Detection capabilities
  - Tested contaminants detectable under vacuum conditions
  - Sublimation rates of contaminants significantly increase with IR lamps
  - Decontamination of EMU crew is accommodated
  - Decontamination of affected worksites and other external EVAS equipment not fully addressed
    - Detection unit is portable
    - Portable IR lamps for decontamination of affected worksites and other external equipment may be necessary if operations time is critical

EVA OPERATIONS DATA REQUIREMENTS

The baseline C&T System provided the capability to transmit high data rates over the Ku-band space-to-space communications link to the EVA crewmembers prior to Tanner Audit and Scrub 89 program redirections. This capability afforded EVA astronauts rapid access to EVA crew operations data. It also provided the EVA astronaut access to new data generated by ground personnel that addressed unforseen EVA circumstances. This capability is significantly reduced, if not totally eliminated, by the imminent implementation of a UHF space-to-space communications link to EVA.

Potential EVA tasks at space station were assessed to provide a preliminary estimate of EVA operations data requirements. Tasks include those necessary for EMU and EVA operation, SSF maintenance (AMIDD), LTV refurbishment (Ref 9), MTV assembly (Ref 10), and contingencies. It is assumed that the EVA crewmembers need access to the data equivalent of one NSTS EVA cuff checklist page for each task. This approach provided an order of magnitude estimate of the volume of EVA operations data to be maintained on-orbit. Preliminary results indicate that more than 645 separate EVA tasks are likely. This estimate is likely to increase as SSF designs, transportation node and STV configurations, and user requirements mature.

Other factors affecting EVA operations data requirements include the need to easily update EVA datafiles, and those data requirements associated with concurrent or shared robotics and manned EVA tasks. A summary of USA EVA experience indicates that the flexibility to quickly update/augment EVA operations is highly desirable. An average of sixty percent of Skylab and Shuttle EVA were to fix problems. A few EVAs required on-orbit mission planning prior to EVA. An ability to update or generate specific EVA operations data by ground and on-board personnel with subsequent transmission to EVA crewmembers will enhance the likelihood of mission success.

Of the options available for the handling and display of EVA information, the baseline configuration satisfied all data access, update, and display needs. Least desired would be a return to a carry-around printed cuff checklist. Printed cuff checklists are not easily revised, require special materials and printing processes for vacuum compatability, and would require IV time to replace cuff checklist pages. Remaining options do not satisfy all needs but should be further investigated. A portable electronic display that plugged into worksite power and data interfaces would satisfy rapid data access and update needs. Power/data interfaces may not be available or practical at all worksite locations. Downloading task specific information into a memory chip in each EMU prior to EVA eliminates the dependence on space-to-space or exterior data links but also eliminates real-time updates. It is estimated that the equivalent of 50 cuff checklist pages consisting of 60% text and 40% graphics can be stored on one 286 Kbyte chip with a power penalty of 0.4 watts.

ASSESSMENT OF EVA OPERATIONS DATA REQUIREMENTS

- Approach
  - Estimate quantity of EVA operations data for the evolutionary station
    - EMU and EVA equipment operations
    - SSF Maintenance
      - (SSF Assembly and Maintenance Implementation Definition Document)
    - Lunar Vehicle Refurbishment
    - Mars Vehicle Assembly
    - Contingencies
  - Assess other requirements for crew operations data
  - Assess best approach for accessing EVA operations data
    - RF link to EMU Display (Baseline)
    - Worksite display link to DMS database
    - Data downloaded to EMU memory prior to EVA

RESULTS

- Quick assessment of EVA tasks (prime, backup, and contingency) associated with the evolutionary SSF indicates that a high quantity of EVA operational data is maintained on-orbit

	TASKS
● SSF WP2 Maintenance Tasks (AMIDD)	
— ORU Replacement	280
— ORU Clearing	46
— ORU Lubrication	35
— ORU Adjustment	85
● Other SSF WPs	TBD (44)
● EMU Operations (NSTS EMU)	38
● Lunar Vehicle Refurbishment	
— Planned	> 44
— Planned Contingency	6
● Mars (Phobos/Gateway) Vehicle Assembly	
— Planned	38
— Planned Contingency (one per external system)	6
● Hanger Operations/Contingencies	TBD (5)
● EVA System Contingencies	TBD (5)
● MSC/EVA Workstation Operations	1
● User Support payloads approved	12

RESULTS (CONTINUED)

- U.S.A. EVA experience indicates that flexibility to easily update EVA operations data is highly desirable
  - 60% of recent EVA experience (Skylab, Shuttle) were to fix problems
    - Most of these were payload related
    - Some required real-time mission planning prior to EVA (fly swatter EVA)
- A need for near real-time operations feed back to EVA crewmember is also indicated
  - Update of robot and robot task status during robot assisted EVA tasks

- Of the options identified, the baseline configuration satisfied these needs
  - RF link to EMU display (best)

- A paper system is inadequate to support those needs
  - Cuff checklist update not easy
  - Special materials and printing process required
  - IV time for logistics
  - No real-time update

RESULTS

- Remaining options should be further investigated
  - Portable display plugged into SSF power and data ports at worksite
    - Satisfies data flexibility
    - High degree of power data/interfaces indicated
  - Download necessary operational data into a memory chip in the EMU prior to EVA
    - Satisfies data flexibility except for real-time interfaces
    - Equivalent of 50 pgs. of cuff checklist (60% text, 40% graphics) can be stored on one 286 K byte chip
    - Power penalty of .4 watt for data storage

POTENTIAL SSF EVA DTO'S TO SUPPORT TRANSPORTATION NODE

Assembly and servicing of lunar and Mars transfer vehicles will require extensive EVA operations not currently practiced. DTO's will be necessary for many of these operations to assure success and safety.

Aerobrake assembly is among the most challenging. Methods of manipulating and securing portions of these large structures as well as inspection and repair over the large surface must be tested due to the distance of these from current operations.

Safety critical operations such as fuel transfer and decontamination or EVA outside of LEO, such as in transit to Mars, should be identified and tested.

EVA relationship to telerobotics must be explored to be properly exploited. Telerobotic development will produce new tools that could be used effectively by EVA crewman. The telerobotic systems themselves must be evaluated as tools for EVA. Contingency scenarios for telerobot failure should also be tested as the reliance on telerobotic systems increases.

POTENTIAL SSF EVA DTOs TO SUPPORT TRANSPORTATION NODE

- Evaluate aerobrake assembly techniques
  - Torquing large number of bolts
- On-orbit fuel transfer techniques
- Aerobrake inspection and TPS repair techniques
- Practice possible contingency EVAs for Lunar and Mars vehicles during transit
  - TEIS manual jettison
- Evaluate special tool and end effectors
- Evaluate EVA backup capabilities and techniques to work around RMS/FTS contingencies during assembly and/or other prime robot tasks
- Evaluate decontamination scenarios
- Evaluate shared EVA crew and robotic tasks

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