JSC/EC5 U.S. Spacesuit Knowledge Capture (KC) Series Synopsis

All KC events will be approved for public release using NASA Form 1676.

This synopsis provides information about the Knowledge Capture event below.

Topic: Interviews with Apollo Lunar Surface Astronauts in Support of EVA Systems Design

Date: 2/23/2010 **Time:** 3:30-5:00 pm **Location:** JSC/B4S

DAA 1676 Form #: 29714

A PDF of the presentation is attached to the DAA 1676 and this is a link to all lecture material and video: \\js-ea-fs-03\pd01\EC\Knowledge-Capture\FY10 Knowledge Capture\20100223_D.Eppler_ApolloEVAInterviews\ApolloInterviews-for 1676 review

*A copy of the video will be provided to NASA Center for AeroSpace Information (CASI) via the Agency's Large File Transfer (LFT), or by DVD using the USPS when the DAA 1676 review is complete.

Assessment of Export Control Applicability:

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* This PDF is also attached to this 1676 and will be used for CASI public distribution. *US Spacesuit KC-Eppler-Apollo Interviews_2-23-2010.pdf*

Presenter: Dean Eppler, Ph.D.

Synopsis: A 3-person team interviewed 8 of the 11 surviving Apollo crewmembers in a series of focused interviews to discuss their experiences on the lunar surface. Eppler presented the results of these interviews, along with recommendations for the design of future lunar surface systems.

Biography: Dr. Dean Eppler earned a bachelor of science in geology from St. Lawrence University in 1974, a master of science in geology from the University of New Mexico in 1976, and a doctor of philosophy (Ph.D.) in geology from Arizona State University in 1984. From 1986 to 2009, he was a senior scientist with Science Applications International Corporation, which included 20 years of support to NASA at JSC. During that time, he was a lead suit test subject for advanced planetary spacesuit development and geologic field testing from 1996 to 2005; the ISS Payloads Office Program lead on development of a high-quality research window on the ISS from 1994 to 2005; the program originator and lead scientist on the ISS Window Observational Research Facility (WORF) from 1998 to 2003; and the lead for Science Operations and Logistics Concept Development for Advanced Planetary Exploration Programs, including two years in the lunar surface systems for Constellation. In 2009, he transitioned to NASA and began working in the Astromaterials Research and Exploration Science (ARES) Directorate doing science operations development for lunar missions including creating science operations concepts

for Desert Research and Technology Studies (RATS) and developing and implementing the geologic training curriculum for the 2009 Astronaut Class. During his career, Eppler has published more than 30 scientific publications and has been awarded the Army Commendation Medal, the Antarctic Service Medal, and the NASA Exceptional Public Service Medal.

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JSC/EC5 U.S. Spacesuit Knowledge Capture (KC) Series Synopsis

Topic: Interviews with Apollo Lunar Surface Astronauts in Support of EVA Systems Design

Date: February 23, 2010 **Location:** Johnson Space Center (JSC), Houston, TX

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Video Length and Size: 1:00:50 (0.87332 GB)

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Interviews with Apollo Lunar Surface Astronauts in Support of EVA Systems Design

Dean Eppler, ARES Directorate
Exploration Sciences Office

Introduction

- This work was undertaken in 1993 at the behest of Jay Greene to offset the effects of two rampant syndromes that affected some (but by no means all) people in SEI
  - The first was referred to as Apollo Nostalgia Syndrome, or Apollonius Memorilapsus
    - » This generally struck white males in the 50-60 year age demographic who were later found to have had done little, if anything, with Apollo EVA
    - » Symptoms are glassy eyes, a wistful expression, memory alteration, and repetition of the phrase, “On Apollo, we...”
  - The second was Apollo Ignorance Syndrome, or Apollonius Ignoranimus
    - » This generally struck white males under 40 who had been with NASA less than 10 years
    - » Symptoms are a blank expression, and the repetition of the phrase, “What do you mean, we went to the Moon once!?”
- In short, the work was meant to set the record straight about Apollo EVA, and to learn something from the astronauts who went to the Moon on Apollo

The Interview Process

- Invitations were extended to all the surviving Apollo moon walkers; ultimately, 8 accepted our invitation
  - The final list of interviewees were Buzz Aldrin (Apollo 11), Alan Bean (Apollo 12), Ed Mitchell (Apollo 14), Dave Scott (Apollo 15), John Young (Apollo 16), Charlie Duke (Apollo 16), Gene Cernan (Apollo 17) and Jack Schmitt (Apollo 17)
- The interview process, which was designed by Dr. Mary Connors, an aviation accident investigator from Ames Research Center, took 1/2 day for each astronaut, and involved a briefing on the First Lunar Outpost plans, a hands-on session with the Apollo EMU, Shuttle EMU and Advanced EMUs, and an ≈2 hour focused interview session
  - The hands on session was designed to jog “physical” memories, and included a look at the A7LB, the Shuttle EMU, the ZPS Mark III and the AX-5 suits, and a glove-box session with the Apollo glove, the Series 4000 glove and advanced development gloves

The Interview Process (cont.)

- The purpose of the interview was not to get a verbatim record of each crew members recollections; it was rather to get their viewpoints on a number of specific topics related to Apollo and future planetary surface EVA, so as to develop a consensus to be used in planning future EVA
- The topics discussed were
  - Mission approach and structure;
  - EVA suits, including suit & habitat operating pressure, suit breathing gas
  - PLSS
  - Dust control
  - Gloves
  - The use of automation in suit/PLSS function
  - Information, displays and controls;
  - Rovers
  - EVA tools
  - Operational procedures and philosophy
  - Training
  - General comments

Interview Results
Mission Approach and Structure

- Mission design philosophy must include the total system, EVA included, with complete, seamless integration of the crew into the facilities and equipment
  - The equipment should be designed to fit the tasks to be accomplished, NOT THE REVERSE
- Design strategy should be characterized by simplicity and reliability, while anticipating routine tasks and simple emergencies, not the worst case scenario
- The crew should be essentially autonomous, with a more active crew role in mission planning than was available during Apollo

Interview Results: Mission Approach and Structure (cont.)

- Future exploration missions should not be as rigidly scheduled as Apollo
- Two man crew should be the basic unit of exploration, although short, one man contingency EVAs are not unreasonable
- EVAs with 7-8 hours duration, at least every other day is doable, and most felt that every day was the way to go
  - *The autonomy of the crew is a critical component: they should have the authority to decide whether they are safe and up to a particular day's work, rather than following the rigid schedule as was followed during Apollo*

Interview Results: EVA Suits

- Simplicity and reliability should be the rule
- Provide the mobility needed to perform the task, and no more
- Suit mobility should be the driving consideration on the suit pressure-hab pressure-prebreathe time
  - The dominant belief was that the key to suit flexibility is low operating pressure with pure O_2 breathing atmosphere at 3-4 psi
  - Variable pressure suits were considered to be an interesting concept that had good potential, provided it did not interfere simplicity
- There was mixed views on suit mass/weight; some respondents felt that suit weight was a concern, others did not see it as a big issue
  - Testing we have done since 2005 have suggested that on-the-back weight for our systems is less of an issue on the Moon than it will be for Mars

Interview Results: EVA Suits (cont.)

- Simplicity in suit maintenance must be a key design provision for long duration planetary missions
- Hard suits, rear entry suits and docking a suit to the outside of the hab drew mixed response
  - Rear entry was viewed as a potentially useful approach to the problem of one-person donning, but many expressed concern that the seal would get beat up by inevitable exposure to lunar dust
  - All things being equal, soft suits were favored over hard suits, but the vehemence of that belief was varied
  - Docking was viewed as an interesting design idea, but one that needed more study before it could be evaluated properly
    - » Rear docking is an approach that is starting to receive critical engineering analysis at present

Interview Results: PLSS

- The Apollo PLSS was given high marks for it's reliability, functionality and capabilities
- The key to future PLSS design will be lowest possible mass and the highest possible reliability
- The question of PLSS recharge during EVA was met with some skepticism
  - Most felt that it would be a good approach to reducing mass, but expressed concern about safety and the wisdom of leaving the hab on a long EVA without enough consumables in the PLSS to make it back
- Use of umbilical rather than an independent PLSS was viewed as unworkable and dangerous
- Integrating the suit and the PLSS, as is done with the STS EMU, was viewed as good

Interview Results: Dust Control

- Lunar dust is a pain in the @#@&%*#@!
- Keep equipment that is exposed to dust separated from the living quarters
- Suits will need to be cleaned after every EVA, inside and out, particularly TMGs, bearings and suit seals
- Stabilize areas of high traffic, such as around the hab
- Although it wasn't a health issue on Apollo, it might be on a longer mission (e.g., pulmonary problems associated with inhalation of fine grained silicate particulates)
  - Note this is *not* a subject to become hysterical about
  - There have been suggestions recently that we had imminent CRIT 1A failures on Apollo due to abrasion of suit components from lunar dust; based on all the interviews and historical research I've done, there is no record of any "loss of crew/loss of mission" concerns due to lunar dust abrasion

Interview Results: Gloves

- Better gloves, better gloves, better gloves
- General approval of the improvements in the Series 4000 gloves over the Apollo glove, but more work needs to be done
  - The glove folks in NASA and ILC have made HUGE strides here…the Phase VI gloves that I have used are so sweet, I no longer devote workout time to hand exercises…
- The Apollo gloves imposed serious limitations on hand mobility, finger dexterity and tactility, and resulted in serious arm fatigue that basically began within minutes of the start of an EVA and continued all day without let-up
- Custom gloves, custom gloves, custom gloves
- End effectors may be useful under some circumstances, but needed further study

Interview Results: Automation

- Automate the PLSS and suit where appropriate, but remember the KISS principle
- Always provide manual backups and overrides
- Automated suit checkout was viewed as a very positive thing
- Automate all you want, but don’t make the crew’s job or the mission more complex from the automation
  - We need to do a better job in this area, as the automation systems being tested increase the crew’s workload, not reduces it

Interview Results: Information, Displays and Controls

- KISS; give only the information needed; don't overload the crew member
- Safety-related status information should be available on a call-up basis
  - Alarms should be used for critical situations
  - Crew in the habitat should be available to monitor routine information and act as cut-out with FCR
- Use visual displays for task information, with aural warnings for alarms
- HUDs, voice activated controls are interesting, but see bullet 1
- Electronic checklists are good, provided they can be updated as mission progresses
  - We are making good progress here with Helmet Mounted Displays tested on Desert RATS in 2004 and 2005

Interview Results: Rovers

- Adding life support capability to the rover was considered good, as long as attachment to the EMU was not hazardous
- Loading, storage and access to equipment and tools needs to be improved over Apollo
- Rovers should be repairable (particularly with something other than maps, grey tape and air photos)

Interview Results: Tools

- Tool control in 1/6 g is almost as difficult as in 0 g, particular on a moving rover
- Biggest problem was gripping
  - It was just not easy to grip the tools using the Apollo glove
- Manipulating hand tools caused the most fatigue
  - Some way of holding the tool in the hand without continuous gripping was seen as a must
- Storing samples was seen as a problem, particular when on the run
  - Charlie Duke made the observation that a simple shopping bag (a Sakowitz bag) with handles would have been a great help

Interview Results: Operations

- Crew on long-term missions are going to need greater autonomy in day-to-day planning and executing EVAs
  - The concept was a daily planning meeting with mission ops and science personnel to plot out the next days activities, based on the previous results
  - We have evolved to this on ISS, and hopefully, we'll bring that operations approach across we prepare for lunar exploration
- A real need is to spend as much time as necessary at a given site to document and investigate the site
  - A number of crew expressed the frustration that there was never enough time to properly investigate a given site
  - A common lament - you spent all this time to teach us how to become geologists, and then didn't give us enough time on the lunar surface to put the training into practice
- Experiments should be sturdy, and not easily broken
  - A number of ALSEP items were poorly designed for crew setup and calibration; see the report of Tom Sullivan's excellent investigation at

    http://ares.jsc.nasa.gov/HumanExplore/Exploration/EXLibrary/docs/ApolloCat/Part1/ALSEP.htm
- Initial mission should have the FCR doing much of the oversight, but that role should shift to the habitat crew over time, particularly if Mars was one of our destinations

Interview Results: Operations (cont.)

- Contingency/emergency operations were looked at as a two part problem
  - For each projected failure, a response needs to be understood beforehand: fight or flight
  - Mission rules need to be developed and enforced based on that understanding
- Walkbacks of up to 20 km were considered possible
- Operations under Earthshine or Lunar noon were looked at as doable, provided thermal conditions were understood and compensated for
- Teleoperations of robotic rovers should be integrated into operations planning

Interview Results: Training

- Train hard: you're going to the Moon or Mars, dammit, not on a vacation!
  - Dave Scott observed that if you want to be in the NFL, you don't complain about all those hard practice sessions in July and August…
- Train under realistic conditions, including, where possible, simulating 1/6 or 1/3 g
  - A number of problems with Apollo equipment or experiments could have been avoided if an adequate understanding of the effects of 1/6 g were known
- Train to the mission, including contingencies; practice everything, so you don't have to make it up as you go
- Sustained mental performance will be the toughest training issue, as well as for interpersonal relations during a long mission

Interview Conclusions

- Emphasis should be given on the integration of the crew, equipment and facilities as a total system
- All subsystems should be designed based on the principles of simplicity and reliability.
  - Don’t increase functionality and decrease reliability
- More flexible suits, more flexible suits, more flexible suits
- Better gloves, better gloves, better gloves
- Equipment should be designed to fit the task, not vice versa

Interview Conclusions (cont.)

- The habitat will become increasingly important in supporting EVA activities, replacing some or many of the duties currently performed by the Earth-based FCR
- Increase crew autonomy
- High levels of maintainability and reliability must be built into the suits, PLSS and equipment
- Sustaining high-level mental performance will be a significant training and operational issue
- We (the space program) do not pay enough attention to crewmembers and test subjects when problems are reported that can be fixed

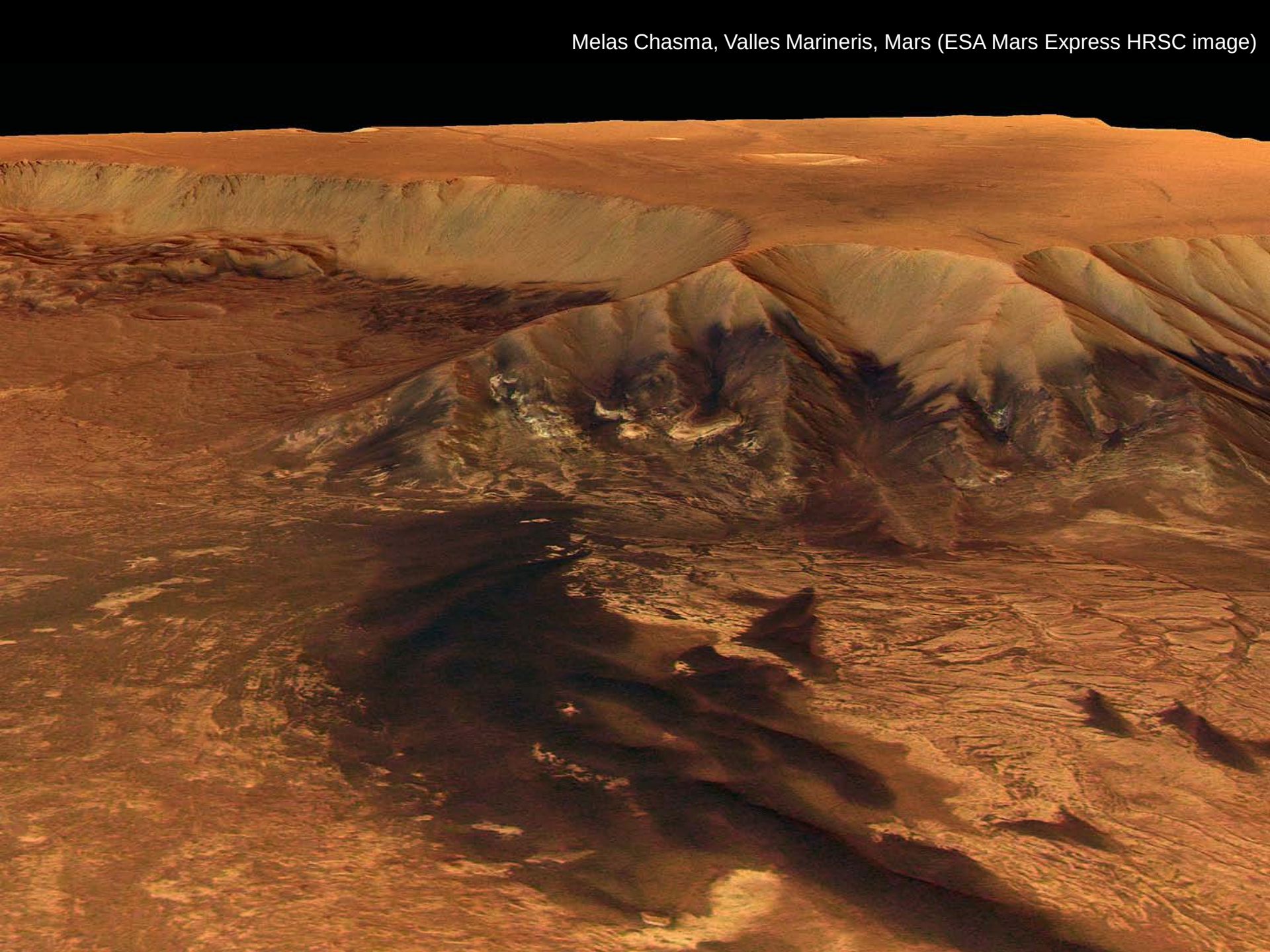
Areas of Further Research

- Effects of breathing pure O_2 at reduced pressure
- Flammability issues for low total pressure, high O_2 environments
- New suit materials
- Task requirements for advanced EVA missions
- Developing and understanding bodily mobility requirements
- Better gloves, better gloves, better gloves

Notes Added, 2007

- After 12+ years, the outcome of these interviews are still valid and applicable to our present direction
- The Apollo Program still has much to teach us; however, having said that, the Apollo crews have been interviewed to death over the years and some are probably getting tired of it
- There are fantastic references available on the net on Apollo…go there first, and spend time reading before you start bugging guys that are retired and may want to spend more time fishing or skiing than talking to you
  - The best Apollo reference information, BAR NONE, is the Apollo Lunar Surface Journal (http://www.hq.nasa.gov/alsj/), which is now available in book form (Heiken and Jones, 2007, On The Moon - The Apollo Journals, Springer/Praxis Publishing)
  - There are also a number of other books that are either being published now, or being reprinted, that are good reference works on Apollo
- The advice I can give anyone who wants to talk to these guys is do your homework…know what we already know, and formulate specific questions that need answering, and only then bug these guys
  - If you want them to get them irritable, 1) ask them a non-specific question, such as “Gee, what was it like?”, or 2) ask them something you could have learned if you’d done a little research before hand

Charlie Duke on the Descartes Plains, Apollo 16


Melas Chasma, Valles Marineris, Mars (ESA Mars Express HRSC image)

If you would like a copy of this presentation and/or the companion publication, please drop me a note at:

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