

Proposed Androgynous Docking Airlock/Utility Module

Gary L. Harris

De Leon Technologies LLC

Pablo de León

Department of Space Studies, University of North Dakota

Copyright © 2009 SAE International

ABSTRACT

The objective of this paper is to detail a proposal for an Androgynous Docking Airlock/Utility Module (ADAM) that would allow extravehicular (EVA) crews, working from the Orion spacecraft, to avoid depressurizing the command module of the Orion vehicle for planned EVA repair, maintenance and interdiction of orbital structures. Unlike the Space Shuttle, Russian Soyuz vehicle or the Chinese Shenzhou manned spacecraft, the proposed Orion space vehicle has no airlock. This necessitates the depressurizing of the entire Command Module cabin during EVA activity. It also means that all crewmembers will have to wear space suits during contingency and planned EVAs. This inordinately dangerous situation will require all crewmembers to be exposed to the space vacuum for as much as seven hours or more if a working EVA becomes necessary. It also means that if an airlock is not employed on Orion, as indeed none is presently envisioned, the space suits the crew wears will be severely compromised in design as they will have to be employed as EVA suits and emergency launch/escape suits as well, a function that is preclusive on design, engineering and optimization levels.

The ADAM module, which is a lightweight, disposable, inflatable airlock/utility carrier, could be launch separately by SpaceX Corporation from launch Complex 40 at Cape Canaveral Air Force Station. Following the successful launch and orbit of the manned Orion spacecraft, ADAM would be launched into a similar orbit. Upon reaching orbit ADAM would automatically inflate,

initiate its beacon and radar transponder. With the Orion orbiter acting as the active vehicle, the two spacecraft would rendezvous and dock in a manner not unlike that of the old Gemini/Agenda docking system of the 1960s.

The ADAM module is deflated and tightly packed during the launch phase. This allows the module to impose the least stowage penalty within the launch shroud and also the least mass, thus, it can be launched by a relatively small booster utilizing the smallest payload fairing dimensions. On the forward and aft ends of the inflatable, cylindrical ADAM module are rigid structural hemispheres with a docking adaptor on the side interfacing to the Orion Vehicle. On the opposite end is an airlock hatch/docking adaptor. Between the two hemispherical ends the ADAM module is composed of a rugged fabric outer restraint layer (to hold the module into a cylindrical shape) and underneath is a polyurethane/Nylon bladder to hold in airlock life support gasses/pressure. Covering both is a thermal-micrometeoroid layer. When the ADAM module is sealed off from the Orion Command Module and deflated during EVA activity, aerobeams running longitudinally (as part of the inner bladder) along the modules fore-aft length, would maintain the shape/geometry of the inflatable structure.

Stowed inside the ADAM module hemispherical ends are two EVA space suits, and their supporting equipment and tools, etc. Also stowed in the ADAM module would be a lightweight fan and carbon dioxide scrubber to enhance and work with the Orion's life

The Engineering Meetings Board has approved this paper for publication. It has successfully completed SAE's peer review process under the supervision of the session organizer. This process requires a minimum of three (3) reviews by industry experts.

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE.

ISSN 0148-7191

Positions and opinions advanced in this paper are those of the author(s) and not necessarily those of SAE. The author is solely responsible for the content of the paper.

SAE Customer Service: Tel: 877-606-7323 (inside USA and Canada)
Tel: 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org

SAE Web Address: <http://www.sae.org>

Printed in USA

SAE *International*

support system. When the planned EVA activity is completed at mission termination, tools, etc. are stowed inside the upper torsos of the EVA space suits and they are then transferred into the Orion Command Module, strapped into two unused seats, and are deorbited, along with the Orion vehicle, to be used again for future missions. The ADAM module is undocked from the Orion vehicle and allowed to deorbit and burn up upon eventual atmospheric reentry.

INTRODUCTION

The Space Shuttle Transportation System (STS) has, since the 1980s, served as an excellent Extravehicular Activity (EVA) platform. Regardless of its other shortcomings, the shuttle has proven itself to be a stable and relatively spacious vehicle in which to carry out EVA work on the Hubble Space Telescope, retrieval of satellites, construction of the International Space Station, etc. The shuttle is equipped with an excellent and versatile robotic arm, spacious cargo bay, and well designed, relatively spacious airlock facility for the storage and deployment of multiple orbital configured EVA space suits. The crew has the work and cabin volume to wear dedicated emergency pressure suits for launch and reentry; but, it also has the volume and facilities to support separate, dedicated orbital configured EVA space suits.

When the Space Shuttle was first proposed in the early to middle 1970s NASA management had such little faith in EVA as an effective working tool they elected the shuttle be designed with no EVA capability at all. It was only through the efforts of middle management NASA engineers within Crew Systems Division (CSD) of the Johnson Space Center, such as James V. Correale Jr. and James McBarron that upper management relented and decreed that the shuttle be “designed in such a manner so as to not preclude EVA;” certainly a less than ringing endorsement and not a formula for optimization (Layton et al. 1973; Kosmo 1994, Bell 1994).

Interestingly enough, the visionary stance of Correale, McBarron and other CSD engineers was finally vindicated as the shuttle program matured and EVA became not just an essential component of the shuttles repertoire of capabilities, indeed near the end of its operational life EVA related activity has become a seminal reason for the shuttle’s existence. Repair of the Hubble Space telescope and the arduous construction of the International Space Station bespeak of this fact. At the end of its life the STS system has but two purposes: to deliver modules/supplies to the International Space Station, and to act as an EVA construction and maintenance/repair platform.

However, with the retirement of the Space Shuttle and its replacement by the Orion spacecraft, an important portion of the United States’ orbital EVA capability and

versatility will be retired as well. The Orion vehicle, as presently envisioned, will have no airlock and no storage area for dedicated, optimized orbital EVA suits. While NASA management has proposed that the Orion vehicle have “contingency EVA capability,” it will, nevertheless, have only limited potential for planned EVA operations. This does not mean that the Orion space vehicle will be unable to undertake a planned EVA, rather it can do so only with increased risk to the crew and increased difficulty.

The Orion vehicle is much like its parent vehicle the Apollo capsule, at least in general operational profile and broad geometry. Orion essentially has two purposes: to deliver approximately six crew members to and from the International Space Station, and four crew members to lunar orbit (and earth return). For these two functions Orion appears to be relatively well adept; however, for any EVA operations in earth orbit it is not well suited. Because the Orion capsule has no airlock, the vehicle crew cabin will have to be depressurized for EVA exit from the vehicle. This will entail exposing the crewmembers remaining in the cabin to the space vacuum. Moreover, these crewmembers might have to sit in their protective pressure suits for up to seven hours or more during a lengthy EVA. It also indicates that the crewmembers in the cabin may have to be equipped with more sophisticated and complex space suits (rather than a relatively simple, lightweight launch escape suit). Additionally, non-EVA crewmembers might need to be equipped with enhanced thermal protection of their suit systems and even liquid cooling garments and accompanying appurtenances. Moreover, the failure of any single member’s pressure suit to operate properly (leakage outside of nominal tolerance, circulating fan failure, various electrical and mechanical failure modes and failure of bio sensors, etc.) could prematurely terminate a very expensive EVA, or even preclude it from occurring in the first place. Or, under some circumstances endanger the crew or vehicle (Seedhouse 2009, Harris et al. 2006).

In addition to these complications, any space suit employed on Orion will have to be less than optimal for orbital working applications due also to the volume restricted cabin. During the Apollo period, spacesuit designers were confronted with a series of design trade-offs due to the small volume of the Apollo Command Module. Only 23 inches of width was allowed for each astronaut’s couch (shoulder width). This meant that the astronauts, while suited in the A7L or A7LB suits lay literally shoulder upon shoulder. In addition to shoulder width restriction the Apollo suit designers found no way to incorporate highly mobile scye bearings into the shoulder joints of the Apollo Extravehicular Mobility Units (Apollo EMU suits). The difficulty lay in that a scye bearing is very uncomfortable while lying supine in a launch couch. When the suit is pressurized to only a few inches of water vent pressure (such as during launch), or even while fully pressurized, the scye bearings quickly become painful in a launch couch at 1 G or greater. For

this and volume reasons the Apollo suit designers elected to use a cable assisted shoulder joint (Durney 1972).

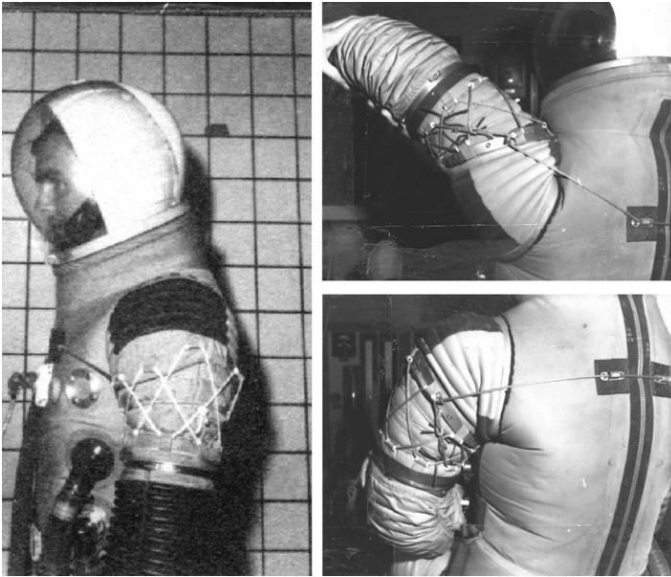


FIGURE-1 Apollo A7L Cable Assisted Shoulder Joint

Cable assisted shoulder joints, while effective in imparting from zero to 180 degrees lateral/medial motion, and from about 45 to 134 degrees adduction/abduction motion to the shoulder, nevertheless, have the trade-off of high torque in the adduction/abduction direction of motion. Moreover, they have no shoulder rotation capability. The high torque is caused by longitudinal end loading pulling the stainless steel cable taught against the Teflon coated guide tubes and pulleys. The resultant friction, will, in only a very limited operation time, saw through the guide tubes. This was one of the major factors in limiting the A7L and A7LB Apollo suit's time use on the moon.

In retrospect the Apollo A7L and A7LB suits can be viewed not as pure intravehicular (IVA) space suits or even as pure, dedicated EVA suits, but rather as what has come to be called an Intravehicular/Extravehicular Activity (IEVA) suit: a suit that performs both functions. Unfortunately, as is the case with the cable assisted shoulder joint (and other trade-offs), such a suit configuration forces compromises onto the suit design that make it non-optimal for either purpose (IVA or EVA). However, the Apollo suit was an extraordinary achievement, given the tasks ask of it.

Eventually NASA chose for its shuttle program to use one suit for launch and reentry (for example the David Clark ACES), and a separate, dedicated EVA space suit for orbital operations (Shuttle EMU). This demarcation of functions further optimized the application and design of both suit types.

Unfortunately, until a comfortable scye bearing is developed that can be used in an IEVA suit while lying in

a launch couch (or a launch couch that can accompany scye bearings comfortably), along with a way to fit multiple bulky EVA capable suits into a volume restricted launch vehicle like Orion, compromises will be forced onto the space suit design that will rob them of their ability to perform well in orbit and may preclude their long term use on the Moon entirely.

Is there a solution? In an ICES paper titled: Crew Protection, Contingency EVA and the Crew Exploration Vehicle (SAE paper 2006-01-2137) presented in 2006 we suggested that NASA build an inflatable airlock/orbital module that could be stored in the aeroshroud behind the Orion vehicle's service module. This orbital module/airlock was dubbed the Androgynous Docking Airlock/Utility Module (ADAM). ADAM was envisioned as a simple fabric and bladder cylinder sealed on both ends by hemispheres. On the fore and aft ends of ADAM would be androgynous docking adaptors capable of mating to the front of Orion and to docking mechanisms on the International Space Station. These docking adaptors would also serve the dual purpose of use as airlock hatches (Harris et al. 2006).

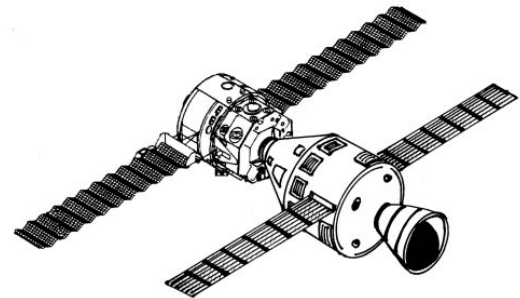


FIGURE-2 Original Proposed ADAM configuration

After achieving orbit the Orion would pull away from the aeroshroud, come about 180 degrees, and dock with ADAM inside the shroud. This process would be akin to the 1960s Apollo vehicle joining with the LM (Lunar Module). ADAM would then be inflated. Inside ADAM would be stored two dedicated EVA suits and the equipment/ tools necessary to perform the planned EVA. ADAM could then be depressurized, work performed, then repressurized all without depressurizing the Orion command module. To keep the ADAM structure acceptably rigid when depressurized the inner polyurethane/nylon bladder would have heat-sealed fabric aerobeams set along its longitudinal inner hull surface (forming longitudinal striations). The striated aerobeams would be passively pressurized; that is, left at sea level pressure during fabrication. In vacuum the striations would stiffen on their own: a simple elegant system. In addition, the striations would act as a "hot-

standby” or backup bladder in case the outer bladder was penetrated, passively making the whole structure more robust. When the EVA task is completed the two EVA suits are strapped into two empty seats in the Orion Command Module, ADAM is undocked and cast off to burn up upon reentry. ADAM has the added benefit of having the provision of a simple inflatable toilet, allowing privacy and some dignity for male/female crewmembers; certainly a desirable alternative to sitting in Orion’s tiny toilet with nothing more than a fabric curtain between the crewmember and the rest of the crew

As the Orion vehicle design progressed, however, it became apparent that the Ares-I booster would not have the lifting thrust to place the Orion capsule and an orbital module both into low Earth Orbit (LEO). Nevertheless, the ADAM inflatable orbital module/airlock is a viable alternative, if instead of it being lofted by Ares-I, it is launched by a separate, smaller affordable booster such as the SpaceX Falcon-9 (Seedhouse 2009).

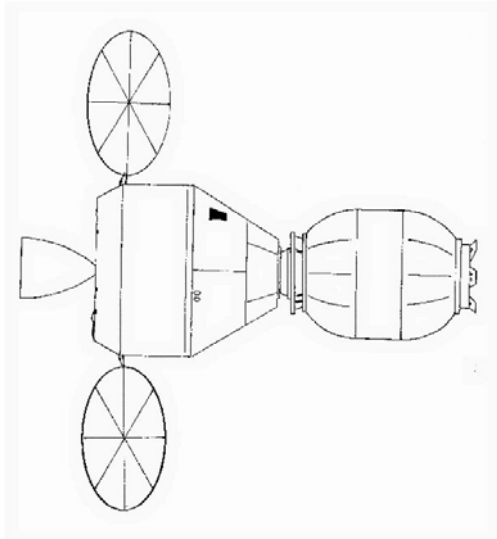


FIGURE-3 ADAM Orbital Module

The Falcon-9 is projected to be first launched in 2009 from SpaceX’s Complex-40 at Cape Canaveral Air Station. The Falcon-9 vehicle will be able to loft 10,450 kg. to low earth orbit (LEO) at 28.5° orbital inclination. Cape Canaveral is an excellent location from which to launch ADAM as it places it into the same orbital inclinations achievable by the Orion/Ares system.

The ADAM system would be vacuum packed within the launch shroud of the Falcon-9 booster, creating the least volume penalty. Upon reaching LEO ADAM would use a small oxygen/nitrogen gas bottle to inflate the module and help push away the payload fairing, or the payload fairing could be retained if any part of it is deemed useful for the mission (for example the internal part of the fairing could be lined with solar cells to be used to help power ADAM or add power to Orion – the payload fairing would split along its long axis and fold out – hinged at the nose – to expose the solar cells to sunlight). Upon

ground command (or automatically), ADAM would switch on its on-board radar transponder, radio beacon and docking locator strobes.

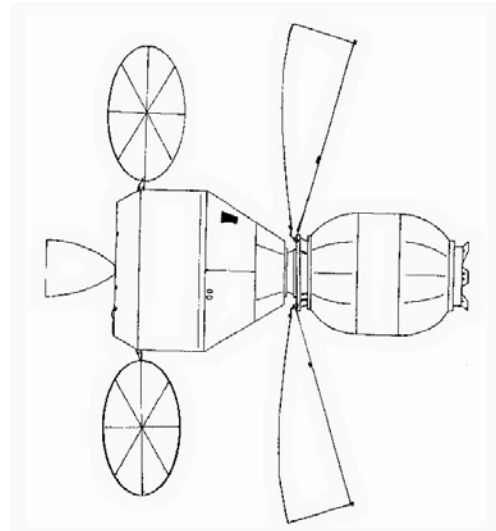


FIGURE-4 ADAM Orbital Module with payload fairing Deployed as Solar Collector/Radio Relay

With ADAM acting as the passive vehicle, Orion would than rendezvous and dock with the module and proceed with its mission. As in the earlier ADAM concept, two EVA suits would be stored in ADAM, along with EVA tools, etc. All other features of ADAM would remain similar to the earlier design, including a simple toilet (if required), simple passive carbon dioxide scrubber and high emissive thermal blankets on the external hull.

OTHER POTENTIAL USES FOR THE ADAM MODULE

A simple inflatable module such as ADAM has multiple applications only limited by our imaginations. Since ADAM is capable of docking with the International Space Station (when attached to Orion) it could serve as an affordable module in which to carry out experiments.

It might also serve the ISS as a garbage disposal structure, then deorbited and allowed to burn up upon reentry much like the Russian Progress vehicle.

Since ADAM is low mass, it potentially could be docked with the Orion/LSAM combination and utilized for extra living room during the trans-lunar and trans-earth flight phases.

After achieving lunar orbit ADAM could serve as the module to carry lunar mapping and reconnaissance hardware. This would prevent expensive redesign and hardware changes to the Orion vehicle and its accompanying Service Module. To accomplish this, the forward hatch (within the forward Androgynous Docking Adaptor) would mount a transparent port through which high resolution mapping cameras could see. The Orion

vehicle is slated to work in the automatic mode while the crew is on the Moon's surface, so Orion's thrusters would act as directional pointing and stability controls. Or, ADAM itself could be equipped with cold gas thrusters.

Once the lunar mission is completed ADAM might be left in lunar orbit to act as a crude radio relay, akin to the old Echo orbital balloon. This would allow lunar surface crews to use ADAM's modified reflective surface to bounce radio signals (in compressed burst mode) around the moon to base receivers. If three such ADAM modules were left to fly in lunar orbit it might be possible to use them not just as radio relays, but also as a cheap inexpensive, simple Global Positioning System (GPS). This would allow surface crews to fix their position on the moon; it would also greatly assist in lunar geology studies (by creating more accurate measurements) and allow more rapid rescue of a crew during an emergency. Lastly, components of ADAM might possibly be attached to the LSAM to provide extra temporary living or storage room for the crew on the lunar surface.

CONCLUSION

The technology now appears to have reached maturity sufficient to allow orbital and planetary use of inflatable, man-rated structures. The UND Space Suit Laboratory, at the Space Studies Department of the University of North Dakota is now carrying out low level studies of the ADAM inflatable structure wall and other space inflatable structure configurations in partnership with private industry and the North Dakota university system.

REFERENCES

Bell, "Larry" Lawrence, Engineer retired, NASA Johnson Space Center, Crew Systems Division, Personal communications 2 June 1994.

Durney, George P., Engineer, ILC Industries, Dover, Del., Patent 3,699,589 October 24, 1972.

Harris, Gary L., Pablo de Leon, Department of Space Studies, University of North Dakota. Crew Protection, Contingency EVA and the Crew Exploration Vehicle. SAE paper 2006-01-2137. Presented at ICES 2006.

Kosmo, Joseph, Engineer, NASA Johnson Space Center, Crew and Thermal Systems Division, Personal communications 1 June 1994.

Layton, Preston J. and Jerry Grey, Editors, New Space Transportation System: An AIAA Assessment. American Institute of Aeronautics and Astronautics, New York, 9 January 1973.

Seedhouse, Erik Dr. F.B.I.S., As.M.A, Lunar Outpost: The Challenge of Establishing a Human Settlement on the Moon. Pp 102,107,221, Springer Praxis, Chichester, UK, 2009.

CONTACT

Gary L. Harris, Principal Designer, De Leon Technologies LLC. Consultant to the Space Suit Laboratory, Department of Space Studies, University of North Dakota. Email address: harris@deleontechnologies.com

Pablo de León, Research Associate, Department of Space Studies, University of North Dakota. Email address: deleon@space.edu