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Extravehicular Activity Systems: 1994-2004

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Extra Vehicular Systems: 1994-2004

A Custom Bibliography From the
NASA Scientific and Technical Information Program

October 2004

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OCTOBER 2004

20040102922

The Soviet-Russian space suits a historical overview of the 1960's

Skoog, A. Ingemar, Author; Abramov, Isaac P., Author; Stoklitsky, Anatoly Y., Author; Doodnik, Michail N., Author; Acta astronautica; Jul-Nov 2002; ISSN 0094-5765; Volume 51, 1-9; In English; Copyright; Avail: Other Sources

The development of protective suits for space use started with the Vostok-suit SK-1, first used by Yu. Gagarin on April 12, 1961, and then used on all subsequent Vostok-flights. The technical background for the design of these suits was the work on full pressure protective suits for military pilots and stratospheric flights in the 1930's through 50's. The Soviet-Russian space programme contains a large number of 'firsts', and one of the most well known is the first EVA by Leonov in 1965. This event is also the starting point for a long series of space suit development for Extravehicular Activities over the last 35 years. The next step to come was the transfer in void space of crew members between the two spacecraft Soyuz 4 and 5 in 1969. As has later become known this was an essential element in the planned Soviet lunar exploration programme, which in itself required a new space suit. After the termination of the lunar programme in 1972, the space suit development concentrated on suits applicable to zero-gravity work around the manned space stations Salyut 6, Salyut 7 and MIR. These suits have become known as the ORLAN-family of suits, and an advanced version of this suit (ORLAN-M) will be used on the International Space Station together with the American EMU. This paper covers the space suit development in the Soviet Union in the 1960's and the experience used from the pre-space era. c2002 Published by Elsevier Science Ltd.

NLM

Extravehicular Activity; Histories; Life Support Systems; Space Suits; U.S.S.R. Space Program; Weightlessness

20040102921

Long-term operation of 'Orlan' space suits in the 'Mir' orbiting station: experience obtained and its application

Abramov, I. P., Author; Glazov, G. M., Author; Svertshek, V. I., Author; Acta astronautica; Jul-Nov 2002; ISSN 0094-5765; Volume 51, 1-9; In English; Copyright; Avail: Other Sources

The started assembly of the International Space Station (ISS) and its further operation will call for a great number of extravehicular activity sorties (EVA) to be performed by ISS crews. Therefore, of great importance is to make use of the EVA experience gained by cosmonauts in the process of 15-year operation of the Mir orbiting station (OS). Over the 15-year period, Mir crewmembers wearing Orlan type semi-rigid space suits have accumulated 158 man/sorties from the orbiting station. Crewmembers used 15 suits in orbit and some of the suits were in operation for more than 3 years. The paper presents principal design features, which provide effective and safe operation of orbit-based suits, and briefly describes procedures for preparation and maintenance of suit systems, which ensure long-term operation of space suit in orbit. The paper gives results of the space suit modifications, presents suit performance characteristics and lists novel or upgraded components of the space suit and its systems. The paper also summarizes improvements in the Orlan type suits described in some earlier publications. They refer, in the first run, to the improvement of space suit operations characteristics and reliability, and the utilization of the Orlan type space suit in the ISS program. The paper analyses the experience gained and drawbacks detected and observations made, and gives statistical data on long-term space suit operations aboard the Mir station. The paper reviews certain problems in the process of EVAs performed from the station, and describes the ways of their solution as applied to the further utilization of the suit within the ISS program. c2002 International Astronautical Federation. Published by Elsevier Science Ltd. All rights reserved.

NLM

Extravehicular Activity; Life Support Systems; Space Suits; Weightlessness

20040102917

One hundred US EVAs: a perspective on spacewalks

Wilde, Richard C., Author; McBarron, James W 2nd, Author; Manatt, Scott A., Author; McMann, Harold J., Author; Fullerton, Richard K., Author; Acta astronautica; Jul-Nov 2002; ISSN 0094-5765; Volume 51, 1-9; In English; Copyright; Avail: Other Sources

In the 36 years between June 1965 and February 2001, the US human space flight program has conducted 100 spacewalks, or extravehicular activities (EVAs), as NASA officially calls them. EVA occurs when astronauts wearing spacesuits travel outside their protective spacecraft to perform tasks in the space vacuum environment. US EVA started with pioneering feasibility tests during the Gemini Program. The Apollo Program required sending astronauts to the moon and performing EVA to explore the lunar surface. EVA supported scientific mission objectives of the Skylab program, but may be best remembered for repairing launch damage to the vehicle and thus saving the program. EVA capability on Shuttle was initially planned to be a kit that could be flown at will, and was primarily intended for coping with vehicle return emergencies. The Skylab emergency and the pivotal role of EVA in salvaging that program quickly promoted Shuttle EVA to an essential element for achieving mission objectives, including retrieving satellites and developing techniques to assemble and maintain the International Space Station (ISS). Now, EVA is supporting assembly of ISS. This paper highlights development of US EVA capability within the context of the overarching mission objectives of the US human space flight program. c2002 International Astronautical Federation. Published by Elsevier Science Ltd. All rights reserved.

NLM

Extravehicular Activity; Life Support Systems; Weightlessness

20040102332

[A dynamic model of the extravehicular (correction of extravehicuar) activity space suit]

Yang, Feng, Author; Yuan, Xiu-gan, Author; Hang tian yi xue yu yi xue gong cheng = Space medicine & medical engineering; Dec 2002; ISSN 1002-0837; Volume 15, 6; In Chinese; Copyright; Avail: Other Sources

Objective. To establish a dynamic model of the space suit base on the particular configuration of the space suit. Method. The mass of the space suit components, moment of inertia, mobility of the joints of space suit, as well as the suit-generated torques, were considered in this model. The expressions to calculate the moment of inertia were developed by simplifying the geometry of the space suit. A modified Preisach model was used to mathematically describe the hysteretic torque characteristics of joints in a pressurized space suit, and it was implemented numerically basing on the observed suit parameters. Result. A dynamic model considering mass, moment of inertia and suit-generated torques was established. Conclusion. This dynamic model provides some elements for the dynamic simulation of the astronaut extravehicular activity.

NLM

Dynamic Models; Extravehicular Activity; Space Suits; Weightlessness

20040096965

[A robot measurement system for spacesuit joint torque]

Du, Li-Bin, Author; Gao, Xiao-Hui, Author; Liu, Hong, Author; Li, Tan-qiu, Author; Hang tian yi xue yu yi xue gong cheng = Space medicine & medical engineering; Jun 2003; ISSN 1002-0837; Volume 16, 3; In Chinese; Copyright; Avail: Other Sources

Objective: To measure the joint torque of spacesuit so as to evaluate its dynamic force/torque performance. Method: A method for measuring the spacesuit joint torque by use of robot technology was proposed in this paper. The design of the measuring strategy and measuring robot was put forward and a mathematical model of the system was given. Then the working space of the robot was analyzed. Result: The robot designed is light, compact, easy to operate, and has a large working space. Experimental results demonstrated the effectiveness of the measuring principle and the reliability of the measuring system. Conclusion: The system can satisfy the requirements of the spacesuit joint torque measurement.

NLM

Joints (Anatomy); Models; Robotics; Robots; Space Suits; Torque

20040096552

The Chameleon Suit--a liberated future for space explorers

Hodgson, Edward, Author; Gravitational and space biology bulletin : publication of the American Society for Gravitational and Space Biology; Jun 2003; ISSN 1089-988X; Volume 16, 2; In English; Copyright; Avail: Other Sources

Mankind’s spacefaring future demands the ability to work freely and frequently in space. Traditional spacesuit systems

burden both the spacefarer and the mission, limiting the extent to which this is possible. The spacefarer is burdened by a pressure suit designed for isolation from the environment and a life support system designed to replace everything our environment normally provides. The space mission is burdened by this equipment and the expendable materials to operate and maintain it. We aren't free to work in space as frequently, as long, or in all of the locations envisioned. The NASA Institute for Advanced Concepts (NIAC) has sponsored research on an alternative concept, the 'Chameleon Suit', that seeks to liberate future explorers and missions from these limitations. The Chameleon Suit system works with the environment in an adaptive fashion to minimize hardware and expendable materials. To achieve this, functions of the life support system are integrated with the pressure suit using emerging materials and design technology. Technologies under study include shape change polymers and electroemissive materials to modify heat transfer characteristics of the spacesuit 'skin' achieving thermoregulation analogous to that in natural biological systems. This approach was shown to be feasible for many space missions during the Phase 1 study program. The current Phase 2 program is investigating more aggressive concepts aimed at eliminating most of the hardware currently included in the spacesuit's life support backpack. This paper describes the concept, study results to date, and possible impacts on future human space exploration.
NLM
Biomimetics; Extravehicular Activity; Life Support Systems; Materials; Space Suits

20040088894

Life in extreme environments: how will humans perform on Mars?

Newman, D. J., Author; Gravitational and space biology bulletin : publication of the American Society for Gravitational and Space Biology; Jun 2000; ISSN 1089-988X; Volume 13, 2; In English; Copyright; Avail: Other Sources

This review of astronaut extravehicular activity (EVA) and the details of American and Soviet/Russian spacesuit design focuses on design recommendations to enhance astronaut safety and effectiveness. Innovative spacesuit design is essential, given the challenges of future exploration-class missions in which astronauts will be called upon to perform increasingly complex and physically demanding tasks in the extreme environments of microgravity and partial gravity.
NLM
Aerospace Medicine; Extravehicular Activity; Mars (Planet); Space Suits

20040087996

Skin microvascular flow during hypobaric exposure with and without a mechanical counter-pressure space suit glove

Tanaka, Kunihiko, Author; Waldie, James, Author; Steinbach, Gregory C., Author; Webb, Paul, Author; Tourbier, Dietmar, Author; Knudsen, Jeffrey, Author; Jarvis, Christine W., Author; Hargens, Alan R., Author; Aviation, space, and environmental medicine; Nov 2002; ISSN 0095-6562; Volume 73, 11; In English; Copyright; Avail: Other Sources

INTRODUCTION: Current space suits are rigid, gas-pressurized shells that protect astronauts from the vacuum of space. A tight elastic garment or mechanical-counter-pressure (MCP) suit generates pressure by compression and may have several advantages over current space suit technology. In this study, we investigated local microcirculatory effects produced with and without a prototype MCP glove. METHODS: The right hand of eight normal volunteers was studied at normal ambient pressure and during exposure to -50, -100 and -150 mm Hg with and without the MCP glove. Measurements included the pressure against the hand, skin microvascular flow, temperature on the dorsum of the hand, and middle finger girth. RESULTS: Without the glove, skin microvascular flow and finger girth significantly increased with negative pressure, and the skin temperature decreased compared with the control condition. The MCP glove generated approximately 200 mm Hg at the skin surface; all measured values remained at control levels during exposure to negative pressure. DISCUSSION: Without the glove, skin microvascular flow and finger girth increased with negative pressure, probably due to a blood shift toward the hand. The elastic compression of the material of the MCP glove generated pressure on the hand similar to that in current gas-pressurized space suit gloves. The MCP glove prevented the apparent blood shift and thus maintained baseline values of the measured variables despite exposure of the hand to negative pressure.
NLM
Anoxia; Atmospheric Pressure; Capillary Flow; Exposure; Gloves; Pressure; Skin (Anatomy); Space Suits

20040087466

Compression under a mechanical counter pressure space suit glove

Waldie, James M A., Author; Tanaka, Kunihiko, Author; Tourbier, Dietmar, Author; Webb, Paul, Author; Jarvis, Christine W., Author; Hargens, Alan R., Author; Journal of gravitational physiology : a journal of the International Society for Gravitational Physiology; Dec 2002; ISSN 1077-9248; Volume 9, 2; In English
Contract(s)/Grant(s): NAG9-1916; Copyright; Avail: Other Sources

Background: Current gas-pressurized space suits are bulky stiff shells severely limiting astronaut function and capability. A mechanical counter pressure (MCP) space suit in the form of a tight elastic garment could dramatically improve extravehicular activity (EVA) dexterity, but also be advantageous in safety, cost, mass and volume. The purpose of this study was to verify that a prototype MCP glove exerts the design compression of 200 mmHg, a pressure similar to the current NASA EVA suit. Methods: Seven male subjects donned a pressure measurement array and MCP glove on the right hand, which was placed into a partial vacuum chamber. Average compression was recorded on the palm, the bottom of the middle finger, the top of the middle finger and the dorsum of the hand at pressures of 760 (ambient), 660 and 580 mmHg. The vacuum chamber was used to simulate the pressure difference between the low breathing pressure of the current NASA space suits (approximately 200 mmHg) and an unprotected hand in space. Results: At ambient conditions, the MCP glove compressed the dorsum of the hand at 203.5 +/- 22.7 mmHg, the bottom of the middle finger at 179.4 +/- 16.0 mmHg, and the top of the middle finger at 183.8 +/- 22.6 mmHg. The palm compression was significantly lower (59.6 +/- 18.8 mmHg, p\h0.001). There was no significant change in glove compression with the chamber pressure reductions. Conclusions: The MCP glove compressed the dorsum of the hand and middle finger at the design pressure.
NLM
Extravehicular Activity; Gloves; Pressure Suits; Space Suits; Weightlessness

20040086020 NASA Langley Research Center, Hampton, VA, USA
Shuttle Spacesuit: Fabric/LCVG Model Validation
Wilson, J. W.; Tweed, J.; Zeitlin, C.; Kim, M.-H. Y.; Anderson, B. M.; Cucinotta, F. A.; Ware, J.; Persans, A. E.; [2001]; In English
Report No.(s): SAE Paper 01ICES-2372; Copyright; Avail: CASI; A01, Hardcopy

A detailed spacesuit computational model is being developed at the Langley Research Center for radiation exposure evaluation studies. The details of the construction of the spacesuit are critical to estimation of exposures and assessing the risk to the astronaut on EVA. Past evaluations of spacesuit shielding properties assumed the basic fabric lay-up (Thermal Micrometeoroid Garment, fabric restraints, and pressure envelope) and Liquid Cooling and Ventilation Garment (LCVG) could be homogenized as a single layer overestimating the protective properties over 60 percent of the fabric area. The present spacesuit model represents the inhomogeneous distributions of LCVG materials (mainly the water filled cooling tubes). An experimental test is performed using a 34-MeV proton beam and highresolution detectors to compare with model-predicted transmission factors. Some suggestions are made on possible improved construction methods to improve the spacesuit's protection properties.
Author
Space Suits; Mathematical Models; Space Shuttles; Extraterrestrial Radiation

20040084466 NASA Ames Research Center, Moffett Field, CA, USA
Inner Space and Outer Space: Pressure Suits & Life Support Systems for Space Workers
Webbon, Bruce; January 2004; In English, 21 Apr. 2004, Silverdale, WA, USA; No Copyright; Avail: CASI; A03, Hardcopy

This slide presentation presents an overview of work system requirements, extravehicular activity system evolution, key issues, future needs, and a summary. Key issues include pressure suits, life support systems, system integration, biomedical requirements, and work and mobility aids.
CASI
Extravehicular Activity; Life Support Systems; Space Suits

20040068092 NASA Johnson Space Center, Houston, TX, USA
Summary and Recommendations for Future Work, Chapter 12
Cucinotta, Francis A.; Shavers, Mark R.; Saganti, Premkumar B.; Miller, Jack; Radiation Protection Studies of International Space Station Extravehicular Activity Space Suits; See also Doc ID 20040031719; December 2003; In English; No Copyright; Avail: CASI; A01, Hardcopy

The safety of astronauts is the primary concern of all space missions. Space radiation has been identified as a major concern for ISS, and minimizing radiation risks during EVA is a principle component of NASA s radiation protection program. The space suit plays a critical role in shielding astronauts from EVA radiation exposures. In cooperation with the JSC Extravehicular Activity Project Office, and the Space Radiation Health Project Office, the NASA EMU and RSA Orlan space suits were taken to the LLUPTF for a series of measurements with proton and electron beams to simulate exposures during EVA operations. Additional tests with material layouts of the EMU suit sleeve were made in collaboration with NASA LaRC

at the LBNL 88-inch cyclotron and at the Brookhaven National Laboratory Alternating Gradient Synchrotron.
Derived from text
Astronauts; Extraterrestrial Radiation; Radiation Protection; Radiation Shielding; Space Suits; Recommendations

20040065983 Eril Research, Inc., San Rafael, CA, USA
Characterization of the Radiation Shielding Properties of U.S. and Russian Extravehicular Activity Suits, Chapter 4
Benton, E. R.; Benton, E. V.; Frank, A. L.; December 2003; In English; No Copyright; Avail: CASI; A03, Hardcopy

Reported herein are results from the Eril Research, Inc. (ERI) participation in the JSC-sponsored study characterizing the radiation shielding properties of the two types of space suit that astronauts are wearing during the EVA on-orbit assembly of ISS. Measurements using passive detectors were carried out to assess the shielding properties of the U.S. EMU Suit and the Russian Orlan-M suit during irradiations of the suits and a tissue-equivalent phantom to monoenergetic proton and electron beams at LLUMC. During irradiations of 6 MeV electrons and 60 MeV protons, absorbed dose as a function of depth was measured using TLDs exposed behind swatches of the two suit materials and inside the two EVA helmets. Considerable reduction in electron dose was measured behind all suit materials in exposures to 6 MeV electrons. Slowing of the proton beam in the suit materials led to an increase in dose measured in exposures to 60 MeV protons. During 232 MeV proton irradiations, measurements were made with TLDs and CR-39 PNTDs at five organ locations inside a tissue-equivalent phantom, exposed both with and without the two EVA suits. The EVA helmets produce a 13% to 27% reduction in total dose and a 0% to 25% reduction in dose equivalent when compared to measurements made in the phantom head alone. Differences in dose and dose equivalent between the suit and non-suit irradiations for the lower portions of the two EVA suits tended to be smaller. Proton-induced target fragmentation was found to be a significant source of increased dose equivalent, especially within the two EVA helmets, and average quality factor inside the EMU and Orlan-M helmets was 2% to 14% greater than that measured in the bare phantom head.
Author
Radiation Shielding; Extravehicular Mobility Units; Astronauts; Cosmonauts

20040065980 Loma Linda Univ., CA, USA
Proton and Electron Threshold Energy Measurements for Extravehicular Activity Space Suits, Chapter 2
Moyers, M. F.; Nelson, G. D.; Saganti, P. B.; December 2003; In English
Contract(s)/Grant(s): NCC9-79; No Copyright; Avail: CASI; A03, Hardcopy

Construction of ISS will require more than 1000 hours of EVA. Outside of ISS during EVA, astronauts and cosmonauts are likely to be exposed to a large fluence of electrons and protons. Development of radiation protection guidelines requires the determination of the minimum energy of electrons and protons that penetrate the suits at various locations. Measurements of the water-equivalent thickness of both US. and Russian EVA suits were obtained by performing CT scans. Specific regions of interest of the suits were further evaluated using a differential range shift technique. This technique involved measuring thickness ionization curves for 6-MeV electron and 155-MeV proton beams with ionization chambers using a constant source-to-detector distance. The thicknesses were obtained by stacking polystyrene slabs immediately upstream of the detector. The thicknesses of the 50% ionizations relative to the maximum ionizations were determined. The detectors were then placed within the suit and the stack thickness adjusted until the 50% ionization was reestablished. The difference in thickness between the 50% thicknesses was then used with standard range-energy tables to determine the threshold energy for penetration. This report provides a detailed description of the experimental arrangement and results.
Author
Protons; Electrons; Radiation Measurement; Extravehicular Mobility Units

20040065979 NASA Johnson Space Center, Houston, TX, USA
Introduction to Radiation Issues for International Space Station Extravehicular Activities, Chapter 1
Shavers, M. R.; Saganti, P. B.; Miller, J.; Cucinotta, F. A.; Radiation Protection Studies of International Space Station Extravehicular Activity Space Suits; See also Doc ID 20040031719; December 2003; In English; No Copyright; Avail: CASI; A03, Hardcopy

The International Space Station (ISS) provides significant challenges for radiation protection of the crew due to a combination of circumstances including: the extended duration of missions for many crewmembers, the exceptionally dynamic nature of the radiation environment in ISS orbit, and the necessity for numerous planned extravehicular activities (EVA) for station construction and maintenance. Radiation protection requires accurate radiation dose measurements and precise risk modeling of the transmission of high fluxes of energetic electrons and protons through the relatively thin shielding

provided by the space suits worn during EVA. Experiments and analyses have been performed due to the necessity to assure complete radiation safety for the EVA crew and thereby ensure mission success. The detailed characterization described of the material and topological properties of the ISS space suits can be used as a basis for design of space suits used in future exploration missions. In radiation protection practices, risk from exposure to ionizing radiation is determined analytically by the level of exposure, the detrimental quality of the radiation field, the inherent radiosensitivity of the tissues or organs irradiated, and the age and gender of the person at the time of exposure. During low Earth orbit (LEO) EVA, the relatively high fluxes of low-energy electrons and protons lead to large variations in exposure of the skin, lens of the eye, and tissues in other shallow anatomical locations. The technical papers in this publication describe a number of ground-based experiments that precisely measure the thickness of the NASA extravehicular mobility unit (EMU) and Russian Zvezda Orlan-M suits using medical computerized tomography (CT) X-ray analysis, and particle accelerator experiments that measure the minimum kinetic energy required by electrons and photons to penetrate major components of the suits. These studies provide information necessary for improving the understanding of the current ISS space suits and provide insights into improved approaches for the design of future suits. This chapter begins with a summary of the dynamic ionizing radiation environment in LEO space and introduces the concepts and quantities used to quantify exposure to space radiation in LEO. The space suits used for EVA and the experimental partial human phantom are described. Subsequent chapters report results from measured charged particle fields before and after incident protons and secondary particles are transported through the space suits and into organs and tissues.
Author
Radiation Protection; Extravehicular Mobility Units; Earth Orbital Environments

20040031719 NASA Johnson Space Center, Houston, TX, USA
Radiation Protection Studies of International Space Station Extravehicular Activity Space Suits
Cucinotta, Francis A., Editor; Shavers, Mark R., Editor; Saganti, Premkumar B., Editor; Miller, Jack, Editor; December 2003; In English
Report No.(s): NASA/TP-2003-212051; S-904; No Copyright; Avail: CASI; A09, Hardcopy

This publication describes recent investigations that evaluate radiation shielding characteristics of NASA's and the Russian Space Agency's space suits. The introduction describes the suits and presents goals of several experiments performed with them. The first chapter provides background information about the dynamic radiation environment experienced at ISS and summarized radiation health and protection requirements for activities in low Earth orbit. Supporting studies report the development and application of a computer model of the EMU space suit and the difficulty of shielding EVA crewmembers from high-energy reentrant electrons, a previously unevaluated component of the space radiation environment. Chapters 2 through 6 describe experiments that evaluate the space suits' radiation shielding characteristics. Chapter 7 describes a study of the potential radiological health impact on EVA crewmembers of two virtually unexamined environmental sources of high-energy electrons-reentrant trapped electrons and atmospheric albedo or 'splash' electrons. The radiological consequences of those sources have not been evaluated previously and, under closer scrutiny. A detailed computational model of the shielding distribution provided by components of the NASA astronauts' EMU is being developed for exposure evaluation studies. The model is introduced in Chapters 8 and 9 and used in Chapter 10 to investigate how trapped particle anisotropy impacts female organ doses during EVA. Chapter 11 presents a review of issues related to estimating skin cancer risk form space radiation. The final chapter contains conclusions about the protective qualities of the suit brought to light form these studies, as well as recommendations for future operational radiation protection.
Author
Extravehicular Activity; International Space Station; Radiation Protection; Extraterrestrial Radiation; Extravehicular Mobility Units

20040016058 NASA Ames Research Center, Moffett Field, CA, USA
Requirements Development Issues for Advanced Life Support Systems: Solid Waste Management
Levri, Julie A.; Fisher, John W.; Alazraki, Michael P.; Hogan, John A.; [2002]; In English, 15-18 Jul. 2002, San Antonio, TX, USA; Original contains black and white illustrations
Contract(s)/Grant(s): NAS9-19100; 131-20-01
Report No.(s): SAE-02ICES-76; Copyright; Avail: CASI; A02, Hardcopy

Long duration missions pose substantial new challenges for solid waste management in Advanced Life Support (ALS) systems. These possibly include storing large volumes of waste material in a safe manner, rendering wastes stable or sterilized for extended periods of time, and/or processing wastes for recovery of vital resources. This is further complicated because future missions remain ill-defined with respect to waste stream quantity, composition and generation schedule. Without

definitive knowledge of this information, development of requirements is hampered. Additionally, even if waste streams were well characterized, other operational and processing needs require clarification (e.g. resource recovery requirements, planetary protection constraints). Therefore, the development of solid waste management (SWM) subsystem requirements for long duration space missions is an inherently uncertain, complex and iterative process. The intent of this paper is to address some of the difficulties in writing requirements for missions that are not completely defined. This paper discusses an approach and motivation for ALS SWM requirements development, the characteristics of effective requirements, and the presence of those characteristics in requirements that are developed for uncertain missions. Associated drivers for life support system technological capability are also presented. A general means of requirements forecasting is discussed, including successive modification of requirements and the need to consider requirements integration among subsystems.
Author
Life Support Systems; Solid Wastes; Technology Utilization; Systems Engineering; Waste Management

20040015105 NASA Ames Research Center, Moffett Field, CA, USA
Solid Waste Management Requirements Definition for Advanced Life Support Missions: Results
Alazraki, Michael P.; Hogan, John; Levri, Julie; Fisher, John; Drysdale, Alan; [2002]; In English, 15-18 Jul. 2002, San Antonio, TX, USA; Original contains black and white illustrations
Contract(s)/Grant(s): NAS9-19100; 131-20-10; Copyright; Avail: CASI; A02, Hardcopy

Prior to determining what Solid Waste Management (SWM) technologies should be researched and developed by the Advanced Life Support (ALS) Project for future missions, there is a need to define SWM requirements. Because future waste streams will be highly mission-dependent, missions need to be defined prior to developing SWM requirements. The SWM Working Group has used the mission architecture outlined in the System Integration, Modeling and Analysis (SIMA) Element Reference Missions Document (RMD) as a starting point in the requirement development process. The missions examined include the International Space Station (ISS), a Mars Dual Lander mission, and a Mars Base. The SWM Element has also identified common SWM functionalities needed for future missions. These functionalities include: acceptance, transport, processing, storage, monitoring and control, and disposal. Requirements in each of these six areas are currently being developed for the selected missions. This paper reviews the results of this ongoing effort and identifies mission-dependent resource recovery requirements.
Author
Solid Wastes; Waste Management; Space Missions; Technology Utilization; Life Support Systems

20030063917 NASA Johnson Space Center, Houston, TX, USA
Description of 103 Cases of Hypobaric Sickness from NASA-sponsored Research
Conkin, Johnny; Klein, Jill S.; Acock, Keena E.; July 2003; In English
Report No.(s): NASA/TM-2003-212052; NAS 1.15:212052; No Copyright; Avail: CASI; A06, Hardcopy

One hundred and three cases of hypobaric decompression sickness (DCS) are documented, with 6 classified as Type II DCS. The presence and grade of venous gas emboli (VGE) are part of the case descriptions. Cases were diagnosed from 731 exposures in 5 different altitude chambers from 4 different laboratories between the years 1982 and 1999. Research was funded by NASA to develop operational prebreathe (PB) procedures that would permit safe extravehicular activity from the Space Shuttle and International Space Station using an extravehicular mobility unit (spacesuit) operated at 4.3 psia. Both vehicles operate at 14.7 psia with an ‘air’ atmosphere, so a PB procedure is required to reduce nitrogen partial pressure in the tissues to an acceptable level prior to depressurization to 4.3 psia. Thirty-two additional descriptions of symptoms that were not diagnosed as DCS together with VGE information are also included. The information for each case resides in logbooks from 32 different tests. Additional information is stored in the NASA Decompression Sickness Database and the Prebreathe Reduction Protocol Database, both maintained by the Environmental Physiology Laboratory at the Johnson Space Center. Both sources were reviewed to provide the narratives that follow.
Author
Decompression Sickness; Extravehicular Activity; Extravehicular Mobility Units; Space Suits; Aeroembolism

20030056700 Massachusetts Inst. of Tech., Cambridge, MA, USA
Quantifying Astronaut Tasks: Robotic Technology and Future Space Suit Design
Newman, Dava; May 30, 2003; In English; Original contains color and black and white illustrations
Contract(s)/Grant(s): NAG9-1089; No Copyright; Avail: CASI; A04, Hardcopy

The primary aim of this research effort was to advance the current understanding of astronauts’ capabilities and limitations

in space-suited EVA by developing models of the constitutive and compatibility relations of a space suit, based on experimental data gained from human test subjects as well as a 12 degree-of-freedom human-sized robot, and utilizing these fundamental relations to estimate a human factors performance metric for space suited EVA work. The three specific objectives are to: 1) Compile a detailed database of torques required to bend the joints of a space suit, using realistic, multi- joint human motions. 2) Develop a mathematical model of the constitutive relations between space suit joint torques and joint angular positions, based on experimental data and compare other investigators' physics-based models to experimental data. 3) Estimate the work envelope of a space suited astronaut, using the constitutive and compatibility relations of the space suit. The body of work that makes up this report includes experimentation, empirical and physics-based modeling, and model applications. A detailed space suit joint torque-angle database was compiled with a novel experimental approach that used space-suited human test subjects to generate realistic, multi-joint motions and an instrumented robot to measure the torques required to accomplish these motions in a space suit. Based on the experimental data, a mathematical model is developed to predict joint torque from the joint angle history. Two physics-based models of pressurized fabric cylinder bending are compared to experimental data, yielding design insights. The mathematical model is applied to EVA operations in an inverse kinematic analysis coupled to the space suit model to calculate the volume in which space-suited astronauts can work with their hands, demonstrating that operational human factors metrics can be predicted from fundamental space suit information.
Derived from text
Human Factors Engineering; Extravehicular Activity; Space Suits; Astronauts; Robotics

20030033907 NASA Langley Research Center, Hampton, VA, USA
Analysis of a Radiation Model of the Shuttle Space Suit
Anderson, Brooke M.; Nealy, John E.; Kim, Myung-Hee; Qualls, Garry D.; Wilson, John W.; March 2003; In English
Contract(s)/Grant(s): RTOP 732-50-00-01
Report No.(s): NASA/TP-2003-212158; NAS 1.60:212158; L-18235; Copyright; Avail: CASI; A03, Hardcopy

The extravehicular activity (EVA) required to assemble the International Space Station (ISS) will take approximately 1500 hours with 400 hours of EVA per year in operations and maintenance. With the Space Station at an inclination of 51.6 deg the radiation environment is highly variable with solar activity being of great concern. Thus, it is important to study the dose gradients about the body during an EVA to help determine the cancer risk associated with the different environments the ISS will encounter. In this paper we are concerned only with the trapped radiation (electrons and protons). Two different scenarios are looked at: the first is the quiet geomagnetic periods in low Earth orbit (LEO) and the second is during a large solar particle event in the deep space environment. This study includes a description of how the space suit's computer aided design (CAD) model was developed along with a description of the human model. Also included is a brief description of the transport codes used to determine the total integrated dose at several locations within the body. Finally, the results of the transport codes when applied to the space suit and human model and a brief description of the results are presented.
Author
Radiation Dosage; Space Suits; Radiation Protection; Trapped Particles; Human Beings; Models

20030017891 Beijing Univ. of Aeronautics and Astronautics, Beijing, China
A Dynamic Model of the Extravehicular Activity Space Suit
Yang, Feng; Yuan, Xiu-Gan; Space Medicine and Medical Engineering; December 2002; ISSN 1002-0837; Volume 15, No. 6; In Chinese; Copyright; Avail: Other Sources

The objective of this research was to establish a dynamic model of the space suit base on the particular configuration of the space suit. The mass of the space suit components, moment of inertia, mobility of the joints of space suit, as well as the suit-generated torques, were considered in this model. The expressions to calculate the moment of inertia were developed by simplifying the geometry of the space suit. A modified Preisach model was used to mathematically describe the hysteretic torque characteristics of joints in a pressurized space suit, and it was implemented numerically basing on the observed suit parameters. A dynamic model considering mass, moment of inertia and suit-generated torques was established. This dynamic model provides some elements for the dynamic simulation of the astronaut extravehicular activity.
Author
Dynamic Models; Extravehicular Activity; Space Suits

20030004254 NASA Johnson Space Center, Houston, TX USA
An Illumination Modeling System for Human Factors Analyses
Huynh, Thong; Maida, James C.; Bond, Robert L., Technical Monitor; [2002]; In English; CAES 99: Computer-Aided Ergonomics and Safety Meeting, 19-21 May 1999, Barcelona, Spain
Contract(s)/Grant(s): NRA-95-OLMSA-01; No Copyright; Avail: CASI; A02, Hardcopy

Seeing is critical to human performance. Lighting is critical for seeing. Therefore, lighting is critical to human performance. This is common sense, and here on earth, it is easily taken for granted. However, on orbit, because the sun will rise or set every 45 minutes on average, humans working in space must cope with extremely dynamic lighting conditions. Contrast conditions of harsh shadowing and glare is also severe. The prediction of lighting conditions for critical operations is essential. Crew training can factor lighting into the lesson plans when necessary. Mission planners can determine whether low-light video cameras are required or whether additional luminaires need to be flown. The optimization of the quantity and quality of light is needed because of the effects on crew safety, on electrical power and on equipment maintainability. To address all of these issues, an illumination modeling system has been developed by the Graphics Research and Analyses Facility (GRAF) and Lighting Environment Test Facility (LETF) in the Space Human Factors Laboratory at NASA Johnson Space Center. The system uses physically based ray tracing software (Radiance) developed at Lawrence Berkeley Laboratories, a human factors oriented geometric modeling system (PLAID) and an extensive database of humans and environments. Material reflectivity properties of major surfaces and critical surfaces are measured using a gonio-reflectometer. Luminaires (lights) are measured for beam spread distribution, color and intensity. Video camera performances are measured for color and light sensitivity. 3D geometric models of humans and the environment are combined with the material and light models to form a system capable of predicting lighting conditions and visibility conditions in space.
Author
Human Factors Engineering; Illuminating; Test Facilities; Mathematical Models; Computer Graphics; Computer Systems Programs

20030002666 NASA Johnson Space Center, Houston, TX USA
Work and Fatigue Characteristics of Unsuited and Suited Humans During Isolated, Isokinetic Joint Motions
Gonzalez, L. Javier; Maida, James C.; Miles, Erica H.; Rajulu, S. L.; Pandya, A. K.; Russo, Dane M., Technical Monitor; [2001]; In English
Contract(s)/Grant(s): NRA-96-HEDS-05; No Copyright; Avail: Other Sources; Abstract Only

The effects of a pressurized suit on human performance were investigated. The suit is known as an Extra-vehicular Mobility Unit (EMU) and is worn by astronauts while working outside of their space craft in low earth orbit. Isolated isokinetic joint torques of three female and three male subjects (all experienced users of the suit) were measured while working at 100% and 80% of their maximum voluntary torque (MVT). It was found that the average decrease in the total amount of work done when the subjects were wearing the EMU was 48% and 41% while working at 100% and 80% MVT, respectively. There is a clear relationship between the MVT and the time and amount of work done until fatigue. In general the stronger joints took longer to fatigue and did more work than the weaker joints. However, it is not clear which joints are most affected by the EMU suit in terms of the amount of work done. The average amount of total work done increased by 5.2% and 20.4% for the unsuited and suited cases, respectively, when the subject went from working at 100% to 80% MVT. Also, the average time to fatigue increased by 9.2% and 25.6% for the unsuited and suited cases, respectively, when the subjects went from working at 100% to 80% MVT. The EMU also decreased the joint range of motion. It was also found that the experimentally measured torque decay could be predicted by a logarithmic equation. The absolute average error in the predictions was found to be 18.3% and 18.9% for the unsuited and suited subject, respectively, working at 100% MVT, and 22.5% and 18.8% for the unsuited and suited subject, respectively, working at 80% MVT. These results could be very useful in the design of future EMU suits, and planning of Extra-Vehicular Activit). (EVA) for the upcoming International Space Station assembly operations.
Author
Extravehicular Activity; Extravehicular Mobility Units; Astronauts; Torque; Joints (Anatomy); Human Performance; Fatigue (Biology)

20030002655 NASA Johnson Space Center, Houston, TX USA
Predicting Strength and Fatigue for Suited and Unsuited Conditions from Empirical Data
Maida, James C.; Gonzalez, L. J.; Rajulu, S.; Russo, Dane M., Technical Monitor; [2001]; In English; Bioastronautics Investigators' Workshop 2001, 2001, Galveston, TX, USA
Contract(s)/Grant(s): NRA-96-HEDS-05; No Copyright; Avail: Other Sources; Abstract Only

The need for longer and more labor-intensive extra-vehicular activities (EVA) is required for construction and maintenance of the International Space Station (ISS). Issues pertaining to human performance while wearing a space suit (EMU) for prolonged periods have become more important. This project was conducted to investigate how a pressurized

Extra-vehicular Mobility Unit (EMU) affects human upper body joint strength and fatigue and how to predict it from computer models based on the data collected.
Author
Extravehicular Activity; Extravehicular Mobility Units; Joints (Anatomy); Human Performance; Fatigue (Biology); Performance Prediction

20020086358 NASA Johnson Space Center, Houston, TX USA
STS-112 Crew Training Clip
Sep. 03, 2002; In English; 47 min. playing time, in color, with sound
Report No.(s): JSC-1927; NONP-NASA-VT-2002137513; No Copyright; Avail: CASI; B03, Videotape-Beta; V03, Videotape-VHS

Footage shows the crew of STS-112 (Jeffrey Ashby, Commander; Pamela Melroy, Pilot; David Wolf, Piers Sellers, Sandra Magnus, and Fyodor Yurchikhin, Mission Specialists) during several parts of their training. The video is arranged into short segments. In 'Topside Activities at the NBL', Wolf and Sellers are fitted with EVA suits for pool training. 'Pre-Launch Bailout Training in CCT II' shows all six crew members exiting from the hatch on a model of a shuttle orbiter cockpit. 'EVA Training in the VR Lab' shows a crew member training with a virtual reality simulator, interspersed with footage of Magnus, and Wolf with Melroy, at monitors. There is a 'Crew Photo Session', and 'Pam Melroy and Sandy Magnus at the SES Dome' also features a virtual reality simulator. The final two segments of the video involve hands-on training. 'Post Landing Egress at the FFT' shows the crew suiting up into their flight suits, and being raised on a harness, to practice rapelling from the cockpit hatch. 'EVA Prep and Post at the ISS Airlock' shows the crew assembling an empty EVA suit onboard a model of a module. The crew tests oxygen masks, and Sellers is shown on an exercise bicycle with an oxygen mask, with his heart rate monitored (not shown).
CASI
Space Shuttle Orbiters; Spacecrews; Astronaut Training; Extravehicular Mobility Units; Extravehicular Activity; Training Simulators

20020073485 NASA Johnson Space Center, Houston, TX USA
A Review of the Effects of Exposure of EMU Materials to Hypergolic Propellants in Space-Like Vacuum
Davis, Dennis D.; Baker, David L.; JANNAF 30th Propellant Development and Characterization Subcommittee Meeting; March 2002; Volume 1; In English; No Copyright; Avail: CPIA, 10630 Little Patuxent Pkwy., Suite 202, Columbia, MD 21044-3320

International Space Station and Shuttle operations have requirements for extra vehicular activities during which the extravehicular mobility unit (EMU) may be exposed to leaking hypergolic propellants. Compatibility testing of EMU materials with hypergolic propellants has been performed at the NASA White Sands Test Facility and other NASA sites to identify the effects of such exposures. This presentation is designed to review the key test results on the compatibility of EMU materials when exposed to hypergolic propellants in a space-like vacuum.
Author
Extravehicular Mobility Units; Hypergolic Rocket Propellants; Space Environment Simulation; Dimethylhydrazines; Destructive Tests; Exposure

20020052632 NASA Marshall Space Flight Center, Huntsville, AL USA
Minimum Arc Threshold Voltage Experiments on Extravehicular Mobility Unit Samples
Schneider, Todd; Hansen, Harold; Caruth, M. Ralph, Jr.; [2002]; In English, 13-17 Jan. 2002, Reno, NV, USA; No Copyright; Avail: Other Sources; Abstract Only

The International Space Station (ISS) is now under construction in Low Earth Orbit (LEO). The process of building the ISS requires that astronauts carry out many Extravehicular Activities. To protect the astronauts form the hazardous space environment, they are required to wear a suit known as the Extravehicular Mobility Unit (EMU). For most Extra-Vehicular Activities (EVAs) the EMU is tethered to ISS via a steel safety tether. During the course of an EVA it is common for the safety tether to contact exposed metal on both the ISS and the EMU. In this case, the single point ground of the EMU would be at the same potential as the ISS with respect to the LEO Plasma. In the event that the metal structure of the ISS begins to charge negative of the plasma potential as a result of electron collection by the ISS photovoltaic arrays, then the EMU would also be driven to a negative potential. Anodized aluminum components on the EMU would then begin to develop a charge across their amortization layer as ions from the plasma are collected. In the case where large negative potentials are applied to the

EMU, dielectric breakdown may occur as a large voltage difference is developed across the thin amortization layer (oxide). The resulting arc plasma may in turn couple to the charge accumulated on the nearby ISS anodized debris shields and thereby generate a large current flow through the metal EMU structure. Current flow through the EMU could result in an electrocution hazard for the Crew Member inside the EMU - and therefore represents an important safety concern. To address this concern, a series of experiments have been undertaken. In each experiment specially prepared anodized aluminum samples were placed in a LEO representative plasma and charged until dielectric breakdown occurred in the form of an arc. This process was repeated a number of times for three sets of samples. During each test the arc voltage and current were monitored. A statistical treatment of the arc voltage threshold will be presented. In addition, safe operating voltages for the EMU are suggested.
Author
Extravehicular Mobility Units; Photovoltaic Cells; Plasmas (Physics); Threshold Voltage; Plasma Potentials

20010106943 Institute of Space Medico-Engineering, Beijing, China
Appraisal and Analysis of Heat Removing Characteristic of Liquid Cooling Garment Using Thermal Manikin
Zhang, Wan-Xin; Chen, Jing-Shan; Li, Tan-Qiu; Zhao, Yong-Jun; Li, Zhi; Space Medicine and Medical Engineering; August 2001; ISSN 1002-0837; Volume 14, No. 4; In Chinese; Copyright; Avail: Other Sources

The objective of this research was to analyze the relation of the design parameters and appraise the heat removing characteristic of liquid cooling garment(LCG) using thermal manikin. To appraise the design of LCG, the thermal manikin wearing LCG and heat insulation garment was put in the temperature cabin, then the inlet and outlet temperature of cooling liquid in the LCG were measured and the heat removed was calculated. The relationship between the design parameters and beat removed, and also that between the design parameters and temperature ratio efficiency were found. And the beat removed was calculated. It provided a reasonable basis for appraisal of LCG. The design of the LCG for the EVA space suit was found to be reasonable. The flow rate regulation range was too narrow, and the change of heat removing capacity depended on the change of inlet temperature.
Author
Liquid Cooling; Space Suits; Design Analysis; Temperature Control; Temperature Ratio

20010023081 Baylor Coll. of Medicine, Houston, TX USA
Habitat Options to Protect Against Decompression Sickness on Mars
Conkin, J.; Concepts and Approaches for Mars Exploration; July 2000, Part 1; In English; No Copyright; Avail: CASI; A01, Hardcopy

Men and women are alive today, although perhaps still in diapers, who will explore the surface of Mars. Two achievable goals to enable this exploration are to use Martian resources, and to provide a safe means for unrestricted access to the surface. A cost-effective approach for Mars exploration is to use the available resources, such as water and atmospheric gases. Nitrogen (N2) and Argon (Ar) in a concentration ratio of 1.68/1.0 are available, and could form the inert gas component of a habitat atmosphere at 8.0, 9.0, or 10.0 pounds per square inch absolute (psia). The habitat and space suit must be designed as an integrated, complementary, system: a comfortable living environment about 85% of the time and a safe working environment about 15% of the time. A goal is to provide a system that permits unrestricted exploration of Mars. However the risk of decompression sickness (DCS) during the extravehicular activity (EVA) in a 3.75 psia suit after exposure to either of the three habitat conditions may limit unrestricted exploration.
Derived from text
Mars Exploration; Decompression Sickness; Space Suits; Mars Environment; Habitability

20010000394 NASA Marshall Space Flight Center, Huntsville, AL USA
Evaluation of a Human Modeling Software Tool in the Prediction of Extra Vehicular Activity Tasks for an International Space Station Assembly Mission
Dischinger, H. Charles; Loughead, Tomas E.; NASA University Research Centers Technical Advances in Education, Aeronautics, Space, Autonomy, Earth and Environment; February 1997; Volume 1; In English; CD-ROM contains the entire conference proceedings presented in PDF format
Report No.(s): URC97035; No Copyright; Avail: CASI; A01, Hardcopy; C01, CD-ROM

The difficulty of accomplishing work in extravehicular activity (EVA) is well documented. It arises as a result of motion constraints imposed by a pressurized spacesuit in a near-vacuum and of the frictionless environment induced in microgravity. The appropriate placement of foot restraints is crucial to ensuring that astronauts can remove and drive bolts, mate and demate connectors, and actuate levers. The location on structural members of the foot restraint sockets, to which the portable foot

restraint is attached, must provide for an orientation of the restraint that affords the astronaut adequate visual and reach envelopes. Previously, the initial location of these sockets was dependent upon the experienced designer's ability to estimate placement. The design was tested in a simulated zero-gravity environment; spacesuited astronauts performed the tasks with mockups while submerged in water. Crew evaluation of the tasks based on these designs often indicated the bolt or other structure to which force needed to be applied was not within an acceptable work envelope, resulting in redesign. The development of improved methods for location of crew aids prior to testing would result in savings to the design effort for EVA hardware. Such an effort to streamline EVA design is especially relevant to International Space Station construction and maintenance. Assembly operations alone are expected to require in excess of four hundred hours of EVA. Thus, techniques which conserve design resources for assembly missions can have significant impact. We describe an effort to implement a human modelling application in the design effort for an International Space Station Assembly Mission. On Assembly Flight 6A, the Canadian-built Space Station Remote Manipulator System will be delivered to the U.S. Laboratory. It will be released from its launch restraints by astronauts in EVA. The design of the placement of foot restraint sockets was carried out using the human model Jack, and the modelling results were compared with actual underwater test results. The predicted locations of the sockets was found to be acceptable for 94% of the tasks attempted by the astronauts, This effort provides confidence in the capabilities of this package to accurately model tasks. It therefore increases assurance that the tool maybe used early in the design process.
Author
Dynamic Models; Systems Engineering; Extravehicular Activity; Human Factors Engineering; Computer Programs; Man Machine Systems

20000096524 NASA Johnson Space Center, Houston, TX USA
Space Human Factors Engineering Challenges in Long Duration Space Flight
Garland, Daniel J.; Endsley, Mica R.; Ellison, June; Caldwell, Barrett S.; Mount, Frances E.; Bond, Robert L., Technical Monitor; [1999]; In English; Human Factors Engineering Challenges in Long Duration Space Flight, 27 Sep. - 1 Oct. 1999, Houston, TX, USA; No Copyright; Avail: Other Sources; Abstract Only

The focus of this panel is on identifying and discussing the critical human factors challenges facing long duration space flight. Living and working aboard the International Space Station (ISS) will build on the experience humans have had to date aboard the Shuttle and MIR. More extended missions, involving lunar and planetary missions to Mars are being planned. These missions will involve many human factors challenges regarding a number of issues on which more research is needed.
Author
Human Factors Engineering; International Space Station; Long Duration Space Flight; Manned Space Flight

20000081742 NASA Johnson Space Center, Houston, TX USA
Space Suit Thermal Dynamics
Campbell, Anthony B.; Nair, Satish S.; Miles, John B.; Iovine, John V.; Lin, Chin H.; [1998]; In English
Contract(s)/Grant(s): NAG9-915; PWC-260981; No Copyright; Avail: CASI; A03, Hardcopy

The present NASA space suit (the Shuttle EMU) is a self-contained environmental control system, providing life support, environmental protection, earth-like mobility, and communications. This study considers the thermal dynamics of the space suit as they relate to astronaut thermal comfort control. A detailed dynamic lumped capacitance thermal model of the present space suit is used to analyze the thermal dynamics of the suit with observations verified using experimental and flight data. Prior to using the model to define performance characteristics and limitations for the space suit, the model is first evaluated and improved. This evaluation includes determining the effect of various model parameters on model performance and quantifying various temperature prediction errors in terms of heat transfer and heat storage. The observations from this study are being utilized in two future design efforts, automatic thermal comfort control design for the present space suit and design of future space suit systems for Space Station, Lunar, and Martian missions.
Author
Dynamic Models; Thermal Comfort; Extravehicular Mobility Units; Temperature Control; Thermal Environments; Automatic Control

20000081720 NASA Johnson Space Center, Houston, TX USA
Terrestrial EVA Suit = Fire Fighter's Protective Clothing
Foley, Tico; Brown, Robert G.; Burrell, Eddie; DelRosso, Dominic; Krishen, Kumar; Moffitt, Harold; Orndoff, Evelyne; Santos, Beatrice; Butzer, Melissa; Dasgupta, Rajib, et al.; [1999]; In English, 12-15 Jul. 1999, Denver, CO, USA
Report No.(s): Rept-1999-01-1964; No Copyright; Avail: CASI; A02, Hardcopy

Firefighters want to go to work, do their job well, and go home alive and uninjured. For their most important job, saving lives, firefighters want protective equipment that will allow more extended and effective time at fire scenes in order to perform victim search and rescue. A team, including engineers at NASA JSC and firefighters from Houston, has developed a list of problem areas for which NASA technology and know-how can recommend improvements for firefighter suits and gear. Prototypes for solutions have been developed and are being evaluated. This effort will spin back to NASA as improvements for lunar and planetary suits.
Author
Protective Clothing; Technology Transfer; Fire Fighting; Extravehicular Activity; Space Suits

20000053485 NASA Johnson Space Center, Houston, TX USA
The Mars Project: Avoiding Decompression Sickness on a Distant Planet
Conkin, Johnny; May 2000; In English
Report No.(s): NASA/TM-2000-210188; S-863; NAS 1.15:210188; No Copyright; Avail: CASI; A04, Hardcopy

A cost-effective approach for Mars exploration is to use available resources, such as water and atmospheric gases. Nitrogen (N2) and argon (Ar) are available and could form the inert gas component of a habitat atmosphere at 8.0, 9.0, or 10.0 pounds per square inch (psia). The habitat and space suit are designed as an integrated system: a comfortable living environment about 85% of the time and a safe working environment about 15% of the time. A goal is to provide a system that permits unrestricted exploration of Mars, but the risk of decompression sickness (DCS) during the extravehicular activity in a 3.75-psia suit, after exposure to any of the three habitat conditions, may limit unrestricted exploration. I evaluate here the risk of DCS since a significant proportion of a trinary breathing gas in the habitat might contain Ar. I draw on past experience and published information to extrapolate into untested, multivariable conditions to evaluate risk. A rigorous assessment of risk as a probability of DCS for each habitat condition is not yet possible. Based on many assumptions about Ar in hypobaric decompressions, I conclude that the presence of Ar significantly increases the risk of DCS. The risk is significant even with the best habitat option: 2.56 psia oxygen, 3.41 psia N2, and 2.20 psia Ar. Several hours of prebreathing 100% 02, a higher suit pressure, or a combination of other important variables such as limited exposure time on the surface or exercise during prebreathe would be necessary to reduce the risk of DCS to an acceptable level. The acceptable level for DCS risk on Mars has not yet been determined. Mars is a great distance from Earth and therefore from primary medical care. The acceptable risk would necessarily be defined by the capability to treat DCS in the Rover vehicle, in the habitat, or both.
Author
Argon; Decompression Sickness; Gas Mixtures; Mars Exploration; Nitrogen; Oxygen; Space Suits; Habitats; Manned Mars Missions; Mars Atmosphere

20000032264 NASA Marshall Space Flight Center, Huntsville, AL USA
Comparison Of Human Modeling Tools For Efficiency Of Prediction Of EVA Tasks
Dischinger, H. Charles, Jr.; Loughead, Tomas E.; NASA University Research Centers Technical Advances in Aeronautics, Space Sciences and Technology, Earth Systems Sciences, Global Hydrology, and Education; Feb. 22, 1998; Volumes 2 and 3; In English
Report No.(s): 98URC030; No Copyright; Avail: CASI; A01, Hardcopy; C01, CD-ROM

Construction of the International Space Station (ISS) will require extensive extravehicular activity (EVA, spacewalks), and estimates of the actual time needed continue to rise. As recently as September, 1996, the amount of time to be spent in EVA was believed to be about 400 hours, excluding spacewalks on the Russian segment. This estimate has recently risen to over 1100 hours, and it could go higher before assembly begins in the summer of 1998. These activities are extremely expensive and hazardous, so any design tools which help assure mission success and improve the efficiency of the astronaut in task completion can pay off in reduced design and EVA costs and increased astronaut safety. The tasks which astronauts can accomplish in EVA are limited by spacesuit mobility. They are therefore relatively simple, from an ergonomic standpoint, requiring gross movements rather than time motor skills. The actual tasks include driving bolts, mating and demating electric and fluid connectors, and actuating levers; the important characteristics to be considered in design improvement include the ability of the astronaut to see and reach the item to be manipulated and the clearance required to accomplish the manipulation. This makes the tasks amenable to simulation in a Computer-Assisted Design (CAD) environment. For EVA, the spacesuited astronaut must have his or her feet attached on a work platform called a foot restraint to obtain a purchase against which work forces may be actuated. An important component of the design is therefore the proper placement of foot restraints.
Derived from text
Extravehicular Activity; Computerized Simulation; Human Factors Engineering; Astronauts; Computer Aided Design; Performance Prediction

20000031749 Beijing Univ., China

Research Progress of Thermal Control System for Extravehicular Activity Space Suit

Wu, Zhi-qiang; Yuan, Xiu-gan; Shen, Li-ping; Space Medicine and Medical Engineering; August 1999; ISSN 1002-0837; Volume 12, No. 4; In Chinese; Copyright; Avail: Other Sources; US Distribution and Sales Only

New research progress of thermal control system for oversea Extravehicular Activity (EVA)space suit is presented. Characteristics of several thermal control systems are analyzed in detail . Some research tendencies and problems are discussed, which are worthwhile to be specially noted. Finally, author's opinion about thermal control system in the future is put forward.

Author

Temperature Control; Extravehicular Activity; Space Suits

20000028289 Cornell Univ., Ithaca, NY USA

Extravehicular Activity Suit Systems Design: How to Walk, Talk, and Breathe on Mars

Barton, George; Cox, Akio; DeFlores, Lauren; Garber, Ari; Goldsmith, Randall; Lee, Brett; Mathews, Saemi; Diehl, Alison; Haenlein, Joel; Mitchell, Jonathan, et al.; Second Annual HEDS-UP Forum; 1999; In English; No Copyright; Avail: CASI; A03, Hardcopy

Design parameters for a Mars Extravehicular Mobility Unit (EMU) are different from current space shuttle and past Apollo EMU designs. This report derives functional requirements for the life support, communication, and power subsystems of a Mars EMU from the HEDS reference mission and Mars surface conditions and proposes a design that satisfies all of the currently understood functional requirements for each subsystem. Design for the life support system incorporates 02 storage, possible 02 production, C02 absorption, humidity control, thermal regulation, and radiation protection. The communication system design centers on a reconfigurable wireless network, virtual retinal display, and emergency locator beacons. Portable power options are analyzed, and Direct Methanol Liquid Feed Fuel cells are selected for use in a design that satisfies the power requirements. Mass, cost, and technological readiness are considered for each system. This paper concludes with a recommended combination of subsystem designs that combine to form the primary subsystems of a Mars EMU.

Author

Extravehicular Mobility Units; Functional Design Specifications; Life Support Systems; Mars Surface; Mars (Planet); Manned Mars Missions; Mars Exploration

20000027411 Science Applications International Corp., Houston, TX USA

Mars Surface Reference Mission, 1998 Excerpts, Appendix 1

Hoffman, Stephen; Mars Field Geology, Biology. and Paleontology Workshop: Summary and Recommendations; [1998], Appendix 1; In English; No Copyright; Avail: CASI; A03, Hardcopy

This presentation discusses the geological field work which will be the key objective to the Mars surface mission. Section one discusses one of the means by which the crew will get into the field, the use of the EVA in the vicinity of the outpost. Guidelines are given for the development of the EVA suit, and conduct of the EVA itself. The next section discusses the use of the unpressurized and pressurized rovers that will be used to transport the crew to sites which are too far to walk and that are of interest. The next section discusses the field camp which will be used for extended exploration of a site too distant to explore with the use of the rovers. The next section discusses mechanisms to evaluate the different toxic and biological hazards which the crew will possibly encounter in all phases of their mission. The methods for sample curation and storage is discussed next. The last section discusses some of the analytical capabilities that are likely to be used on the martian surface, including the possibility of handling biologically active samples.

CASI

Extravehicular Activity; Geology; Mars Surface; Roving Vehicles; Toxic Hazards; Manned Maneuvering Units; Astronaut Locomotion; Life Support Systems; Mars (Planet); Extravehicular Mobility Units; Mars Sample Return Missions

20000024934 Beijing Univ. of Aeronautics and Astronautics, Beijing, China

The Present Status and Development of Thermal Control System of Spacesuits for Extravehicular Activity

Zhao, Chao-Yi; Sun, Jin-Biao; Yuan, Xiu-Gan; Space Medicine and Medical Engineering; Apr. 1999; ISSN 1002-0837; Volume 12, No. 2; In Chinese

Report No.(s): CN-11-2774/R; No Copyright; Avail: CASI; A01, Hardcopy; US Distribution and Sales Only

With the extension of extravehicular activity(EVA) duration, the need for more effective thermal control of EVA spacesuits is required. The specific schemes investigated in heat sink system for EVA are discussed, including radiator, ice

storage, metal hydride heat pump, phase-change storage/radiator and sublimator. The importance and requirements of automatic thermal control for EVA are also discussed. Existing automatic thermal control for EVA are reviewed. Prospects of further developments of thermal control of spacesuits for EVA are proposed.
Author
Extravehicular Activity; Space Suits; Temperature Control; Cooling Systems; Heat Sinks; Thermal Absorption

20000005091 Stanford Univ., Stanford, CA USA
Modeling and Testing of Lightweight Mars Space Suit on Devon Island
Crawford, Sekou S.; Jun. 09, 1999; In English; No Copyright; Avail: CASI; A03, Hardcopy

In order for manned missions to Mars to be successful, a thorough investigation into new and existing planetary spacesua't designs must be carried out. Development of a suitable EVA suit will be a significant technological challenge. A primary concern is the excessive weight of existing planetary spacesuits. Mars has approximately 1/3 of the Earth's gravitational pull. Therefore, heavy suits will significantly hamper effective EVA operations. A new design proposed by research groups from Stanford University and Berkeley uses semi-permeable membranes as a passive thermal control system. This design replaces the bulky air-conditioning systems in more traditional spacesuit designs. This novel idea is only possible due to the unique Martian atmosphere and the normal way in which the human body regulates its own temperature via sweat. The suit has been shown to effectively control the body temperature on Mars using a heat-balance model that simulates astronaut and suit for various exploration scenarios. A similar model is used to explore the suit's ability to control body temperature in the Arctic on Earth. A strategy is explored in which the Stanford spacesuit design can be simulated and tested at the Devon Island Arctic Research Station. Assuming that the model provides adequate results, ways in which this promising new design can be successfully implemented in future missions to Mars will be discussed.
Author
Temperature Control; Space Suits; Mars Missions; Manned Space Flight; Human Body; Extravehicular Activity; Air Conditioning Equipment

19990117041 Beijing Univ. of Aeronautics and Astronautics, Beijing, China
Research Progress of Thermal Control System for Extravehicular Activity Space Suit
Wu, Zhi-Qiang; Shen, Li-Ping; Yuan, Xiu-Gan; Space Medicine and Medical Engineering; Aug. 1999; ISSN 1002-0837; Volume 12, No. 4; In Chinese
Report No.(s): CN-11-2774/R; No Copyright; Avail: CASI; A01, Hardcopy; US Distribution and Sales Only

New research progress of thermal control system for overseas Extravehicular Activity (EVA) space suit is presented. Characteristics of several thermal control systems are analyzed in detail. Some research tendencies and problems are discussed, which are worthwhile to be specially noted. Finally, author's opinion about thermal control system in the future is put forward.
Author
Temperature Control; Extravehicular Activity; Space Suits

19990111454 Science Applications International Corp., Houston, TX USA
Mars Surface Reference Mission: Excerpts, Appendix 1
Hoffman, Stephen; Mars Field Geology, Biology, and Paleontology Workshop: Summary and Recommendations; 1999; In English; No Copyright; Avail: CASI; A03, Hardcopy

This report has five sections. Examples described in the first section point out several guidelines for surface operations and for development of surface EVA suits and the equipment used by the crews while in these suits. The second section discussed the types of surface transportation that will be available to the crew and the variety of missions on which they can be deployed. The next section discusses the key mission objectives satisfied by and the functional capabilities of a remote field camp. The next section discusses the ongoing need for the crew to evaluate the level of toxicity of potential for biological activity throughout all phases of the surface mission. The next section discusses the curatorial activities which the astronaut crews will conduct while on the Martian surface. The last section discusses the sample examination and analytical capabilities that are likely to be used on the martian surface.
CASI
Mars Missions; Mars Surface; Mars Sample Return Missions; Manned Mars Missions; Return to Earth Space Flight; Topography; Mars (Planet); Planetary Geology; Bioastronautics; Space Suits

19990025825 NASA Johnson Space Center, Houston, TX USA

EVA Roadmap: New Space Suit for the 21st Century

Yowell, Robert; HEDS-UP Mars Exploration Forum; 1998; In English; No Copyright; Avail: CASI; A01, Hardcopy

New spacesuit design considerations for the extra vehicular activity (EVA) of a manned Martian exploration mission are discussed. Considerations of the design includes:(1) regenerable CO2 removal, (2) a portable life support system (PLSS) which would include cryogenic oxygen produced from in-situ manufacture, (3) a power supply for the EVA, (4) the thermal control systems, (5) systems engineering, (5) space suit systems (materials, and mobility), (6) human considerations, such as improved biomedical sensors and astronaut comfort, (7) displays and controls, and robotic interfaces, such as rovers, and telerobotic commands.

CASI

Astronauts; Carbon Dioxide Removal; Extravehicular Activity; Life Support Systems; Mars (Planet); Portable Life Support Systems; Roving Vehicles; Space Suits; Manned Mars Missions; Robotics; Exobiology; Oxygen Supply Equipment; Waste Management

19990025584 Montana State Univ., Bozeman, MT USA

More Favored than the Birds: The Manned Maneuvering Unit in Space, Chapter 13

Millbrooke, Anne; From Engineering Science to Big Science: The NACA and NASA Collier Trophy Research Project Winners; 1998; In English; No Copyright; Avail: CASI; A03, Hardcopy

The Manned Maneuvering Unit (MMU) gave astronauts the ability to maneuver in outer space, outside of the spacecraft free of tether lines. This allows the astronauts the freedom to engage in extravehicular activity independent of the constraints of a tether. Without the development of protective, pressurized suits capable withstanding the extremes of outer space, the manned maneuvering unit would not have been useful. Thus there is included in this essay, a description of the development of the space suits. The first use of the MMU was in 1984, and involved testing the unit for the rescue of the Solar Max satellite. The MMU has not been used since 1984. This is due in part because extravehicular activity has been as effective using tethers, safety grips, hand holds and other restraints. The development of the robotic arm has proved effective at retrieving errant satellites, and the MMU has not had a mission, or a customer.

CASI

Extravehicular Activity; Manned Maneuvering Units; Rescue Operations; Space Suits; Self Maneuvering Units

19990009917 NASA Johnson Space Center, Houston, TX USA

Thermal Vacuum Testing of the Crew and Equipment Translation Aid for the International Space Station

Blanco, Raul A.; Montz, Michael; Gill, Mark; 20th Space Simulation Conference: The Changing Testing Paradigm; Oct. 1998; In English; No Copyright; Avail: Other Sources; Abstract Only;

The Crew and Equipment Translation Aid (CETA) is a human powered cart that will aid astronauts in conducting extra-vehicular activity (EVA) maintenance on the International Space Station (ISS). There are two critical EVA tasks relevant to the successful operation of the CETA. These are the removal of the launch restraint bolts during its initial deployment from the Space Shuttle payload bay and the manual deceleration of the cart, its two onboard astronauts, and a payload. To validate the launch restraint and braking system designs, the hardware engineers needed to verify their performance in an environment similar to that in which it will be used. This environment includes the vacuum of low earth orbit and temperatures as low as -11O F and as high as +200 F. The desire for quantitative data, as opposed to subjective information which could be provided by a suited astronaut, coupled with test scheduling conflicts resulted in an unmanned testing scenario. Accommodating these test objectives in an unmanned test required a solution that would provide remotely actuated thermal vacuum compatible torque sources of up to 25 ft-lbs at four horizontally oriented and four vertically oriented bolts, a variable input force of up to 125 lbs at the four brake actuators, and thermal vacuum compatible torque and force sensors. The test objectives were successfully met in both the thermal Chamber H and the thermal vacuum Chamber B at NASA's Johnson Space Center.

Author

Space Environment Simulation; Extravehicular Activity; Astronaut Maneuvering Equipment; Thermal Vacuum Tests; Extravehicular Mobility Units

19980210008 NASA Johnson Space Center, Houston, TX USA

Understanding Skill in EVA Mass Handling, Volume 3, Empirical Developments and Conclusions

Riccio, Gary E.; McDonald, P. Vernon; Jul. 1998; In English

Contract(s)/Grant(s): RTOP 199-16-11-48

Report No.(s): NASA/TP-1998-3684/Vol-3; NAS 1.60:3684/Vol-3; S-827; No Copyright; Avail: CASI; A03, Hardcopy

Key attributes of skilled mass handling were identified through an examination of lessons learned by the extravehicular activity operational community. These qualities were translated into measurable quantities. The operational validity of the ground-based investigation was improved by building a device that increased the degrees of freedom of extravehicular mobility unit motion on the Precision Air-Bearing Floor. The results revealed subtle patterns of interaction between motions of an orbital replacement unit mockup and mass handler that should be important for effective performance on orbit. The investigation also demonstrated that such patterns can be measured with a variety of common instruments and under imperfect conditions of observation.

Author

Extravehicular Activity; Extravehicular Mobility Units; Mass; Human Behavior

19980206161 Alabama Univ., Tuscaloosa, AL USA

An Assessment of Molten Metal Detachment Hazards During Electron Beam Welding in the Space Shuttle Bay at LEO for the International Space Welding Experiment

Fragomeni, James M.; Oct. 1996; In English; No Copyright; Avail: CASI; A02, Hardcopy

In 1997, the USA [NASA] and the Paton Electric Welding Institute are scheduled to cooperate in a flight demonstration on the U.S. Space Shuttle to demonstrate the feasibility of welding in space for a possible repair option for the International Space Station Alpha. This endeavor, known as the International Space Welding Experiment (ISWE), will involve astronauts performing various welding exercises such as brazing, cutting, welding, and coating using an electron beam space welding system that was developed by the E.O. Paton Electric Welding Institute (PWI), Kiev Ukraine. This electron beam welding system known as the 'Universal Weld System' consists of hand tools capable of brazing, cutting, autogeneous welding, and coating using an 8 kV (8000 volts) electron beam. The electron beam hand tools have also been developed by the Paton Welding Institute with greater capabilities than the original hand tool, including filler wire feeding, to be used with the Universal Weld System on the U.S. Space Shuttle Bay as part of ISWE. The hand tool(s) known as the Ukrainian Universal Hand [Electron Beam Welding] Tool (UHT) will be utilized for the ISWE Space Shuttle flight welding exercises to perform welding on various metal alloy samples. A total of 61 metal alloy samples, which include 304 stainless steel, Ti-6AI-4V, 2219 aluminum, and 5456 aluminum alloys, have been provided by NASA for the ISWE electron beam welding exercises using the UHT. These samples were chosen to replicate both the U.S. and Russian module materials. The ISWE requires extravehicular activity (EVA) of two astronauts to perform the space shuttle electron beam welding operations of the 61 alloy samples. This study was undertaken to determine if a hazard could exist with ISWE during the electron beam welding exercises in the Space Shuttle Bay using the Ukrainian Universal Weld System with the UHT. The safety issue has been raised with regard to molten metal detachments as a result of several possible causes such as welder procedural error, externally applied impulsive forces(s), filler wire entrainment and snap-out, cutting expulsion, and puddle expulsion. Molten metal detachment from either the weld/cut substrate or weld wire could present harm to a astronaut in the space environment it the detachment was ti burn through the fabric of the astronaut Extravehicular Mobility Unit (EMC). In this paper an experimental test was performed in a 4 ft. x 4 ft. vacuum chamber at MSFC enabling protective garment to be exposed to the molten metal drop detachments to over 12 inches. The chamber was evacuated to vacuum levels of at least 1 x 10(exp -5) torr (50 micro-torr) during operation of the 1.0 kW Universal Hand Tool (UHT). The UHT was manually operated at the power mode appropriate for each material and thickness. The space suit protective welding garment, made of Teflon fabric (10 oz. per yard) with a plain weave, was placed on the floor of the vacuum chamber to catch the molten metal drop detachments. A pendulum release mechanism consisting of four hammers, each weighing approximately 3.65 lbs, was used to apply an impact forces to the weld sample/plate during both the electron beam welding and cutting exercises. Measurements were made of the horizontal fling distances of the detached molten metal drops. The volume of a molten metal drop can also be estimated from the size of the cut. Utilizing equations, calculations were made to determine chande in surafec area (Delat a(surface)) for 304 stainless steel for cutting based on measurements of metal drop sizes at the cut edges. For the cut sample of 304 stainless steel based on measurement of the drop size at the edge, Delta-a(surface) was determined to be 0.0054 2 in . Calculations have indicated only a small amount of energy is required to detach a liquid metal drop. For example, approximately only 0.000005 ft-lb of energy is necessary to detach a liquid metal steel drop based on the above theoretical analysis. However, some of the energy will be absorbed by the plate before it reaches the metal drop. Based on the theoretical calculations, it was determined that during a weld cutting exercise, the titanium alloy would be the most difficult to detach molten metal droplets followed by stainless steel and then by aluminum. The results of the experimental effort have shown that molten metal will detach if large enough of a hammer blow is applied to the weld sample plate during the full penetration welding and cutting exercises. However, no molten metal detachments occurred as a result of the filler wire snap-out tests from the weld puddle since it was too difficult to cause the metal to flick-out from the pool. Molten metal detachments, though not large in size, did result from the direct application of the electron beam on the end of the filler weld wire.

Derived from text

Electron Beam Welding; Liquid Metals; Space Suits; Alloys; Microgravity; Low Earth Orbits; Orbital Servicing; Detachment; Drops (Liquids)

19980206160 Texas A&M Univ., College Station, TX USA

Evaluation of an Anthropometric Human Body Model for Simulated EVA Task Assessment

Etter, Brad; Oct. 1996; In English; No Copyright; Avail: CASI; A02, Hardcopy

One of the more mission-critical tasks performed in space is extravehicular activity (EVA) which requires the astronaut to be external to the station or spacecraft, and subsequently at risk from the many threats posed by space. These threats include, but are not limited to: no significant atmosphere, harmful electromagnetic radiation, micrometeoroids, and space debris. To protect the astronaut from this environment, a special EVA suit is worn which is designed to maintain a sustainable atmosphere (at 1/3 atmosphere) and provide protection against the hazards of space. While the EVA suit serves these functions well, it does impose limitations on the astronaut as a consequence of the safety it provides. Since the astronaut is in a virtual vacuum, any atmospheric pressure inside the suit serves to pressurize the suit and restricts mobility of flexible joints (such as fabric). Although some of the EVA suit joints are fixed, rotary-style joints, most of the mobility is achieved by the simple flexibility of the fabric. There are multiple layers of fabric, each of which serves a special purpose in the safety of the astronaut. These multiple layers add to the restriction of motion the astronaut experiences in the space environment. Ground-based testing is implemented to evaluate the capability of EVA-suited astronauts to perform the various tasks in space. In addition to the restriction of motion imposed by the EVA suit, most EVA activity is performed in a micro-gravity (weight less) environment. To simulate weightlessness EVA-suited testing is performed in a neutral buoyancy simulator (NBS). The NBS is composed of a large container of water (pool) in which a weightless environment can be simulated. A subject is normally buoyant in the pressurized suit; however he/she can be made neutrally buoyant with the addition of weights. In addition, most objects the astronaut must interface with in the NBS sink in water and flotation must be added to render them ‘weightless’. The implementation of NBS testing has proven to invaluable in the assessment of EVA activities performed with the Orbiter and is considered to be a key step in the construction of the International Space Station (ISS). While the NBS testing is extremely valuable, it does require considerable overhead to maintain and operate. It has been estimated that the cost of utilizing the facility is approximately $10,000 per day. Therefore it is important to maximize the utility of NBS testing for optimal results. One important aspect to consider in any human/worksite interface is the considerable wealth of anthropometric and ergonomic data available. A subset of this information specific to EVA activity is available in NASA standard 3000. The difficulty in implementing this data is that most of the anthropometric information is represented in a two-dimensional format. This poses some limitations in complete evaluation of the astronaut’s capabilities in a three-dimensional environment. Advances in computer hardware and software have provided for three-dimensional design and implementation of hardware with the advance of computer aided design (CAD) software. There are a number of CAD products available and most companies and agencies have adopted CAD as a fundamental aspect of the design process. Another factor which supports the use of CAD is the implementation of computer aided manufacturing (CAM) software and hardware which provides for rapid prototyping and decreases the time to product in the design process. It is probable that most hardware to be accessed by astronauts in EVA or IVA (intravehicular activity) has been designed by a CAD system, and is therefore represented in three-dimensional space for evaluation. Because of the implementation of CAD systems and the movement towards early prototyping, a need has arisen in industry and government for tools which facilitate the evaluation of ergonomic consideration in a three-dimensional environment where the hardware has been designed by the CAD tools. One such product is Jack which was developed by the University of Pennsylvania with funding from several government agencies, including NASA. While the primary purpose of Jack is to model human figures in a ground-based (gravity) environment, it can be utilized to evaluate EVA-suited activities as well. The effects of simulated gravity must be turned off by turning off ‘behaviors’. Although Jack provides human figures for manipulation, the primary instrument to be evaluated for EVA mobility is the work envelope provided by the EVA suit. An EVA Jack suit model has been developed by NASA-JSC and was utilized in this study. This suit model provided a more restrictive motion environment as expected for an EVA suited subject. As part of this study, the anthropometric dimensions for a 50th percentile male were compared with basic anthropometric data and were found to be representative for the population group expected in the NASA flight program. The joints for the suit were created in a manner which provided consistent performance with EVA reach envelopes published in NASA standard #3000.

Derived from text

Anthropometry; Space Suits; Extravehicular Activity; Human Body; Human Factors Engineering; Models; Joints (Junctions); Computerized Simulation; Neutral Buoyancy Simulation

19980017419 Stanford Univ., Stanford, CA USA

Assessment and Management of the Risks of Debris Hits During Space Station EVAs

Pate-Cornell, Elisabeth; Sachon, Marc; Aug. 1997; In English

Contract(s)/Grant(s): NAG2-980

Report No.(s): NASA/CR-97-112981; NAS 1.26:112981; SU-DIEEM-97-1; No Copyright; Avail: CASI; A03, Hardcopy

The risk of EVAs is critical to the decision of whether or not to automate a large part of the construction of the International Space Station (ISS). Furthermore, the choice of the technologies of the space suit and the life support system will determine (1) the immediate safety of these operations, and (2) the long-run costs and risks of human presence in space, not only in lower orbit (as is the case of the ISS) but also perhaps, outside these orbits, or on the surface of other planets. The problem is therefore both an immediate one and a long-term one. The fundamental question is how and when to shift from the existing EMU system (suit, helmet, gloves and life support system) to another type (e.g. a hard suit), given the potential trade-offs among life-cycle costs, risks to the astronauts, performance of tasks, and uncertainties about new systems' safety inherent to such a shift in technology. A more immediate issue is how to manage the risks of EVAs during the construction and operation of the ISS in order to make the astronauts (in the words of the NASA Administrator) 'as safe outside as inside'. For the moment (June 1997), the plan is to construct the Space Station using the low-pressure space suits that have been developed for the space shuttle. In the following, we will refer to this suit assembly as EMU (External Maneuvering Unit). It is the product of a long evolution, starting from the U.S. Air Force pilot suits through the various versions and changes that occurred for the purpose of NASA space exploration, in particular during the Gemini and the Apollo programs. The Shuttle EMU is composed of both soft fabrics and hard plates. As an alternative to the shuttle suit, at least two hard suits were developed by NASA: the AX5 and the MRKIII. The problem of producing hard suits for space exploration is very similar to that of producing deep-sea diving suits. There was thus an opportunity to develop a suit that could be manufactured for both purposes with the economies of scale that could be gained from a two-branch manufacturing line (space and deep sea). Of course, the space suit would need to be space qualified. Some of the problems in adopting one of the hard suits were first that the testing had to be completed, and second that it required additional storage space. The decision was made not to develop a hard suit in time for the construction and operation of the ISS. Instead, to improve the safety of the current suit, it was decided to reinforce the soft parts of the shuttle EMU with KEVLAR linings to strengthen it against debris impacts. Test results, however, show that this advanced suit design has little effect on the penetration characteristics.

Derived from text

Debris; International Space Station; Space Suits; Life Support Systems; Safety; Risk; Costs; Space Shuttles; Pressure Suits; Astronaut Performance

19980007975 ILC Dover, Frederica, DE USA

NASA Research Announcement Phase 2 Final Report for the Development of a Power Assisted Space Suit Glove

Lingo, Robert; Cadogan, Dave; Sanner, Rob; Sorenson, Beth; Dec. 24, 1997; In English; Original contains color illustrations

Contract(s)/Grant(s): NASw-96015

Report No.(s): NASA/CR-97-206657; NAS 1.26:206657; No Copyright; Avail: CASI; A03, Hardcopy

The main goal of this program was to develop an unobtrusive power-assisted EVA glove metacarpalphalangeal (MCP) joint that could provide the crew member with as close to nude body performance as possible, and to demonstrate the technology feasibility of power assisted space suit components in general. The MCP joint was selected due to its being representative of other space suit joints, such as the shoulder, hip and carpometacarpal joint, that would also greatly benefit from this technology. In order to meet this objective, a development team of highly skilled and experienced personnel was assembled. The team consisted of two main entities. The first was comprised of ILC's experienced EVA space suit glove designers, who had the responsibility of designing and fabricating a low torque MCP joint which would be compatible with power assisted technology. The second part of the team consisted of space robotics experts from the University of Maryland's Space Systems Laboratory. This team took on the responsibility of designing and building the robotics aspects of the power-assist system. Both parties addressed final system integration responsibilities.

Author

Gloves; Joints (Anatomy); Robotics; Space Suits; Systems Integration; Human Factors Engineering; Man Machine Systems; Performance Tests

19970040747 ILC Dover, Frederica, DE USA

NASA Research Announcement Phase 1 Report and Phase 2 Proposal for the Development of a Power Assisted Space Suit Glove Assembly

Cadogan, Dave; Lingo, Bob; Oct. 30, 1996; In English

Contract(s)/Grant(s): NASw-96015

Report No.(s): NASA/CR-97-206051; NAS 1.26:206051; No Copyright; Avail: CASI; A04, Hardcopy

In July of 1996, ILC Dover was awarded Phase 1 of a contract for NASA to develop a prototype Power Assisted Space Suit glove to enhance the performance of astronauts during Extra-Vehicular Activity (EVA). This report summarizes the work performed to date on Phase 1, and details the work to be conducted on Phase 2 of the program. Phase 1 of the program consisted of research and review of related technical sources, concept brainstorming, baseline design development, modeling and analysis, component mock-up testing, and test data analysis. ILC worked in conjunction with the University of Maryland's Space Systems Laboratory (SSL) to develop the power assisted glove. Phase 2 activities will focus on the design maturation and the manufacture of a working prototype system. The prototype will be tested and evaluated in conjunction with existing space suit glove technology to determine the performance enhancement anticipated with the implementation of the power assisted joint technology in space suit gloves.

Author

Space Suits; Gloves; Product Development

19970027854 Allied-Signal Aerospace Co., Torrance, CA USA

Enhanced Molecular Sieve CO2 Removal Evaluation

Rose, Susan; ElSherif, Dina; MacKnight, Allen; Sep. 05, 1996; In English

Contract(s)/Grant(s): NASw-5033

Report No.(s): NASA-CR-205324; Rept-97-69288; NAS 1.26:205324; No Copyright; Avail: CASI; A04, Hardcopy

The objective of this research is to quantitatively characterize the performance of two major types of molecular sieves for two-bed regenerative carbon dioxide removal at the conditions compatible with both a spacesuit and station application. One sorbent is a zeolite-based molecular sieve that has been substantially improved over the materials used in Skylab. The second sorbent is a recently developed carbon-based molecular sieve. Both molecular sieves offer the potential of high payoff for future manned missions by reducing system complexity, weight (including consumables), and power consumption in comparison with competing concepts. The research reported here provides the technical data required to improve CO2 removal systems for regenerative life support systems for future IVA and EVA missions.

Author

Carbon Dioxide Removal; Life Support Systems; Absorbents; Spacecraft Environments; Air Purification

19970026898 Texas A&M Univ., College Station, TX USA

A Human Factors Analysis of EVA Time Requirements

Pate, Dennis W.; National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program: 1996; Jun. 1997; Volume 2; In English

Contract(s)/Grant(s): NGT-44-001-800; No Copyright; Avail: CASI; A03, Hardcopy

Human Factors Engineering (HFE) is a discipline whose goal is to engineer a safer, more efficient interface between humans and machines. HFE makes use of a wide range of tools and techniques to fulfill this goal. One of these tools is known as motion and time study, a technique used to develop time standards for given tasks. During the summer of 1995, a human factors motion and time study was initiated with the goals of developing a database of EVA task times and developing a method of utilizing the database to predict how long an EVA should take. Initial development relied on the EVA activities performed during the STS-61 (Hubble) mission. The first step of the study was to become familiar with EVA's, the previous task-time studies, and documents produced on EVA's. After reviewing these documents, an initial set of task primitives and task-time modifiers was developed. Data was collected from videotaped footage of two entire STS-61 EVA missions and portions of several others, each with two EVA astronauts. Feedback from the analysis of the data was used to further refine the primitives and modifiers used. The project was continued during the summer of 1996, during which data on human errors was also collected and analyzed. Additional data from the STS-71 mission was also collected. Analysis of variance techniques for categorical data was used to determine which factors may affect the primitive times and how much of an effect they have. Probability distributions for the various task were also generated. Further analysis of the modifiers and interactions is planned.

Author

Space Transportation System; Human Factors Engineering; Extravehicular Activity; Astronauts

19970025438 NASA Johnson Space Center, Houston, TX USA
Development of Methods to Evaluate Safer Flight Characteristics
Basciano, Thomas E., Jr.; Erickson, Jon D.; National Aeronautics and Space Administration (NASA) /American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program; Jun. 1997; Volume 1; In English
Contract(s)/Grant(s): NAG9-867; No Copyright; Avail: CASI; A03, Hardcopy

The goal of the proposed research is to begin development of a simulation that models the flight characteristics of the Simplified Aid For EVA Rescue (SAFER) pack. Development of such a simulation was initiated to ultimately study the effect an Orbital Replacement Unit (ORU) has on SAFER dynamics. A major function of this program will be to calculate fuel consumption for many ORUs with different masses and locations. This will ultimately determine the maximum ORU mass an astronaut can carry and still perform a self-rescue without jettisoning the unit. A second primary goal is to eventually simulate relative motion (vibration) between the ORU and astronaut. After relative motion is accurately modeled it will be possible to evaluate the robustness of the control system and optimize performance as needed. The first stage in developing the simulation is the ability to model a standardized, total, self-rescue scenario, making it possible to accurately compare different program runs. In orbit an astronaut has only limited data and will not be able to follow the most fuel efficient trajectory; therefore, it is important to correctly model the procedures an astronaut would use in orbit so that good fuel consumption data can be obtained. Once this part of the program is well tested and verified, the vibration (relative motion) of the ORU with respect to the astronaut can be studied.
Author
Extravehicular Activity; Rescue Operations; Astronaut Locomotion; Extravehicular Mobility Units; Manned Space Flight; Astronaut Maneuvering Equipment

19970005012 NASA Ames Research Center, Moffett Field, CA USA
The Suitport's Progress
Cohen, Marc M.; 1995; In English, 3-5 Apr. 1995, Houston, TX, USA
Report No.(s): NASA-TM-111836; NAS 1.15:111836; AIAA Paper 95-1062; No Copyright; Avail: CASI; A03, Hardcopy

NASA-Ames Research Center developed the Suitport as an advanced space suit airlock to support a Space Station suit based on the AX-5 hard suit. Several third parties proposed their own variations of the Suitport on the moon and Mars. The Suitport recently found its first practical use as a terrestrial application in the NASA-Ames Hazmat vehicle for the clean-up of hazardous and toxic materials. In the Hazmat application, the Suitport offers substantial improvements over conventional hazard suits by eliminating the necessity to decontaminate before doffing the suit.
Author
Air Locks; Space Stations; Space Suits; Extravehicular Activity; Extravehicular Mobility Units

19970003265 Daimler-Benz Aerospace A.G., Friedrichshafen Germany
EVA safety: Space suit system interoperability
Skoog, A. I.; McBarron, J. W.; Abramov, L. P.; Zvezda, A. O.; Jan. 1995; In English; 46th, 2 - 6 Oct. 1995, Oslo, Norway
Report No.(s): OTN-035928; IAA Paper 95-10103; Copyright; Avail: CASI; A03, Hardcopy

The results and the recommendations of the International Academy of Astronautics extravehicular activities (IAA EVA) Committee work are presented. The IAA EVA protocols and operation were analyzed for harmonization procedures and for the standardization of safety critical and operationally important interfaces. The key role of EVA and how to improve the situation based on the identified EVA space suit system interoperability deficiencies were considered.
Author (ESA)
Extravehicular Activity; Extravehicular Mobility Units; Recommendations; Space Suits; Life Support Systems; Design Analysis; Safety

19960050283 Rice Univ., Houston, TX USA
Materials Assessment of Components of the Extravehicular Mobility Unit
Olivas, John D.; Barrera, Enrique V.; National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program: 1995; Aug. 1996; Volume 1; In English; No Copyright; Avail: CASI; A03, Hardcopy

Current research interests for Extravehicular Mobility Unit (EMU) design and development are directed toward enhancements of the Shuttle EMU, implementation of the Mark 3 technology for Shuttle applications, and development of a next generation suit (the X suit) which has applications for prolonged space flight, longer extravehicular activity (EVA), and

Moon and Mars missions. In this research project two principal components of the EMU were studied from the vantage point of the materials and their design criteria. An investigation of the flexible materials which make up the lay-up of materials for abrasion and tear protection, thermal insulation, pressure restrain, etc. was initiated. A central focus was on the thermal insulation. A vacuum apparatus for measuring the flexibility of the materials was built to access their durability in vacuum. Plans are to include a Residual Gas Analyzer on the vacuum chamber to measure volatiles during the durability testing. These tests will more accurately simulate space conditions and provide information which has not been available on the materials currently used on the EMU. Durability testing of the aluminized mylar with a nylon scrim showed that the material strength varied in the machine and transverse directions. Study of components of the EMU also included a study of the EMU Bearing Assemblies as to materials selection, engineered materials, use of coatings and flammability issues. A comprehensive analysis of the performance of the current design, which is a stainless steel assembly, was conducted and use of titanium alloys or engineered alloy systems and coatings was investigated. The friction and wear properties are of interest as are the general manufacturing costs. Recognizing that the bearing assembly is subject to an oxygen environment, all currently used materials as well as titanium and engineered alloys were evaluated as to their flammability. An aim of the project is to provide weight reduction since bearing weights constitute 1/3 of the total EMU weight. Our investigations have shown favorable properties using a titanium or nickel base alloy in conjunction with a coating system. Interest lies in developing titanium as a more nonflammable material. Methodology for doing this lies in adding coatings and surface alloying the titanium. This report is brief and does not give all necessary details. The reader should contact the authors as to the detailed study and for viewing of raw data.
Author
Extravehicular Mobility Units; Thermal Insulation; Durability; Stainless Steels; Titanium Alloys; Flexibility; Wear Resistance; Flammability

19960050113 Texas A&M Univ., College Station, TX USA
A human factors analysis of EVA time requirements
Pate, D. W.; National Aeronautics and Space Administration (NASA)/American Society for Engineering Education (ASEE) Summer Faculty Fellowship Program: 1995.; Aug. 1996; In English; No Copyright; Avail: CASI; A03, Hardcopy

Human Factors Engineering (HFE), also known as Ergonomics, is a discipline whose goal is to engineer a safer, more efficient interface between humans and machines. HFE makes use of a wide range of tools and techniques to fulfill this goal. One of these tools is known as motion and time study, a technique used to develop time standards for given tasks. A human factors motion and time study was initiated with the goal of developing a database of EVA task times and a method of utilizing the database to predict how long an ExtraVehicular Activity (EVA) should take. Initial development relied on the EVA activities performed during the STS-61 mission (Hubble repair). The first step of the analysis was to become familiar with EVAs and with the previous studies and documents produced on EVAs. After reviewing these documents, an initial set of task primitives and task time modifiers was developed. Videotaped footage of STS-61 EVAs were analyzed using these primitives and task time modifiers. Data for two entire EVA missions and portions of several others, each with two EVA astronauts, was collected for analysis. Feedback from the analysis of the data will be used to further refine the primitives and task time modifiers used. Analysis of variance techniques for categorical data will be used to determine which factors may, individually or by interactions, effect the primitive times and how much of an effect they have.
Author
Human Factors Engineering; Human-Computer Interface; Safety Factors; Time Functions

19960022260 Cincinnati Univ., OH USA
Techniques for Improving the Performance of Future EVA Maneuvering Systems
Williams, Trevor W.; [Dec. 1995]; In English
Contract(s)/Grant(s): NAG9-799
Report No.(s): NASA-CR-200882; NAS 1.26:200882; No Copyright; Avail: CASI; A03, Hardcopy

The Simplified Aid for EVA Rescue (SAFER) is a small propulsive backpack that was developed as an in-house effort at Johnson Space Center; it is a lightweight system which attaches to the underside of the Primary Life Support Subsystem (PLSS) backpack of the Extravehicular Mobility Unit (EMU). SAFER provides full six-axis control, as well as Automatic Attitude Hold (AAH), by means of a set of cold-gas nitrogen thrusters and a rate sensor-based control system. For compactness, a single hand controller is used, together with mode switching, to command all six axes. SAFER was successfully test-flown on the STS-64 mission in September 1994 as a Development Test Objective (DTO); development of an operational version is now proceeding. This version will be available for EVA self-rescue on the International Space Station and Mir, starting with the STS-86/Mir-7 mission in September 1997. The DTO SAFER was heavily instrumented, and

produced in-flight data that was stored in a 12 MB computer memory on-board. This has allowed post-flight analysis to yield good estimates for the actual mass properties (moments and products of inertia and center of mass location) encountered on-orbit. By contrast, Manned Maneuvering Unit (MMU) post-flight results were generated mainly from analysis of video images, and so were not very accurate. The main goal of the research reported here was to use the detailed SAFER on-orbit mass properties data to optimize the design of future EVA maneuvering systems, with the aim being to improve flying qualities and/or reduce propellant consumption. The Automation, Robotics and Simulation Division Virtual Reality (VR) Laboratory proved to be a valuable research tool for such studies. A second objective of the grant was to generate an accurate dynamics model in support of the reflight of the DTO SAFER on STS-76/Mir-3. One complicating factor was the fact that a hand controller stowage box was added to the underside of SAFER on this flight; the position of this box was such that two of the SAFER jets plume it. A second complication was that the EVA astronaut will sometimes be transporting a massive experiment package. This will not only alter the overall mass properties significantly, but can itself also be plumed.
Author
Extravehicular Activity; Extravehicular Mobility Units; Moments of Inertia; Propellant Consumption; Design Analysis; Plumes

19960006743 NASA Johnson Space Center, Houston, TX, USA
Man-systems integration standards, volume 1. Revision B
Jul 1, 1995; In English
Report No.(s): NASA-STD-3000-VOL-1-REV-B; NAS 1.82:3000-VOL-1-REV-B; No Copyright; Avail: CASI; A99, Hardcopy

Man-systems integration design considerations, design requirements, and example design solutions for development of manned space systems are described. A NASA-level standards document applicable to all manned space programs, including NASA, military, and commercial programs, is presented.
Derived from text
Aerospace Engineering; Aerospace Environments; Data Base Management Systems; Human Factors Engineering; Man Machine Systems; Manned Space Flight; Manned Spacecraft; Safety Management; Space Stations; Spacecraft Design; Standards

19960003442 Massachusetts Inst. of Tech., Cambridge, MA, USA
Dynamic analysis of astronaut motions in microgravity: Applications for Extravehicular Activity (EVA)
Newman, Dava J.; Nov 3, 1995; In English; 4 functional color pages
Contract(s)/Grant(s): NAGW-4336
Report No.(s): NASA-CR-199668; NAS 1.26:199668; NIPS-95-05667; No Copyright; Avail: CASI; A05, Hardcopy; 4 functional color pages

Simulations of astronaut motions during extravehicular activity (EVA) tasks were performed using computational multibody dynamics methods. The application of computational dynamic simulation to EVA was prompted by the realization that physical microgravity simulators have inherent limitations: viscosity in neutral buoyancy tanks; friction in air bearing floors; short duration for parabolic aircraft; and inertia and friction in suspension mechanisms. These limitations can mask critical dynamic effects that later cause problems during actual EVA's performed in space. Methods of formulating dynamic equations of motion for multibody systems are discussed with emphasis on Kane's method, which forms the basis of the simulations presented herein. Formulation of the equations of motion for a two degree of freedom arm is presented as an explicit example. The four basic steps in creating the computational simulations were: system description, in which the geometry, mass properties, and interconnection of system bodies are input to the computer; equation formulation based on the system description; inverse kinematics, in which the angles, velocities, and accelerations of joints are calculated for prescribed motion of the endpoint (hand) of the arm; and inverse dynamics, in which joint torques are calculated for a prescribed motion. A graphical animation and data plotting program, EVADS (EVA Dynamics Simulation), was developed and used to analyze the results of the simulations that were performed on a Silicon Graphics Indigo2 computer. EVA tasks involving manipulation of the Spartan 204 free flying astronomy payload, as performed during Space Shuttle mission STS-63 (February 1995), served as the subject for two dynamic simulations. An EVA crewmember was modeled as a seven segment system with an eighth segment representing the massive payload attached to the hand. For both simulations, the initial configuration of the lower body (trunk, upper leg, and lower leg) was a neutral microgravity posture. In the first simulation, the payload was manipulated around a circular trajectory of 0.15 m radius in 10 seconds. It was found that the wrist joint theoretically exceeded its ulnal deviation limit by as much as 49. 8 deg and was required to exert torques as high as 26 N-m to accomplish the task, well in excess of the wrist physiological limit of 12 N-m. The largest torque in the first simulation, 52 N-m, occurred in the ankle joint.

To avoid these problems, the second simulation placed the arm in a more comfortable initial position and the radius and speed of the circular trajectory were reduced by half. As a result, the joint angles and torques were reduced to values well within their physiological limits. In particular, the maximum wrist torque for the second simulation was only 3 N-m and the maximum ankle torque was only 6 N-m.
Author
Computerized Simulation; Dynamic Characteristics; Extravehicular Activity; Gravitational Effects; Human Factors Engineering; Microgravity; Physical Work

19960002583 NASA Johnson Space Center, Houston, TX, USA
STS-69 flight day 7 highlights
Sep 13, 1995; In English
Report No.(s): NASA-TM-110600; BRF-1370G; NONP-NASA-VT-95-72083; No Copyright; Avail: CASI; B01, Videotape-Beta; V01, Videotape-VHS

On the seventh day of the STS-69 mission, the astronauts, Cmdr. Dave Walker, Pilot Ken Cockrell, and Mission Specialists Jim Voss, Jim Newman, and Mike Gernhardt, were awakened by the theme song from the movie 'Patten.' Voss and Gernhardt performed a pre-EVA (Extravehicular Activity) checkout of the new thermal spacesuits that they will be wearing in two days. Solving problems with the Wake Shield Facility (WSF) occupied the other astronauts for most of this day. Earth views included tropical storm Marilyn in the Caribbean.
CASI
Checkout; Scientific Satellites; Space Shuttle Missions; Space Shuttles; Space Suits; Space Transportation System; Space Transportation System Flights; Spacecrews

19950027040 National Space Development Agency, Ibaraki, Japan
Working Group 5: Infrastructure both before and after the Moon becomes inhabited
Iwata, T.; Parkinson, R.; ESA, International Lunar Workshop: Towards a World Strategy for the Exploration and Utilisation of Our Natural Satellite; Nov 1, 1994; In English; Copyright; Avail: CASI; A01, Hardcopy; US Distribution and Sales Only

Key features identified in the area of establishing a lunar program 'infrastructure' were addressed. These include: robotic and teleoperation capabilities, communication and navigation (including far side operations), habitation and EVA (extravehicular activity) capabilities, the capability for limited 'civil engineering' activity, and in particular exploitation of lunar liquid oxygen to support a manned return robotics activities, human support and EVA, lunar liquid oxygen for human activities support thereby reducing transport requirements, and the problem of power, are discussed. It is observed that there is currently multiple activity around the world in a number of areas, in particular robotics and teleoperation, in situ resource utilization and communications and navigation. It is felt that international collaboration and information exchange in these areas would be valuable now.
ESA
Human Factors Engineering; Lunar Bases; Lunar Exploration; Mission Planning; Moon

19950020391 European Space Agency. European Space Research and Technology Center, ESTEC, Noordwijk, Netherlands
Human factors, volume 2
Jul 1, 1994; In English
Report No.(s): ESA-PSS-03-70-ISSUE-1-VOL-2; Copyright; Avail: CASI; A22, Hardcopy; US Distribution and Sales Only

ESA PSS-03-70 contains Procedures, Specification and Standards for generic criteria for space facilities (and related equipment) which directly interface with crew members. Specific user information to ensure proper integration of the man-system interface criteria with those of other aerospace disciplines is provided. The criteria applies to launch, entry, in-orbit, and extraterrestrial space environments. The document is for use as the basis for project specific requirements documents. Concise design considerations, design criteria, and design examples are provided. Criteria specified are applicable to all European manned space flight programs. Volume 2 contains sections on: architecture; workstations; activity centers; hardware and equipment; design for maintainability; facility management; and extravehicular activity.
ESA
Architecture; Design Analysis; Extravehicular Activity; Hardware; Human Factors Engineering; Man Machine Systems; Manned Space Flight; Spacecraft Design; Workstations

19950017775 NASA Johnson Space Center, Houston, TX, USA

Go for EVA

Apr 5, 1995; In English

Report No.(s): NASA-TM-110537; NONP-NASA-VT-95-43940; No Copyright; Avail: CASI; B01, Videotape-Beta; V01, Videotape-VHS

In this educational video series, 'Liftoff to Learning', astronauts from the STS-37 Space Shuttle Mission (Jay Apt, Jerry Ross, Ken Cameron, Steve Nagel, and Linda Godwin) show what EVA (extravehicular activity) means, talk about the history and design of the space suits and why they are designed the way they are, describe different ways they are used (payload work, testing and maintenance of equipment, space environment experiments) in EVA work, and briefly discuss the future applications of the space suits. Computer graphics and animation is included.

CASI

Aerospace Environments; Equipment Specifications; Extravehicular Mobility Units; Space Exploration; Space Shuttle Payloads; Spaceborne Experiments; Spacecraft Maintenance; Structural Design; Umbilical Connectors; Weightlessness

19950007475 NASA, Washington, DC, USA

Suited for spacewalking: Teacher's guide with activities for physical and life science

Vogt, Gregory L.; Manning, Cheryl A.; Rosenberg, Carla B.; Aug 1, 1994; In English

Report No.(s): NASA-EG-101; NAS 1.19/4:101; No Copyright; Avail: CASI; A04, Hardcopy

Space walking has captured the imagination of generations of children and adults since science-fiction authors first placed their characters on the Moon. This publication is an activity guide for teachers interested in using the intense interest many children have in space exploration as a launching point for exciting hands-on learning opportunities. The guide begins with brief discussions of the space environment, the history of space walking, the Space Shuttle spacesuit, and working in space. These are followed by a series of activities that enable children to explore the space environment as well as the science and technology behind the functions of spacesuits. The activities are not rated for specific grade levels because they can be adapted for students of many ages. The chart on curriculum application at the back of the book is designed to help teachers incorporate activities into various subject areas.

Derived from text

Education; Extravehicular Activity; Extravehicular Mobility Units; Space

19950005948 Universities Space Research Association, Columbia, MD, USA

M.E.366-J embodiment design project: Portable foot restraint

Heaton, Randall; Meyer, Eikar; Schmidt, Davey; Enders, Kevin; Apr 25, 1994; In English

Contract(s)/Grant(s): NASW-4435

Report No.(s): NASA-CR-197163; NAS 1.26:197163; No Copyright; Avail: CASI; A03, Hardcopy

During space shuttle operations, astronauts require support to carry out tasks in the weightless environment. In the past, portable foot restraints (PFR) with orientations adjustable in pitch, roll, and yaw provided this support for payload bay operations. These foot restraints, however, were designed for specific tasks with a load limit of 111.2 Newtons. Since the original design, new applications for foot restraints have been identified. New designs for the foot restraints have been created to boost the operational work load to 444.8 Newtons and decrease setup times. What remains to be designed is an interface between the restraint system and the extravehicular mobility unit (EMU) boots. NASA provided a proposed locking device involving a spring-loaded mechanism. This locking mechanism must withstand loads of 1334.4 Newtons in any direction and weigh less than 222.4 Newtons. This paper develops an embodiment design for the interface between the PFR and the EMU boots. This involves design of the locking mechanism and a removable cleat that allows the boot to interface with this mechanism. The design team used the Paul Beitz engineering methodology to present the systematic development, structural analysis, and production considerations of the embodiment design. This methodology provides a basis for understanding the justification behind the decisions made in the design.

Author

Anchors (Fasteners); Constraints; Extravehicular Mobility Units; Human Factors Engineering; Structural Design

19950005492 NASA Ames Research Center, Moffett Field, CA, USA

Interviews with the Apollo lunar surface astronauts in support of planning for EVA systems design

Connors, Mary M.; Eppler, Dean B.; Morrow, Daniel G.; Sep 1, 1994; In English

Contract(s)/Grant(s): RTOP 199-06-12

Report No.(s): NASA-TM-108846; A-94131; NAS 1.15:108846; No Copyright; Avail: CASI; A03, Hardcopy

Focused interviews were conducted with the Apollo astronauts who landed on the moon. The purpose of these interviews was to help define extravehicular activity (EVA) system requirements for future lunar and planetary missions. Information from the interviews was examined with particular attention to identifying areas of consensus, since some commonality of experience is necessary to aid in the design of advanced systems. Results are presented under the following categories: mission approach; mission structure; suits; portable life support systems; dust control; gloves; automation; information, displays, and controls; rovers and remotes; tools; operations; training; and general comments. Research recommendations are offered, along with supporting information.
Author
Apollo Project; Astronaut Maneuvering Equipment; Astronauts; Extravehicular Activity; Human Factors Engineering; Lunar Exploration; Portable Life Support Systems; Space Exploration; Space Suits

19940029529 NASA Goddard Space Flight Center, Greenbelt, MD, USA
EVA-SCRAM operations
Flanigan, Lee A.; Tamir, David; Weeks, Jack L.; Mcclure, Sidney R.; Kimbrough, Andrew G.; NASA. Johnson Space Center, The Seventh Annual Workshop on Space Operations Applications and Research (SOAR 1993), Volume 1; Jan 1, 1994; In English; No Copyright; Avail: CASI; A02, Hardcopy

This paper wrestles with the on-orbit operational challenges introduced by the proposed Space Construction, Repair, and Maintenance (SCRAM) tool kit for Extra-Vehicular Activity (EVA). SCRAM undertakes a new challenging series of on-orbit tasks in support of the near-term Hubble Space Telescope, Extended Duration Orbiter, Long Duration Orbiter, Space Station Freedom, other orbital platforms, and even the future manned Lunar/Mars missions. These new EVA tasks involve welding, brazing, cutting, coating, heat-treating, and cleaning operations. Anticipated near-term EVA-SCRAM applications include construction of fluid lines and structural members, repair of punctures by orbital debris, refurbishment of surfaces eroded by atomic oxygen, and cleaning of optical, solar panel, and high emissivity radiator surfaces which have been degraded by contaminants. Future EVA-SCRAM applications are also examined, involving mass production tasks automated with robotics and artificial intelligence, for construction of large truss, aerobrake, and reactor shadow shield structures. Realistically achieving EVA-SCRAM is examined by addressing manual, teleoperated, semi-automated, and fully-automated operation modes. The operational challenges posed by EVA-SCRAM tasks are reviewed with respect to capabilities of existing and upcoming EVA systems, such as the Extravehicular Mobility Unit, the Shuttle Remote Manipulating System, the Dexterous End Effector, and the Servicing Aid Tool.
Author
Artificial Intelligence; Control Equipment; Extravehicular Activity; Extravehicular Mobility Units; Orbital Servicing; Remote Control; Robotics; Spacecraft Maintenance; Structural Members; Teleoperators

19940029126 NASA Johnson Space Center, Houston, TX, USA
The PLAID graphics analysis impact on the space program
Nguyen, Jennifer P.; Wheaton, Aneice L.; Maida, James C.; Seventh Annual Workshop on Space Operations Applications and Research (SOAR 1993), Volume 2; Jan 1, 1994; In English; No Copyright; Abstract Only; Available from CASI only as part of the entire parent document

An ongoing project design often requires visual verification at various stages. These requirements are critically important because the subsequent phases of that project might depend on the complete verification of a particular stage. Currently, there are several software packages at JSC that provide such simulation capabilities. We present the simulation capabilities of the PLAID modeling system used in the Flight Crew Support Division for human factors analyses. We summarize some ongoing studies in kinematics, lighting, EVA activities, and discuss various applications in the mission planning of the current Space Shuttle flights and the assembly sequence of the Space Station Freedom with emphasis on the redesign effort.
Author (revised)
Applications Programs (Computers); Astronauts; Computer Graphics; Computerized Simulation; Flight Crews; Human Factors Engineering; Mission Planning; Space Missions

19940029123 NASA Johnson Space Center, Houston, TX, USA
An overview of Space Shuttle anthropometry and biomechanics research with emphasis on STS/Mir recumbent seat system design
Klute, Glenn K.; Stoycos, Lara E.; Seventh Annual Workshop on Space Operations Applications and Research (SOAR 1993), Volume 2; Jan 1, 1994; In English; No Copyright; Abstract Only; Available from CASI only as part of the entire parent document

The Anthropometry and Biomechanics Laboratory (ABL) at JSC conducts multi-disciplinary research focusing on maximizing astronaut intravehicular (IVA) and extravehicular (EVA) capabilities to provide the most effective work conditions for manned space flight and exploration missions. Biomechanics involves the measurement and modeling of the strength characteristics of the human body. Current research for the Space Shuttle Program includes the measurement of torque wrench capability during weightlessness, optimization of foot restraint, and hand hold placement, measurements of the strength and dexterity of the pressure gloved hand to improve glove design, quantification of the ability to move and manipulate heavy masses (6672 N or 1500 lb) in weightlessness, and verification of the capability of EVA crewmembers to perform Hubble Space Telescope repair tasks. Anthropometry is the measurement and modeling of the dimensions of the human body. Current research for the Space Shuttle Program includes the measurement of 14 anthropometric parameters of every astronaut candidate, identification of EVA finger entrapment hazards by measuring the dimensions of the gloved hand, definition of flight deck reach envelopes during launch and landing accelerations, and measurement of anthropometric design parameters for the recumbent seat system required for the Shuttle/Mir mission (STS-71, Spacelab M) scheduled for Jun. 1995.
Author (revised)

Anthropometry; Astronauts; Biodynamics; Extravehicular Activity; Gloves; Human Factors Engineering; Intravehicular Activity; Seats; Space Shuttle Missions; Space Shuttles; Spacecraft Design; Spacecrews; Weightlessness

19940029102 NASA Ames Research Center, Moffett Field, CA, USA

An ethnographic object-oriented analysis of explorer presence in a volcanic terrain environment: Claims and evidence

Mcgreevy, Michael W.; May 1, 1994; In English

Contract(s)/Grant(s): RTOP 506-59-65

Report No.(s): NASA-TM-108823; A-94083; NAS 1.15:108823; No Copyright; Avail: CASI; A04, Hardcopy

An ethnographic field study was conducted to investigate the nature of presence in field geology, and to develop specifications for domain-based planetary exploration systems utilizing virtual presence. Two planetary geologists were accompanied on a multi-day geologic field trip that they had arranged for their own scientific purposes, which centered on an investigation of the extraordinary xenolith/nodule deposits in the Kaupulehu lava flow of Hualalai Volcano, on the island of Hawaii. The geologists were observed during the course of their field investigations and interviewed regarding their activities and ideas. Analysis of the interview resulted in the identification of key domain entities and their attributes, relations among the entities, and explorer interactions with the environment. The results support and extend the author's previously reported continuity theory of presence, indicating that presence in field geology is characterized by persistent engagement with objects associated by metonymic relations. The results also provide design specifications for virtual planetary exploration systems, including an integrating structure for disparate data integration. Finally, the results suggest that unobtrusive participant observation coupled with field interviews is an effective research methodology for engineering ethnography.
Author

Extravehicular Activity; Geology; Human Factors Engineering; Planetary Geology; Terrain; Virtual Reality

19940025705 NASA Johnson Space Center, Houston, TX, USA

Tactility as a function of grasp force: Effects of glove, orientation, pressure, load, and handle

Bishu, Ram R.; Bronkema, Lisa A.; Garcia, Dishayne; Klute, Glenn; Rajulu, Sudhakar; May 1, 1994; In English

Report No.(s): NASA-TP-3474; S-761; NAS 1.60:3474; No Copyright; Avail: CASI; A03, Hardcopy

One of the reasons for reduction in performance when gloves are donned is the lack of tactile sensitivity. It was argued that grasping force for a weight to be grasped will be a function of the weight to be lifted and the hand conditions. It was further reasoned that the differences in grasping force for various hand conditions will be a correlate of the tactile sensitivity of the corresponding hand conditions. The objective of this experiment, therefore, was to determine the effects of glove type, pressure, and weight of load on the initial grasping force and stable grasping force. It was hypothesized that when a person grasps an object, he/she grasps very firmly initially and then releases the grasp slightly after realizing what force is needed to maintain a steady grasp. This would seem to be particularly true when a person is wearing a glove and has lost some tactile sensitivity and force feedback during the grasp. Therefore, the ratio of initial force and stable force and the stable force itself would represent the amount of tactile adjustment that is made when picking up an object, and this adjustment should vary with the use of gloves. A dynamometer was fabricated to measure the grasping force; the tests were performed inside a glove box. Four female and four male subjects participated in the study, which measured the effects of four variables: load effect, gender effect, glove type, and pressure variance. The only significant effects on the peak and stable force were caused by gender and the weight of the load lifted. Neither gloves nor pressure altered these forces when compared to a bare-handed condition, as

was suspected before the test. It is possible that gloves facilitate in holding due to coefficient of friction while they deter in peak grasp strength.
Author (revised)
Astronaut Performance; Extravehicular Activity; Gloves; Human Factors Engineering; Manual Control; Tactile Discrimination

19940023449 NASA Marshall Space Flight Center, Huntsville, AL, USA
Extra-Vehicular Activity (EVA) glove evaluation test protocol
Hinman-Sweeney, E. M.; Mar 1, 1994; In English
Report No.(s): NASA-TM-108442; NAS 1.15:108442; No Copyright; Avail: CASI; A08, Hardcopy

One of the most critical components of a space suit is the gloves, yet gloves have traditionally presented significant design challenges. With continued efforts at glove development, a method for evaluating glove performance is needed. This paper presents a pressure-glove evaluation protocol. A description of this evaluation protocol, and its development is provided. The protocol allows comparison of one glove design to another, or any one design to bare-handed performance. Gloves for higher pressure suits may be evaluated at current and future design pressures to drive out differences in performance due to pressure effects. Using this protocol, gloves may be evaluated during design to drive out design problems and determine areas for improvement, or fully mature designs may be evaluated with respect to mission requirements. Several different test configurations are presented to handle these cases. This protocol was run on a prototype glove. The prototype was evaluated at two operating pressures and in the unpressurized state, with results compared to bare-handed performance. Results and analysis from this test series are provided, as is a description of the configuration used for this test.
Author (revised)
Extravehicular Activity; Gloves; Human Factors Engineering; Performance Tests; Space Suits

Subject Terms

Corporate Sources

Document Authors