NASA Contractor Report 3857

Space Station Crew Safety Alternatives Study—Final Report

Volume IV—Appendices

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Prepared for
Langley Research Center
under Contract NAS1-17242

National Aeronautics
and Space Administration

**Scientific and Technical
Information Branch**

1985

ACKNOWLEDGEMENTS

In addition to assessing risks, this report aggregates related data that has been in preparation by the aerospace community since 1968. The report surveys broad areas of interest and calls on reference data to support concept development and risk assessment. Rather than footnoting individual references, each reference is identified by a parenthetical number that correlates with the entry number in the Literature Search printout, appendix A of volume IV of this report.

The co-monitors of Contract NAS1-17242, Bob Witcofski of NASA-Langley Research Center, and Marc Cohen of NASA-Ames Research Center supported the development, data input and direction for this study report. This help was appreciated.

The Rockwell Safety Group contributors included G. H. Mead and R. F. Raasch.

FOREWORD

This report is one of five documents covering the results of the Space Station Crew Safety Alternatives Study conducted under Contract NAS1-17242. The study documentation is designated as follows:

Vol. I - Final Summary Report (NASA CR-3854)
Vol. II - Threat Development (NASA CR-3855)
Vol. III - Safety Impact of Human Factors (NASA CR-3856)
Vol. IV - Appendices (NASA CR-3857)
Vol. V - Space Station Safety Plan (NASA CR-3858)

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ATTACHMENT (4)

CREW SAFETY LITERATURE SEARCH SUMMARY

TITLE, AUTHOR, PUBLICATION, PUBLISHER, DATE, DOCUMENT NUMBER, (ACCESSION NUMBER)	CREW SAFETY	SPACE STATION	FIELD A	FIELD B	FIELD C	FIELD D	FIELD E	FIELD F	FIELD G	FIELD H
001- "OV-099 Operational Configuration, FMEA, Crew Provisions, Accommodations and Emergency Egress Subsystems", STS-82-0038, RI-STSI&O, March 1, 1982, M8200659	X	X							X	
002- * "Crew Accommodations Subsystem - FMECA Report", NA-81-894-2, RI-NAAD, March 1, 1982, L-135827										
003- "Space Operations Center - Shuttle Interaction Study Extension", Stefan, A., SSD 81-0194, RI-SD, February 1982		X				X	X		X	
004- "Space Operations Center - Shuttle Interaction Study", Stefan, A. J., SSD-81-0076, RI-SD, April 17, 1981		X		X						
005- "Engineering Analysis Report, Crew Escape System Installation, Crew Provisions and Accommodations", Owens, W. L., SOD-79-0190, RI-SOD, October 24, 1979, M7901127	NA	NA								
006- "Shuttle Compatible Orbital Transfer Vehicle" SSV-79-8, RI-SD, February 9, 1979		X		X				X	X	X
007- "Shuttle Orbiter OV-102 CDR Safety Analysis Report - Volume 8 Crew Station Systems", SD-77-SH-0001-Vol-8, RI-SD, April 27, 1977, M7700452										

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008- "Space Station Supported SPS Development Testing", Tonelli, A. D.; Reed, D. A., SD-76-SA-0091, August 20, 1976, M7601329										
009- "PCM X-3 Fire Investigation Summary Report", Adams, J., NA-75-204, RI-B-1 Div., March 21, 1975, L-117756	NA	NA								
010- "Maintainability Design Guide Space Shuttle Orbiter - Volume 7 - Crew Station and Equipment, SD-73-SH-0257-7, RI-SD, October 1, 1973, M7400120	X		X	X		X	X			X
011- "Space Shuttle Orbiter and Subsystems", Smith, E. P., SD-73-SH-0144, RI-SD, June 1973, M7301466	X		X	X		X	X			X
012- "CSM Skylab/Saturn S-11 Safety Plan", SD-72-CE-0011, RI-SD, December 31, 1972, M7300937	X	X	X	X			X	X		X
013- "Requirements/Definition Document - Crew Station and Equipment - Volume 7", SD-72-SH-0107, RI-SD, March 23, 1973, M7300868	X	X						X	X	

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014- "Safety in Earth Orbit Study. Volume V. Space Shuttle Payloads - Safety Requirements & Guidelines", Canetti, G. S., SD-72-SA-0094-5, RI-SD, July 12, 1972	X	X	X			X	X		X	
015- "Safety in Earth Orbit Study. Volume III. Analysis of Tumbling Spacecraft; Escape and Rescue", Canetti, G. S., SD-72SA-0094-3, RI-SD, July 12, 1972	X	X	X				X	X	X	
016- "Safety in Earth Orbit Study. Final Report Final Report. Volume I. Technical Summary" SD-72-SA-0094-1, RI-SD, July 12, 1972, M7200681	X	X				X	X		X	
017- "In-Space Propellant System Safety. Volume III. Safety Analysis", SD-72-SA-0054-3, RI-SD, June 23, 1972, M7200621	X	X	X				X	X	X	
018- "Safety in Earth Orbit Study. Space Station Safety Requirements and Guidelines volume VI", SD-72-SA-0037-Volume-6, RI-SD, February 21, 1972, M720026B	X	X	X				X	X	X	
019- "Safety in Earth Orbit. Study Plan", SD-71-545, RI-SD, August 4, 1971, M7101050	X	X	X				X	X	X	X

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020- "System Safety of Manned Operations in Earth-Orbital Missions", Canetti, G. S., SD-71-230, RI-SD, July 15, 1971	X	X	X				X	X	X	X
021- "Modular Space Station Phase B Extension. Safety Analysis Report", SD-71-224, RI-SD, November 30, 1971, M7200098	X	X	X	X	X	X	X	X	X	X
022- "Modular Space Station Phase B Extension: Shuttle Interface Requirements", SD-71-221, RI-SD, 1971, 72N14873	X	X	X				X	X	X	X
023- "Habitability Criteria Databook for Manned Space Vehicles/Stations", Greek, D. C., SD-70-340, RI-SD, September 1970, M7002046	X	X	X				X	X	X	X
024- * "Technical Proposal For A Space Base Nuclear System Safety Study", SD-70-313, RI-SD, May 15, 1970, M7001609										
025- "Space Station Program Phase B Definition - Solar Powered Space Station Preliminary Design", SD-70-159-4, RI-SD, July 1970		X				X				

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026- "Space Station Program Phase C/D - System Safety Plan", Canetti, G. S., SD-70-133, RI-SD, July 1970, 70X17279	X	X	X				X	X	X	X
027- "DSRV-2 Manipulator System, Final Design Review. Summary Report", SD-70-124, RI-RD, April 10, 1970, M7001600	NA	NA								
028- "Space Station Crew Activity Safety and Damage Containment and Control procedures for Manned Spacecraft", Jones, A. L.; Starkey, R. C., SD-58-506, RI-SD, July 22, 1968, M6803707	X	X				X		X	X	X
029- "Human Factors Visual Simulation Study Final Report", SID-67-288, RI-SD, April 1967, M6701937	X	X	X	X			X	X		
030- "Space Station Safety Study - Subsystem Analysis", NASA-CR-108287, BAC-Seattle, January 1970, 70N20812	X	X	X				X	X	X	X
031- "Space Station Safety Study - Fault Tree Analysis", NASA-CR-108289, BAC-Seattle, January 1970, 70N20811	X	X	X				X	X	X	

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032- "Space Station Safety Study - Logic Diagram", NASA-CR-108291, BAC-Seattle, January 1970, 70N20810	X	X	X				X	X	X	
033- "Space Station Safety Study - Crew Safety Guidelines, Volume 1", NASA-CR-108286, BAC-Seattle, January 1970, 70N20807	X	X	X				X			
034- "Space Station Safety Study - Crew Safety Guidelines, Volume 2", NASA-CR-108288, BAC-Seattle, January 1970, 70N20808	X	X	X				X			
035-* "Space Station Systems Analysis. Executive Summary", NASA-CR-150392, Grumman aerospace-Bethpage, NY, July 1977, 77N84668										
036-* "Spacecraft Damage Containment and Control Procedures", Mc Cabe, E. L. et.al., International Atronautical Federation Congress, 20th, Argentina, October 5-10, 1969, BAC-Seattle, 70A14933										
037- "Systems Safety for Manned Operations in Earth Orbital Missions", Canetti, G. S., AIAA Paper 71-826, RI-SD, July 1971, 71A35425	X	X					X	X	X	X

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038- "Safety Design of Space Station Against Collision Hazards with Artifical Orbiting Bodies", Nagatomo, M. et al., International Astronautical Federation 23rd Congress, Vienna, October 8-15, 1972, University of Tokyo, 72A45143	X		X				X	X		X
039- "Safety and Survival in a Manned Space Laboratory", Survival and Flight Equipment 10th ANnual Symposium, Phoenix, October 2-5, 1972, 73A32673	X	X	X			X	X	X	X	
040- * "An Optimized Space Rescue System. Crew Escape Techniques", 24th International Astronautical Congress, Baku, SSR, October 7-13, 1973, TRW-Redondo Beach, 74A12857										
041- * "Spacelab Environmental Control/Life Support System - Design Safety", Gaertner, R., Journal of the Astronautical Sciences, Volume 23, July-September, 1975, pages 205-224, Dornier-System GmbH, 76A3597										
042- "Premanently Manned Platform Habitation Needs/LEO and GEO", Goodwin, C. J., AIAA Conference on Large Space Platforms, Los Angeles, September 27-29, 1978, Grumman Aerospace, Bethpage, NY, 7852744	X	X				X	X	X		

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043- * "Space Exploration Prospects and Psychology", Leonov, A.A., (In Russian), Izdatel'stvo Nauko, pages 25-29 1979, 80A32979										
044- "Assessment of the Effects of the Zero Gravity Environment on the Health and Safety of Space Workers", NASA-TM-81122, February 18, 1980, N80-30038/7	X	X	X				X			X
045- * "MOL Safety Evaluation Based on Apollo 204 Review Board Findings and Recommendations, and Brocks Air Force Base Investigation Board Concul̈sions", TOR-0158 (3107-20)-1, Aerospace Corp., EL Segundo, September 1967, AD-856 687/9ST										
046- "A Smoke Detection System for Manned Spacecraft Applications", Trumble Terry M., AFAPL-TR-97, June 1975, AD-A015 744/6ST	X		X				X	X		X
047- "Radiation Safety of Cosmonauts", Golovachev, V., NASA-TT-F-16323, Trud, Page 2, February 1, 1975, N75-25541/4ST	X	X	X				X			X
048- "Aeronautics and Space Report of the President; 1973 Activities", NASA, H-030831	NA	NA								

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049- * "Aerospace Systems Conference, Los Angeles, June 27-30, 1967", SAE Conference Proceedings H-023945										
050- * "Third International Simulation and Training Conference, New York, April 24-27, 1967, SAE Conference Proceedings, H-019320										
051- * "Investigation of Independent Structure (Space) Crew Escape Concepts, USAF, March 1966, AFFDL-TR-65-226, H-015693										
052- * "Test Requirements and Procedures Interior Lighting", TFD-274, TR-LAD, May 31, 1979, L-132095										
053- "Human Engineering Evaluation During FLight Test - Phase 2", TFD-79-2, RI-LAD, December 15, 1978, L-131310	NA	NA								
054- * "Aviation Safety - Volume 2 - Aircraft Cabin Environment", 94-99, Congress of the United States, February 5, 1978, L-129322										
055- "Evaluation of Non-Avionics Control and Displays", TFD-77-738, RI-B-1 Div., July 21, 1977, L-127562	NA	NA								

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056-* "Human Engineering Evaluation of Data Storage Provisions", TFD-77-5F4, RI-B-1 Div., May 25, 1977, L-126774										
057-* "Human Engineering Evaluation During FLight Test - Phase I", TFD-77-319, RI-B-1 Div., March 31, 1977, L-126070										
058- "B-1 Subsystem Safety Summary Crew Escape", Morris, R.; Scott, N., TFD-74-340-20, RI-B-1 DIv., February 1, 1977, L-125801	NA	NA								
059- "Crew Station Acoustic Noise Engineering Test and Evaluation", Cummings, R. J., TFD-77-230, RI-B-1 Div., February 1977, L-125667	X		X				X			X
060-* "B-1 Study to Determine Environmental Control Provisionns for the Crew Station PLZT Thermal/Flash Protective Devices", Argosan, T.; Suter, T., TFD-77-56, RI-B-1 Div., March 18, 1977, L-125539										
061-* "B-1 Crew Area Toucn Temperature Preliminary Qualification", Logan, T. T., TFD-75-101, RI-B-1 Div., January 29, 1975, L-117292										

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062- "Aircraft Penetration of Clouds Generated by Nuclear Bursts", Patrick, R. P.; Arnett, G. D.; Yingling, W. A., AFWL-TR-73-82, Air Force Weapons Laboratory, September 1974, L-116410	NA	NA								
063- "Summary of B-1 Flight Simulator Studies to Evaluate Aircraft Environmental Factor's, Lefritz, N. M., TFD-74-1029, RI-B-1 Div., November 5, 1974, L-116386	NA	NA								
064- * "Test Requirements and Procedures visability Exterior to the Air Vehicle from the Flight Station In-Flight Operations", Greek, D. C., TFD-74-932, RI-B-1 Div., October 25, 1974, L-116379										
065- "The Application of System Analysis Techniques for the Solution of Complex Helicopter Crew Station Design Problems", Belcher, J. J., Preprint 723, American Helicopter Society, May 1973, L-112464	NA	NA								
066- * "B-1 Crew Station Reach, Vision, and Accessibility Demonstration", Cummings, R. J., NA-73-365, RI-B-1 Div., June 29, 1973, L-111527										

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067- * "Human Engineering Data on Control and Display Design for the B-1 Crew Accommodations Systems", Jensen, L. V.; Kennedy, P. R., NA-73-340-9, RI-B-1 Div., January 30, 1976 L-111067										
068- * "Cockpit and Control-Display Design Criteria for Tactical STOL and V/STOL - Volume 1: Analysis", Musgrave, J. S., AFFDL-TR-72-72, Air Force Flight Dynamics Laboratory, November 1972, L-110574										
069- "B-1 Crew Systems RFA Dispositions", Billica, B. M.; Rader, D. A., TFD-73-59, RI-B-1 Div., February 26, 1973, L-110043	NA	NA								
070- * "A Critical Review of Manned Submersibles used in Oceanographic Research", Lange, P.A., R-69-12, NYU School of Engineering and Science, December 1969, L-102326										
071- * "Handbook of Soviet Manned Space Flight", Johnson, N. L., AAS Science and Technology Series, Volume 48, American Astronautical Society, Note Univelt, 1980, M8001136										

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072- "Ion Propulsion: Techniques and Applications, Brewer, G. R., Note Gordon and Breach Science Publishers, 1970, M7700491	NA	NA								
073- * "National Conference on Space Maintenance and Extravehicular Activities, March 1, 2, 3, 1966, Orlando", National Technical Information Service, N72-75119-N72-75150, M7700228										
074- * "Power Sources Symposium, Proceedings, 23-24-25 May 1972, Altantic City, Note PSC Publications Committee, M7501562										
075- "Space Rescue and Safety: Proceedings of a Symposium Held in Conjunction with the Congress of the International Astronautical Federation, Amsterdam, September 30 to October 5, 1974 (25th)," Bolger, P. H. (ed), AAS Science and Technology Series, Volume 37, American AStronautical Society, M7501056	X		X				X		X	
076- * "USAF Technical Objective Document: Aerospace Biotechnology", AMD-TR-73-1, Aerospace Medical Division, Brooks AFB, Texas, FY 1974, M7301826										

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077- * "Space Shuttles and Interplanetary Missions, Based on Shuttle, Precursor Missions, and Planetary Lunar Space Station Sessions of AAS 16th Annual Meetings, June 8-10, 1970, Anaheim, Larmore, L.; Gervais, L. (eds), Advances in Astronautical Sciences, Volume 28 AAS, M100672										
078- "Space Stations, Based on Space Stations Safety, and International Sessions of AAS 16th Annual Meeting, June 8-10, 1970, Anaheim". Larmore, L.; Gervais, R. L. (eds), Advances in Astronautical Sciences, Volume 27, AAS, M7100671	X	X	X				X	X	X	X
079- "Naval Architecture of Submarine Work Boats for Off-Shore Work", Bodey, C. E.; Friedland, M., X6-243/-2-, RI-OSO, February 1966, M7000544	NA	NA								
080- * "Safety and Operational Guidelines for Undersea Vehicles", Note Marine Technology Society, 1968, M6900351										
081- "Space Manufacturing Facilities (Space Colonies)", Grey, J., AIAA, 1977, R-054886	X	X	X				X	X		

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082- "Man Beneath the Sea: A Review of Underwater Ocean Engineering", Penzias, W.; Goodman, M. W., Wiley-Interscience, New York, 1973, R-037672	NA	NA								
083- * "Resupply/Repair of Solid or Hybrid Attitude Propulsion Subsystems. Final Report. Volume II - Technical Study", Murphy, J. M.; Humphrey, J. M., MCR-71-11-Vol 2, MMC-Denver Div., April 1971, R-028083										
084- * "Resupply/Repair of Solid or Hybird Attitude Propulsion Subsystems. Final Report. Volume I - Program Summary", Murphy, J. M., MCR-71-11-Vol-1, MMC-Denver Div., April 1971, R-028082										
085- * "Propulsion Requirements for Space Station Erection", Bottorff, J. A.; Ellis, H. B., ASMF-P-59-AV-17, ASME, March 1959, R-027361										
086- "Future Direction for Selecting Personnel. Spacecrews for Long Duration Space Flight", Natani, K., In Human Factors of Outer Space Productions, A82-15851 04-54, Westview Press, Boulder, CO., 1980, pages 25-63, 82A15853	NA	NA								

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087- * "Psychobiological Factors Associated with Monotony Tolerance", Myers, T. I., AD-747272 AIR-R72-1, American Institute for Research, Silver Springs, MD., May 31, 1972, 73N13098										
088- "Sociological Aspects of Permanent Manned Occupancy of Space", Bluth, B. J., AIAA Student Journal, Volume 19, Fall 1981, pages 11-15, 82A33910	X	X	X		X		X	X		
089- "Staying Sane in Space", Bluth, B. J., Mechanical Engineering, Vol. 104, January 1982, Pages 24-29, 82A19743	X		X					X		
090- "Investigation on Air Samples from the Submarine Sjoehunden", Linnarson, A.; Ringqvist, G., FOA-C-54035-H1, Research Institute of National Defense, Stockholm, August 1979, 82N18744										
091- "Evaluation of the CNS and Cardiovascular Effects of Prolonged Exposure to Bromotrifluromethane (CBrF3)", Geller, I.; Garcia, C.; Gleiser, C.; Haines, R.; Hamilton, M.; Hartmann, R.; Mendex, V.; Samuels, .; Miguel, M. S., NASA-CR-16078, Southwest Foundation for Research an Education, San Antonio, May 1, 1981, 81N32853	X				X					

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092- * "Determination of the Concentration of of Cadmium Aerosol and some other Contaminants present in the atmospher of a Submarine of the Royal Dutch Navy, Desenburg, F., CL-1976-23 TDCK-68819, Chemical Laboratory, Rijswikj (Netherlands), December 1976, 78N26744										
093- * "NRL's Central Atmosphere Monitor Program", Saalfeld, F. E.; Wyatt, J. R., AD-AO-35744 NRL-MR-3432, Naval Research Laboratory, Washington, DC, December 1976, 77N25795										
094- * "Evaluation of Liquid Amine System for Spacecraft Carbon Dioxide Control", Breaux, D. K. et al., NASA-CR-137560 Airsearch-74-10178, Airesearch, Torrance, September 1974, 74N34566										
095- "Submarine Crew Effectriveness During Submerged Missions of Sixty or more days Duration". Weybrew, B. B., AD-740796, NSMMRL 686, Naval Submarine Medical Center, Groton, CT, October 28, 1971, 72N31129	X				X		X			
096- "Behavioral, Psychiatric, and Sociological Problems of Long-Duration Space Missions", Kanas, N. A. et al., NAS-TM-X-58067, NASA-JSC, October 1971, 72N16016	X	X	X	X	X					

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097- * "System for the Emergency Rescue of Cosmonauts from Orbital Stations (SADKOS)", Translated from Russian periodical, 5 pages, Belonogov, Y. K. et.al., September 17, 1980, 81X72253										
098- * "Study of Damage Control Systems for Space Station and Preliminary Design of a Space Station Simulator, Volume 2", Ikola, G. H., MDC-G2156-Vol-2, MACDAC, March 1973, 72X72259										
099- * "Development of Flameproof Fibrous Material for Space Station Applications. Final Report", Follett, A. E. et. al., NASA-CR-115197 MRC-DA-282, December 1970, 71X82581										
100- * "Study of Space Station Propulsion System Resupply and Repair", NASA-CR-107424 MCR-69-534 QPR-1, MMMC-Denver, October 1, 1969, 70X70641										
101- * "A Study of an Intermediate Orbital Workshop System. Volume 6 - Flight Operations", NASA-TM-X-61925, NASA-LaRC, August 1968, 69X76996										
102- * "Investigation of Independent Structure/Space /Crew Escape Concepts," Little, G. et al., RAZ-00-160 AFFDL-TR-65-226, Canadair, March 1966, 69X75008										

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103-* "Design Study of Teleoperator Space Spider", Britton, W. R., et al., NASA-CR-161175 MCR-79-522, MMC-Denver, February 1979, 79X10038										
104-* "Advanced Mission Operations Concepts, USAF/NASA Task 4, Volume 3: Special Study on Collision Avoidance", Hecht, H., NASA-CR-127775 TOR-0059 (6759-05)-1-Volume-3, Aerospace Corp., July 15, 1970 72X10537										
105-* "Crew Cargo Module Definition, Appendixes (Structural Design Criteria and Safety Factors for Space Station Components)", NASA-CR-116565 MDC-G0787- App MSFC-DRL-231-13, MACDAC, February 1971, 71X10267										
106-* "Space Station Safety Study - Final Oral Review", NASA-CR-102167, BAC-Seattle, January 1970, 70N18702										
107-* "Red Star in Orbit", Oberg, J. E., Random House, New York, 1981 81A41872										
108-* "Mission Utility Influences on Space Operations Center Design, Woodcock, G. R., AIAA Paper 81-0440, BaaC - Seattle, 1981, 81A22755										

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TITLE, AUTHOR, PUBLICATION, PUBLISHER, DATE, DOCUMENT NUMBER, (ACCESSION NUMBER)	CREW SAFETY	SPACE STATION	FIELD A	FIELD B	FIELD C	FIELD D	FIELD E	FIELD F	FIELD G	FIELD H
109- * "Man's Extension into the Sea - Transactions of the Joint Symposium 11-12 January 1966, Washington, D. C.,", Marine Technology Society, H-015530										
110- "Undersea Vehicles for Oceanography" Federal Council for Science and Technology, October 1965, ICO Pamphlet 18, H-015399	NA	NA								
111- "MOSES/Manned Orbital Space Escape System - A Hypothetical Application", Meyer, R. T., AIAA Paper 81-0438, General Electric - Re-Entry Systems Division, Philadelphia, 1981, 81A22754	X						X	X	X	X
112- * "Pilot Workload: A Survey of Operational Problems", Buterbaugh, L., et al, AWAL-TR-81-3011, Air Force Dynamics Laboratory, August 1981, L-135569										
113- * "Ocean System Operations IR&D Programs, CFY 1966-1067", NAR-Autonetics, S7-68/020, H-017555										
114- "[illegible]-1 Crew Station Noise Limits", Cummings, [illegible] J., TFD-76-1200, RI-B-1 Div., November 12, 1976, L-124487	X		X				X			X

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115- * "Crew Station Protective Provisions", Greek, D. C., TFD-76-382, RI-B-1, Div., March 26, 1976, L121863										
116- "Recovery from a Tumbling Condition in Space", Canetti, G. S., A-76-04 IAF Reprint, October 1976.	X	X				X	X		X	
117- "System Safety/Crew Systems (Skylab)", McNail E. M., AAS 74-109, MMC-Denver, August 1974.	X	X	X			X	X			X
118- "Contingency Planning for Space-Flight Emergencies", Dole, S. H. et al., NASr-21- (13), Rand Corporation, Santa Monica, January 1967.	X		X	X	X				X	X
119- "Human Factors of Outer Space Production", Cheston, T. S.; Winter D. L., AAAS Selected Symposium 50, Undated.	X	X		X		X	X		X	
120- "Space Station Program Phase B Definition - Special Emphasis Tasks - Summary Report", SD 69-611, RI-SD, December 12, 1969	X	X	X				X	X		X
121- "Space Station Program Phase B Definition Study - May Progress Report", SD 70-152, RI-SD, May 26, 1970		X	X	X		X		X		

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122- "Advances in the Astronautical Sciences, Volume 35, Bicentennial Space Symposium", American Astronautical Society, Proceedings, 22nd AAS Annual Meeting, october 6-8, 1976	X	X	X	X			X	X		
123- "Advanced in the Astronautical Sciences, Volume 16, Part One, Space Rendezvous, Rescue and Recovery", American Astronautical Society, Proceedings, September 10-12, 1963	X	X	X	X			X	X		
124- "Effects of Stimulated Artificial Gravity on Human Performance", J. A. Green and J. L. Peacock, NASA CR-2129, November 1972	X						X	X		
125- "Causes of Fatigue Among Crews of Civil Aviation Helicopters", Kamenskiy, Yu.N., Space Biologyance Aerospace Medicine, Vol. 15, No. 6, Nov-Dec 1981, JPRS 79849	NA	NA								
126- "Physiological and Hygienic Evaluation of Vibration in the Cockpit of a Cargo Halicopter", Matveyev, Yu. G. and Kamneskiy, Space Biologyance Aerospace Medicine, Vol. 15, No. 6, Nov-Dec 1981, JPRS 79849	NA	NA								

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127- "Evaluation of Man's Endurance of Local Pressure to the Head and Objective Assessment of Hygenic Specifications for Protective Helmets, Singinin, V. M., Space Biologyance Aerospace Medicine, Vol. 15, No. 6, Nov-Dec 1981, JPRS 79849	NA	NA								
128- "Simulation of Some of Man's Movements in Different Gravity Fields", Znkkovskily, A. V., et al., Space Biologyance Aerospace Medicine, Vol. 15, No. 6, Nov-Dec 1981, JPRS 79849	NA	NA								
129- "Hygenic Principles of On-going Monitoring of Quality of Recycled Water During Space Flights", Skuratov, V. M. et al., Space Biologyance Aerospace Medicine, Vol. 15, No. 6, Nov-Dec 1981, JPRS 79849	X	X	X	X			X	X		
130- "Toxicological and Hygenic Aspects of Improving Additional Purifiation of Water Reclaimed from Urine", Pak, Z. P., et al, Space Biologyance Aerospace Medicine, Vol. 15, No. 5 Nov-Dec 1981, JPRS 79849	X	X	X	X			X	X		

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131- "Results of Study of Hemodynamics and Phase Structure of the Cardiac Cycle During Functional Test with Lower Body Negative Pressure During 140-Day Solyut-6 Station Flight", Yegorov, A. D., et al., Space Biologyance Aerospace Medicine, Vol. 15, No. 6, Ncv-Dec 1981, JPRS 79849	X		X	X						
132- "Skylab Experiment M487, Habitability/Crew Quarters", AAS74-133, C.C. Johnson, NASA-JSC, August 1974	X	X	X	X			X	X		X
133- "Skylab Experiment M516, Crew Activities/ Maintenance Study," AAS74-133, Robert L. Bond, 1974	X	X	X	X			X	X		X
134- "Working in Space", Butler, G. V. et al, MCDAC	X	X	X	X			X			X
135- "Designing a Village in Space", Larry Bell, The Futurist, October 1981	X	X	X	X			X	X		
136- "Design, Development and Operation of a Zero Gravity Shower", Middleton, A. C., et al, NASA-MSFC - Science and Engineering 1974	X	X		X			X	X		X
137- "Probing the Light Fantastic", Marcia Bartusick, Science Digest, November 1982	X	X	X				X	X		

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138- "Collison Hazard in Space", Vladimir A. Chobotov, AIAA, September 1980	X	X		X			X			
139- "Growing Peril of Space Debris", Jim Schefter, Poplar Science, July 1982	X	X		X			X			
140- "Skylab Experiment M509, Astronaut Maneuvering Equipment Orbital Test Results and Future Applications", Whitsett and McCandless, NASA-JSC, 1974	X	X	X	X			X	X	X	
141- "Space Station Safety Study - Supporting Analysis" NASA CR108290, BAC, Seattle, 1980	X	X	X				X	X	X	X
142- "Shuttle Considerations for the Design of Large Space Structures", RI, NASA Contractor Report 160861, NAS9-15718, Amend/Mod 4S, Nov 1980	X	X	X			X	X			X
143- "In-Flight Maintenance Requirements and Planning Document", RI, STS 82-0609, Sept 1982	X	X	X	X		X	X	X		X
144- "Manned Spacecraft In-Flight Tools Source Document", TI, STS-81-0716, Jan 1982	X	X	X	X			X			X
145- "Innovative Structures for Space Applic.", Goodyear Aerospace Corporation, GAC 19-1563, Rev. A, Nov 1982		X	X					X		X

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146- "Skylab - Orbital Workshop Criteria and Tolerances for Determining Responses to Orbital Fires", MacDac, MDC G2190-P, Jan 1973	X	X	X	X			X	X		X
147- * "Advanced Military Spacecraft Capabilities (AMSC) Technclogy Identification Study RI, STS 81-0309-1, March 1981										
148- "Space Shuttle Sortie Payload Safety Criteria Study", RI, SD 72-SA-0045, March 1972	X		X			X	X		X	X
149- "American National Standard, For the Safe Use of Lasers", ANSI 2136.1-1980	X						X			X
150- "Crew Operations Development for Space Shuttle Payload Integration", RI, SOD 80-0358A, August 1981	X		X	X		X				X
151- "Space Construction System Analysis Study", RI, SD 78-AP-0076-1, July 1978	X		X			X				X
152- "Emergency and Rescue Considerations for Manned Space Missions", H. R. Griswold and R. B. Trusch, Hamilton Standard Division of United Technologies Corporation, 1981	X					X	X	X	X	

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153- "High - Pressure Protective Systems Technology" H. C. Vy Rukal, R. W. Wibbon: ASME - 79-ENAS-15 July 1979	X	X	X				X	X		X
154- "Military Man in Space Ionizing Radiation Exposures" John E. Pickering, USAF School of Aerospace Medicine, Radiation Sciences Division, Brooks Air Force Base, Texas.	X	X	X				X	X		X
155- "Social and Psychological Problems of Extended Space Missions" B. J. Bluth, AIAA international meeting & technical display"Global Technology 2000" May 1980, Baltimore, Md.	X		X				X			
156- "Space Motion Sickness - Skylab Revisited" Ashton Graybill, Aviation, Apace and Environmental Medicine August 1980	X			X			X			
157- "Autogenic Feedback Training for Controlling Vestibular Symptomatology" Patricia S. Cowings, Ph. D. Biomedical Research Division, NASA, Ames Research Center, Moffett Field, Calif.	X						X			
158- "Shuttle EVA Description and Design Criteria" JSC-10615 May 1983, REVISION A	X	X	X	X		X	X		X	X

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159- "Apollo-Soyuz Phamphlet No. 6, Cosmic Ray Dosage" Lou Williams Page and Thorton Page NASA, Oct. 1977	X	X	X	X			X			
160- "Prevention of Psychoemotional Disturbances During Long-Term Space Flights by Means of Psychological Support" Moscow No. 2 Mar-Apr 1981 pp 25-29 V. I. MMyasnikov and O. P. Kozcrenko, Oct. 1980	X		X	X			X			
161- "An evaluation of the time course of Efficacy of Transdermally Administered Scopolamine in the Prevention of Motion Sickness" Terry L. Homick, Joseph Degioanni; Willard F. Reschki, Carolyn S. Leach NASA/JSC, Houston, Texas Randall L. Kohl and Patrical C. Ryan, Technology Incorporated, Houston, Texas	X						X			
162- "Study of EVA Operations Associated with Satellite Services" United Technologies Hamilton Standard, NAS 9-16120, April 1982.	X	X	X	X		X	X	X		X

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163- "Space Shuttle EVA/IVA Support Equipment Requirements Study," Hamilton Standard, NAS 9-12506, Vol. I & III, April 30,1973	X	X	X	X		X	X		X	X
164- Space and Planetary Environment Criteria Guidelines for Use in Space Vehicle Development, NASA Technical Memorandum 78119, Edited by G. A. West, Jr., J. J. Wright & H. C. Euler, MSFC, Nov.1977	X		X	X		X	X			X
165- Human Engineering Design Criteria for Military Systems, Equipment and Facilities, MIL-STD-1472C, May 1981	X	X	X							
166- Human Factors in Space Construction, J. A. Roebuck, Jr., SSD 81-0112, IRD 375, July 1981		X				X		X		X
167- The Astronaut's Role in Large Space Structures Construction, J. A. Roebuck, Jr., and A. N. Lilenas, SD77-AP-0095, IRD 917, August 1978	X	X	X				X		X	X
168- Human Factors Standards and Guidelines for Space Construction, J. A. Roebuck, Jr., SSD 81-0113, IRD 375, July 1981		X	X	X		X		X		X

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169- Extravehicular Crewman Work System (ECWS) Study Program Final Report, Vol. 3, "Satellite Service", NAS9-15290, Hamilton Standard, July 1980	X	X								
170- Parallels in Isolation: Managing Space Problems in Antarctica, Peter X. Harding, The Fletcher Forum; A Journal of Studies in International Affairs, Vol. 5, No. 2, 1981	X				X		X	X		
171- U.S. Navy Diving Manual, NAVSEA 0994-LP-001-9010, Vol. 1 & 2, June 1978, Navy Dept., Washington, D.C. 20362	X		X		X		X			X
172- Space Settlements, The Medical Perspective, Journal of the British Interplanetary Society, Vol. 34, pp. 429-434, 1981	X						X			
173- Soviet Space Stress, B. J. Bluth, Science 81, Vol. L, No. 7	X			X		X				
174- Medical Considerations for Manned Interstellar Flight, Journal of the British Interplanetary Society, Vol. 34, pp. 466-476, 1981 "J. R. Murphy"	X	X	X	X			X	X		X

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175- Consciousness Alteration in Space, Fourth Princeton/AIAA Conference on Space Manufacturing Facilities, May 1979, 79-1430 B. J. Bluth	X	X	X	X		X		X		
176- Influential Factors of Negative Effects in the Isolated and Confined Environments, Fifth Princeton/AIAA/SSI Conference on Space Manufacturing, May 1981, S.R. McNeal and B. J. Bluth	X	X	X		X	X	X	X		
177- The Human Spirit in Space, Presented at 19th Space Congress, Cocoa Beach, Florida, April 1982, B. J. Bluth, PhD	X	X	X	X	X	X	X	X		
178- Man/System Requirements for Weightless Environments, MSFC-570-512A, Dec. 1, 1976, NAS 8-31457	X	X	X				X	X		X
179- The Orbiting Junkyard, Technology Illustrated, June 1983, Tom Logsdon		X	X	X			X			X
180- "Survival In Space" GaGarin, Yuri and Lebedev, Vladimir, Frederick A. Praeger, Publishers, New York, Washington, 1969	X	X	X	X			X			X

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181- "Colonies in Space - The Next Giant Step," Frederi Golde, Harcourt Brace Jovanovich, New York and London, 1977	NA	NA								
182- "Life Sciences and Space Research Vol II," Proceedings of the Open Meeting of Working Group V at the Twelfth Planetary Meeting of Cospar, Prague, 1969, North-Holland Publishing Company	X	X	X							
183- "Space Manufacturing Facilities II", Proceedings of the Third Princeton/AIAA Conference, May 1977, American Institute of Aeronautics and Astronautics	X	X		X				X		
184- "Space Manufacturing III," Proceedings of the Fourth Princeton, AIAA Conference, May 1979, American Institute of Aeronautics and Astronautics	X	X		X				X		X
185- Borrowman, Gerald L., "Orbital Construction" Spaceflight, October 1981 (Vol 23) p. 238		X					X	X		X
186- Dooling, Dave, "Space Factories in 1977," Spaceflight, October 1977, Vol. 19, p. 390		X					X	X		

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187- Grislun, Sergei and Leonest Leskow, "Into Space for New Material," Spaceflight, March 1980, Vol 22, p. 142	X	X	X	X				X		
188- Clark, Phillips, "The Design of Orbital Station," Spaceflight, October 1981, Vol. 23, p. 247		X	X					X		X
189- Dooling, Dave, "Industrial Design in Space," Spaceflight, June 1981, Vol. 23, p. 169	X	X	X					X		X
190- Peebles, Curtis, "The Manned Orbiting Laboratory Part II," Spaceflight, June 1980, Vol. 22, p. 248		X	X					X		X
191- Human Factors of Outer Space Production, Edited by T. Stephen Cheston and David L. Winter, 1980	X	X	X				X			
192- Solar Activity Observations and Predictions, Edited by Patrick S. McIntosh and Murray Dryer, 1972	X		X	X			X			X
193- The Disposal of Nuclear Waste: The Space Option, David H. Hinson, Spaceflight, Vol. 22, 4, April 1980	X	X	X					X		

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194- Meals in Orbit, Spaceflight, Vol. 22, 1 January 1980	X	X		X		X		X		
195- Orbiting Quarantine Facility: The Antaeus Report, Petter Hesselbert, Spaceflight, Vol. 25, 1 January 1983	X		X				X	X		
196- Astronauts for the Shuttle, Curtis Peebles, Spaceflight, Vol. 25, 1 January 1983				X		X				
197- Rescue From Orbit, Gerald L. Borrowman, Spaceflight, Vol. 25, January 1983	X			X		X	X		X	
198- Training Below for Work Above, John Bird, Spaceflight, Vo. 25, 2 February 1983				X		X				X
199- Space Debris - A Growing Hazard, Andrew Thomson, Spaceflight, Vol. 25, 1 January 1983	X	X	X	X			X			X
200- Long-Term Follow-up of Skylab Bone Demineralization, Frederick E. Tilton, Joseph J. C. Degioanni, and Victor S. Schneider, Aviation, Space and Environmental Medicine, Nov. 1980, Vol. 51, #11	X		X	X			X			

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201- Space Motion Sickness: Skylab Revisited Ashton Graybiel, Aviation, Space and Environmental Medicine, August 1980, Vol. 51, #8	X		X	X			X			
202- Effects of Space Flight Factors at the Cellular Level: Results of Cytos Experiment, Hubert Planel, Rene Tixador, Youri Nefedov, Georgi Gretchko, and Gerard Richoilley, Aviation, Space and Environmental Medicine, April 1982, Vol. 53 #4	X		X	X			X			
203- Physiological and Behavorial Effects of Tilt-Induced Body Fluid Shifts, D. E. Parker, O. Tjernstrom, A. Ivarsson, W. L. Gulledge and R. L. Poston, Aviation, Space and Environmental Medicine, May 1983, Vol. 54 #5	X		X	X			X			
204- Flight, Flight Duty and Rest Times: A Comparison Between the Regulations of Different Countries, Hans M. Wegmann, Bernhard Conrad and Karl E. Klein, Aviation, Space and Environmental Medicine, March 1983, Vol. 54 #3	X	X	X		X		X			

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205- The Role of Communications, Sociophychological and Personality Factors in the maintenance of crew coordination, H. Clayton Foushee, Aviation, Space and Environmental Medicine, Nov 1982 Vol 53, #11	X		X				X			X
206- Visual Scanning Behavior and Pilot Workload, R. L. Harris, Sr., J.R. Tole, A. T. Stephens, and A.R. Ephrath, Aviation, Space and Environmental Medicine, Nov 1982 Vol 53 #11	X	X	X				X			X
207- Psychological Testing at High Altitudes Marc Nelson, Aviation, Space and Environmental Medicine,Feb. 1982,Vol 53, #2	NA	NA								
208- Inflight Medical Facilities, Gordon R.W. Davies and P.R. Degotardi, Aviation, Space and Environmental Medicine, July 1982 Vol 53 #7	X	X	X	X			X	X		X
209- Relation of breathing oxygen-argon gas mixtures to altitude decompression sickness Julian P. Cooke, Kenneth G. Ikels, Jimmy D. Adams and Richard L. Miller, Aviation, Space and Environmental Medicine, June 1980 Vol #61	X	X								X

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210- Electrogustometric Investigations During Manned Space Flight, S. Baranski, J. Kubicykowa, A. Piorko, F. Skibniewski, I.I. Bryanov, E. P. Milova, M. V. Wefedova, and I. J. Yakovleva, Aviation, Space and Environmental Medicine, Jan 1983 Vol 54 #1	NA	NA								
211- Meteoroid Environment Model -1969- (Near Earth to Lunar Surface) NASA SP-8013	X	X	X	X			X			X
212- Orbiter Meteroid Analysis, 1978, SD77-SH-0178	X		X	X		X	X			X
213- Life Science and Space Research VII, North-Holland, Amsterdam (1969), "Intestinal Hydrogen and Methane of Men Fed Space Diet" D. Howes Calloway and E.L. Murphy, University of Calif. Berkeley (USA)	NA	NA								
214- "A Closed Ecosystem For Space Colonies" Journal of the British Interplanetary Society, Vol 34, pp. 392-399, 1981, I.R. Richards	NA	NA								
215- "Oberth's Thoughts on an Extraterrestrial Sphere of Existence" Journal of the British Interplanetary Society, Vol 34, pp. 352-354, 1981 H. Barth	NA	NA								

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216- Commercial Space Report, February 1982, Gary C. Hudson, "Space law"	NA	NA								
217- Space World, June-July 1983, Vol T-6-7-234-235, National Space Institute, "Designing a home in Space" Dave Dooling		X	X				X	X		X
218- "Intestinal Hydrogen and Methane of Men Fed Space Diet" D. Howes Calloway and E.L. Murphy, Life Sciences and Space Research VII, North-Holland, Amsterdam 1969	NA	NA								
219- "The First Space Factories" Dave Dooling Space World, March 1982		X	X				X	X		X
220- A Comparison of Limb Plethysmograph Systems Proposal for Use on the Space Shuttle" B. M. Levitan, L.D. Montgomery, P.K. B. Hagat, and J.F. Zieglschmid, Aviation, Space and Environmental Medicine, Jan. 1983, Vol 54, #1	NA	NA								
221- "Effects of Partial Anti-G Suite Inflation on Thoracic Volume and Breathing Patterns", T.S. Chadha, F. Lopez, G. Jenouri, S. Birch and M.A. Sackner, Aviation, Space and Environmental Medicine, April 1983, Vol 54 #4	NA	NA								

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222- * "Correction of Changes in Fluid-Electrolyte Metabolism in Manned Space Flights", A. I. Grigoriev, MD, Aviation, Space and Environmental Medicine, April 1983, Vol.54 #4										
223- "Space Motion Sickness: Phenomenology, Counter-Measures/and Mechanisms," E. I. Matsnev, I. Y. Yakovleva, I. K. Tarasov, V. N. Aleksuv, L. M. Kornelova, A. D. Mateuv and G. I. Gorgiladze, Aviation, Space and Environmental Medicine, April 1983, Vol. 54, #4	X		X	X		X				
224- "Motion Sickness: Acquisition and Retention of Adaptation Effects Compared in Three Motion Environments," Ashton Graybiel and James R. Lackner, Aviation, Space and Environmental Medicine, April 1983, Vol.54 #3	X		X			X				

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225- "Effects of Various Countermeasures Against the Adverse Effects of Weightlessness on Cental Circulation in the Healthy Man," O. G. Gazenko, V. I. Shumakov, L. I.Kakurin, V. E. Katkov, V. V. Chestukhin, E. M. Nikolayenko, S. V. Gvozdev, V. V. Rumyantsev, and V. K. Vasilyev, Aviation, Space and Environmental Medicine, June 1982, Vol 53, #6	X	X					X			X
226- "Reducing Motion Sickness: A Comparison of Autogenic-Feedback Training and on Alternative Cognitive Task," William B. Toscano and Patricia S. Cowings, Aviation, Space and Environmental Medicine, May 1982, Vol. 53, #5.	X						X			X
227- "Neutron Radiation Dosimetry in High Altitude Flight Personnel," Philip E.Baily, Aviation, Space and Environmental Medicine, August 1982, Vol. 53, #8	X	X	X				X			
228- "Sensory Conflict Theory of Space Motion Sickness: An Anatomical Location for the Neuoconflict," Randall Ker Kohl, PhD, Aviation, Space and Environmental Medicine, May 1983, Vol 54, #5	X						X			

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229- "Skylab Plus 10 Years," Leonard Davis, Space World, May 1983	X		X	X						
230- "Make Way for Private Citizens in Space," Leonard Davis, Space World, January 1983	X	X	X							
231- "Analysis of Health Data from 10 Years of Polaris Submarine Patrols," W. A. Tansey, J. M. Wilson and K. E. Schaefer, Undersea Biomedical Research, Submarine Supplement 1979	X		X		X		X			
232- Radiation Exposures during Spaceflight and Their Measurements, E.V. Benton and R.P. Henke, Department of Physics, USF 1983	X	X	X	X			X			X
233- Psychonautics "Space", Nick Engler, Omni, P. 20	NA	NA								
234- Radiological Protection and Medical Dosimetry For the Skylab Crewman, J. Vernon Bailey, B.S., M.S., R.A. Hoffman, AV.M; R.A. English, Ph.D. JSC-09275, NASA TMX 58154 Nov. 1974 (The Proceedings of the Skylab Life Science Symposium) Vol. 1	X		X	X			X			X

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235- Venting a Spacecraft During or After a Fire, J.H. Kemizey, Structurals and Mechanics Division, Materials Technology Branch	X	X	X	X			X	X		X
236- Ionizing Radiation Risks to Satellite Power Systems (SPS) Workers in Space, Dec. 1980, DOE/ER-0094, Contract No. W-7405-ENG-48	X	X	X				X			X
237- Space Settlements - A Design Study, NASA SP-413, Edited by Richard D. Johnson, NASA Ames. Research Center, Charles Holbrow, Colgate University, 1977	X	X	X					X		
238- AGARD Advisory Report No. 84 on Biophysical Problems in Aerospace Medicine, North Atlantic Treaty Organization Advisory Group for Aerospace Research and Development, Dec. 1976	X		X				X			
239- "Cosmic Tool Kit", Spaceflignt Vol. 25,6, June, 1983		X	X	X				X		
240- The Soviet Space Shuttle, Borrowman, Gauld Spaceflight Vol. 25,4, April, 1983	X								X	X
241- Weight Optimization Methods in Space Radiation Shield Design, John W. Wilson, J. Spacecraft, Vol. 12, No. 12, Dec. 1975	X	X	X				X	X		X

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242- Space Resources and Space Settlements, NASA Sp-428, 1979	X	X	X					X		
243- Radiation Fields in Spacecraft, Curtis, Stanley B., IEEE Transactions On Nuclear Science, Vol. NS-23, No. 4, Aug. 1976	X	X	X				X			X
244- "Experimental Analysis of Small Group Performance Effectiveness: Behavorial and Biological Interactions", Emurian, Henry H.; Brady, Joseph V., John Hopkins University of Baltimore, MD., Division of Behavorial Biology, Contract No. 0014-80C-0467, Report No. TR-ONR4 April 1982	X		X		X		X			
245- "History of Military Psychology at the U.S. Naval Submarine Medical Research Laboratory", Weybrew, Benjamin B., Naval Submarine Medical Research Lab., Groton, CT. Report No. NSM RL-917, October 1979	X		X		X		X			
246- "Factors Involved in the Negative Transfer From Isolated Learning to Simultaneous Learning", Underwood, Benton J.; Lund, Arnold M. Contract No. N00014-78-C-0661, Northwestern University Evenston, IL. Dept. of Psychology, June 1980	X		X		X		X			

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247- "Behavorial and Biological Interractions With Confined Microsocieties in a Programmed Environment:, Emurian, Henry H.; Brady, Joseph V.; Myerhoff, James L.; Mongey, Edward H., John Hopkins University, Baltimore, MD, Division of Behavorial Biology Contract No. N00014-80C-0467, Report No. TR-3 May 1981	X	X	X		X		X			
248- "Psysiological Responses to Intermittant Oxygen and Exercise Exposures", Hendler, Edwin Naval Air Development Center, Warminster, PA, Crew Systems Dept., Report No. NADC-74241-40, November 1974	X									
249- "Barrack's Living: The Effects of Stimulus Reduction/Enrichment on Performance Skills", Miller, Richard L., General Research Corp., McLean VA Operations Analysis Division; Contract No. DA HC19-75-C-0009, Report No. GRC-DAD-CR-177, Project 2 Q 163731A768, June 1978	X	X	X		X		X			
250- "Food Preference Acceptance and Consumption in a Simulated, Isolated Duty Station", Sullins, James R.; Roger, Jon G., Alabama University, Huntsville, Contract No. DA AD03-74-C-0180, Project IL762724AH99, May 1977	X	X	X		X		X			

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251- "The Effects of Sensory Perceptual Isolation on Single Motor Unit Conditioning", Lloyd, Andree J.; Shurley, Jay T., Letterman Army Institute of Research, San Francisco, CA Report No. LAIR-7T-4; Project No. 3A161102B71R July 1975	NA	NA								
252- "Tolocology of Hypobaric and Hyperbaric Environments", Small, Alfred; Freiss, Seymour, Naval Medical Research Institute, Bethesda, MD Project No. M4306, MR04106, 1975	X	X	X				X			
253- "Territoriality in Carrel Design", Spangenbery, Ronald W., Air Force Human Resources Lab, Brooks AFB, Texas, Dept. AFHRL-TR077-21, Project 1121, June 1977	X	X	X		X		X	X		
254- "Factors Affecting the Stability of Job Attitudes in Long-Term Isolated Groups", Ryman, D.H., Gunderson, E.K. Eric, Navy Medical Neuropsychiatric Research Unit, S.D.C.A. Report No. NMURU-70-13, Project No. MF51-524, January 1970	X	X	X		X		X	X		
255- "Introduction, Physhological Studies in Antarctica", Gunderson, E.K. Eric, Report No. NMNRU-71-14, Project No. MF12-524, 1974, Navy Medical Neuropsychiatric Research Unit, S.D., California	X	X	X		X		X			

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256- "The Relationship Between Cohesiveness and Effectiveness in Small Isolated Groups: A Field Study", Vallachep, Robin R.; Seymour, George E.; Gunderson, E.K. Eric, Report No. 74-50, Project No. F51524, July 1974	X	X	X				X			
257- Space Station/Nuclear Submarine Analogs U.S. Naval Submarine Interview Report Space Station Crew System Interface Study Boeing Aerospace Company IR&D CC0271, October 1983	X		X				X			
258- It's Lonely at the Bottom Susan West, Science 1984, Jan/Feb	X		X				X			
259- "A Facility For the Simulation of Low Orbit Atmosphere Oxygen Atom Bombardment" G. S. Arnold, R. R. Helm, and D. R. Peplinski The Aerospace Corporation		X	X							X
260- "Oxygen Atom Reaction with Shuttle Materials at Orbital Altitudes" Labert J. Leger, JSC NASA Technical Memorandum 58246, 1982		X	X	X	X		X	X		

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261- AIAA-83-2631-CP STS Flight 56 LEO Effects Experiment - Background Description and Thin Film Results L. J. Leger, I. K. Spiker, J. F. Kuminecz, T. J. Ballentine, and J. T. Visentine NASA Lyndon B. Johnson Space Center, Houston, Texas AIAA Shuttle Environment and Operations Mtg. Oct/Nov 1983, Washington, D.C.		X		X		X				
262- Shuttle Environment Workshop Office of Space Science and Applications NASA, Oct. 1982		X		X		X				
263- Identification of Crew Compartment Debris, STS-6, TRS134704-005, RI, July 1983	X	X	X	X		X	X			
264- Space Shuttle Orbiter Materials Control and Verification Plan, June 1979 Contract NAS 9-14000	X	X	X			X		X		X
265- Geostationary Junk: Problem for the Future Geoffrey Fallworth, Satellite News, Sept 1983	X	X	X				X			
266- Human Response to Fire Stanley C. Knapp, M.D., and Francis S. Knox, III, Ph.D. U.S. Army Aeromedical Research Laboratory	X		X		X		X			

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267- "Freon 1301 as a Fire Fighting Medium in an Oxygen-Rich Atmosphere" J.H. Kimzey, NASA MSC-ES-R-67-11 October 15, 1967	X		X				X			
268- Flammable and Toxic Materials in the Oxygen Atmosphere of Manned Spacecraft, J.H. Kimzey NASA, May 1968, NASA TN D-3415	X	X	X	X			X	X		X
269- Flammability in Zero Gravity Environment J.H. Kimzey, W.R. Downs, C.H. Eldred, C.W. Norris NASA, October 1966, NASA TR-R246	X		X	X			X	X		X
270- Review of Factors Affecting Ignition of Metals in High Pressure Oxygen Systems, J.H. Kimzey, NASA October 28, 1970, MSC-03461	X		X	X			X			
271- Skylab Experiment M-479, Zero Gravity Flammability, J.H. Kimzey, NASA-JSC March 20, 1974	X	X	X	X						
272- Gravity Effects on Combustion, J.H. Kimzey, NASA October 10, 1967, MSC-ES-R-67-10	X									
273- Flammability During Weightlessness, J.H. Kimzey, NASA, May 1966, NASA TMX-58001	X	X	X				X	X		X

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274- Space Flight Research Relevant to Health, Physical Education, and Recreation (w/Ref. to Skylab's Life Science Experiments) W.D. Van Huss, W.W. Heusner, NASA June 1979	X	X	X	X			X			
275- Skylab Experiments - Volume 2 Remote Sensing of Earth Resources, NASA May 1973				X						
276- NASA Facts-Skylab 1973-1974, NASA/JSC 1973-74	X	X		X						
277- Stepping Out - Fourteen Years of Extra-vehicular Activity, K.T. Wilson, Spaceflight, Vol. 21, 12 Dec. 1979, p. 482-486	X	X	X	X			X			
278- EVA and the Space Shuttle, J.E. Catchpole, Spaceflight (No. Vol #) p. 174-175	X		X	X		X				X
279- Crew Preparing for First Shuttle EVA, Craig Covault, Aviation Week & Space Tech., October 11, 1982, p. 75-92	X		X			X				
280- Shuttle Space Suit - NASA Educational Briefs NASA EB-81-2	X		X	X		X	X			X
281- Meteroid Bumper Experiment on Explorer 46, Donald H. Humes, NASA 1981, 7306229, p. 9-17	X	X	X	X			X	X		

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282- Man-Made Debris in Low Earth Orbit - A Threat to Future Space Operations, R. Reynolds, N. Fischer, E. Rice, AIAA Vol. 20, No. 3 May-June 1983	X	X	X				X	X		X
283- Sources of Orbital Debris and the Projected Environment for Future Spacecraft, D.J. Kessler, AIAA 80-0855R, Vol. 18, No. 4 July-August 1981	X	X	X				X	X		X
284- Meteroid Bumper Experiment on Explorer 46, Donald Humes, NASA Technical Paper 1879, Langley Research Center 1981		X	X	X						
285- Retinal Changes in Rats Flown on Cosmos 936: A Cosmic Ray Experiment, Aviation, Space and Environmental Medicine. June 1980 Delbert E. Philpott, Robert Corbelt, Charles Turnbell, Sam Black, Deborah Dayhoff, Jackie McGourty, Robert Lee, Gladys Harrison, Loya Savick	X	X	X	X			X			
286- Cosmic Ray Effects on the Eyes of Rats Flown on Cosmos No. 782, Experiment K-007, Aviation, Space and Environmental Medicine, June 1978. Delbert E. Philphott, Robert Corbelt, Charles Turnbell, Gladys Harrison, David Leaffer, Sam Black, Walter Sapp, Gloria Klein, Loya Savik	X	X	X	X			X			

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287- Response of the Seminiferous Epitheliun of the Mouse Exposed to Low Dose High Energy (HZE) and Electromagnetic Radiation. Scanning Electron Microslopy/1983/III/p. 1345-1351 Seminc AMF O'Hare (Chicago, Il, 60666, USA. De Philpott, W. Sapp, C. Williams, J. Stevenson, R. Corbett and S. Black	X						X			
288- Radioprotective Agents, Vol. 19	X		X							X
289- * Life Support Systems Requirements Contract F33657-70-C-0374 NA-70-397, Part II, North American Aviation, Los Angeles, July 70										
290- An Analysis of the Space Debris Problem - Present and Future IR&D Project 371, 580 82-0011, Jan. 1982, J. W. Haffner	X	X	X	X			X			
291- Workbook For Predicting Pressure Wave and Fragment Effects of Exploding Propellant Tanks and Gas Storage Vessels, W. E. Baker, So-West Research Institute, San Antonio, TX Nov. 1975	X		X		X		X			
292- Workbook for Estimating Effects of Accidental Explosions in Propellant Ground Handling and Transport Systems, W. Baker, J. Kulesz, R. Ricker, P. Westine, V. Parr, L. Vargas, P. Mosley, NASA Rpt. 3023, August 1978	X		X		X		X			

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293- Explosive Shocks in Air, Gilbert Kinney, The Macmillan Company, New York. U.S. Naval Postgraduate School, Monterey, CA	X				X		X			
294- Prediction of Explosive Yield and Other Characteristics of Liquid Rocket Propellant Explosions, Final Report June 30, 1973, NASA, KSC, Farber, Smith, Watts	X		X		X		X			
295- * Life Support Systems Requirements Contract #F33657-70-C-0374, M.N. Goldbert, July 1970, N. American Aviation, Los Angeles										
296- Environmental Requirements and Test Criteria For the Orbiter Vehicle, J. C. Woltz, R.I. Space Division - April 26, 1978	X	X	X				X	X		X
297- * Life Sciences and Space Research Vol. XVIII, Proceedings of the Open Meeting of Working Group on Spac Biology of the 22nd Plenary Meeting of COSPAR, Bangalore, India May 29 - June 9, 1979, Pergamon Press										
298- Lessons Learned on the Skylab Program, JSC Houston, Texas NASA JSC-09096, July 18, 1974	X		X	X			X			
299- Astronauts Conduct First Shuttle EVA, Aviation Week and Space Technology, April 18, 1983	X		X	X		X				

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300- Mission 6 EVA Clears Way for Untethered Operations, Aviation Week & Space Technology, April 11, 1983	X	X	X	X		X	X		X	X
301- Some Unsuitable Workmanship, Time, Dec. 20,'82	X	X	X	X			X			
302- Spacesuits Become Fashionable, Spaceflight December 24, 1983										
303- The Wrong Stuff Can Make Your Helmet Crazy, American Wheelman, Jim Palluge, Feb. 1983, Vol. 19, Number 2	X	X	X				X			X
304- Weekly Activity Report - Materials Technology Branch - Hydrazine Leak Simulation, JSC May 2, 1983, Robert L. Johnston	X		X				X	X		X
305- Radiation Protection During Space Flight, E. E. Kovalev, Aviation, Space and Environmental Medicine, Dec. 1983, No. 12, Sect. II, Pg. S16-S23	X	X	X	X			X			X
306- The Space Shuttle's Operator's Manual, Kerry Mark Joels, Gregory P. Kennedy, JSC, Houston, Texas, October 1982	X		X	X		X	X		X	X
307- Man in Space: An Overview, Oleg G. Gazenko, Aviation, Space and Environmental Medicine December 1983, No. 12, Sect. II, Pg. S3-S5	X	X	X	X			X			X

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308- Medical Results of Salyut-6 Manned Space Flights, Vorobyov, Gazenko, Genin, Egorov. Aviation, Space & Environmental Medicine, December 1983, No. 12, Vol. II, Pg. S31-S40	X	X	X	X			X			
309- Biomedical Results of the Space Shuttle Orbital Flight Test Program, Pool, Nicogossian Aviation, Space & Environmental Medicine, Dec. 1983, No. 12, Vol. II, Pg. S41-S49	X		X	X		X	X			
310- Medical Results from STS-1-4: Analysis of Body Fluids, Leach. Aviation, Space & Environmental Medicine, Dec. 1983, No. 12, Vol. II, Pg. S50-S594	X		X	X		X	X			
311- Human Cellular Immune Responsiveness Following Space Flight, Taylor, Dardano. Aviation, Space & Environmental Medicine, Dec. 1983, No. 12, Vol. II, Pg. S55-S59	X		X	X			X			
312- Toxicological Evaluation of the Columbia Spacecraft, Rippstein, Jr., Coleman. Aviation, Space & Environmental Medicine, Dec. 1983, No. 12, Vol. II, Pg. S60-S67	X		X	X		X	X			
313- Concepts for NASA Longitudinal Health Studies, Nicogossian, Pool, Leach, Moseley, Rambaut. Aviation, Space & Environmental Medicine, Dec. 1983, No. 12, Vol. II, Pg. S68-S72	X	X	X					X		X

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314- Dressing For Space, Robert Nichols, Technology Illustrated, May 18, 1983	X									
316- White Sands Test Facility Test Plan, TP-WSTF-221, June 19, 1977					X					X
317- White Sands Test Facility Test Report, TR-221-001, July 7, 1978					X					X
318- White Sands Test Facility Test Report, TR-225-001, June 12, 1978					X					X
319- Spacelab Mission 4 - The First Dedicated Life Sciences Mission. Perry, Reid. Aviation, Space & Environmental Medicine, Dec. 1983, No. 12, Sec. I, Pg. 1123-1128	X		X							
320- Europe and the Space Station, Roy Gibson, Space Flight, Jan. 1984, Vol. 26, No. 1		X	X					X		
321- STS-6: First Flight for Challenger, John Pfannerstill, Spaceflight, Jan. 1984, Vol. 26 No. 1	X			X		X				

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322- Lasers in Space, Spaceflight, Feb. 84, Vol. 26 No. 2, Pg. 71-72	X		X				X			
323- Spacelab 1 - A Striking Success, Dave Dooling, Spaceworld, March 1984, Pg. 12-16						X				
324- Vestibular Experiments, Sue Butler-Hannifin, Spaceworld, March 1984, Pg. 17, 36	X		X			X	X			
325- Soviet Shuttle Tested, Space Update-Spaceworld, Oct. 1983, Pg. 38										
326- Spacelab 1, Dave Dooling, Spaceworld, Aug/Sept., 1983, Pg. 9-14						X				
327- Faking Zero-G: Underwater, Dave Dooling, Spaceworld, Feb. 1983, Pg. 4-10					X					
328- China in Space, Leonard David, Spaceworld, March 83, Pg. 25							X			
329- Indian Cosmonaut To Fly in 1984, Space Update, Spaceworld, Dec. 1983, Pg. 31							X			
330- Canada Screens Astronaut Applicants, Space Update, Spaceworld, January 1984			X				X			

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331- Final Report on Biotechnology Research Requirements for Aeronautical Systems Through The Year 2000, Southwest Research Institute, San Antonio, TX, Jan. 1982, AFOSR-82-0643	X	X	X				X			X
332- Letter From the Space Center, Henry S. F. Cooper, Jr., The New Yorker, Oct. 3, 1983, Pg. 54	X									
333- Astronaut Selection and Training, NASA NF121/3-81	X	X	X			X	X			
334- The Private Astronauts are Coming, Anne Van den Berg, Spaceflight, Vol. 25, April 1983	X	X	X				X			
335- Space Rendezvous, Rescue, and Recovery, Vol 16 Part One, Sept. 12-12, 1963, Edited by Norman Petersen	X		X				X		X	
336- B-1B System Safety Engineering Report, NA-82-322, RI-B-1 Division, April 1982	X						X			
337- Solar Power Satellite - System Definition Study, G. R. Woodcock, Part II Midterm Briefing, Boeing Aerospace Co, Aug. 24, 1977	NA	NA								
338- Space Stations of the Imagination, Leonard W. Davis, AIAA Student Journal, Winter 1983, Pg. 7-13		X						X		

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339- USSR Report-Space Biology and Aerospace Medicine, Vol. 15, No. 2, March-April 1981	X	X	X	X			X			X
340- USSR Report - Space Biology and Aerospace Medicine, Vol. 15, No. 1, January-February 81	X	X	X	X			X			X
341- USSR Report - Spce Biology and Aerospace Medicine, Vol. 15, No. 3, May-June 1981	X	X	X	X			X			X
342- USSR Report - Sace Biology and Aerospace Medicine, Vol. 15, No. 4, July-Aug. 1981	X	X	X	X			X			X
343- Operations Hazard Analysis Report for the Solar Maximum Repair Mission (STS-13, J. O. Webb, NASA JSC, March 1984	X		X	X		X	X		X	X
344- Colonies in Space, T. A. Heppenheimer, Stackpole Books, 1977		X						X		
345- Accident Prevention Manual for Industrial Operations, 6th Edition, National Safety Council, 1969	X		X				X			X
346- Space Sickness Institute, Space Flight, Feb. 1984, Vol. 26, No. 2	X						X			
347- Growing Dinner in Space May Be Cheaper Than Take-Out, (Space World Staff Report) Space World December 1983, Pg. 22-23			X							

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348- Cardiovascular Examinations and Observations of Deconditioning During the Space Shuttle Orbital Flight Test Program, Bungo, Johnson Aviation, Space & Environmental Medicine, Nov. 1983, Pg. 1001-1004	X		X	X		X				
349- Communications Satellite Systems, James Martin 1978, Telecom Library New York, New York	NA	NA								
350- Human Engineering Design Criteria for Military systems, Equipment & Facilities, Dec. 31, 1974 MIL-STD-1472B, Department of Defense	X		X		X					
351- Stress Effects of High Noise Levels on Lower Body Negative Pressure Experiments, R. E. Allen, R.L. Trobaugh & B.B. Henson. Marshall Space Flight Center, NASA, Sept. 1970	NA	NA								
352- Summaries of Alternative Analogues To A NASA Space Station and Description of Evaluation Methodology, Jac. W. Stuster, Ph.D, Contract Number NAS2-11690, January 1984	X	X	X	X	X		X			
353- Inclusion of Radiation Protection in the Environment Shelter Planned for the Space Station, July 7, 1983. Dr. Delbert Philpott NASA-ARC	X	X	X				X	X		X

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TITLE, AUTHOR, PUBLICATION, PUBLISHER, DATE, DOCUMENT NUMBER, (ACCESSION NUMBER)	CREW SAFETY	SPACE STATION	FIELD A	FIELD B	FIELD C	FIELD D	FIELD E	FIELD F	FIELD G	FIELD H
354- Radiation Shields for Ships and Settlements, Journal of the British Interplanetary Society Vol. 35, p. 515-519, 1982, Paul Birch.	X	X	X				X	X		
355- Life Sciences and Space Research XVII, 1978, E.E. Kovalev and V. V. Markelov	X		X	X			X			
356- Akad. Nasuk, CCCR,M Radiobiologia XVII, 1977 V. N. Benevolenski, L. K. Vekshina, and I. V. Vnutskich	X			X			X			
357- Proceedings of the VIth Symposium on Micro-dosimetry, Harwood Academic Publishers Ltd., London, 1978, p. 977, R. Facius, H. Buecker, G. Reitz, and M. Schaefer	X						X			
358- Life Sciences and Space Research XV, 1977 W. Heinrich	X		X	X			X			
359- Paper Presented at the XIXth Plenary Meeting of Cospar, Philadelphia, 1976, R. Facius	X			X			X			
360- Life Sciences and Space Research XV, 1977 Peterson, Benton, Tan, Yang, Freeling, Craise, Tobias	X			X			X			
361- Life Sciences and Space Research XI - 1973 Todd, Budinger, Lyman	X			X			X			

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362- Life Sciences and Space Research XI - 1973 Todd, Schroy, Schimmerling and Vosburgh	X									
363- Radiation Effects, Unpblshd., W. Heinrich, '79	X		X				X			X
364- An Anlaysis of Energetic Space Radiation and Dose Rates, M. O. Burrell, et.al. (NASA)	X	X	X				X			X
365- Meteoroid Environment Model 1969, (Near Earth To Lunar Space), NASA SP-8013, NASA Space Vehicle Design Criteria, 1969	X	X	X				X	X		X
366- Meteoroid Damage Assessment, NASA Space Vehicle Design Criteria (Structures) NASA SP-8042, 1970	X		X	X			X			
367- Space Station Crew Safety Human Factors Interaction Model, Marc M. Cohen and Maria K. Junge, Proceedings of the 28th Annual Meeting of the Human Factors Society, 10/21-26/84, San Antonio, Texas.	X	X	X				X			
368- Life Considerations for Space Station NASA Washington, D.C., 9-14-82	X	X	X				X			
369- Briefing on Space Suit Improvements to Support Space Station Program, ILC Dover NASA, Williamsburg, Virginia, March 28-31, 1983	X	X	X				X			X

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370- Flammability, Odor, and Offgassing Requirements and Test Procedures for Materials in Environments That Support Combustion. NASA Sept. 1981	X	X	X				X	X		X
371- British Airways Warns Staff in Food Incident, Aviation Week, March 1984	X		X		X		X			
372- Medical Operations and Life Sciences Activities on Space Station, JSC-NASA #58248 October 1982	X	X	X	X			X	X		X
373- An Approach Toward Function Allocations Between Humans and Machines in Space Station Activities, Von Tiesenhausen, Georg, NASA TM-82510, Nov. 1982	X	X	X				X	X		X
374- Encyclopedia of Chemical Technology, 3rd Edit. Kirk-Othmer, John Wiley and Sons, 1978	X	X				X	X			X
375- Air Force Manual, "Liquid Propellants" Volume II, AFM 161-30, April 10, 1973	X		X			X	X	X		X
376- II. 4.0 Bioacoustic Requirements	X		X	X		X	X	X		
377- The Skylab Results, Proceedings Volume I, August 20-22, 1974	X		X	X	X		X	X	X	

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TITLE, AUTHOR, PUBLICATION, PUBLISHER, DATE, DOCUMENT NUMBER, (ACCESSION NUMBER)	CREW SAFETY	SPACE STATION	FIELD A	FIELD B	FIELD C	FIELD D	FIELD E	FIELD F	FIELD G	FIELD H
378- The Skylab Results, Proceedings, Volume II, August 20-22, 1974	X	X	X	X		X	X	X	X	X
379- "Pilots of Outer Space", Bluth, B. J. Social Science and Modern Society, Volume 21, No. 2 January/February 1984.		X				X	X			
380- "Antarctica: Earth's-Warning Station", Browne, Malcom W., Discover, Feb. 1984					X		X			
381- "Collision Probability of Future Manned Missions with Objects in Earth Orbit", Donahoo,ME NASA/MSC Internal Note No. 70-FM-168, 10-20-70	X	X	X	X		X	X	X	X	
382- "Predicting the Probability that Earth-Orbiting Spacecraft will Collide with Man-Made Objects in Space," Brooks, D.R., Gibson, G.G., and Bess, T.D., " Space Rescue and Safety, American Astronautical Society Publications Office, Tarzana, CA, 1975, pp. 79-139	X	X	X	X		X	X	X	X	
383- "Collision Frequency of Artificial Satellites: The Creation of a Debris Belt," Kessler, D.J. and Cour-Palais, B.G., Journal of Geophysical Research, Vol. 83, June 1, 1978, pp. 2637-46.	X	X	X	X		X	X	X	X	

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384- NASA CR-1205 (III), Copendium of Human Responses to the Aerospace Environment, Vol. III, Sections 10 and 12, Nov. 1968.	X	X	X			X	X			
385- NASA, Satellite Situation Report, Vol. 19 No. 6, Office of Public Affairs, Goddard Space Flight Center, Greenbelt, Md. 1979	X	X		X		X	X			X
386- "Satellite Catalog Compilation as of 1-1-80", Aerospace Defense Command, Peterson Air Force Base, Colo., 1980.	X	X		X		X	X			X
387- "Satellite Catalog Compilations as of 10-1-78" Aerospace Defense Command, Peterson Air Force Base, Colo., 1978	X	X		X		X	X			X
388- Space Station Definition and Preliminary Design Request for Proposal, NASA. 9-15-84	X	X	X	X		X	X	X	X	X
389- "Human Exposure in Low Earth Orbit", Wilson, John W. and Cucinotta, Frank. NASA Technical Paper 2344, August 1984.	X	X	X			X	X	X	X	X
390- "TRW Space Log", Cartwright, E.S., ed., TRW Defense and Space Systems Group, TRW, Inc., 1975, 1976, and 1977	X	X	X	X			X			X

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391- NASA, Satellite Situation Report, Vol. 18, No. 6, Office of Public Affairs, Goddard Space Flight Center, Greenbelt, Md, 1978	X	X	X	X		X	X	X	X	
392- "Mass Distribution of Orbiting Man-Made Space Debris," Bess, T.D., NASA Technical Note TND-8108, 1975	X	X	X	X		X	X	X	X	
393- "Comparison of the Perimeter Acquisition Radar (PAR) Satellite Track Capability to the Space Defense Center, (SDC) Satellite Catalog-Unknown Satellite Track Equipment," Hedren, J.K. and Anderson, A., Report SAI-77-701-HU, Scientific Applications, Inc., Huntsville, AL 1976.	X	X	X	X		X	X	X	X	
394- "Meteoroid Environment Model-1969 (Near Earth to Lunar Surface)," Reynolds, R.C. and Fisher, N.H., NASA SP-8013, NASA Space Vehicle Design Criteria, 1969	X	X	X	X		X	X	X	X	
395- "The Hazard Presented to the Shuttle by Other Satellites in its Operating Environment," Reynolds, R.C. and Fisher, N.H., Proceedings of the 1980 JANNAF Safety and Environmental Protection Session, CPIA Publication No. 313, March 1980.	X	X	X	X		X	X	X	X	

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396- "On the Probability of Satellite Collisions in Earth's Orbits," Chobotov, V.A., TOR-0079 (4071-071)-1, The Aerospace Corp., El Segundo, CA, June 1979	X	X	X	X		X	X	X	X	
397- "Spacetrack Systems Data Related to Some Non-Routine Events Through May, 1981," Gabbard, J. G., NORAD/ADCOM Technical Memo 81-G, June 30, 1981	X	X		X		X				
398- The Hammond Almanac, Bacheller, M.A., ed., Hammond Almanac, Inc., Maplewood, NJ, 1980							X			
399- "A Study of the Lifetimes of Geosynchronous Transfer Orbits", Mueller, A.C. and Graf, O.F. Jr., AAS/AIAA Astrodynamics Specialist Conference, Provincetown, Mass, 6/25-27/79.	X	X		X		X				X
400- JSC Radiation Conference, November 16-18., Philpott, Delbert, et.al.	X	X	X			X	X	X	X	X
401- "Crew System Concepts for Expanded Space Operations and Extra-Vehicular Activity", Carlson, A.D. Rockwell International STS 83-093, 19-83.	X	X	X			X	X		X	X
402- "Workshop On the Radiation Environment of the Satellite Power System", Schimmerling, W. and Curtis, S., Lawrence Berkeley Laboratory, University of Calif., Sept. 15, 1978.		X		X			X			X
403- "Dictionary of Technical Terms for Aerospace", Allen, William, NASA SP-7, Washington D.C., 1965,				X						

*Report Not Available For Contract Performance Period

APPENDIX B

PRELIMINARY SPACE STATION CREW SAFETY THREAT LIST

The threats listed here are generic in that each threat may have more than one possible cause. Further in this study, potential hazards will be developed for these threats, allowing specific identification of controlling safety criteria and guidelines.

The scope of issues covered are threats that affect crew health and well being directly and threats that impact the space station and its ability to continue functioning. Sources of threats can be external to the space station, crew initiated, space station hardware/software responsible, or generated by hardware/software and processes dedicated to space station experiments, payloads, and cargo.

Design and operational guidelines eventually will have to be drawn up for the space station and its dedicated crew equipment, for crew functions, as well as for carry-ons: experiments, payloads and cargo.

FIRE

A fire in an area containing subsystems equipment, electrical wiring, or laboratory equipment, or in personnel areas which damages and puts out of commission all unprotected operating equipment in a compartment. Fire prevention in design leans heavily on isolating the elements of combustion: Fuel, Oxidizer and Ignition. In a two-gas system (80% N_2 and 20% O_2) the fuel is excluded only if <u>all</u> materials are screened for flammability. Applying "NASA MSC Requirements for Materials and Processes", JSC-SE-0006B, through the RI-SD Material Control (MATCO) program screened shuttle materials for flammability. In a 100% O_2 environment (such as in EVA pre-breathing areas), all surface temperatures must be analyzed to ensure that no ignition sources are available and the contained materials are not flammable at high O_2 concentrations. "Environment Requirements and Test Criteria for the Orbiter Vehicle", MF0004-014C, cites maximum allowable surface temperatures in each of the compartments based on the potential fluid leaked into the compartment. Fluid leaks are considered credible. Additionally, smoke/fire sensing and supression could be included in Damage Control design.

LEAKAGE

Leakage of any gas or liquid which is produced, stored, or routed through the pressurized areas of Space Station volumes, including any chemicals used or that may be produced in experiments. The leakage may occur at any point through which the fluid is routed. Leakage rates must be assumed and increased margins and/or system make-up capability must be included in the design. Selection of materials and seals for faying surfaces is critical to the life of the Space Station in orbit. Seal selection, expected life, condition at installation, and installation techniques determine leak susceptibility at all penetrations.

TUMBLING/LOSS OF CONTROL

Space Station attitude maintenance systems require at least fail-operational/fail safe capability. Consideration of a requirement for maintenance and returning the system to operable status should be given. Forces that may cause tumbling or loss of control, other than attitude maintenance system failure, could include: moments imparted by Orbiter/OTV docking or collision, fluid or gaseous systems leaking/venting, crew activity within the station, and the like. Recovery from and immediate reaction to Space Station tumbling should be a system design requirement including center of gravity and mass distribution effects.

BIOLOGICAL OR TOXIC CONTAMINATION

Contamination threats are those associated with biological or toxic contamination of the food or water supply. All similarly packaged food stored in any one area (e.g., all vacuum-packed food stored in one pantry) will be assumed unfit to eat. Similarly, all potable water in connected tanks will also be assumed toxic; the water, however, may be reprocessed through the water purification system and the tanks decontaminated to render water potable. This threat is associated with the release of toxic, flammable, corrosive, condensible, or particulate matter. Contamination is caused by leakage, spillage, outgassing, loose objects, abrasion and from the growth of fungus or release of volatile condensible materials. Leakage of or out gassing of hazardous materials should be prevented by eliminating suspect materials through MATCO screening. Close looks at materials interactions are also required. Where hazardous materials are brought on board, special containment consideration must be given. All materials brought on board should be screened, including astronaut personal effects.

INJURY/ILLNESS

Physical injuries may be caused by impact or collision with stationary objects having sharp edges or protruding parts or with shrapnel or projectiles from exploding tanks or accelerated loose objects. Physical injuries may also be caused by ingesting particulate matter, touching hot or cold surfaces, and by breathing oxygen deficient air. Care and control to prevent sharp and abrading protrusions and the inclusion of hand holds and other convenient restraints for astronauts minimizes exposure to injury. Crew illness could result from exposure to pathogenic bacteria, toxic materials, or to excessive radiation levels. The physiological/behavioral impact of microgravity of the crew for long time exposure is not clearly understood. Personal hygiene and close control of food preparation minimizes exposure to illness. Crew illness and injury must be treatable within the Space Station. The sophistication of medical facilities is yet to be determined. Death of an astronaut cannot be ruled out, raising the question of what procedure is to be followed for the disposition of the remains, i.e., return to earth or burial in space - burial at sea precedence.

GRAZING/COLLISION

This threat concerns internal as well as external elements and can be caused by structural failure, procedural error or inadequate stowage and handling rationale. External threats can be caused by Orbiter/OTV or EVA astronauts coming into unplanned contact with the Space Station. A grazing collision with another vehicle which damages equipment outside the spacecraft, such as RCS jets, radiators, solar panels, antennas, tanks, fluid lines, docking mechanisms, etc., is considered here. The collision is not severe enough to cause a penetration of primary structure but may damage exposed equipment. Potential collision candidates must be identified and the specific threat defined.

CORROSION

This threat concerns structural degradation of metallic and nonmetallic equipment. Leakage of corrosive or reactive materials can degrade an equipment's usefulness and/or cause structural or mechanical failures. Material incompatibility at joints of dissimilar metals can lead to corrosion when subjected to internal environment extremes of temperature and humidity accelerating corrosion in carbon or most organic materials. Examples of corrosive processes include stress corrosion, electrolytic corrosion, and polymerization. Causative agents include acid, salts, solvents, halogens, etc. The MATCON program is set up to screen against corrosive agents and processes.

MECHANICAL DAMAGE

Mechanical damage is defined as being caused by collision inside the vehicle with loose out-of-control masses. Damage potential of systems requires assessment as to impact on mission continuation, type of emergency precipitated, postulated damage, protection affordable in design and mission recovery impact. External causes (Fire, Explosion, Collision, Penetrations, Attack, Sabotage or Human Error) may not be preventable and requires that system damage tolerance should be a significant design consideration for critical systems.

EXPLOSION

In the event of an explosion, the damage will be confined to one compartment and will consist of overpressure, heat, shrapnel, and atmospheric contaminants. All equipment in the compartment may be damaged and made inoperative, unless armor-plated for protection. Violent release of energy as a result of equipment overpressurization, fire, chemical reaction, excessive temperature, equipment malfunction or structural failure are candidate causes for explosion. For instance, an explosion of .025 lb TNT equivalent, releasing 50 BTU of energy in the form of heat, shock waves and kinetic and thermal energy of shrapnel damage could be confined to one compartment and would consist of overpressure, heat, shrapnel and atmospheric contaminants. The equipment would require repair/replacement, depending on the damage an explosion can produce. Further hazards which can result in a compartment by such an explosion, such as fire, etc., should also be considered as part of the threat. Walls and primary structure, or equipment outside the affected compartment, would probably not be damaged. (021) Equipment which can disintegrate explosively includes pumps, motors, blowers, rocket motors, generators, laser, etc. In excluding equipment and materials from Space Sation habitable volumes whose TNT equivalency exceeds TBD, explosion impact can be minimized. Equipment and material mounted externally to the Space Station habitable volumes that exceed the threshold TBD TNT equivalency should include shrapnel diverter shields or other buffers to protect the habitable volumes from catastrophic penetrations. Guidelines concerning pressure sensing, relieving and control, chemical screening to prevent use of violent reagents, and system heat rejection are key elements controlling explosion risks.

LOSS OF PRESSURIZATION

A loss of pressurization in a habitable volume may be caused by an accidental penetration of an outside wall or bulkhead. Pressure sensing, leakage and maintenance imply the need for a Damage Control System on-board the Space Station. Such a system would include pressure, temperature and toxicity sensing with additional capability for smoke sensing and fire suppression for each isolatable compartment in the Space Station with primmary and back-up readout panels located in separate Space Station areas. If compartment size and criticality so indicate, a need may exist for automatic control of hatch actuation. These design constraints are dependent upon assumed penetration size, size of each isolatable volume, use frequency of the compartment and criticality of the adjacent compartments.

RADIATION

Radiation threats are associated with the exposure of the astronauts as well as equipment to ionizing radiation, ultraviolet or infrared light, lasers, and electromagnetic or radio frequency radiation. Ionizing radiation threats may be caused by leaking or inadequately shielded radioactive equipment such as RTG's, particle accelerators, liquid metal heat exchangers, etc. RF and electromagnetic radiation from RF generators can trigger ordnance devices or interfere with the operation of critical equipment. Allowable levels of each of these energies must be established, and design accommodation made to ensure that the Space Station astronauts and equipment are protected.

OUT OF CONTROL IVA/EVA ASTRONAUT

Loss of control of astronauts during IVA/EVA may be caused by malfunctioning maneuvering devices or lack of adequate handholds and other restraints. The issue of aberrant astronaut actions causing a problem must be considered. Rapid rescue is required by a companion already suited and conditioned to the suit atmosphere, who is waiting in an airlock or is also performing EVA or IVA. Equipment adequacy and redundancy could address the former issue, the latter may require some physical restraint system, equipment or facility.

INADVERTENT OPERATIONS

Critical tasks and systems controls should be analyzed to assess the impact of inadvertent operations. Hardware can be protected by switch wickets, lever-locks, etc. Software can be protected by two or three "and"-ing requirements, as well as being protected from astronaut modification on-board. Recommendatons are for automating all routine functions, with manual work-arounds as required.

LACK OF CREW COORDINATION

Within the aviation industry - both civilian and military - experience has shown that lack of crew coordination in times of crisis has almost invariably resulted in catastrophe. Some of the recent major disasters in commercial air travel have occurred as a result of the entire crews' attention being diverted to trouble shooting the problem affecting the airplane while no one paid attention to the ordinary chores of piloting and navigating the airplane. One major airline radically changed crew training and upgrading techniques to address this problem. Similar problems of lack of crew coordination could arise in a Space Station. It is important that critical routine functions be manned at all times, if not automated. This will allow investigation of malfunctioning equipment by personnel not dedicated to routine, but essential, Space Station equipment. Crew tasks should be reviewed carefully with this potential problem in mind.

ABANDONMENT OF SPACE STATION

There should be a passive capability of the Space Station to survive abandonment. A combination of accidents and/or subsystems degradation requiring the abandonment of the station by some or all of the occupying personnel is considered here. Such abandonment will not be a time-critical emergency but a deliberate abandonment planned over a period of days to months. The worst design case is when one of the separate pressure volumes has been evacuated and sealed off for some time because of major damage or contamination, and all personnel are in the remaining volume. If the cause for abandonment concerns the inability of the station to support human habitation, the station should be able to maintain critical functions, such as attitude maintenance. A cause for abandonment could be loss of a breathable atmosphere. Critical avionic equipment should be able to function in the absence of an atmosphere. An important task related to the above hazard, that was considered during this effort was the Escape and Rescue. The philosophy adopted with respect to escape and rescue is stated below:

Increased Reliability or Redundancy	Preventive		Built-In
Damage Control Compartmentalization	Preventive		Built-In
Improved Emergency Sensors	Preventive		Built-In
On-Board Preventive Maintenance	Preventive		Built-In
Abort Capability	Remedial		Built-In
Personal Survival Equipment	Remedial	Separate	Built-In
On-Board Repair Capability	Remedial	Separate	Built-In
On-Board Medical Aid	Remedial	Separate	Built-In
On-Board Emergency "RED" Systems	Remedial	Separate	Built-In
"Buddy" Concept (Separate Type)	Remedial	Separate	
On-Board Escape and Wait	Remedial	Separate	
On-Board Escape and Return	Remedial	Separate	
Spare Earth Return Module	Remedial	Separate	
Unmanned/Manned Assistance or Rescue			
Earth Launched (Post Emergency)	Remedial	Separate	
"Pre-Deployed"	Remedial	Separate	

ELECTRICAL SHOCK

When personnel, during the normal operations of equipment or due to single point failures or masked dual point failures, are exposed to electrically energized components, terminal strips, buss bars, stored charge apparatus, etc., that through a combination of electrical potential, current and body resistance would allow a person's body to offer a path for current flow to ground and result in shock or electrocution, a hazard potential exists. A hazardous voltage or power source is any potential source of power that can produce serious shock or burns or a fatal current,dependent upon body resistance, contact conditions, and path through the body (see table below). Also equipment which senses or controls critical control parameters of flight systems or is reasonably capable of applying damaging electrical energy to supported systems is classified as Safety Critical.

PROBABLE EFFECTS OF SHOCK

Current Values (Milliamps)

AC 60HZ	DC	Effects
0-1	0-4	Perception
1-4	4-15	Surprise
4-21*	15-80*	Reflex Action
21-40*	80-160*	Muscular Inhibition
40-100*	160-300*	Respiratory Block
Over 100*	Over 300*	Usually Fatal

*Serious Shock or Burns.

METEOROID PENETRATION

A fallout of space debris studies will have to be a probability of strike and an assumed size of meteoroid. The potential impact of this threat has not been specifically defined at this time. However, basic assumptions should consider potential meteoroid penetration of the primary structure. Physical damage should be confined to one compartment and is assumed to consist of finely divided molten high-speed shrapnel (from spallation of the inner wall).

STORES/CONSUMABLES DEPLETION

Consumables, both for the Space Station as well as for the astronauts, require establishing levels that account for leakage, spoilage, unexpected high consumption rates, etc. The key to establishing quantities, is determining what survival time, without support from the ground is required: 96 hours, seven days, or what? Automatic inventorying of critical consumables should be considered.

INTRUSION/ATTACK

Screening related literature indicates that intra-crew member hostility was an issue on the longer space flights. When space stations evolve and less highly motivated and dedicated personnel are included in crews, special screening of candidates will be required. This threat could be psychological as well as physical. STS-5, and subsequent flights where more than two crew members are on board, will be watched closely as crew interaction will be more complex. How to approach the impact of this threat: with sedation, by employing "Polaris Pajamas", by isolating offending crew members, etc. - must be determined. Overt military action and external intrusion/attack is a fallout of a space station survivability analysis and is beyond the scope of this study.

STRUCTURAL EROSION

This issue has been observed in long lived spacecraft. Space debris and other minutia progressively can erode metallic or non-metallic enclosures to the point where leakage could occur. If the eroded skins allow fluid or gas containment systems to leak, undesirable spin/tumbling moments could be reacted into the space station and/or consumables could be lost overboard. This is a downstream "wear" issue but appears to be real enough to address in the program.

ORBIT DECAY

Consumables needed to update orbital position or to overcome the effects of space station drag may become an issue when large captive structures are being constructed prior to separation from the space station. Credibility of this threat is understood when one considers a fully operational space station in its planned working environment. This threat impacts consumable margins.

LOSS OF ACCESS TO A HATCH

The loss of access to any one hatch, door, or other personnel or cargo transfer opening because of jamming of the mechanism, either open or closed; or because of obstruction by cargo; or because of a localized hazardous situation (fire, chemical spillage, electrical hazard, etc.). Compartmentation to allow access to "safe havens" requires a minimum of two egress paths from each habitable volume. Present space station design philosophy appears to provide this capability. Design drivers are hazards that destroy compartment habitability and require survival workarounds.

TEMPERATURE EXTREMES

Ability of crew and equipment to function under varying temperature stresses needs to be considered. Emergencies such as the Apollo 13 Service Module tank explosion, may be postulated to determine the credibility of this threat. Unexpected heat inputs from experiments/payloads/cargo need be addressed early to ensure the space station's ability to grow into its operational phase. This threat deals indirectly with planned margins and absolute capabilities.

DEBRIS

The threat category of external debris excludes meteoroids and is usually referred to as space garbage. Nominally, space debris, as opposed to meteoroids, would have lower closure rates allowing the possible option of collision avoidance. Internal debris, on the other hand, can clog filters and directly affect equipment operation and crew performance. The Orbiter has experienced clogged filters due to lint, affecting air cooled avionics and overloading fan motors.

FREE-ORBIT

One of the threats to extravehicular activity (EVA) is drifting into a free-orbit from which there is no autonomous return capability. Such an event could be caused by an MMU failure at a remote work site, drift through loss of tether, or the unexpected release of stored energy which results in inadvertent detachment from local structure. Some primary sources of stored energy are: propulsive Pressure Garment Assembly leaks, RCS plume impingement, and impact from auto-deployable structures. Most hazardous are those propulsive type failures that could boost a crewman into a free-orbit which is not coplanar with his prime habitat.

Appendix C
SPACE STATION
CREW SAFETY CRITERIA

These criteria were eclectically assembled from industry space station studies beginning as early as 1968. Those criteria that were relevant to the current space station studies were carried forward, if not in detail, at least in intent. Reassessment of threats under Contract NAS1-17242 evolved additional criteria that are included.

20 January 1984
Rockwell International
Space Transportation and
Systems Group

DAMAGE TOLERANCE

A-1 No credible single space station failure, operational error or radio frequency signal should result in damage to space station or mission/payload equipment or in the use of emergency equipment; some limited degradation in mission/payload accommodations, crew convenience/comfort, or space station attitude or orbit may be allowed

A-2 No credible combination of two space station failures, mission/payload equipment failures, operator errors, or radio frequency signals should result in the potential for crew injury or permanent loss of the space station or primary mission/payload capability; institution of emergency procedure/equipment may be necessary, but no hazardous operational level will be reached

A-3 All subsystem/equipment critical to preservation of life and space station survival shall be fail-operational/fail-safe (excepting primary structure and pressure vessels)

A-4 Fail-operational/fail-safe designed subsystems should allow maintenance to upgrade the subsystem/equipment without being degraded below fail-safe during the maintenance actions following the second failure

A-5 Potentially rupturable containers should contain less material (gas, liquid, solid) than would cause unacceptable overpressure if all the material were released in a leakage, rupture or explosion

A-6 Redundant accommodations for command and control of the space station shall be provided such that the primary control center has complete capability, but the backup control center will have, as a minimum, control of critical functions

A-7 Design inhibits to prevent failure propagation from one volume/subsystem/component to another should be incorporated

A-8 The space station should be designed and operated so that any damaged module can be isolated from the rest of the Station in TBD seconds, as required. Provisions shall be made for pressure isolation within the volumes. Modules should be equipped so that the crew can safely continue a degraded mission and take corrective action to either repair or replace the damaged module

A-9 Any volume should be capable of sustaining the whole crew, and capability should be provided for performing critical functions at an emergency level until the crew can be rescued. Electrical and fluid lines in each pressure-isolatable volume required for critical functions should be protected against the effects of explosion, fire, vacuum, and corrosion

A-10 Capability should be provided for performing critical functions with a portion of a subsystem inoperative for maintenance, and any pressure-isolatable volume inactivated and not accessible

A-11 Redundant equipment, lines, cables, and utility runs, which are critical for safety of personnel or mission continuation, should either be located and routed in separate compartments (i.e., separated by a structural wall) or should be protected against fire, smoke, contamination, loss of pressure, overpressure, and shrapnel

A-12 All walls, bulkheads, hatches and seals whose integrity is required to maintain pressurization or atmospheric isolation shall be readily accessible for inspection and repair by crewmen in pressurized suits

A-13 As a design goal, inspection, maintenance and repair of critical subsystems by shirt-sleeved crewmembers shall be accommodated.

CREW PROTECTION

B-1 Provisions should be made for a safe haven within the space station, isolatable from the hazard capable of sustaining the crew for 21 days beyond normal resupply and allowing rescue by a Shuttle. Provisions shall be made to monitor the health of the remaining habitable modules from this safe haven

B-2 Personnel protection from electrical shock, radiation, mechanical and thermal hazards should be provided

B-3 Accessways between compartments should be sized such that an IVA/EVA-suited crewman is allowed free passage

B-4 Provisions shall be made for the protection and survival of the whole crew during solar storm activity as defined by the TBD design mission radiation model

B-5 Personnel escape routes should be provided in all hazardous situations

B-6 Provisions and habitable facilities should be adequate to sustain the entire crew for a minimum of 22 days during an emergency situation when damage repair is in progress

B-7 Atmospheric stores and subsystem capability sufficient for two full repressurizations of each pressurized habitable volume should be maintained on/at the space station during manned operations

B-8 Access to EVA and IVA airlock and suit station(s) should be provided for all credible emergency conditions. Airlock chamber(s) should be provided to permit crew access for EVA/IVA operations

B-9 Two or more suited crewmen should participate in any pressure suit activity and rescue provisions should be provided to allow safe return to space station, following the incapacitation of any one crewman

B-10 Real-time monitoring of the atmosphere constituents, including harmful airborne trace contaminants and odors should be performed. Control shall be provided for each pressurized habitable volume

B-11 Two or more entry/egress paths should be provided to and from every module or pressure-isolatable volume. The two paths should be separated by airtight partitions, or shall be at least 10 feet apart, and should each lead to an area in which the crew can survive until escape, rescue or removal of the hazard

B-12 Materials used in the habitable areas should not outgass toxic constituents in the lowest pressure environment and highest temperature to which they will be exposed

B-13 All EVA and unpressurized compartment IVA should be conducted using the "buddy system". (Note: buddy system criteria can be met with suited crew to station exit in visual contact with subject.) The buddy system should also be used during shirtsleeve operations in hazardous areas

B-14 A margin of consumables should be provided onboard, sufficient for performing critical functions for TBD hours at a reduced level following any credible accident which renders one pressure-isolatable compartment unavailable

B-15 At least two egress paths should be available from each module for emergency egress of personnel during manned ground operations

B-16 Emergency pressure suits required in the space station, sized to fit any crewman, should be in readily accessible locations within each pressure-isolatable volume

B-17 Provisions should be made for emergency medical treatment of credible accidents and illnesses for durations compatible with the rescue provisions

B-18 The safe environment and the safe operational status of activated subsystems within the space station should be verified prior to personnel entry, initially, and prior to reentry following temporary station abandonment

B-19 Deployment and initiation of operations considered hazardous should be checked out from a safe location before exposing crewmen to the potential hazards

B-20 Provision should be made for the return of a crewman incapacitated while performing EVA

B-21 Provisions should be made for the detection, handling, containment and/or disposal of toxic, flammable, combustible and hazardous materials

B-22 Pressurized volumes should have adequate free volume (not occupied by equipment) to allow crew freedom of movement to support long-duration habitation

B-23 Hazardous or toxic fluid storage, conduits and interconnects between modules should be external to the pressurized volume. Exceptions may be made for flammable but nontoxic gases where the maximum possible quantity released by a leak cannot result in a flammable mixture

B-24 Provisions should be made for detection and control of pathogenic agents onboard the space station using methods harmless to crew and equipment

B-25 Planned crew tasks should be assessed initially, for compliance intent with TBD regulations before performing such tasks; and crew training provided for each specialized and/or hazardous task

B-26 Provision should be made for handling irrational crewmembers and the remains of deceased crewmembers

B-27 The occupied compartment's acoustical noise environment should be within human tolerance noise exposure limitations, permit intelligible auditory communications, have a minimum of pure tone or narrow frequency band(s), a minimum of intermittent or discontinuous noises and a minimum of high-frequency noises. System and equipment design (including subcontractors) should be accomplished from the outset to produce an acceptable noise environment. Desirably, the noise environment should meet NC TBD-or-lower noise contour for work periods and NC TBD-or-lower for sleep periods

B-28 Any module designated as a safe haven shall be provided with an airlock chamber at the port assigned for orbiter docking and rescue to allow crew transfer and rescue from a degraded and/or marginal safe haven. The rescue hatch shall provide for actuation from inside or outside to accommodate contingencies

B-29 Subsystems shall be designed to prevent inadvertent or accidental activation or deactivation of functions or equipment that would be hazardous to personnel or the Space Station

B-30 Radiation doses that affect personnel safety must be considered from all sources, including natural environment, external isotope and reactor sources (if any), electromagnetic, solar radiation and internally allowable radiation levels from experiments, processes and health maintenance/diagnostic equipment

B-31 Exposed surfaces within habitable modules shall not exceed a temperature of 113°F (with a design goal of 105°F) and a low temperature of no less than 40°F

B-32 Except for contingencies, EVA shall not be used for hazardous operations or when a maneuvering spacecraft is within the proximity operating zone (±5 nm)

STATION INTEGRITY

C-1 Primary pressure structural materials should be nonflammable. Interior walls and secondary structure should be self-extinguishing

C-2 Normally exposed nonmetallic materials should be self-extinguishing in the most severe oxidizing environment to which they will be exposed. Means shall be provided for fireproof storage of medical supplies, maintenance supplies, food, tissue, clothing, trash, and for other non-self-extinguishing items, when they are not in use

C-3 Potentially explosive containers, such as high pressure vessels or volatile gas storage containers, shall be placed outside of and as remotely as possible from personnel living and operating quarters. Wherever possible the containers should be isolated and protected so that failure of one will not propagate to others

C-4 Containment of all materials requiring return via the STS to prevent contamination of the space station environment should be provided to reduce the hazard of potential fire and toxic conditions

C-5 Tank supports should be designed to restrain the tank under propulsive effect of rapidly escaping gas

C-6 Design provisions should be incorporated to prevent uncontrollable hatch opening due to pressure differentials, and to allow controlled closing of hatch openings with or against pressure differentials, for the worst care pressure differentials anticipated

C-7 Equipment or materials sensitive to contamination should be handled in a controlled environment. Fluids and materials should be compatible with the combined environment in which they are employed

C-8 Provisions should be made to allow communication between any and all isolatable/habitable volumes on a primary and backup basis

C-9 Provisions should be made for material usage, identification and location mapping to allow real-time evaluation to determine adequate inspection/maintenance replacement frequencies

C-10 Fluid or gaseous flow, such as pressure relief valves/exhausts, fuel transfer disconnects, etc., should be designed to prevent torquing/turning or undesirable translation motions to the space station

C-11 All reaction control thrusting devices used primarily for altitude positioning of the space station, and occasionally for velocity changes, should be located such that the exhaust plume does not impinge upon other structural elements such as solar cells, areas requiring EVA maintenance or other vehicles docking with the space station

C-12 Space station modules should be tumbled to rid them of internal debris and contaminants immediately prior to preparation for launch

C-13 Provisions shall be made for in-flight servicing, adjusting, cleaning, removal and replacement of offending components, testing and repairing of all critical subsystems

C-14 Wear items should be life cycle tested in a realistic environment

C-15 All personal items should be screened for flammability and toxicity

C-16 Space Station protective enclosures shall be provided for all high mass/high speed rotating machinery

C-17 Active/passive compartmentation should be provided to contain and/or prevent fire/explosion/depressurization initiation or impact propagation. Compartments should be inspectable to support damage control and maintenance operations.

CONTINGENCY CONTROL

D-1 Identified hazards should be eliminated, reduced to controlled hazards, or specified as residual hazards

D-2 Provision should be made for detecting, annunciating, containing/confirming, controlling and restoring to a safe condition emergencies such as fire, toxic contamination, depressurization, structural damage, etc. The tools, tasks, spares, workspace, storage volumes necessary for these provisions shall be included in space station design planning

D-3 For those malfunctions and/or hazards which may result in time-critical emergencies, provision should be made for the automatic switching to a safe mode of operation and for caution and warning of personnel

D-4 The capability should be provided on the space station for the detection of malfunctions and/or hazards, tracing to the failed replaceable unit and the display of information to the crew necessary for corrective action

D-5 Provisions should be made for the crew to ascertain the hazard status of any habitable module external to the inhabited module and to mitigate or control remotely those hazards which would preclude safe entry to the module in question

D-6 The crew must be able to override any automatic safing or switchover capability. All overrides should be two-step operations with positive feedback to the initiator, which report impending results of the override command, prior to the acceptance of an execute command

D-7 Windows should be provided in the space station to enable adequate visibility to accomplish safe docking operations with the orbiter or other vehicles. Additional windows will be necessary to monitor EVA operations, logistic resupply operations and to support photographic requirements. Transmission through the windows should be such as to protect the crew from harmful UV and IR radiation. Thermal flux from the windows should be controlled to prevent excessive heat from the crewman's face and head

D-8 An independent self-contained illumination system should be provided that will be automatically activated in the event of a major primary power failure or main lighting circuit malfunction resulting in circuit breaker interruption

D-9 Materials and components subject to insidious degradation in the Space Station ionizing radiation environment shall not be used where that degradation can cause or contribute to a crew hazard

D-10 Provisions shall be made for safe disposal of the Space Station or any auxiliary part thereof without danger to flight or ground crew-members or the public

SELECTION/INDOCTRINATION

E-1 Crew selection should be based on selectees cross-trainability in fields other than speciality

E-2 Orbital crews should be an integral part of the air/ground system active interface with on-orbit crews

E-3 Station crews and teaming should allow equal thirds of schedule for on-orbit, ground interface operation and recycle operations (post orbit rehabilitation, leave, additional training, public relations, etc.)

E-4 Assurance should be provided that each mission segment crew is familiar with 1) Station Operations and Maintenance as concerns critical subsystem and 2) Procedures necessary to render SAFE all experiments and/or user-processes

E-5 Screening criteria should include assessment of attitudes, physical needs, psychological needs, personality traits, ability to function under stress, ability to accept direction, and TBD

Appendix D
SPACE STATION
CREW SAFETY DESIGN GUIDELINES

These design guidelines were eclectically assembled from industry space station studies beginning as early as 1968. Those guidelines that were relevant to the current space station studies were carried forward, if not in detail, at least in intent. Reassessment of threats under Contract NAS1-17242 evolved additional guidelines that are included.

21 February 1984
Rockwell International
Space Transportation and
Systems Group

SPACE STATION SAFETY GUIDELINES

Design Guidelines Acronyms

AOM = Attitude/Orbit Maintenance Systems
C&W = Caution and Warning Systems
CME = Crew Messing Equipment
COM = Communication Equipment
CPH = Cargo/Payload Handling Systems
CSE = Crew Safety Equipment
CWS = Crew Water Systems
DPS = Data Processing Systems
DUS = Docking/Undocking Systems
ECS = Environment Control System
EPD = Electrical Power Distribution Systems
EPG = Electrical Power Generating Equipment
FSE = Fluid System Equipment
HMS = Health Maintenance Systems
IFM = In-Flight Maintenance
INT = Integration, two or more systems involved
MSE = Mechanical Systems Equipment
NUC = Nuclear/Ionizing Radiation Systems Equipment
OPS = Operations
RSD = Radiation Shielding Devices
STR = Structural Systems

SPACE STATION CANDIDATE SAFETY DESIGN GUIDELINES

DG-INT-001. Normally habitable compartments of more than 25 cubic meters (880 cubic feet) in volume shall have two or more exits into areas which provide for personnel survival. These exits shall be at least 3 meters (10 feet) apart.

DG-INT-002. Flammable, explosive or gas generating material shall be located so that the energy content which can be propagated at any one location shall not result in overpressurization of the compartment from heat and gas production.

DG-INT-003. Flammable, explosive or gas generating material within 3 meters (10 feet) of the entrance to compartments with only one entry/egress path shall be limited so that the energy content, if released, will not result in damage of an environment which prevents shirtsleeve access through the entrance.

DG-INT-004. Two or more entrances into normally habitable compartments of more than 25 cubic meters (880 cubic feet) in volume shall be shirtsleeve accessible from each of the other normally inhabited compartments. These entrances shall be at least 3 meters (10 feet) apart.

DG-INT-005. Where only one shirtsleeve ingress/egress path is provided into a compartment or module, redundant means shall be available for opening the connecting hatch(es) from either side.

DG-INT-006. Capability shall be provided to depressurize adjacent volumes before undocking.

DG-ECS-007. Capability shall be provided to reduce the pressure in each habitable volume, sufficiently, or increase it in the adjoining habitable volumes, and to cut off air circulation, so that in an emergency the atmosphere in the affected volume will not be propagated into adjoining compartments. This capability shall be controlled remotely from each compartment.

DG-ECS-008. Automatic venting capability shall be provided in each habitable volume so that in the event of a fire or release of gases within the volume the pressure will not exceed the structural limits of the structure or the capability of the seals to other volumes to exclude the contaminated atmosphere.

DG-INT-009. Double contained toxic flammable or corrosive fluid containers shall be provided, with means to detect leakage of the toxic flammable or corrosive fluid into the volume in between the containers, and with means to detect penetration of the outside container.

DG-INT-010. Capability shall be provided to detect potential tank failures by measurement of fluid pressures, temperatures, tank strains, or other means.

DG-INT-011. The reflectance of surfaces of docking vehicles and the docking system that are visible to the controlling crew and TV cameras shall be below eye and vidicon damage levels.

DG-DUS-012. The vidicon tubes for docking shall be designed for low sensitivity to tube image burn.

DG-DUS-013. Redundant or replaceable lighting provisions shall be provided for docking.

DG-DUS-014. Redundant or replaceable vidicon tubes shall be provided for docking.

DG-DUS-015. Redundant or replaceable video monitors shall be provided.

DG-DUS-016. Docking system rapid emergency release capability shall be provided.

DG-DUS-017. The docking system shall be designed to withstand normal jackknifing vehicle dynamics and will limit attitude excursions to within prescribed limits as determined by space station geometry to prevent inadvertent contact from the docking vehicle.

DG-DUS-018. The docking system shall be capable of withstanding vehicle oscillations and loads generated by inadvertent attitude control system activity of either or both vehicles during draw down to rigidize the capture interface.

DG-INT-019. Thermal protection shall be provided to prevent jet plume impingement damage to the space station from docking vehicles within the design angular and linear misalignments.

DG-IFM-020. Capability shall be provided to recycle both capture and seal latches on the docking system from any phase of their status.

DG-INT-021. All hardware in the docking tunnel will be flush mounted to interior walls of the cargo/crew transfer tunnel.

DG-MSE-022. Stops shall be provided on hatches to prevent uncontrolled opening if opened when a pressure differential exists.

DG-DUS-023. All docking interface equipment shall be grounded.

DG-DUS-024. At the docking ports, all electrical umbilicals shall be grounded until connection of the docking interface.

DG-INT-025. Capability shall be provided for the emergency shirtsleeve survival of all on-board personnel until the next resupply or emergency shuttle flight following the loss of access to any one module/compartment. A shirtsleeve accessible docking port shall be available. If the loss of the habitable volume divides the space station into two or more isolated habitable sections, then each section shall provide the survival capability for all on-board personnel, including an available docking port.

DG-INT-026. A backup EVA egress/ingress hatch which can be used for contingency EVA shall be available. Capability for depressurization and repressurization of the connecting habitable volume shall be provided.

DG-INT-027. An emergency IVA or EVA return route shall be available for any planned IVA activity independent of the normal IVA airlock route. Depressurization and repressurization capability shall be provided for the additional volumes which must be used.

DG-CSE-028. Emergency portable life support systems shall be available in the airlock sufficient to sustain IVA personnel in an emergency IVA or EVA return from planned IVA or EVA activity.

DG-COM-029. Communication between any and all habitable/isolatable volumes on a primary and backup basis shall be provided.

DG-EPG-030. Adequate venting of batteries shall be provided to prevent contamination, overpressure or explosion.

DG-FSE-031. All filters, screens or other devices used to collect contaminants or waste products shall be designed so they can be easily serviced or replaced without releasing contaminants into the atmosphere.

DG-C&W-032. An audible and visual alarm shall be provided to warn the crew of habitable volume CO2 partial pressure not within the prescribed limits for crew safety. This alarm shall be provided both in the affected habitable volumes and at the command and control center(s).

DG-EPD-033. Equipment, including electrical wiring, that could become contaminated or damaged by leaking propellants shall be located to prevent contact with possible leakage or shall be provided with suitable protection.

DG-INT-034. Means shall be provided for collecting and/or containing any loose fluids or debris that may result during replacement of system conponents.

DG-FSE-035. Fluid systems shall have provisions for shutting off the flow of fluid to sections of the system or equipment which are susceptible to damage or leakage.

DG-FSE-036. All orifices, close tolerance valves and contamination-sensitive equipment in fluid systems, shall be adequately protected from contamination. Futhermore, if the system is designed for periodic flow reversal, or a possibility exists that flow reversal can occur, both sides of these items shall be protected.

DG-CME-037. Food supplies shall be stored in more than one storage container.

DG-CME-038. A means for sterilizing containers where food is stored shall be provided.

DG-CME-039. Food supplies which require cooling or refrigeration shall be protected by a redundant capability.

DG-HMS-040. Means for controlling insects in the space station shall be provided. The control method should be harmless to men and equipment.

DG-INT-041. The use of mercury on-board space stations should be prohibited.

DG-ECS-042. Provision shall be made for the removal of ozone generated by X ray equipment or electrical arcs.

DG-FSE-043. The number of connectors used to connect plumbing or components in fluid systems should be kept to a minimum.

DG-FSE-044. Safety requirements for all subsystems/experiments/internal payloads are needed.

DG-FSE-045. Fluids required for operation of subsystems located in habitable volumes shall be non-toxic, non-flammable, and non-corrosive.

DG-INT-046. Pressurized containers should not be installed in normally habitable volumes. When installed externally to normally habitable volumes, shrapnel shields shall be provided to protect the normally habitable volumes.

DG-C&W-047. Visual and audible alarm shall be provided to warn the crew of atmosphere contamination which exceeds the limits established for crew safety. This alarm shall be provided at a minimum in the affected habitable volume and at the command and control center(s).

DG-C&W-048. Where the possibility exists that a fluid in a system could become contaminated, means shall be provided to detect contamination and provide an alarm at the command and control center(s).

DG-C&W-049. A system shall be provided to monitor the environmental status of all potentially hazardous (explosive, flammable, toxic, etc.) materials stored on-board the space station, and display a warning signal in the command and control center(s) when established limits are exceeded.

DG-C&W-050. A warning and alarm system shall be provided to alert the crew of atmosphere relative humidity levels which are not within prescribed limits, with the warning displayed at the command and control center(s).

DG-ECS-051. Provisions shall be made for containing, venting or eliminating odors and bacteria generated by waste products and other sources.

DG-ECS-052. The composition of the space station water supply shall be checked at regular intervals to ensure that contamination does not exceed prescribed limits.

DG-CWS-053. A capability shall be provided for maintaining the sterility of on-board water supplies.

DG-CWS-054. Water storage systems shall have provisions for isolating parts of the system which may have become contaminated.

DG-CWS-055. Water supplies shall be stored in areas which will minimize the possibility of contamination from other space station systems.

DG-INT-056. System components shall be designed to withstand the overpressure and heat pulse attendant to meteroid penetration.

DG-ECS-057. Materials used for insulation or filler in space station walls shall be non-combustible.

DG-IFM-058. Windows shall be designed to permit replacement without degrading the pressure or structural integrity of the space station.

DG-STR-059. Individual habitable volumes shall be designed to withstand a rapid decompression of any adjacent compartment.

DG-STR-060. Space station structure shall be designed as a structural matrix with the capability of arresting crack and tear growth.

DG-INT-061. Equipment located in habitable volumes shall be designed to create no hazard to occupants during the changing environment associated with rapid decompression of the space station.

DG-MSE-062. Automatic closure of hatches between habitable volumes, when pressure decreases below a specified limit, should be considered as a design feature.

DG-OPS-063. Hatches between compartments should be closed except when required for crew transit.

DG-C&W-064. A means shall be provided for visual inspection of the hatch as well as the warning system, a safety check to assure that hatches or other accesses to an area at a different pressure level have been secured properly. Warning system displays shall be at the hatch and at the command and control center(s).

DG-MSE-065. Pressure hatches providing access to an area of differential pressure should be of a type that becomes more positively engaged under pressure loading.

DG-ECS-066. Hatch design should be such that loss of a hatch seal element will not result in a pressure leakage rate which exceeds the emergency recompression system capability.

DG-INT-067. Provision should be made for an airlock in the hatch or hatchway between separately pressurizable compartments.

DG-INT-068. A leakage repair system employing techniques and equipment appropriate to the vacuum and gravity environment of the space station shall be provided as a kitable part of the damage control system.

DG-HMS-069. Consideration should be given to providing the equipment and supplies necessary for general cardiopulmonary resuscitation and other equipment and supplies that might be required for the individualized treatment of residual effects of decompression.

DG-FSE-070. All pressure relief valves shall be designed to protect against a regulator failed or stuck in the full open position.

DG-FSE-071. Plumbing systems which carry cryogenic fluids or hydrogen peroxide should be designed such that adequate pressure relief capability exists in those areas most likely to trap the fluids. Furthermore, to guard against the possibility that a relief valve in these systems becomes frozen shut or otherwise rendered inoperative, a backup pressure relief device, such as burst disks, should be incorporated.

DG-INT-072. All pressure systems should be designed to enable a planned depressurization; accurate sensors should be incorporated to ensure that the pressure is totally relieved prior to opening the system should that requirement arise for maintenance or other reasons.

DG-ECS-073. Any pressurizable volume that can be confined or isolated by any means, such as by valves, should include some means for automatic protection from overpressure.

DG-FSE-074. Pressurized gas supplies should include restrictions that will limit gas flow in the event of a pressurized gas plumbing failure, to that which can be handled by the relief valves or venting system.

DG-IFM-075. Design of space station structure and equipment, including their interfaces, should be such that all portions of the pressure shell, bulkheads and seals will be accessible for damage inspection and repair. This should apply to exterior as well as interior space station surfaces.

DG-INT-076. Potentially harmful effects on the crew members of rapid decompression should be minimized through engineering considerations in selection of space station atmosphere composition, pressure and habitable compartment net volume.

DG-STR-077. The space station shall be of sufficient structural strength to safely maintain the required internal pressure within the expected launch and mission environment for the period of orbital stay.

DG-IFM-078. Components which are vented to space (vacuum) shall be replaceable without requiring cabin depressurization.

DG-IFM-079. Cabin pressure shall not be vented to space through compartments or outlets that are used to vent fluids.

DG-ECS-080. Pressure relief devices for all pressurized volumes shall be vented to areas that will not endanger the crew or equipment.

DG-ECS-081. All cabin atmosphere overboard relief or "dump" valves (any valve venting into space) shall be fail-safe in the closed position and should be self-indicating when failed. Manual override or redundant manual valving should be provided as backup.

DG-C&W-082. Total cabin pressure sensors shall be provided to detect out-of-tolerance values of the total cabin pressure. Detection of pressure change at an excessive rate, or outside the desired operating range, should activate an alarm system to warn the crew to initiate appropriate remedial action. The alarm should be activated both in the affected habitable volume and at the command and control center(s).

DG-C&W-083. All pressure warning systems shall include provisions for self-test and shall be self-indicating in the failed state.

DG-EPD-084. Wire bundles shall be routed and protected as to preclude damage to the insulation through flexing or bumping.

DG-EPD-085. Suitable positive means, such as keying, shall be provided to preclude accidental mismating of electrical connectors. This would be especially significant for connectors which are to be connected and disconnected during orbital operations (e.g., experiments).

DG-EPD-086. Consideration should be given to the design of electrical subsystem components (e.g., wall switches, light bulbs, or hot plates) to protect them from wear-out or inadvertent breakage, which could result in generating shorts or arcing.

DG-INT-087. Enclosed air duct systems that include potential sources of atmosphere contamination should provide sensors immediately downstream of the contamination source, which, if activated, would shut off the airflow through this equipment and provide a visual and audible alarm at the command and control center(s).

DG-ECS-088. Active redundancy should be provided for equipment which is essential to the control and detection of atmosphere contaminants.

DG-EPD-089. All temporary electrical connections (outlets, connectors, etc.) shall be so designed and/or operated as to eliminate the possibility of arcing.

DG-EPD-090. Wire bundles should not be located near potential heat sources, including those areas where potential for fire exists.

DG-EPD-091. Provisions should be made to ensure proper pin connection at all critical electrical connectors prior to the application of system power. Verification should be made to ensure that all pin connections exist as designed, no pin-to-pin shorts exist, and that no pin-to-shell shorts exist.

DG-INT-092. All equipment and substructure shall be grounded to the basic space station.

DG-INT-093. A means should be provided to equalize electric potential differences between docking spacecraft.

DG-EPD-094. Multiple power distribution paths to essential electrical equipment should be provided.

DG-C&W-095. Sensors shall be provided to detect out-of-tolerance values for critical electrical power source parameters, such as voltage, frequency, current, temperature, etc., or momentary excessive power surges resulting from ...ent turn-on or turn-off. The sensors should activate an alarm system at ...nd and control center(s) of deviations from the desired parameters.

...PG-096. Multiple or redundant primary electrical power sources shall ...ed such that a single failure will not result in a complete loss of prim... electrical power, or cause failure of equipment which is unable to survive momentary power interruption.

DG-EPD-097. Protective covers shall be provided for all portions of the electrical subsystem to which access is required (switch boards, terminal boards, etc.).

DG-EPD-098. Redundant electrical circuits for items critical to crew safety should not be included in the same wire bundle.

DG-EPD-099. Power distribution lines should be routed in such a manner that any damage resulting from fire, caused by a fault in the distribution system, will have a minimal effect on other power distribution wires in the vicinity.

DG-OPS-100. Procedures should be established and means provided the crew for controlling and/or eliminating contamination that is in excess of the ECS capability to control on a timely basis.

DG-ECS-101. Redundant CO2 removal equipment with capability of manual override of automatic operation should be provided to ensure a continuous capability to keep the CO2 partial pressure within allowable limits.

DG-ECS-102. The amount of toxic or potentially toxic materials (such as materials or chemicals utilized in experiments) on-board the space station should be limited such that accidental release of the total quantity of the material will not produce contamination above the capability of the environmental control system to remove on a timely basis.

DG-HMS-103. Threshold Limit Values (TLV's) of contaminants for long term human exposure should be established for space station environments.

DG-OPS-104. Strict configuration control procedures should be established over all materials incorporated in or brought on-board he spacecraft.

DG-OPS-105. The original orbital flight path selection and changes required by station-keeping during the mission should be such that the probability of collision with man-made debris or other spacecraft is sufficiently low to provide adequate confidence in orbit selection and program decision to proceed.

DG-CPH-106. All bulk cargo should be properly tethered or otherwise controlled during zero-gravity or partial gravity operations.

DG-OPS-107. Procedures and equipment should be available for use in event of death of a crew member.

DG-HMS-108. Procedures and equipment should be provided for the preservation or disposal of the remains of deceased experimental plants or animals.

DG-OPS-109. The program of selection, training, mission support, physical conditioning, daily activities, and recreation should insure that crew members remain confident in the mission and their roles in it.

DG-HMS-110. Procedures and equipment should be provided for restraint and control of irrational crew members.

DG-HMS-111. Unauthorized personnel should be restricted from using radiation-producing equipment or handling and using on-board radioisotopes. Consider the installation of appropriate caution signs and/or other means of warning, featuring visible or audible signals.

DG-HMS-112. Safe procedures should be established for the disposal of radioactive waste or radiation-contaminated material. The procedures should also include the actions necessary for the disposal of a spent or failed nuclear power reactor.

DG-HMS-113. On-board handling and use of radioactive material or radiation-producing equipment should conform or be consistent with established NASA and Nuclear Regulatory Commission policy and procedures for radiation protection standards.

DG-HMS-114. Positive protective measures should be taken to prevent accidental exposure to personnel from RF or X-radiation.

DG-EPG-115. Nuclear powered electrical power sources should be located and shielded to protect crew members from accumulating excessive radiation dosage.

DG-HMS-116. Crew location during the nuclear power unit activation should be restricted to refuge areas affording high protective shielding, until radiation levels have been checked in all habitable areas within the space station and have been found to be within acceptable limits.

DG-NUC-117. Space station installed/residing active nuclear reactor shall provide fail-operational/fail-safe measures for emergency shutdown of a reactor and provide alternate methods of reactor heat dissipation in event of failure of the primary cooling system.

DG-RSD-118. The space station radiation protection provisions shall be consistent with the orbital flight path type, orbital height, and inclination selected.

DG-CPH-119. Space station design and layout should make maximum use of any on-board mass as radiation shielding.

DG-RSD-120. Protection of the space station crew against the effects of a nuclear device explosion in space that releases radiation into the space station's orbital path should be considered.

DG-C&W-121. The location and characteristics of the radiation detectors should be consistent with the expected radiation environment.

DG-INT-122. Radiation effects upon space station electronic materials, microelectronic circuit elements, electrical systems, metals, ceramics, polymers, and other organic and inorganic materials should be thoroughly investigated for radiation-induced transient and permanent effects in terms of false signals, degradation, catastrophic failures, and contamination.

DG-OPS-123. In low-inclination (up to 60 degrees), low altitude orbits, Extra-Vehicular Activity should not be scheduled while the space station is passing through the South Atlantic Anomaly. For polar orbit, the same guideline applies. In addition, the occurrence of a solar event should require that EVA be avoided.

DG-OPS-124. A mission radiation control program should be instituted to develop radiation exposure limits, procedures, design criteria, and responsibilities consistent with the expected mission environment and period of orbital stay.

DG-HMS-125. A cumulative radiation exposure record should be kept on each crew member, and personnel who have reached the limit of safe radiation exposure should be returned to earth without delay.

DG-INT-126. Provision should be made in the space station for a designated shelter that would serve as a haven for radiation protection against possible high-intensity radiation events. This shelter should contain the necessary life support equipment and provisions consistent with the maximum expected stay time for the particular mission profile.

DG-HMS-127. Space station radiation monitoring, including cumulative radiation level records, should be maintained to ensure the precise determination and provide clear notification of radiation conditions, and warning of possible over-irradiation of the space station.

DG-C&W-128. The space station detection system should continuously monitor the interior and exterior radiation levels and record the accumulated dosage for the mission.

DG-RSD-129. Additional protection for crew members performing EVA in the proximity of a nuclear power source should be provided.

DG-INT-130. Precautions should be taken in the selection of spacecraft materials to ensure that the materials will not support induced radiation.

DG-OPS-131. Maintenance procedures for CO2 control equipment should take into account the possible high operating temperatures of the equipment and the possibility of release of contaminants.

DG-OPS-132. The storage and disposal of combustible waste materials should be such that a fire hazard or traffic obstruction is not created.

DG-INT-133. Flame arrestors should be provided in all ducting through which flame could propagate.

DG-INT-134. Cryogenic piping systems should provide for both automatic and manual emergency shutoff.

DG-EPG-135. Adequate cooling capability should be provided to prevent overheating of electrical power sources even during worst-case conditions.

DG-INT-136. Power generating and distribution equipment which is a potential source of fire should be located in unpressurized areas in the space station.

DG-INT-137. Fire control equipment and/or methods should be provided which can be automatically initiated, or are readily accessible and can be manually controlled.

DG-INT-138. Electrical insulation should be, as a minimum, self-extinguishing in the space station atmosphere.

DG-INT-139. Power equipment racks and cables should be as resistant to fire as possible. Emergency equipment and casualty mode/damage control operations should be developed.

DG-INT-140. All fluid lines should be adequately protected from freezing due to proximity to cryogenics, or exposure to black space.

DG-INT-141. Heating elements which must be exposed to the atmosphere should be provided with a device to prevent the propagation of flame.

DG-C&W-142. Areas where radioactive materials are used or stored should be monitored for radioactive contamination, and suitable warnings provided if radioactivity exceeds established limits.

DG-INT-143. Components which could generate excessive heat due to friction should be automatically monitored for temperature increase and sealed from the atmosphere. An overheat warning signal should be provided.

DG-INT-144. The amounts of hypergolic, pyrophoric, or other easily ignitable materials on board the space station should be restricted to the minimum necessary, and close control should be exercised over their handling and use.

DG-INT-145. Potential ignition sources, such as lighted cigarettes or open flames, etc., should not be permitted within the pressurized inhabited compartment of the space station unless rigid control can be exercised to insure that a fire hazard is not present.

DG-INT-146. If absence of oxygen is utilized as a means of preventing fires, design should provide that no single failure could produce an oxygen atmosphere.

DG-INT-147. Passageways should be kept free of all combustible materials and oxidizers.

DG-MSE-148. Lubricants used in mechanical components which are essential for survival should be capable of withstanding extreme temperatures.

DG-ECS-149. A capability for manually controlling operation of equipment used for cabin and equipment temperature control should be considered.

DG-EPD-150. Current limiting devices or techniques should be used to preclude hazardous overcurrents. Devices should be readily accessible, provide visible indication of their state, and be resistant to inadvertent or accidental de-activiation, fire, explosion, shock and explosive decompression. They should provide protection both to the current source and to the "using" equipment.

DG-INT-151. Design provisions should be made which assure that no heated surfaces would provide a source of injury to crew members or provide a source of ignition.

DG-FSE-152. Propellant supply system equipment and plumbing which uses toxic or potentially flammable fluids should be located in uninhabited areas.

DG-INT-153. Equipment which has a critical temperature requirement should be protected by redundant or alternate temperature control capability.

DG-INT-154. Materials which are capable of self-propagation of fire should not be on-board the space station in sufficient quantities or concentrations that ignition would result in a hazardous condition.

DG-ECS-155. Valves for oxygen systems of 3000 PSI or higher should be slow opening and closing to minimize the possibility of ignition of contaminants.

DG-ECS-156. Space station thermal protection provisions should be consistent with the orbital flight path, orbital height, and inclination selected.

DG-ECS-157. Thermal control equipment whose operation is critical to crew safety should have redundancy provided.

DG-ECS-158. Temperature sensors should be provided at critical points in thermal control systems to detect out-of-tolerance temperatures. Detection of temperatures which deviate from the normal range should activate an alarm system to warn the crew of the need for remedial action.

DG-INT-159. Procedures should be established and design safeguards provided that will preclude operation of thrusters when it might endanger crew members involved in EVA.

DG-AOM-160. Sensors should be provided to monitor the temperature of attitude control thruster assemblies. The sensors should activate visual and/or audible alarm at the command and control center(s).

DG-AOM-161. Angular rates of the space station should be continuously monitored during attitude change maneuvers. Detection of excessive angular rates should result in automatic/controlled shutdown of operating thrusters.

DG-AOM-162. An automatic system for controlling thrusters to restore a tumbling space station's stability should be provided.

DG-AOM-163. Redundancy should be provided for all components that are located outside pressurized inhabited areas and failure of which could result in a loss of attitude control.

DG-AOM-164. The attitude maintenance system should have the capability to counteract the undesired motion imparted by fluid escaping through a hole in a compartment or pressure vessel.

DG-AOM-165. Interlocks should be provided to prevent simultaneous manual and automatic operation of the attitude control system.

DG-AOM-166. A means for stopping propellant flow to failed OPEN thrusters should be provided.

DG-INT-167. Outlets should be designed so that fluids being vented overboard do not impose any torque on the spacecraft.

DG-FSE-168. Propellants should be stored in more than one tank or other storage device.

DG-INT-169. Accessways between and within compartments should be sized in such a manner that an IVA-suited crew member will be allowed to access to normally used areas.

DG-STR-170. Hatches should be capable of being operated from either side and at least two methods for operating the hatches should be provided.

DG-ECS-171. Space station airlocks should have redundant pressurization capability.

DG-INT-172. An alternate command and control center should be provided in the space station, possibly within the crew refuge area, to ensure continuation of a minimum number of functions which are vital for base control and crew life support, in the event the primary command and control center is rendered incapable of providing these functions.

DG-INT-173. Capability should be provided to allow entry into a compartment, where fire or other emergency exists, to effect rescue of incapacitated crew members or to combat a fire. The means of entry and the procedures involved should assure that the emergency does not escalate or spread to other locations in the space station.

DG-OPS-174. Mission rules should include the requirement that control center "authority to proceed" be obtained immediately prior to the initiation (by any crewmember) of any activity which is hazardous either by itself, or when performed in conjunction with other base activities being conducted simultaneously.

DG-C&W-175. Closed circuit television system with strategically located cameras should provide command and control center operator(s) real-time visual information on hazardous activities/operations.

DG-OPS-176. Simultaneous occupancy (other than momentary) by the space station commander and his deputy, of those compartments or locations which are judged to have the highest safety risk probability, should be minimized.

DG-COM-177. Equipment in the space station for external voice and data communications should have as much commonality as practicable with the equipment used in the logistics vehicles and earth-return vehicles.

DG-AOM-178. Continuous indication of space station attitude or attitude changes should be provided to the command and control center(s).

DG-OPS-179. Crew activity should be restricted during transfer of volatile, flammable, or explosive materials either between docked spacecraft, the logistics vehicle, or within the space station. These restrictions should apply to the use of high voltage equipment, conduct of high temperature experiments, or other activity which would involve a potential source of ignition in the immediate neighborhood of the material transfer route.

DG-OPS-180. The number of crew members in any compartment at one time should be held to a minimum necessary to perform the required functions.

DG-OPS-181. Crew members should be restricted from movement about the station other than within specified and assigned areas.

DG-INT-182. The areas in which the crew spends most of its time (staterooms, dining facilities, personal hygiene areas, exercise and recreation areas) should be designed as the safest parts of the space station.

DG-C&W-183. Critical visual/audible C&W alarms should be displayed in all inhabited compartments.

DG-COM-184. An independent emergency communications system should be provided for directing and controlling operational activities in emergency situations.

DG-OPS-185. A sufficient number of logistics and/or rescue vehicles should be docked to the space station at all times to accomodate every on-board crew member in the event that emergency evacuation is required.

DG-COM-186. Independent emergency communications should be provided to assist EVA personnel in performing their tasks or to facilitate rescue of EVA personnel.

DG-EPD-187. Emergency lighting system should be provided to assist EVA personnel in performing their task or to facilitate rescue of EVA personnel.

DG-OPS-188. Periodic drills for all personnel should be devised, and conducted in response to unscheduled simulated emergencies, so that crew proficiency is maintained in emergency procedures.

DG-OPS-189. "Fire Resistant" areas should be established to provide haven from fire. Emergency procedures should be established to identify such things as optimum routes to haven from any area, and all personnel should be trained in these procedures.

DG-OPS-190. Procedures should be established and training provided to the crew which will enable them to cope with any foreseeable contingency that might arise during EVA.

DG-C&W-191. An adequate fire warning system should be provided. The warning should be activated by smoke or fumes, as well as heat, and should warn the entire space station. The precise location of the fire should be provided to the command and control center(s). All segments of the warning system should be resistant to temperature extremes, decompression/overpressure or shock and should be self-indicating when failed.

DG-FSE-192. A means for monitoring fluid quantity usage should be provided to permit the crew to detect excessive consumption rates and low remaining supply levels.

DG-C&W-193. The commencement, behavior, and completion of all remote hazardous resupply operations (pressurized liquid or gas resupply) should be positively indicated at the command and control center(s).

DG-OPS-194. Overall health and safety responsibilities should be assigned to specific members of the crew with alternates.

DG-OPS-195. Procedures should include the provisions for abort for all incoming vehicles having an on-board emergency which would jeopardize the space station.

DG-EPG-196. An emergency power source which is completely independent of the primary power source should be provided.

DG-OPS-197. An initial advanced manning team should check habitability of the space station prior to duty crew manning.

DG-COM-198. A visual warning should be provided to the command center(s) when any link of the space station communication system fails.

DG-COM-199. At least one intercommunications station should be provided for each separately pressurizable space station compartment that can be occupied by the crew.

DG-INT-200. The maintenance equipment, procedures and skills required to completely analyze and isolate component failures and accomplish the needed replacement or repair should be provided.

DG-C&W-201. Critical subsystems of docked transient vehicles should be continuously monitored in the space station command and control center(s), with appropriate warnings for out-of-tolerance conditions.

DG-OPS-202. All EVA and IVA suited activities shall be backed up and monitored by a suited crew member who is in a position to provide immediate assistance.

DG-OPS-203. A periodic, two-way communications check should be made by the command and control center with all elements that comprise the space station. A "no communications" period would automatically intiate space station emergency procedures.

DG-OPS-204. Armable subsystems that comprise the space station and its docked vehicles should be armed only when they are to be used and immediately disarmed when their function is no longer required.

DG-INT-205. The pressurized compartments of a space station should have adequate free volume (not occupied by equipment or structure) to provide the crew freedom of movement and a psychological and physiological environment that is commensurate with their orbital stay duration.

DG-C&W-206. Leak detectors should be provided for propellant handling equipment located in unpressurized areas of the space station. The detectors should activate an alarm at the command and control center(s).

DG-INT-207. Replacement components should be designed so that it is impossible to inadvertently install the component incorrectly.

DG-INT-208. Universally sized, minimum time to don or place, survival devices should be made available to the crew.

DG-INT-209. All switches should be designed and located so that the possibility of inadvertent activation or improper selection is minimized.

DG-MSE-210. Design of mechanisms shall minimize the number of moving parts or other maintenance task generators.

DG-FSE-211. Small clearances in fluid system should be avoided where fluid entrained particulants could cause binding or jamming of system components.

DG-STR-212. Hatch design shall avoid seal abrading in normal operation.

DG-STR-213. Provisions shall be made for moisture removal between transparency panes.

APPENDIX-E
SPACE STATION
RELIABILITY REQUIREMENTS
(Assumed)

Redundancy

1. All subsystems shall be designed to be fail operational/fail safe restorable as a minimum (except primary structure and pressure vessels) during all operational phases except during assembly and during scheduled/unscheduled maintenance/repair. During assembly and during scheduled/unscheduled maintenance/repair, all subsystems shall be designed to be fail safe as a minimum.

2. Critical functions (i.e., those related to crew safety or space station permanence) shall have backup or workaround modes.

3. Redundant functional paths or subsystems shall be designed so that their operational status can be verified without removal of ORU's. In addition, these redundant functional paths of subsystem shall be designed so that their operational status can be verified in flight to the maximum extent possible. As a minimum, these shall provide capability for redundancy management in the event of a malfunction of a functional path and shall provide information to the crew regarding redundancy status of the affected system sufficient to determine if a failure occurred. Critical redundant items whose failure cannot be detected during flight shall be identified in the individual space station critical items list. Redundancies within a functional path shall be so designed that their operational status can be verified prior to each installation into the vehicle.

4. Alternate or redundant means of performing a critical function shall be physically separated or protected at least to the extent of separating the first means from the alternate means, such that an event which causes the loss of one means from the alternate means, such that an event which causes the loss of one means of performing the function will not result in the loss of alternate or redundant means.

5. Redundant components susceptible to contamination or environmental failure causes such as shock, vibration, acceleration or heat loads shall be physically oriented or separated to reduce the chance of multiple failure from the same cause(s).

6. Repair, service, or checkout of a functional path, including deactivation, shall not degrade the specified redundancy level.

7. For reliability design purposes, a redundant path deactivation for maintenance or repair shall be considered a failure.

8. Redundant equipment, lines, cables, and utility runs which are critical for safety of personnel or continued facility operation shall be routed in separate compartments (i.e., separated by a structural wall) or protected against fire, smoke, contamination, overpressurization, and shrapnel.

9. For systems/subsystems using redundant or alternate functional paths, the following requirements apply.

   a. Redundant paths shall be electrically and physically separated to the extent that an event that causes the loss of one means will not cause the loss of an alternate or redundant means.
   b. Notification of loss of redundacy shall be automatically provided to the crew via caution and warning alert signals.

10. Isolation of anomalies or critical functions shall be provided such that a faulty subsystem element can be deactivated either automatically or manually without disrupting or interrupting alternate or redundant functional paths. Capability to fault-isolate to the line replaceable unit or group of units without disconnections or use of carry-on equipment, shall be provided.

11. System hardware shall be designed to minimize the use of special tools and equipment for maintenance or repair. If special tools are required, and have been authorized, they shall have a life of 10 years minimum.

12. The operational design life goal shall be a minimum of 10 years with scheduled maintenance limited to calibration and to replacment of consumables and hardware whose life is limited by wear or aging.

Avionics

13. All avionics systems/subsystems shall be designed such that any two nonsimultaneous failures (allowing sufficient time for automatic reconfiguration or reconfiguration by the crew) can be detected, isolated, and repairs accomplished without the loss of a mission or compromising system safety.

14. Space station avionics and subsystem electrical components shall meet all the safety and performance requirements when exposed to the as-installed electromagnetic environment from all sources.

15. All electronics containing high density integrated circuitry shall survive repetitive single event state changes caused by ionizing radiation environments of the space station.

Mechanical

16. Primary structures shall be designed to preclude failure by adequate safety factors and relief provisions. Pressure vessels shall also use design safety factors and relief provisions as well as being built to leak rather than explode.

17. Provisions shall be made for arming explosive devices as near to the time of expected use as is feasible. Provisions shall be made to promptly disarm explosive devices when no longer needed.

Definition

Fail-Operational - The ability to sustain a failure and retain full operational capability for mission continuation.
Fail-Safe - The ability to sustain a failure and retain the capability to successfully terminate the mission. For GSE, the ability to sustain a failure without causing loss of vehicles system(s) or loss of personnel capability.

Additional definition of terms:
Mission Termination -

a. For equipment operating in space away from but using the space station as its base is safe return of crew and vehicle to the space station.
b. For the space station is the establishment of safe haven mode of operation for crew and station.
c. For space station end-of-life is the safe removal of the crew and safe disposal of the space station.

Restorable is the ability to repair-replace a failed system or system element prior to the start of a catastrophic sequence of events.

1. Report No. NASA CR-3857	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Space Station Crew Safety Alternatives Study - Final Report. Volume IV - Appendices		5. Report Date June 1985
		6. Performing Organization Code
7. Author(s) R. L. Peercy, Jr., R. F. Raasch, and L. A. Rockoff		8. Performing Organization Report No. SSD84-0053
		10. Work Unit No.
9. Performing Organization Name and Address Rockwell International, Space Station Systems Division, 12214 Lakewood Blvd., Downey, Ca. 90241		11. Contract or Grant No. NAS1-17242
		13. Type of Report and Period Covered Contractor Report
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration, Washington, DC 20546		14. Sponsoring Agency Code 906-54-02

15. Supplementary Notes

Langley Technical Monitor: Robert D. Witcofski
Final Report

16. Abstract

The scope of this study considered the first 15 years of accumulated space station concepts for Initial Operational Capability (IOC) during the early 1990's. Twenty-five threats to the space station are identified and selected threats addressed as impacting safety criteria, escape and rescue, and human factors safety concerns. Of the 25 threats identified, eight are discussed including strategy options for threat control: fire, biological or toxic contamination, injury/illness, explosion, loss of pressurization, radiation, meteoroid penetration and debris. This report consists of five volumes as noted:

Vol. I - Final Summary Report (NASA CR-3854)
Vol. II - Threat Development (NASA CR-3855)
Vol. III - Safety Impact of Human Factors (NASA CR-3856)
Vol. IV - Appendices (NASA CR-3857)
Vol. V - Space Station Safety Plan (NASA CR-3858)

17. Key Words (Suggested by Author(s)) Threats, Hazards, Strategies, Safety Assessment, Human Factors, Safety Criteria, Safety Guidelines, Safety Tasks	18. Distribution Statement Unclassified - Unlimited. Subject Category 15

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	112	A06

For sale by the National Technical Information Service, Springfield, Virginia 22161

NASA-Langley, 1985