

# **HUMAN FACTORS INTERFACE WITH SYSTEMS ENGINEERING FOR NASA HUMAN SPACEFLIGHTS**

Douglas T. Wong

Habitability and Human Factors Branch  
NASA, Johnson Space Center  
2101 NASA Parkway, Mail Code SF3,  
Houston, TX 77058

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## **Topic**

How does Human Systems Integration fit into the Systems Engineering process?

## **ABSTRACT**

This paper summarizes the past and present successes of the Habitability and Human Factors Branch (HHFB) at NASA Johnson Space Center's Space Life Sciences Directorate (SLSD) in including the Human-As-A-System (HAAS) model in many NASA programs and what steps to be taken to integrate the Human-Centered Design Philosophy (HCDP) into NASA's Systems Engineering (SE) process.

The HAAS model stresses systems are ultimately designed for the humans; the humans should therefore be considered as a system within the systems. Therefore, the model places strong emphasis on human factors engineering. Since 1987, the HHFB has been engaging with many major NASA programs with much success. The HHFB helped create the NASA Standard 3000 (a human factors engineering practice guide) and the Human Systems Integration Requirements document. These efforts resulted in the HAAS model being included in many NASA programs. As an example, the HAAS model has been successfully introduced into the programmatic and systems engineering structures of the International Space Station Program (ISSP). Success in the ISSP caused other NASA programs to recognize the importance of the HAAS concept. Also due to this success, the HHFB helped update NASA's Systems Engineering Handbook in December 2007 to include HAAS as a recommended practice.

Nonetheless, the HAAS model has yet to become an integral part of the NASA SE process. Besides continuing in integrating HAAS into current and future NASA programs, the HHFB will investigate incorporating the Human-Centered Design Philosophy (HCDP) into the NASA SE Handbook. The HCDP goes further than the HAAS model by emphasizing a holistic and iterative human-centered systems design concept.

## **LIST OF ACROYNMS**

ABF – Anthropometry and Biomechanics Facility  
CEV – Crew Exploration Vehicle  
CxP – Constellation Program  
FCI – Flight Crew Integration  
GIAG – Government/Industry Advisory Group  
HAAS – Human-As-A-System  
HCDP – Human-Centered Design Philosophy  
HFE – Human Factors Engineering  
HHFB – Habitability and Human Factors Branch  
HIDH – Human Integration Design Handbook  
HMTA – Health and Medical Technical Authority  
HRP – Human Research Program  
HSI – Human Systems Integration  
HSIA – Human Systems Integration Architecture  
HSIG – Human Systems Integration Group  
HSIR – Human Systems Integration Requirements  
ISS – International Space Station  
ISSP – International Space Station Program  
LED – light emitting diodes  
LETF – Lighting Environment Test Facility  
NASA-STD-3000 – Man-Systems Integration Standards  
OLED – Organic light emitting diode  
OpsHab – Operational Habitability  
SE – Systems Engineering  
SE&I – Systems Engineering and Integration  
SFHSS – Space Flight Human Systems Standard  
SHFE – Space Human Factors Engineering  
SLSD – Space and Life Science Directorate

## **THE HABITABILITY AND HUMAN FACTORS BRANCH AT NASA JOHNSON SPACE CENTER**

A portion of NASA's Human Factors Engineering (HFE) expertise resides within the Habitability and Human Factors Branch (HHFB) of the Space Life Sciences Directorate (SLSD) at NASA Johnson Space Center. The HHFB has been successfully supporting and providing many major NASA space programs technical human factors expertise since 1987.

The HHFB facilitates humans to work safely and productively in space by (i) establishing conceptual designs for space habitats and crew systems, and developing requirements and guidelines for programs to implement, (ii) verifying human-machine interfaces and the operational habitability of spacecraft and habitats, and (iii) overseeing and conducting research in space human factors to improve human performance and productivity.

To fulfill these duties, the HHFB ensures space human factors, including human physical parameters and performance capabilities and limitations, are defined, documented, and applied properly. The HHFB also operates several unique facilities and laboratories to support human factors investigations/analyses and crew-station integrations.

### **HUMAN-AS-A-SYSTEM DESIGN PHILOSOPHY**

The HHFB has been promoting the Human-As-A-System (HAAS) design model to NASA's Systems Engineering (SE) process since 1987. The HAAS model stresses that systems are ultimately designed for the humans; the humans should therefore be considered as a system within the systems. To facilitate human accomplishing mission objectives, the human factors discipline should play a prominent role in the systems design so that human and machine interfaces are properly designed.

### **PAST SUCCESSSES IN PROMOTING THE HAAS MODEL**

Since 1987, the HHFB has successfully introduced the HAAS model into the programmatic and SE structures of many NASA programs. Below is a summary of these success stories:

#### **Creation of the NASA-STD-3000 Space Human Factors Standards**

According to Tillman (1987) the Man-Systems Integration Standards (NASA-STD-3000), created by Tillman et al. (1995), was released in 1987. It is a human factors design guide for developers and designers of space equipment to achieve better integration of humans and the equipment in space.

The NASA-STD-3000 provides a single comprehensive document defining all generic requirements for space facilities and related equipment interfaces with crewmembers. The document was assembled for NASA by the Boeing Aerospace Company and subcontractors Lockheed Missiles and Space Co., Essex Corp., and CAMUS, Inc. The team consisted of thirteen authors, a team of six human factors and space flight experts (including two Skylab astronauts), and a Government/Industry Advisory Group (GIAG). The GIAG was a panel of experts and users from NASA centers and Headquarters, prime aerospace contractors and support contractors, other Government agencies, and non-aerospace contractors.

The standard was compiled as follows: The author of each chapter researched publications and prepared the draft. A review group for each chapter, which was formed by experts and advisers from industry and NASA, then reviewed the draft. Comments, questions, and recommendations from the review group were directed to the respective authors, who then made corrections and conducted necessary research to address the problems detected by the review groups. Consequently, the technical contents of these chapters were thoroughly reviewed and the data can be used with confidence.

The NASA-STD-3000/T International Space Station Flight Crew Integration Standard, also called SSP 50005, is a special version of the NASA-STD-3000. The data in this document are a subset of the data in 3000 and serves as the ISSP contractually binding human systems integration design requirements.

Although written for the space environment, much of the information contained in the NASA-STD-3000 has obvious applicability to human interface and engineering problems encountered in terrestrial environments as long as the document users keep in mind those instances that are tailored to the micro-g environment.

## **International Space Station Program Flight Crew Integration**

Besides creating the NASA-STD-3000/T (SSP 50005) for the ISSP, the HHFB also formed the Flight Crew Integration (FCI) group to provide human factors analyses to the International Space Station (ISS). Analyses are performed through participation in design review proceedings, international partner activities, and the Analysis and Integration Team meetings.

A critical component of the FCI group is the Operational Habitability (OpsHab) team. The OpsHab team collects and analyzes information from space flight missions to identify human factors and habitability lessons learned, validate HFE requirements and designs, solve operational challenges, and improve habitability and human performance for future ISS missions.

The OpsHab team's other responsibility is to identify and analyze human-related data captured through crew debriefs, previous findings from long-duration space flights (e.g., Skylab, Mir, ISS) and space-analog environments (e.g., the Antarctic, Submarines, etc.),

as well as research findings from behavioral sciences. Moreover, the team conducts focused evaluations on the ISS to identify human factors and habitability improvements. The information from the OpsHab data collection activities is used to create better human factors requirements to ensure better human-centered hardware and systems designs, provide lessons-learned related to human habitation in space, and offer tracking and resolution to human factors issues on the ISS. In fact, the data is now being incorporated in the Human Interface Design Handbook, a companion to the NASA Standard 3001 (see the “NASA Standard 3001” section.) The lessons-learned data from the ISS also benefits future space programs such as the Orion Crew Exploration Vehicle (CEV).

(NASA point of contact: Laura Duvall, (281) 483-0244, [laura.e.duvall@nasa.gov](mailto:laura.e.duvall@nasa.gov))

## **NASA’s Systems Engineering Handbook Updated to Include the HAAS Design Philosophy**

The staff at the HHFB was the major contributor to the human factors sections in the 2007 Systems Engineering Handbook (NASA/SP-6105). Initially published in 1995, the handbook describes the fundamental concepts and techniques of SE in a way that recognizes the nature of NASA systems and its environment (Woolford et al., 2007).

The 2007 revision updated the Agency’s SE body of knowledge, providing guidance for insight into current best Agency practices, and aligning the handbook with the new Agency SE policy. The update encompasses a top-down compatibility with higher level Agency policy and a bottom-up infusion of guidance from the NASA practitioners in the field. This approach facilitates the opportunity to obtain best practices from across NASA and bridges the information to the established NASA SE process for the handbook. The material for updating this handbook was drawn from many different sources because SE is a holistic, integrative discipline involving a multitude of engineering disciplines including human factors.

The success in the ISSP indirectly offered the HHFB the opportunity to update NASA’s Systems Engineering Handbook in December 2007 to include HFE as a recommended practice. Based on the HAAS model, the 2007 version now stresses the roles of the humans in SE. In human spaceflight, the humans, both as operators and maintainers, are critical components of the mission and systems. Human capabilities and limitations must enter into the designs the same way properties of materials and characteristics of electronic components do. Humans are initially integrated into systems through analysis of the overall mission. Mission functions are then allocated to humans as appropriate to the system architecture, technical capabilities, cost factors, and crew capabilities. Once functions are allocated, human factors analysts work with other system designers to ensure that humans are provided the proper equipment, tools, and interfaces to perform their assigned tasks safely and effectively.

Lastly, the 2007 version also provides a summary of the human factors engineering analysis techniques and methods including task analysis, timeline analysis, modeling and

simulation, usability testing, workload assessment, as well as human error and human reliability assessment.

(NASA point of contact: Barbara J. Woolford, (281) 483-3701, [barbara.j.woolford@nasa.gov](mailto:barbara.j.woolford@nasa.gov))

## **Space Human Factors Engineering Project's HSI Contribution**

The HHFB manages the Space Human Factors Engineering (SHFE) project, which is an element under NASA's Human Research Program. The SHFE is a project under the Space Human Factors and Habitability element of the Human Research Program (HRP). The HRP uses a balance of laboratory, flight, and ground analogs to understand the impact of the space exploration environment on the human system. (Grounds et al., 2007) The goal of the SHFE is to develop standards and models to ensure that the design of spacecraft, habitat systems, and hardware are compatible with the physical and cognitive capabilities of crewmembers during space flight.

In 2005 the SHFE performed a research and technology gap analysis to address key questions on HSI in preparation for the CxP Orion space vehicle development (McCandless et al., 2006). The project conducted white-paper reviews to compare state-of-the-art and state-of-practice with CxP requirements for six critical domains (Manufacturing & Launch Site Operations, Mission Control Operations, Spacecraft Systems & Operations, Extra-Vehicular Activity & Teleoperations, Training & Decision Support, and HSI Engineering Support.) These white papers were supplemented with additional sources of expert knowledge, including (i) in-depth reviews with subject matter experts in both space human factors and the user communities, (ii) historical reports from Apollo and Skylab missions, as well as (iii) debriefs and "lessons learned" from the Space Shuttle and the ISS. The project now sponsors a variety of research and technical development tasks to resolve the lacks and gaps identified in those reviews.

(NASA point of contact: Barbara Woolford, (281) 483-3701, [barbara.j.woolford@nasa.gov](mailto:barbara.j.woolford@nasa.gov))

## **Shuttle and ISS Lighting Improvements**

With the ever-increasing complexities in space operations, the Lighting Environment Test Facility (LETF) at the HHFB felt it would be a great improvement in operation efficiency to mount state-of-the-art lights on all cameras on the current Space Shuttle.

The challenge was that the light sources must be bright, durable, light weight, and low-power. With the birth of bright yet low-power white Light Emitting Diodes (LED) technology in 1995, the LETF immediately adopted this new technology for general illumination in the Shuttle's camera systems several years ahead of the industry. These early LED camera lights were designed as rings mounted around the lens of each camera.

Now, each of the four Shuttle payload bay cameras has LED light systems capable of being pointed with the camera's pan and tilt unit. The two robotic arm cameras were also outfitted with LED rings. In June 1998 on STS-91, the first illumination system of forty white LEDs was flown; in May 1999 on STS-96, a white 180-LED system was flown. These lighting systems are extremely reliable and are still in use today.

Age and increased maintenance cost of the fluorescent lights on board the ISS has prompted NASA to introduce white LED lighting to the ISS. In 2008, NASA flew the first prototype LED system the LETF helped develop on the ISS for evaluation.

(NASA point of contact: James C. Maida, (281) 483-1113, [james.c.maida@nasa.gov](mailto:james.c.maida@nasa.gov))

## **CURRENT ENDEAVORS IN PROMOTING THE HAAS MODEL**

Success in the ISSP and other activities mentioned in the previous section provided the HHFB an experience base that further triggered other NASA programs to recognize our effort. This section summarizes some of the current endeavors at the HHFB in promoting the HAAS model.

### **NASA Standard 3001**

In 2007, the HHFB began the development of the NASA-STD-3001, or NASA Space Flight Human Systems Standard (SFHSS), and an accompanying handbook through the SHFE project. The documents are in final review and edit and are expected to be published in 2009.

The SFHSS will be a two-volume Agency-level standards document established by the Office of the Chief Health and Medical Officer that defines system design standards to achieve acceptable crew health and performance in spaceflight. SFHSS Volume I, Crew Health, sets standards related to crew health. Volume II, Habitability and Environmental Health, defines the environmental, habitability, and human factors standards related to environmental health and human-system interfaces for human spaceflights.

A companion document to the SFHSS is the "Human Integration Design Handbook" (HIDH). The handbook provides the detailed data and guidance needed to derive and implement program-specific requirements that are SFHSS compliant. Much of the information in the HIDH comes from the corresponding updated and expanded information in the SFHSS. The HIDH will provide guidance for crew health, habitability, environment, and human factors design of all NASA human spaceflight programs and projects. The two primary uses for the handbook will be (i) to prepare contractual program-specific human interface requirements, and (ii) to develop designs and operations standards for human interfaces in space vehicles and habitats.

(NASA point of contact: Barry Tillman, (281)-483-7131, [barry.tillman-1@nasa.gov](mailto:barry.tillman-1@nasa.gov))

## **Constellation Program Human Systems Integration Group**

The HHFB's success in the ISSP has drawn attention from other NASA space programs. Among them is NASA's Constellation Program (CxP) and its project elements.

NASA's CxP is developing new human-rated space vehicles that can reach and operate on the moon and eventually on Mars. The HHFB now leads the interdisciplinary Human Systems Integration Group (HSIG) for the CxP.

The HSIG is a program-level authority of the CxP Systems Engineering and Integration (SE&I) group. The HSIG develops and maintains the CxP Human Systems Integration Architecture (HSIA) by ensuring commonality through integration and application of the HSIA among the CxP's program level, project level, and external entities. Through the CxP SE&I's Program Technical Integration Office, the HSIG analyzes, integrates and dispositions technical changes and issues affecting the application of Human Systems Integration (HSI). The group also works with NASA centers and/or external agencies to resolve lower-level issues concerning CxP HSI-focused technical integration work. Today, the HSIG is intimately involved in the following CxP project elements: Crew Exploration Vehicle (CEV) development under the Orion Project, Extra-Vehicular Activities (EVA) spacesuit development under the EVA Project, lunar vehicles development under the Altair Project, ground operations and facilities development under the Ground Operations Project, and the rocket development under the ARES I Project.

### **DEVELOPING THE CXP HUMAN SYSTEMS INTEGRATION REQUIREMENTS (HSIR)**

One of the important contributions of the HSIG to the CxP is the creation and management of the CxP HSIR document (CxP 70024, 2006). The HSIR is a CxP document that defines requirements to ensure proper integration of human-to-system interfaces and is a key mechanism for achieving human rating of CxP systems. The requirements within the HSIR document apply to all CxP mission phases.

During the early stages of the CxP, the HHFB saw the need to tailor the NASA-STD-3000 for the Orion CEV spacecraft development. The CxP's Orion Project element is developing the CEV, a replacement for the current Space Shuttle. The Orion CEV will extend humanity's reach to the moon and Mars. The goal for the tailoring was to use the Standard to create a requirements document with the specificities and the right legal languages for the CEV. In 2004, the HHFB drafted a CEV requirements document. Later, the HSIG was formed, which led to the promotion of the project-level Orion CEV requirements document to the program-level CxP HSIR document. The current version of the HSIR includes an allocation matrix (Appendix J in the HSIR), which allocates requirements as applicable across all CxP projects such as Orion, EVA, and Ground Operations.

## DEVELOPING THE CXP CREW INTERFACE LABELING STANDARD

HSIG's other responsibility is to develop and maintain the Crew Interface Labeling Standard (CxP 70152, 2007). The document presents the standards for labeling and coding of all crew interfaces on flight hardware in the CxP. It drives the design of labels for space vehicles, their subsystems, and equipment that humans interface. These standards ensure the labels designed for the CxP systems can facilitate locating/identifying interfaces, interpreting/following procedures, and avoiding hazards.

(NASA point of contact: Jonathan R. Dory, (281) 483-1162, [jonathan.r.dory@nasa.gov](mailto:jonathan.r.dory@nasa.gov))

### **Orion Project CEV-HSI Team**

The HHFB also leads the Orion Project's CEV-HSI team by managing all things related to Orion's human health and performance concerns. The team's major roles are summarized below:

#### CEV RESOURCE PLANNING AND ALLOCATION

The CEV-HSI team supports the Orion Project Office with resource planning and subject matter expertise for the HFE subsystem and ensures that all assigned resources are allocated and managed properly for human health and performance concerns. The team works with all Orion team members including civil servants, contractors, and other NASA centers. Team members are always ready to provide content for and assist with modifications to the Orion Prime contract as the spacecraft designs and interfaces evolve.

#### OVERSIGHT OF ORION REQUIREMENTS, VALIDATION STUDIES, AND STRATEGIC SUPPORT

Another contribution of the CEV-HSI team is to manage the children flow-down requirements from the HSIR to the Orion Project. This role involves assisting Orion stakeholders in the interpretation of requirements, as well as addressing HSIR issues and determining their impacts on CEV subsystems designs. With their human factors expertise, the HSI team members participate in design reviews and validation studies such as needs assessments, cost credibility studies, and flight demonstration projects.

#### SAFETY OVERSIGHT AND RISK MITIGATION PLANNING

The CEV-HSI team also serves as the liaison for the SLSD in all things related to Orion's human health and performance concerns by being the conduit to the Orion Project Office's Health and Medical Technical Authority (HMTA). The team identifies specific human health and performance related risks and develops the appropriate mitigation plans. When technical concerns regarding human health and performance are unresolved, the CEV-HSI team members serve as an independent entity on Orion boards and panels to address those issues.

(NASA point of contact: Mihriban Whitmore, (281) 244-1004, [mihriban.whitmore-1@nasa.gov](mailto:mihriban.whitmore-1@nasa.gov))

## **Anthropometry in Constellation Spacesuit Development**

The Anthropometry and Biomechanics Facility (ABF) at the HHFB has initiated an effort to overcome the existing limitations of the current spacesuit architecture. The ABF has identified several key anthropometric factors to improved crew-interface accommodation (Jeevarajan and Rajulu 2008): (i) the minimum mobility needed to perform all necessary tasks; (ii) the minimum strength a suited crew population is capable of exerting; and (iii) the dexterity and tactility capabilities and limitations existed on the pressurized gloves.

By benchmarking the existing suits on those critical factors, the human factors engineers at NASA can gauge the constraints of the current spacesuits. From a SE perspective, the data allows human factors engineers to work closely with spacesuit designers and engineers in developing requirements that would eventually eliminate or minimize the potential injuries as well as improve the safety and comfort of the new spacesuits.

(NASA point of contact: Sudhakar Rajulu, (281) 483-3725, [sudhakar.rajulu-1@nasa.gov](mailto:sudhakar.rajulu-1@nasa.gov))

## **OLED Emergency Egress Lighting System Development**

The newest activity from the Lighting Environment Test Facility (LETF) at the HHFB is the emergency egress lighting system that uses Organic LED (OLED). OLED composes of long-lasting photo-luminescent material and extremely low power organic polymer. The system will greatly reduce maintenance costs without compromising safety for future space vehicles.

(NASA point of contact: James C. Maida, (281) 483-1113, [james.c.maida@nasa.gov](mailto:james.c.maida@nasa.gov))

## **FUTURE: INCORPORATING THE HUMAN-CENTERED DESIGN PHILOSOPHY INTO THE NASA SYSTEMS ENGINEERING PROCESS**

As evident in the success the HHFB has made in the past two decades, the HAAS model has gained much visibility at NASA. Besides continuing the endeavor in the upcoming years to promote the HAAS model, the HHFB plans to take a step further by making HFE an integral part of the NASA SE process through introducing the Human-Centered Design Philosophy (HCDP). As a first step, the HHFB plans to update the next version of the NASA SE Handbook with HCDP-relevant language. This first step will enable the NASA engineering community to be more aware of the concept. Through the HHFB's effort on the new Handbook and the introduction of the HAAS model into past and

current programs, future programs will be more receptive to the HCDP and hence more likely to adopt the idea into their systems design.

Unlike the HAAS model, which emphasizes the importance of incorporating the human into the systems design, the HCDP goes further by recommending a holistic and iterative systems design process with the humans as the center the systems development process (Wong 2008). With the HCDP, the entire system is considered as a whole and designed with humans as the ultimate customers.

An effective holistic/iterative systems design process should follow a spiral pattern where more effort is spent on the early design stages to explore feasible concepts. A holistic systems design process looks at the entire system life-cycle in its entirety. The systems development team should be composed of a multidisciplinary team of professionals. An iterative approach with multiple design cycles is more effective than the traditional linear approach to systems design for today's highly complex systems. Multiple design cycles ensure sound designs in each cycle given the maturity level.

The HHFB plans to provide detailed descriptions of the HCDP for consideration of incorporation into the next version of the NASA SE Handbook.

## **CONCLUSION**

The HHFB has come a long way in the past two decades to convey to major NASA programs the benefits of the HAAS model in SE. While the HHFB efforts have been successful, introducing the HAAS model is only the interim solution to HSI. The HHFB's ultimate goal is to introduce the HCDP into the NASA SE process. The HCDP will greatly enhance the qualities of future NASA human and non-human rated space systems with higher efficiency, reduced cost, and increased safety.

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- James C. Maida – “Lighting”
- Dr. Sudhakar Rajulu – “Anthropometry in Constellation Spacesuit Development”
- Barry Tillman – “Creation of the NASA Space Human Factors Standards”
- Dr. Mihriban Whitmore – “Orion Program – Creation of the Human Systems Integration Group”
- Barbara Woolford – “Contribution of the Space Human Factors Engineering Project to HSI” and “2007 Updated the NASA’s Systems Engineering Handbook to Include the HAAS Design Philosophy”

## **AUTHOR INFORMATION**

Douglas T. Wong, P.E.  
Habitability and Human Factors Brach (SF-3)  
Space and Life Science Directorate  
NASA Johnson Space Center  
2101 Nasa Parkway  
Houston, TX 77058-3696  
Work: (281) 483-6077  
Fax: (2810) 483-1847  
[Douglas.t.wong@nasa.gov](mailto:Douglas.t.wong@nasa.gov)

## **Biography**

Douglas Wong is an aerospace human factors engineer at the NASA Johnson Space Center's Habitability and Human Factors Branch in Houston, Texas.

Doug has been with NASA since 1989. His first position at NASA was a wind tunnel instrumentation research engineer at NASA Langley Research Center in Hampton, Virginia. His career on human factors began in 1998 when he joined the Crew/Vehicle Integration Branch at NASA Langley. At the time, he worked on many research projects related to aviation safety, especially in the area of Synthetic Vision Systems. In 2005, he joined NASA Johnson Space Center and has been working on spacecraft related human factors projects. One of his current major projects is the Orion spacecraft, which will be the Space Shuttle replacement. His prime focus on this project is human model validations. Besides the Orion project, Doug has been involved in advocating a human-centered system engineering philosophy at NASA.

Doug is a licensed Profession Engineer in the state of Virginia. He received his Master of Science degree in Mechanical Engineering from the University of Maryland in 1989. He also has both formal and on-the-job training on human factors and statistics.



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# Human Factors Interface With Systems Engineering For Nasa Human Spaceflights

**Douglas T. Wong, P.E.**

**Habitability and Human Factors Branch  
NASA, Johnson Space Center  
Houston, TX**

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# Outline



- **Habitability and Human Factors Branch at NASA JSC**
- **Human-As-A-System (HAAS) Design Philosophy**
- **Past Success in Promoting the HAAS model**
- **Current Endeavors**
- **Future**
- **Conclusion**



# Habitability and Human Factors Branch (SF3) NASA Johnson Space Center



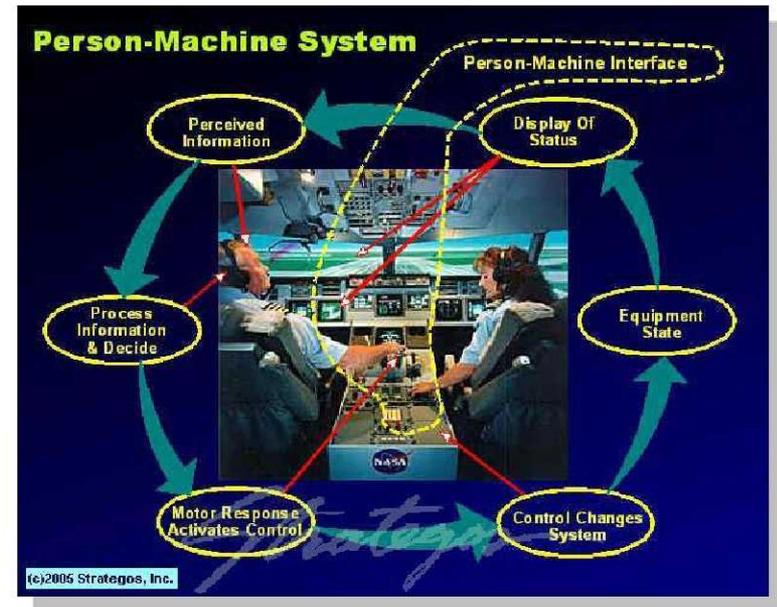
- Part of Space Life Sciences Directorate (SA)
- Human Factors Engineering
- Supporting NASA space programs since 1987
- Facilitates humans to work safely and productively in space
  - Establishing conceptual designs for space habitats and crew systems
  - Developing requirements and guidelines for programs
  - Verifying human-machine interfaces and operational habitability of spacecrafts / habitats
  - Overseeing / conducting research in space human factors to improve human performance and productivity
- Internal Website:
  - <http://jsc-sls-sisl8:1117/HHFO/Default.aspx>



# Human-As-A-System Design Model



- HHFB has been promoting the **Human-As-A-System (HAAS)** design model to NASA's Systems Engineering (SE) process since 1987
- HAAS model
  - Systems are ultimately designed for humans
  - Humans should be considered as a system within the systems
  - Human factors discipline should play an important role in systems development to ensure properly designed human / machine interfaces





# Past Successes in Promoting the HAAS Model

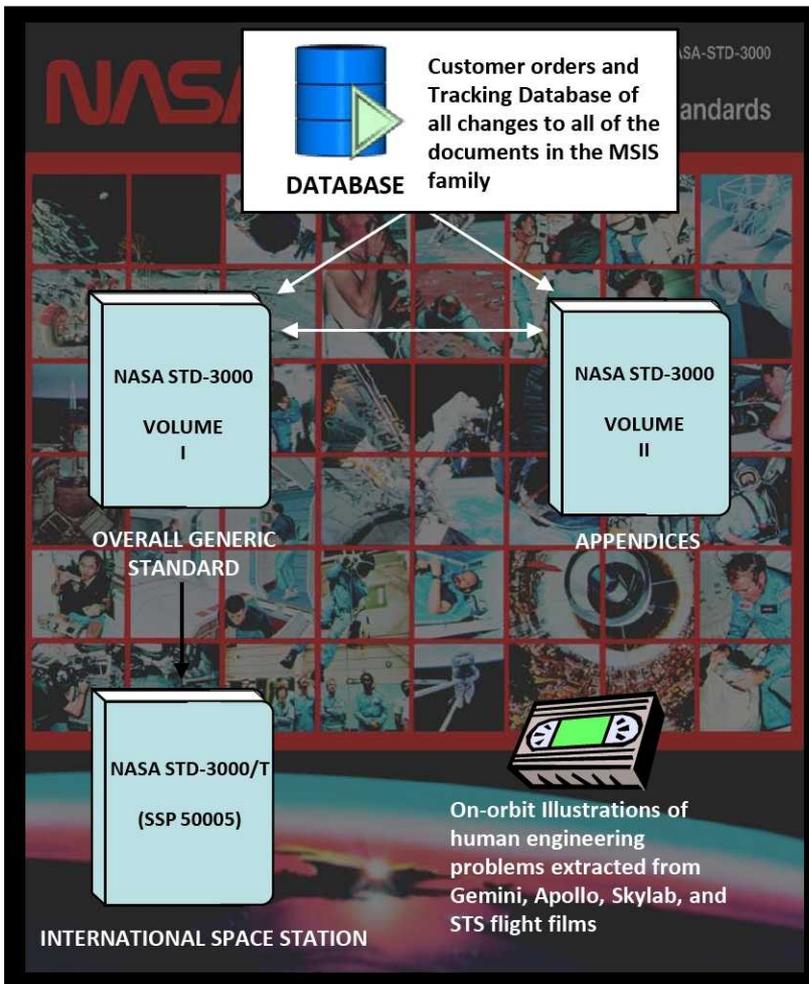
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- **Creation of the NASA-STD-3000 Space Human Factors Standards**
- **International Space Station Program Flight Crew Integration**
- **NASA's Systems Engineering Handbook Update**
- **Space Human Factors Engineering Project's Human Systems Integration (HSI) Contribution**
- **Shuttle and International Space Station (ISS) Lighting Improvements**



# Creation of the NASA-STD-3000 Space Human Factors Standards



- **Man-Systems Integration Standards (NASA-STD-3000):** released in 1987
- Human factors design guide for space equipment
- All generic requirements for space facilities and related equipment interfaces with crewmembers
- Applicable to terrestrial human interface and engineering problems (**Note: some instances are tailored to micro-g environment**)
- **NASA-STD-3000/T**
  - A subset of NASA-STD 3000 data
  - Also called SSP 50005
  - Specific International Space Station (ISS) Flight Crew Integration Standards
  - ISS Program contractually binding human systems integration design requirements
- <http://msis.jsc.nasa.gov/>



# International Space Station Program Flight Crew Integration (FCI)

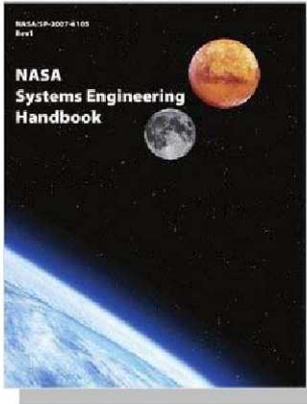


- **Composed of HHFB staff**
- **Provide human factors analyses to the ISS**
- **Analyses performed through**
  - Design review proceedings
  - International partner activities
  - Analysis and Integration Team meetings
- **FCI's Operational Habitability (OpsHab) team**
  - **Collects / analyzes space flight mission data:**
    - identifying human factors and habitability lessons-learned
    - validating human factors engineering requirements and designs
    - solving operational challenges
    - improving habitability and human performance for future ISS missions
  - **Conducts Crew debriefs**
    - long-duration space flights (e.g., Skylab, Mir, ISS)
    - space-analog environments (e.g., the Antarctic, Submarines, etc.)
    - research findings from behavioral science
  - **Focused evaluations on ISS to identify human factors and habitability improvements**
  - **Collected data now incorporated in the upcoming Human Interface Design Handbook, a companion to the NASA Standard 3001**
  - **The lessons-learned data from ISS also benefits subsequent space programs: Orion Crew Exploration Vehicle (CEV)**





# NASA's Systems Engineering Handbook Updated to Include the HAAS Design Philosophy



- **Systems Engineering Handbook (NASA/SP-6105):** HHFB a major contributor to the human factors sections
- First published in 1995
- Fundamental Systems Engineering (SE) concepts and techniques tailored to NASA's systems and environment
- The 2007 Revision
  - Updated the NASA's SE body of knowledge
  - Provide guidance for insight into current best NASA practices
  - Aligning the handbook with the new NASA SE policy
- **2007 Revision: Human Factors Sections**
  - Promote human factors engineering (HFE) as a recommended practice
  - Stress roles of humans in SE for human spaceflight: **The humans (as operators and maintainers) are critical components of the mission and the system**
  - Provide human factors engineering analysis techniques and methods summary
- PDF of SE Handbook
  - <http://education.ksc.nasa.gov/esmdspacegrant/Documents/NASA%20SP-2007-6105%20Rev%201%20Final%2031Dec2007.pdf>



# Space Human Factors Engineering Project's HSI Contribution



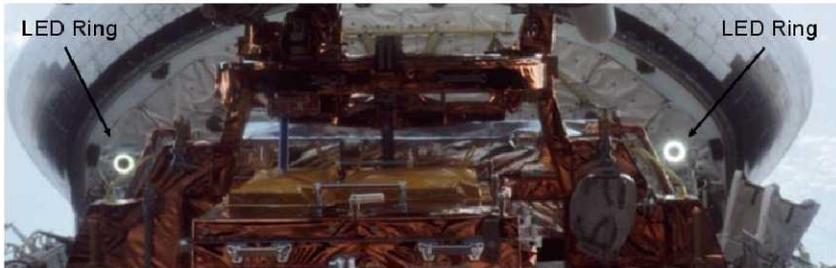
- **HHFB manages the Space Human Factors Engineering (SHFE) project, an element of NASA's Human Research Program**
- **SHFE's goal: Develop human factors standards and models to ensure space system designs are compatible with crewmembers' physical and cognitive capabilities**
- **Research and Technology Gap Analysis in 2005:**
  - **Addressed key questions on Human Systems Integration (HSI) for the Constellation Program (CxP) Orion space vehicle development**
  - **White-paper reviews compared state-of-the-art and state-of-practice human factors technologies with CxP requirements**
  - **White papers were supplemented with expert knowledge:**
    - **in-depth reviews with SMEs (space human factors and users)**
    - **Apollo and Skylab historical reports**
    - **Space Shuttle and ISS debriefs and lessons-learned**
  - **SHFE now sponsors many research and technical development tasks to address the gaps identified**



# Shuttle and ISS Lighting Improvements



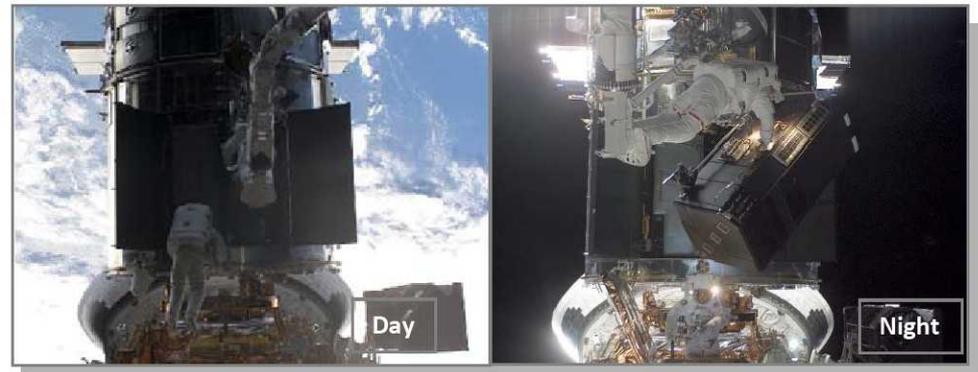
- HHFB's Lighting Environment Test Facility (LETF)
- Shuttle and ISS: Light sources must be bright, durable, light weight, and low-power
- Adopted then new LED technology for general illumination in the Shuttle's camera systems



- June 1998 STS-91: First illumination system of forty white LEDs
- May 1999 STS-96: White 180-LED system
- 2008: First evaluation prototype LED system on ISS

Ring-mounted LED lights around each camera lens:

- Four Shuttle payload bay cameras
- Two robotic arm cameras





# Current Endeavors in Promoting the HAAS Model

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- **NASA Standard 3001**
- **Constellation Program Human Systems Integration Group**
- **Orion Project CEV-HSI Team**
- **Lunar Rover Development**
- **Anthropometry in Constellation Spacesuit Development**
- **OLED Emergency Egress Lighting System Development**



# NASA Standard 3001



- **Update of NASA STD-3000**
- **Developed by HHFB since 2007 through SHFE**
- **Also called Space Flight Human Systems Standard (SFHSS)**
- **To be published in 2009**
- **Defines spaceflight systems design standards for crew health and performance**
- **Established by the Office of the Chief Health and Medical Officer**
- **A two-volume Agency-level standards**
  - **Volume I - Crew Health: Standards related to crew health**
  - **Volume II - Habitability and Environmental Health: Environmental, habitability, and human factors standards for human-system interfaces**
- **“Human Integration Design Handbook” (HIDH)**
  - **Accompanied handbook to NASA STD-3001**
  - **Data and guidance to derive and implement SFHSS-compliant / program-specific requirements**
  - **Crew health, habitability, environment, and human factors design guidance**
  - **Two primary uses**
    - **prepare contractual program-specific human interface requirements**
    - **develop human interfaces designs and operations standards for space vehicles and habitats**



# Constellation Program (CxP) Human Systems Integration Group (HSIG)



- HHFB's success in the International Space Station Program has drawn attention from NASA's CxP
- HHFB leads the CxP HSIG
  - Systems Engineering and Integration (SE&I) group program-level authority
  - Develops and maintains Human Systems Integration Architecture (HSIA)
  - Analyzes, integrates, and dispositions technical changes and issues affecting the application of HSI
  - Works with NASA centers and/or external agencies to resolve lower-level HSI-focused technical issues
  - Plays major roles: Orion Crew Exploration Vehicle, EVA Project, Altair Lunar Vehicles, Ground Operations Project, and ARES I Rocket
  - Develops Human Systems Integration Requirements (CxP 70024)
    - Key mechanism for achieving human rating of CxP systems
    - Apply to all CxP mission phases
  - Develops Crew Interface Labeling Standards (CxP 70152)
    - Standards for labeling and coding of CxP crew interfaces on flight hardware

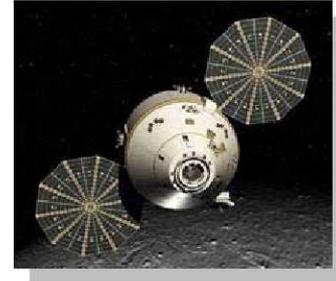




# Constellation Program Orion Project CEV-HSI Team



- **Resource planning and allocation**
- **Spacecraft Designs and Interfaces**
  - Usability Testing and Analysis Facility
  - Habitability Design Center
- **Requirements oversight, validation studies, strategic support**
  - Manages the children flow-down requirements from Human Systems Integration Requirements (HSIR)
  - Assists stakeholders in the interpretation of requirements
  - Addresses HSIR issues and determining their impacts on subsystem designs
  - Participates in design reviews and validation studies (e.g., needs assessments, cost credibility studies, and flight demonstration projects)
- **Safety Oversight and Risk Mitigation Planning**
  - Conduit between Space Life Science Directorate (HHFB's parent organization) and Orion's Health and Medical Technical Authority on human health and performance
  - Identifies / develops mitigation plans for human health and performance related risks
  - Independent entity on boards and panels to address unresolved human health and performance issue





# Constellation Program Lunar Rover Development



- CxP Lunar Architecture / Lunar Surface Systems
- Lunar Unpressurized Rover (UPR)
- Small Pressurized Rover (SPR)
- HHFB's Involvement
  - Usability Testing and Analysis Facility (UTAF)
    - Usability evaluations of UPR and SPR
  - Habitability Design Center
    - Iterative design / evaluations of SPR cabin w/ UTAf



Lunar Unpressurized Rover



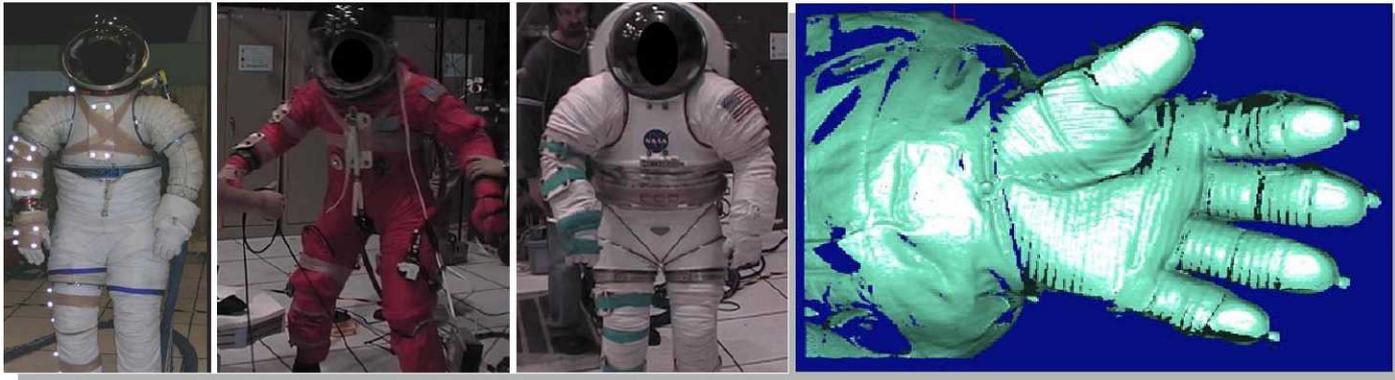
Small Pressurized Rover



# Anthropometry in Constellation Program Spacesuit Development



- **HHFB's Anthropometry and Biomechanics Facility (ABF) identified several key anthropometric factors to improved crew-interface accommodation (Jeevarajan and Rajulu 2008):**
  - **Minimum mobility needed to perform tasks**
  - **Minimum strength a suited crew population can exert**
  - **Capabilities / limitations on pressurized gloves dexterity and tactility**
- **The results facilitate human factors engineers, spacesuit designers, and engineers in developing EVA spacesuits requirements**
  - **Eliminate or minimize potential injuries**
  - **Improve the safety / comfort of new spacesuits**

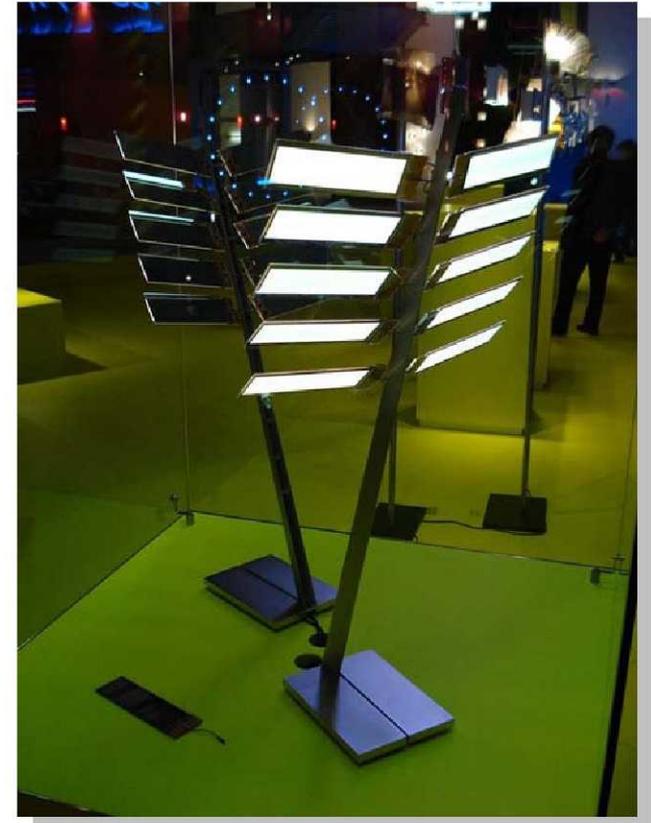
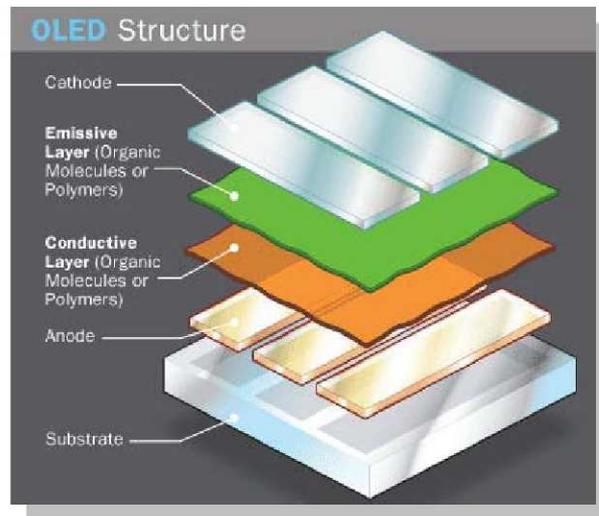




# Organic LED (OLED) Emergency Egress Lighting System Development



- **Lighting Environment Test Facility (LETF):**
  - Future emergency egress lighting system
  - OLED composes of long-lasting photo-luminescent material and ultra low power organic polymer
  - Will greatly reduce maintenance costs without compromising safety for future space vehicles

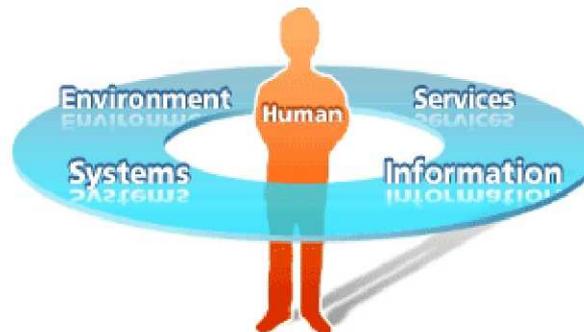




# Future: Human-Centered Design Philosophy for NASA SE Process



- **HHFB plans to make Human Factors Engineering an integral part of the NASA SE process**
- **Introduce the Human-Centered Design Philosophy (HCDP)**
  - **A holistic / iterative human-centered systems design / development process**
  - **Spiral / iterative design where more effort is spent on the early stages to explore feasible concepts**
  - **Entire system life-cycle consideration**
  - **Multidisciplinary team of professionals**
- **First step: update the next NASA SE Handbook with HCDP-relevant language**



Human Centered Design



# Summary



- **The HHFB had much success in the past two decades to convey to major NASA programs the benefits of the Human-As-A-System (HAAS) model in Systems Engineering**
- **Introducing the HAAS model is only the interim solution to HSI**
- **Ultimate goal is to introduce the Human-centered Design Philosophy (HCDP) to the NASA SE process**
- **HCDP will greatly enhance the qualities of future NASA human and non-human rated space systems with higher efficiency, reduced cost, and increased safety**



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