

U.S. Spacesuit Knowledge Capture Accomplishments in Fiscal Year 2014

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Since its 2007 inception, the NASA U.S. Spacesuit Knowledge Capture (SKC) Program has shared historical spacesuit information with engineers and other technical team members to expand their understanding of the spacesuit's evolution, known capability and limitations, and future desires and needs for its use. As part of the SKC Program, subject-matter experts have delivered presentations, held workshops, and participated in interviews to share valuable spacesuit lessons learned to ensure this vital information will survive for existing and future generations to use. These events have included spacesuit knowledge from the inception of NASA's first spacesuit to current spacesuit design. To ensure that this information is shared with the entire NASA community and other interested or invested entities, these SKC events were digitally recorded and transcribed to be uploaded onto several applicable NASA Web sites. This paper discusses the various Web sites to which the SKC events are uploaded and possible future sites that will channel this information.

Nomenclature

BCM	=	Baylor College of Medicine
CS	=	crew survival
CTSD	=	Crew and Thermal Systems Division
DAA	=	Document Availability Authorization
EA	=	Engineering Directorate
EC	=	Crew and Thermal Systems Division
ECLSS	=	Environmental Control and Life Support System
EMU	=	Extravehicular Mobility Unit
EVA	=	extravehicular activity
FY	=	Fiscal Year
ISS	=	International Space Station
JSC	=	Johnson Space Center
K-CAP	=	knowledge capture [lessons]
KM	=	knowledge management
NASM	=	National Air and Space Museum
NESC	=	NASA Engineering and Safety Center
NF	=	NASA Form
NPD	=	NASA Policy Directive
NPR	=	NASA Procedural Requirements
NTRS	=	NASA Technical Reports Server
PLSS	=	portable life support system

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SIPI = Southwestern Indian Polytechnic Institute
SKC = U.S. Spacesuit Knowledge Capture
SME = subject-matter expert
STEM = science, technology, engineering, and math
STI = Scientific and Technical Information
SWME = Spacesuit Water Membrane Evaporator
UTMB = University of Texas Medical Branch

I. Introduction

WITH the successful December 5, 2014 launch of the Orion spacecraft, NASA is one step closer to its mission to explore deep space and harness an asteroid as a precursor to sending humans to Mars within the next 2 decades. With this mission, the U.S. spacesuit remains a priority for NASA; however, sending humans into deep space involves important ancillary aspects, such as astronomy, human factors, crew survival (CS) and escape, and an astronaut's physiological and psychological well-being that are tied to his or her environment that lie outside the spacesuit, as exemplified in Figure 1. These topics are part of the U.S. Spacesuit Knowledge Capture (SKC) Program and are shared with spacesuit developers to design future spacesuits to prepare for human travel into deep space.

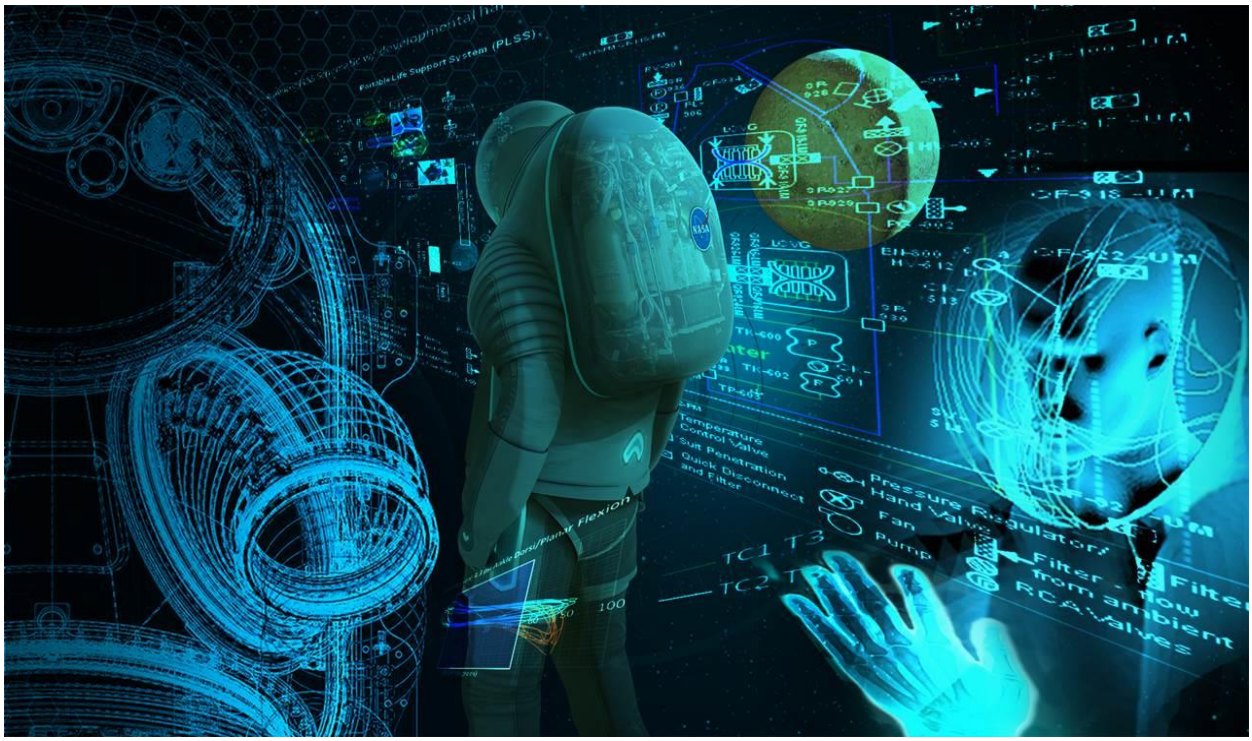

Figure 1. A gallery of ancillary aspects associated with spacesuits (image by Jeannie Corte).

In May 2007, a Johnson Space Center (JSC) center-wide Knowledge Management (KM) assessment was completed. In 2008, a JSC Policy Directive was issued encouraging JSC organizations to promote knowledge transfer, collaborative sharing, and learning required for the success of the NASA missions; this spurred the formation of the SKC Program.[1] The Space Suit & Crew Survival Systems Branch at JSC manages the SKC Program. Since its 2007 inception, the SKC Program team realized the importance of archiving and sharing historic spacesuit knowledge.

The SKC Program collects historical and current spacesuit information and peripheral topics that enhance the development of spacesuits. This program captures this knowledge by hosting events such as lectures, courses, and interviews with subject-matter experts (SME). These SMEs recollect their experience with spacesuits and other ancillary spacesuit-related topics, extrapolate lessons learned, and offer recommendations. This documented information is preserved in written, video, and audio formats and was initially provided to JSC NASA engineers, scientists, and managers to augment their work.

Although the SKC Program has collected a plethora of valuable information, it is important that these lessons not only get conveyed, but also used. As a way to encourage use of this information, the SKC Program is focusing on having this knowledge readily available to current and future spacesuit developers and technical human mission contributors by disseminating it through NASA and public domains.

The "U.S. Spacesuit Knowledge Capture Status and Initiatives" paper discusses NASA's SKC Program from inception through June of Fiscal Year (FY) 2012,[1] and the paper titled "U.S. Spacesuit Knowledge Capture Accomplishments in Fiscal Years 2012 and 2013" focuses on SKC events from July FY 2012 through FY 2013.[2] No SKC events occurred during FY 2014. During this period, the emphasis was on processing the existing events to obtain approval for public release and determining a means of accessing this valuable information. Also, in FY 2014, the NASA Engineering and Safety Center (NESC) became a primary supporter of the SKC Program and began helping the program prepare its information to be viewed on five NASA domains, some of which are publically accessible. This paper, "U.S. Spacesuit Knowledge Capture Accomplishments in Fiscal Year 2014" describes the SKC Program and the NESC's contribution to it, identifies the events that were approved for public release, and explains how to access the released events.

II. Approval and Release of the Spacesuit Knowledge Capture Program Information

Early in the program, the SKC manager realized that other entities such as external aerospace vendors, educational institutions, and the public could benefit from this unique information that is categorized as Scientific and Technical Information (STI). STI is defined as the results (the analyses of data, facts, and resulting conclusions) of basic and applied scientific, technical, and related engineering research and development per NASA Policy Directive (NPD) 2200.1C.[3]

The means in which the SKC information is collected, managed, disseminated, safeguarded, and archived is governed by NPD 2200.1C. As well, NASA Procedural Requirements (NPR) 2200.2 stipulates that all NASA STI subject to review is required to be approved via the Document Availability Authorization (DAA) review process (using NASA Form (NF)-1676) before being published, disseminated, or presented externally to NASA, or presented in internal meetings or conferences at which foreign persons may be present. The DAA review determines whether STI must have restricted access, such as for export-controlled information, proprietary STI, and documents disclosing an invention.[4] The process to disseminate the SKC information involves the SKC administrator completing an NF-1676. The NF-1676 is an electronic form that invokes the DAA process by review and approval of certain technical and managerial representatives. After the form is completed and submitted, it is electronically signed and routed for approval per document JSC-29306.[5] An approved NF-1676 signifies that there is no government sensitive information in the content and that the reviewed information may be released to the public.

After the NF-1676 is approved, the SKC information is archived by uploading it to the following five NASA Web sites:

1) NESC Academy
2) NASA Technical Library and STI Program's YouTube
3) Engineering Directorate (EA) Engineering Academy
4) JSC History Office
5) SKC

The NASA community and public entities can access these events through the NESC Academy, the JSC History Office, and the NASA Technical Library and STI Program's YouTube Web sites. The NASA community can also access these events through the SKC Web site. JSC employees have additional access to these events through the EA Engineering Academy.

III. NASA Engineering and Safety Center and its Contribution

"NASA Engineering and Safety Center's (NESC) mission is to perform value-added independent testing, analysis, and assessments of NASA's high-risk projects to ensure safety and mission success. The NESC engages proactively to help NASA avoid future problems."[6] To accomplish this mission, the NESC retains technical experts in a multitude of disciplines across the NASA agency. The spacesuit falls within the Environmental Control and Life Support System (ECLSS) discipline. Henry (Hank) Rotter, an initial member of NESC as the NASA Technical Fellow for ECLSS and Active Thermal Systems, recognizes the plethora of valuable spacesuit information that the SKC captures, archives, and distributes. He also recognizes that the SKC Program includes a tremendous amount of lessons learned that could be shared across the NASA agency. Therefore, in the spring of FY 2014, Mr. Rotter chose to fund the program, resurrecting it after it lost funding at the beginning of FY 2014. This funding allows the SKC Program to continue processing its recorded information to be released to the spacesuit community, and make this

information readily available to technical experts across the agency through the five Web sites identified in Section II.

The NESC has a collection of electronically recorded events from technical experts of ECLSS and Thermal Systems. Within FY 2015, the NESC will add to its collection by processing and uploading SKC approved-for-release information. The NESC's library is a conduit that makes this information readily available and ensures that technical experts have key information, especially when the information helps ensure safety and mission success. Because of this, the NESC hones in on lessons learned. Much of the SKC Program's content includes lessons learned for future spacesuit designers, which fits with Mr. Rotter's discipline area. Giving the spacesuit community access to this valuable information will enhance current and future spacesuit programs.

IV. How to Access U.S. Spacesuit Knowledge Capture Program Information

Out of the 70 recorded SKC events, 46 of these have been approved for release and are being processed to be uploaded to 5 NASA domains: NESC, NASA Technical Library and STI Program's YouTube, EA Engineering Academy, JSC History Office, and SKC.

A. NASA Engineering and Safety Center

The NESC was formed in July 2003 as a result of the Space Shuttle Columbia incident. The NESC's main purpose is to ensure that NASA's safety and mission assurance organizations have adequate technical expertise and resources for independent, in-depth, technical reviews of NASA's programs. The NESC revealed its mission: "In order to bring the Country's outstanding technical experts to bear on the problems and challenges of NASA programs, the NESC will be comprised of the best engineering expertise from across the Agency and will include partnerships with expert consultants from other government organizations, National Laboratories, universities, and industry."[10] The NESC created a Web site that includes the NESC Academy. The ECLSS technical fellow funded the SKC Program to augment the NESC Academy's archives. This technical information will be readily available to technical experts across the NASA agency through the NESC Web site and other viable NASA entities.

NESC Web site (accessible to the NASA community and the public):
http://nescacademy.nasa.gov/video_catalog.php?catid=5&subcatid=27

B. NASA Technical Library and Scientific and Technical Information Program's YouTube

The NASA Technical Library is a Web site that operates under the NASA Technical Reports Server (NTRS), which is part of the STI Program. This site stores, organizes, and makes publically accessible NASA approved-for-release technical, research, and scientific information.

NASA Technical Library Web site (accessible to the NASA community and the public): https://ntrs.nasa.gov/

JSC manages the NASA STI Program's YouTube, a publically available Web site that resides within the NASA STI Program, a program that collects, organizes, and preserves technical knowledge and lessons learned. The SKC Program approved-for-release events featuring extravehicular activity (EVA), spacesuit, portable life support system (PLSS), and other spacesuit-related topics are archived within this YouTube site.

NASA STI Program's YouTube (accessible to the NASA community and the public):
http://www.youtube.com/playlist?list=PL30B1C44470174A66&feature=plcp

C. Engineering Directorate Engineering Academy

The EA Engineering Academy is a Web site that collects and disseminates, to JSC viewers, technical information that includes training, development, and learning resources. It was created in January 2006 with a primary purpose: "to coordinate and focus learning resources within the Engineering Directorate. The EA Engineering Academy works with the Office of the Chief Engineer, the Human Resources Training and Development Office, the University and Research Affairs Office, and other organizations at JSC to accomplish its mission and objectives."[7]

EA Engineering Academy Web site (accessible to JSC employees):
http://ea.jsc.nasa.gov/Ea_web/html/emplsrv/academy/index.asp

D. Johnson Space Center History Office

The JSC History Office collects, stores, and gives public access to the JSC History Database, JSC Oral Histories, and various recorded JSC history through hundreds of Web sites.

JSC History Office Web site (accessible to the NASA community and the public):
http://www.jsc.nasa.gov/history/spacesuits/index.htm

E. Spacesuit Knowledge Capture

The SKC Web site contains all approved-for-release SKC Program events for NASA and contractor viewing. It includes links to the "U.S. Spacesuit Knowledge Capture Series Catalog Revision A," the Crew and Thermal Systems Division (EC) Share Drive, and spacesuit-related Web sites, which include the EA Engineering Academy, NTRS, and NASA STI Program's YouTube.

SKC Web site (accessible to the NASA community):
https://oasis.jsc.nasa.gov/orgs/EC/SpacesuitKnowledgeCapture/default.aspx

V. Summary of Accomplishments and Events

Since the SKC Program's 2007 inception, 70 events have been recorded and submitted into the DAA 1676 process to be approved for public consumption. Forty-six of these have been approved for release. The events have been delivered in the form of lectures, training courses, lunch-and-learns, workshops, and interviews with spacesuit experts. They are resources to be made readily available to engineers and various technical specialists who can use this information to advance the U.S. spacesuit beyond the boundaries of current technical achievements. These events are electronically recorded and include the presenters' slides and verbal presentations along with attendees' questions asked during the event.

Currently, the SKC Program has processed the 46 approved-for-release events (Table 1) to be archived and made publically available by uploading them to the NESC, the NASA Technical Library and STI Program's YouTube, the EA Engineering Academy, the JSC History Office, and the SKC domains. The "U.S. Spacesuit Knowledge Capture Series Catalog Revision A" Crew and Thermal Systems Division (CTSD)–SS–3487 documents all the SKC events that occurred since the program's inception through FY 2013 and includes the event's topic, presenter, synopsis, and each presenter's biography. The catalog will be available through the NTRS YouTube site [http://www.youtube.com/playlist?list=PL30B1C44470174A66] and is currently available on the SKC Web site [https://oasis.jsc.nasa.gov/orgs/EC/SpacesuitKnowledgeCapture/default.aspx].

Table 1. Approved-for-Release Events

Date Presented	Presenter	Titles of Event
1/14/2008	G. Ryan Lee	Implications of Operational Pressure
2/22/2008	Garret Fitzpatrick	Gen Y Perspectives
2/28/2008	Bruce Conger	Baseline Constellation PLSS Schematic Functions and Operational Modes
3/27/2008	Gretchen A. Thomas and Amy J. Ross	Arizona Geology Field Trip
4/18/2008	Gretchen A. Thomas	Rules of Thumb for Cost Estimating
5/20/2008	Joey Marmolejo, Chris Estrada, Chuck Fulcher, and Brian Peavey	Orlan-M Spacesuit Familiarization Class
6/13/2008	Amy Ross	Gloves 101
8/26/2010	Cinda Chullen and William (Bill) West	Post-Shuttle EVA Operations on ISS
2/17/2010	Lewis Croog	Chinese Spacesuit Analysis
3/15/2010	Dr. Dean Eppler	Conduct of Geologic Field Work during Planetary Exploration: Why Geology Matters
5/20-21/2010	Joe McMann and Mike Rouen	EMU Certification Workshop
6/25/2010	B. Mike Lawson	The Size of the Universe and Where Will We Go?
9/28/2010	Mallory Jennings and Dr. Glenn Waguespack	Constellation Spacesuit PLSS Trace Contaminant Control

Table 1. Approved-for-Release Events (continued)

Date Presented	Presenter	Title of Event
9/30/2010	Grant Bue & Matthew Vogel	Design and Testing of the Sheet and Hollow Fiber Spacesuit Water Membrane Evaporators
10/28/2010	Jennifer Matty	Joint Mobility
1/25/2011	Amy J. Ross	Suit 101
3/31/2011	Gretchen A. Thomas	PLSS 101
12/16/2010	B. Mike Lawson	Mike Lawson's Stories and More
6/30/2011	Joe Chambliss	Alternate Approaches to Exploration – The Single Crew Module Concept
8/16/2011	Joe McMann (interviewed by Pica Kahn)	An Interview with Joe McMann: Lessons Learned in Human and Hardware Behavior
10/20/2011	Mallory Jennings	Packing the PLSS
11/29/2011	Carly Watts and Bruce Conger	PLSS 1.0 Breadboard – Schematics
12/6/2011	Joe Kosmo (interviewed by Amy J. Ross)	Farewell Advice
12/8/2011	Joe McMann	Fifty Years of Observing Hardware and Human Behavior
1/19/2012	Joe McMann and Paul Shack	Shuttle EMU Electronics/Avionics Development Experience as Related to Advanced EMU Development
5/10/2012	Tom Sanzone	The Good Old Days of CTSD
1/24/2012	Dr. Scott Parazynski	EVA Physiology & Medical Considerations Working in the Suit
2/23/2012	Dr. Scott Parazynski	TPS Inspection and Repair
3/6/2012	Dr. Scott Parazynski	EVA Skills Training
3/28/2012	Ron Woods (interviewed by Rebecca Wright)	Apollo, Paintbrushes, and Packaging: An Interview with 40-year Spacesuit Veteran Ron Woods
4/19/2012	Ron Woods	Lessons Learned From a Ship-and-Shoot Philosophy
4/26/2012	Ron Woods	The Road to Final Stow
5/14/2012	Dr. Cathleen Lewis (interviewed by Rebecca Wright)	Interview with Smithsonian NASM Spacesuit Curator Dr. Cathleen Lewis
6/19/2012	Grant Bue & Janice Makinen	SWME Development and Testing for the Advanced Spacesuit
6/25/2012	Joe McMann	PLSS Design and Manufacturing Review Debrief
8/14/2012	Juniper Jairala and Robert Durkin	EVA Development and Verification Testing at NASA's Neutral Buoyancy Laboratory
9/28/2012	Jim McBarron (interviewed by Rebecca Wright)	Personal Background Interview of Jim McBarron
10/16/2012	Joe Chambliss	The Single Habitat Module Concept – A Streamlined Way to Explore

Table 1. Approved-for-release Events (continued)

Date Presented	Presenter	Titles of Event
11/6/2012	Jim McBarron	Spacesuit Development and Qualification for Project Mercury
12/4/2012	Jim McBarron	Spacesuit Development and Qualification for Project Gemini
1/29/2013	Jim McBarron	Apollo Block I Spacesuit Development and Apollo Block II Spacesuit Competition
4/10/2013	Kenneth Thomas	Launch, Entry & Abort, Intra-Vehicular Spacesuits
5/6/2013	Dr. Stan Love	Antarctica EVA
7/25/2013	Dr. Paul Abell	Human Exploration of Near-Earth Asteroids
7/31/2013	Dr. Stan Love	Near-Earth Asteroids: Threats and Opportunities
1/21/2015	Jim McBarron	Early Apollo Spacesuit Development, A-7L Suit Requirements, and Design Details

VI. Featured Spacesuit Knowledge Capture Events

Although the SKC events usually center on the topic of the spacesuit, it is important to recognize the ancillary research and experiences of other experts and learn from them. The SKC has presented other important aspects that are related to the spacesuit, and this paper highlights two such topics.

A. The Size of the Universe and Where Will We Go by B. Mike Lawson

On June 25, 2010, B. Mike Lawson (Figure 2), an avid engineer and amateur astronomer, presented an SKC event that gave a perspective on the size of the universe and asked the question, "Where will we go?"

Figure 2. B. Mike Lawson throughout his engineering career.

During this event, Mr. Lawson illustrated the significance and strengthened an appreciation for Earth and our solar system by showing Earth's interrelation with humans and other planets in our universe, and discussed technical capabilities and limitations of human exploration. This also supports reasons to explore space, which is NASA's mission.

This was an entry-level overview for the average space worker who really wants to understand the size of stars and the distance between objects in space. Mr. Lawson provided information about familiar orbital objects and elaborated more on galaxies during the discussion. He also explored where humans can go in space and the physical limitations of going there.

Mr. Lawson earned a master of science in mechanical engineering with an emphasis in heat transfer and thermodynamics from the University of Texas. He originally worked for General Dynamics, specializing in the environmental control and heat transfer systems for the F-16 fighter aircraft. He came to work for NASA in 1980 and worked on EVA, thermal and environmental control, and life support systems. Mr. Lawson retired from NASA in December 2010.

B. Overview of Spacesuits for Survival and Escape by Dr. Jonathan B. Clark

On September 17, 2013, Dr. Jonathan B. Clark (Figure 3) participated in an SKC event that reviewed the pressure suit used for high altitude and space programs.

Figure 3. Dr. Jonathan B. Clark contributing to the space industry.

To safely travel into deep space, a spacesuit to protect astronauts from the harsh space environment must be designed. Dr. Jonathan B. Clark emphasized that to protect an astronaut, the spacesuit must be readily accessible; the astronaut must be able to don and doff it properly and timely during an emergency. The suit must allow the astronaut to have adequate dexterity and mobility to perform tasks while wearing it.

Learning objectives of this event included understanding the role that spacesuits play in CS and crew escape and recognizing the design trade-offs (capabilities and limitations) and concerns that rescue and escape spacesuits have in a survivability situation.

Dr. Clark received his bachelor of science from Texas A&M University, and medical degree from the Uniformed Services University of the Health Sciences, and is board certified in neurology and aerospace medicine. He worked at NASA from 1997 to 2005. He was a six-time Space Shuttle crew surgeon and was chief of the Medical Operations Branch at JSC. He was a member of the NASA Spacecraft Survival Integrated Investigation Team from 2004 to 2007 and a member of the NASA Constellation Program EVA Systems Project Office Standing Review Board from 2007 to 2010. Before joining NASA, Dr. Clark devoted 26 years to active service with the U.S. Navy.

Currently, he is an associate professor of Neurology and Space Medicine at Baylor College of Medicine (BCM) and teaches operational space medicine at BCM's Center for Space Medicine. He is also the space medicine advisor for the National Space Biomedical Research Institute. He is a clinical assistant professor in the Department of Preventive Medicine and Community Health at the University of Texas Medical Branch (UTMB) in Galveston and teaches at the UTMB Aerospace Medicine Residency. Dr. Clark is a fellow of the Aerospace Medical Association. He is also medical director of the Red Bull Stratos Project. Dr. Clark's professional interests focus on the neurologic effects of extreme environments and CS in space. He accepted this vital role on the Red Bull Stratos team not only to protect Felix Baumgartner from the physical effects of high altitude, but also to establish new protocols to benefit future aviators and astronauts.

VII. Future Outlook for U.S. Spacesuit Knowledge Capture

The spacesuit legacy has many valuable lessons, but only a fraction of what exists has been shared, preserved, and made accessible to those who can apply them for the advancement of spaceflight. With the NESC's support and encouragement, the SKC Program will host at least eight events during FY 2015 to continue disseminating this valuable information; seven events will be presented by Jim McBarron, and one will be prepared for the Southwestern Indian Polytechnic Institute (SIPI).

A. Apollo and Space Shuttle Spacesuit Events by Jim McBarron

Jim McBarron is a former NASA employee who worked with spacesuits for all NASA flight programs thus far, including Mercury, Gemini, Apollo, Apollo-Soyuz Test Project, Skylab, Space Shuttle, and the ISS. He is also a retired CTSD chief engineer for EVA projects and will present seven SKC lectures that focus on the spacesuit development for Apollo 7 through 14 missions, as well as Skylab and the Space Shuttle Extravehicular Mobility Unit (EMU) spacesuit development. With over 50 years of experience with NASA spacesuit development and operations, as well as the U.S. Air Force pressure suit, Mr. McBarron will also share lessons learned from this experience. After this information is approved for release, it will be stored electronically on the NESC, as well as on the NASA Technical Library and STI Program's YouTube, the EA Engineering Academy, the JSC History Office, and the SKC Web sites.

The titles of the seven SKC events that Mr. McBarron will present in FY 2015 are listed below:

1) Early Apollo Spacesuit Development, A-7L Suit Requirements, and Design Details
2) Apollo A-7L Spacesuit Certification and Mission Operations Details
3) Apollo A-7LB Spacesuit Development for Apollo 15 through 17 Missions
4) Skylab A-7LB Spacesuit Development for Skylab SL-2 through SL-4 Missions
5) Apollo Spacesuit Modifications and Development for the Apollo Soyuz Test Space Shuttle
6) Space Shuttle EMU Spacesuit Development for Initial Shuttle Flights
7) Space Shuttle EMU Spacesuit Development for the International Space Station

B. Southwestern Indian Polytechnic Institute Knowledge Capture

The SIPI grant won in FY 2014 engages the SKC Program. As a result of this grant, Scott Askew, a robotics expert will deliver a knowledge capture (K-CAP) lesson to SIPI to facilitate the study of science, technology, engineering, and math (STEM) education. This lesson will be adaptable and targeted to the interest of the students and academia. It will benefit minority high school and college students by sharing valuable scientific insight and application of experiences. This lesson will be provided to SIPI students who will have remote access through online meetings. During this lesson, students will have the opportunity to ask questions to Mr. Askew. The SIPI lesson will be electronically recorded to use in the future and for reference. The recording will also be stored on compact discs to make the material accessible to educators and students. The students may also access the approved-for-release lessons and other non-sensitive technical events on the NASA YouTube and NESC Web sites.

To help share and encourage STEM interests among SIPI students, Scott Askew's presentation to SIPI will be focused on the first humanoid robot in space (Robonaut 2) and its technology spin-offs. Robonaut's development began at the NASA JSC in 1997. Funded as a technology program to push the envelope of space robotics, its journey to space has been circuitous and required perseverance from many engineers over its lifespan. Currently onboard the International Space Station (ISS), Robonaut 2 has spanned six crew expeditions and has been upgraded recently with walking legs. These legs will soon allow it to move inside the ISS to prepare for future robotic EVA outside the habitation modules. Mr. Askew will discuss Robonaut technology and the ways engineers have germinated multiple new projects that are enabling future capabilities for humans in space and on Earth.

VIII. Conclusion

KM is a strategic objective for NASA, and a primary mission of NASA is to send humans deeper into space than ever before. The SKC Program's primary objective is to share and retain pertinent knowledge of the spacesuits, and is especially relevant as a new spacesuit is currently being designed, assembled, and tested, and the mission architecture is being established. The knowledge being archived comes from SMEs' past experiences to assist future generations in continued exploration, to be innovative, to go deeper into space, and discover more valuable and useful information in the process.

In a 2010 visit to the Kennedy Space Center, President Barack Obama discussed NASA's next chapter: "Critical to deep space exploration will be the development of breakthrough propulsion systems and other advanced technologies. So I'm challenging NASA to break through these barriers."[8] To break through barriers and deliver advanced technologies in spacesuit design, the SKC Program's collection of valuable unique information is being tapped.

Although NASA's workforce (civil servants and contractors) is only 26.6% of that during the Apollo era (approximately 218,000 in June 1969[9] compared to approximately 58,000 in January 2015[10]), the information resources are greater than ever in NASA's history. With the abundance of SKC, the time is ripe for spacesuit designers to use this resource to help prepare astronauts for deep space missions. NASA's goal is to take humans farther into space than Apollo did. The SKC Program's goal is to capture and make significant knowledge accessible to spacesuit designers, scientists, and any entity that will enhance the opportunity to increase NASA's ability to reach its goal. Making this knowledge accessible to scientists, designers, engineers, and technologists who will apply it to advance NASA's space program and help make it possible for astronauts to reach and endure the deep space environment will increase this information's value and help keep the United States the world's leader in space science.

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References

[1]Chullen, C., Woods, R., Jairala, J., Bitterly, R., McMann, J., and Lewis, C., "U.S. Spacesuit Knowledge Capture Status and Initiatives," AIAA-2012-3590, 42nd International Conference on Environmental Systems, San Diego, California, 15-19 July 2012.

[2]Chullen, C. and Oliva, V.R., "U.S. Spacesuit Knowledge Capture Accomplishments in Fiscal Years 2012 and 2013," AIAA-2014-230 44th International Conference on Environmental Systems, Tucson, Arizona, July 2014.

[3]NASA Policy Directive, "Management of NASA Scientific and Technical Information," NPD 2200.1C, 9 December 2014.

[4]NASA Procedural Requirements, "Requirements for Documentation, Approval, and Dissemination of NASA Scientific and Technical Information," NPR 2200.2C, 9 December 2014.

[5]McDonald, S., "Document Availability Authorization (DAA) Procedures," JSC-29306, NASA Johnson Space Center, Houston, TX, 8 January 2001, [Rev D by Montasser, A. S., 18 September 2014].

[6]NASA Engineering and Safety Center Web site, URL: http://www.nasa.gov/offices/nesc/home/index.html [cited December 2014].

[7]EA Engineering Academy Web site, URL: http://ea.jsc.nasa.gov/ea_web/html/emplsrv/academy/index.asp (NASA ID required) [cited December 2014].

[8]Lee, Jesse, The White House Blog, URL: http://www.whitehouse.gov/blog/2010/04/15/making-investments-groundbreaking-developments-21st-century-space-exploration, 15 April 2010.

[9]Managing NASA in the Apollo Era, Chapter 5, URL: http://history.nasa.gov/SP-4102/notes.htm#5.3 [cited February 2015].

[10]IMB Cognos PowerPlay Studio-Workforce History, URL: https://wicn.nssc.nasa.gov/ [cited February 2015].