

Altair Lander Life Support: Requirement Analysis Cycles 1 and 2

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Life support systems are a critical part of human exploration beyond low earth orbit. NASA's Altair Lunar Lander has unique missions to perform and will need a unique life support system to complete them. Initial work demonstrated a feasible minimally-functional Lander design. This work was completed in Design Analysis Cycles (DAC) 1, 2, and 3 were reported in a previous paper¹. On October 21, 2008, the Altair project completed the Mission Concept Review (MCR), moving the project into Phase A. In Phase A activities, the project is preparing for the System Requirements Review (SRR). Altair has conducted two Requirements Analysis Cycles (RACs) to begin this work. During this time, the life support team must examine the Altair mission concepts, Constellation Program level requirements, and interfaces with other vehicles and spacesuits to derive the right set of requirements for the new vehicle. The minimum functionality design meets some of these requirements already and can be easily adapted to meet others. But Altair must identify which will be more costly in mass, power, or other resources to meet. These especially costly requirements must be analyzed carefully to be sure they are truly necessary, and are the best way of explaining and meeting the true need. If they are necessary and clear, they become important mass threats to track at the vehicle level. If they are not clear or do not seem necessary to all stakeholders, Altair must work to redefine them or push back on the requirements writers. Additionally, the life support team is evaluating new technologies to see if they are more effective than the existing baseline design at performing necessary functions in Altair's life support system.

I. Introduction

THE Altair lunar lander is part of NASA's Constellation Program and performs three basic missions: sortie, outpost delivery, and cargo. Sorties are 7-day missions that bring a crew of 4 people to explore locations anywhere on the lunar surface. The lander life support system provides habitation and extravehicular activity (EVA) support to enable the crew to live in and out of the lander during the sortie without resources from other vehicles or surface assets. The crew returns in the ascent module (AM) to lunar orbit to rendezvous with the Orion vehicle for the return to Earth. Outpost delivery missions bring 4-person crews to the location of a lunar Outpost. To maximize cargo delivery with the crew, the lander life support does not provide overnight habitation, and the only EVA performed from the lander is the transfer to the Outpost. The crew again returns to orbit in the AM. Cargo missions are unmanned missions to deliver supplies to the lunar surface without a pressurized habitable volume. No part of the cargo vehicle returns to Lunar orbit. To achieve flexibility, but not add the cost of multiple unique designs, Altair is designed to have maximum commonality between versions. The same descent module is designed to support all of these functions. The ascent stage is largely common between missions. Altair has been primarily designing for the sortie mission, and then deleting components unnecessary for the outpost delivery mission. Overall, the vehicle is designed to be an affordable way to provide flexibility for many different mission types.

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A. Project Status

The Altair project began as a small conceptual design team, and has been working through the early phases of the NASA systems engineering process cycle. While there are many processes and tasks going on concurrently, the project management tends to organize most of the domain engineers into Design Analysis Cycles (DACs) or Requirements Analysis Cycles (RACs). The first three Design Analysis Cycles were used to develop confidence that a feasible conceptual design for an Altair lander did exist. On October 18, 2008, Altair passed the Mission Concept Review milestone. Starting in spring 2009, the team turned their focus to performing RACs in order to prepare for a System Requirements Review (SRR) by developing an official System Requirements Document (SRD). The SRR was originally planned for summer or fall of 2010. Eventually the 2010 date was replaced with a synchronization of the lunar architecture between Constellation projects including Orion, EVA, and Lunar Surface Systems (LSS), with the SRR planned for 2011. As the project matures, conceptual design efforts have continued to provide the feasibility or cost of the proposed requirements or answer program questions with parametric models. The team also began planning for the effort required to move from SRR to a Preliminary Design Review (PDR). But the team has changed its primary focus to performing a methodical analysis of the requirements set for the Altair vehicle to create the SRD.

B. Altair Life Support Requirements

The Altair requirements most pertinent to the life support system come largely from the Constellation Architecture Requirements Document (CARD) or the Constellation Human Systems Integration Requirements (HSIR). The CARD includes both requirements that apply to all Constellation vehicles, and requirements allocated specifically to the individual vehicle projects. Some of the CARD requirements describe architecture decisions made to distribute certain functions across each vehicle in the Constellation program. The CARD also contains requirements for many contingency scenarios that are not caused by a failure in the vehicle that needs to respond. Putting these requirements in a program level document allows each vehicle team to understand the role their system plays in the ultimate solution. The document also defines responses to threats from external issues, like a micrometeoroid or orbital debris (MMOD) strike, to help balance the protection from these risks across the program. The HSIR contains requirements that specify what is required to support the crewmembers so that they can perform their mission functions successfully. The HSIR defines acceptable environmental conditions, contains unique functions that the vehicle must perform to support the crew, and describes crew inputs and outputs the life support system must supply or remove. When the HSIR allows a range of environmental conditions, a project Altair is free to set narrower bounds inside that range in the SRD. At the Altair SRD level, many related HSIR requirements are grouped into a top-level functional requirement. The details of the HSIR would be flowed down to children requirements in a life support or other system specification. The Altair project must review all of the requirements in the CARD, HSIR, and many other documents, and either negotiate changes or accept them into the SRD document.

II. Requirements Analysis Cycle 1

In the first Requirements Analysis Cycle (RAC-1), the Altair team tried to focus on key driving requirements (KDRs) or requirements critical to the lander architecture. The life support team supported work on architecture requirements on airlocks, crew access before landing on the moon, and long surface dormancy periods. Several contingency scenarios were also identified as key driving requirements for the life support system. These included fire detection and suppression, cabin pressure leaks, and contingency ascent and microgravity EVA scenarios. The acceptance of these requirements adds unique functionality to the lander and must be addressed early.

A. Airlocks and Lunar Dust Mitigation

Engineers, medical experts, and crew representatives in the Constellation program are very aware that lunar regolith poses threats and challenges to activities on the lunar surfaces. In RAC-1, the Altair project studied a CARD requirement for the lander to include an airlock. The Altair team had already included a detachable airlock in their Sortie vehicle concept, but did not include one for Outpost Delivery missions, and of course did not include one for cargo missions. The team initially found the requirement suspect because it was written for the Altair project as a whole, and not specific to the different configurations. One other issue with this requirement is that it seems to specify an implementation, and not a need, which is not usually considered good systems engineering. After much discussion, the team suggested that there were really two core issues that had led to the initial writing of this requirement. The Constellation program was concerned about lunar dust issues, and an airlock is assumed to

help mitigate the movement of lunar dust into the habitable volumes. The program also wants to have the flexibility to leave some crewmembers in a shirt-sleeve cabin environment, while others go out on EVA. Sometimes called “split operations”, this design allows the mission to continue if a crewmember is temporarily injured or ill, or a single spacesuit fails. Altair already had requirements in place to allow “1, 2, 3, or 4” crewmembers to perform EVAs, and a requirement to mitigate the impacts of lunar dust. After discussion with the program that continued after the RAC-1 end date, it was agreed that the requirement to have an airlock could be removed because Altair accepted the requirements to meet all the functions an airlock provided.

B. Lunar Transit Crew Access

Operations concepts and timelines are an important source of requirements. This is especially important in the early phases of design when detailed documents are not complete. The location, activities, and status of the crewmembers is almost solely documented in these concepts and timelines. Defining whether life support system components like waste collection or food rehydration need to be used in microgravity or only on the surface is an important design driver. The top level functional requirements from the HSIR need to be combined with operations concepts to understand what the more detailed requirement will be.

Nearly all manned spacecraft have minimal habitable volume for crew use to limit launch mass, and the Altair lander and Orion Crew Exploration Vehicle (CEV) are no exception. The CEV makes the trip from lunar orbit back to the moon without the lander, and therefore must be able to independently provide all necessary habitation functions. Understandably, crew representatives and operations experts would still like to have access to the Altair lander volume during the transit from the Earth to the moon.

Activating all of the Altair systems for full crew access adds significant cost to the vehicle making another solution desirable. The total power consumed by required systems like the suit loop compressor would be larger than what Orion transfers to Altair during the transit from the Earth to the moon. Activating the Altair fuel cells adds consumables to the power system. Making habitability systems function in microgravity adds complexity and verification costs, and often adds mass. The teams involved developed a compromise solution. First of all, no requirement for crew access during trans-lunar coast would be added, but the systems would assess what capability could be available with existing components. The Orion vehicle would continue to provide pressure control, air revitalization, and habitability. A small ventilation flow between vehicles would maintain air quality in Altair. Altair would use the cabin fan and heat exchanger (which uses less power than the suit loop compressor) to remove sensible heat loads and mix the cabin air. Analysis performed showed that with a 280 L/min (10cfm) flow of dry, cool, clean air, two crewmembers could be in the Altair volume for up to 90 minutes before humidity levels rose high enough to cause condensation that could cause issues in the Altair vehicle. With higher flow of 420 L/min (15 cfm), two crewmembers could have continuous daytime access. This ventilation arrangement is also used during the brief crew access in Earth orbit for checkout and equipment transfer. A more detailed power budget analysis will be required as the vehicle design matures. But this solution at least provides a concept for more affordable crew access during the transit phase.

C. Lunar Loiter Period

The initial conceptual design studies to prove feasibility for the Altair lander focused on a sortie mission to a south pole location on the moon, but the Constellation program intends for the lander to be able to conduct missions anywhere on the surface of the moon. While the propulsion and navigation options aren’t part of the life support system, the choices made do impact the design of the system. In order for the lander to efficiently reach some sites on the moon’s surface, a loiter in lunar orbit of up to 4 days is necessary. Nominally, Orion should provide life support to crewmembers in microgravity. But Orion is not being designed to manage the transfer to the surface of the moon. The loiter solution is an efficient solution for Altair propulsion, but in trade, Altair must provide the consumables for the extended mission timeline that Orion cannot support.

The functional split between Orion and Altair is determined by the portability of the consumables and the complexity of functioning in microgravity. Pressure control during the extended loiter will be provided by Altair. As a single phase system, pressure control is no more complex for Altair than Orion. However, the interfaces to transfer high pressure gas stores between the two vehicles would be complex. Delivering potable water to the crew may be more complex in microgravity than on the lunar surface, but it would be even more difficult to transfer water between the two vehicles to use in the Orion galley. Waste collection, however, is much more complex in microgravity than on the surface. Conveniently, the Orion waste collection system uses replaceable canisters and baggies, and no consumables are required for urine venting. A food warmer and some food containers that are designed for microgravity may be quite different from one designed for use in a gravity field. Sleeping accommodations will also be significantly different in microgravity and on the surface as well. Overall, Altair is

providing the gas and water consumables for life support, but most habitability systems will still be performed by Orion, with spare components stored in Altair.

D. Dormancy and Water Quality

The long dormancy period that is part of the Outpost Delivery mission poses unique challenges that are not fully explored in concepts for the Sortie mission vehicle. Cabin air and water systems are two life support subsystems that are particularly impacted. The water systems could be at risk of freezing or of excessive microbial contamination. The cabin necessarily has to be at vacuum for the crew to the vehicle and repressurized, so it will be purged and refilled before the crew breathes cabin air. The team did consider the pros and cons of leaving the vehicle at vacuum or pressurizing the vehicle for the long stay. The team assessed the risks in each system associated with the dormant period and developed a strategy to minimize issues.

The architecture of the Altair water system in the DAC-3 and current conceptual design was very important in assessing the risks associated with microbial contamination. The Sortie vehicle adds a silver ion biocide to the potable water tank for crew use, but does not treat water in the EVA liquid cooling garment (LCG) or water used in the sublimator. Most of the water used in the mission is very pure water produced by the fuel cells. In an Outpost Delivery mission, the crew is in spacesuits for almost all of the mission, and no potable water system is included in the current conceptual design. The crew would drink water stored in their spacesuit drink bags provided by Orion or by an Outpost habitat. However, the untreated water in the LCG fluid loop and stored for the sublimators could be at risk during the long surface dormancy.

Two primary strategies were adopted to control microbial growth in the water system. The vehicle will need to be designed for some level of thermal control during the surface stay to protect systems from freezing in the shade, or overheating if they're on a side with sun exposure during the long lunar day. The team agreed that the thermal control system could be designed to keep the vehicle temperatures very low (but above the freezing temperature of water) to slow the rate of growth. The second was to treat the inside of the water system piping with a silver-compatible (and probably silver based) biocidal coating. These two techniques are not expected to kill any free microbes in the water, but they are expected to prevent them from attaching to surfaces and forming biofilm colonies.

E. Contingencies and Emergencies

Altair has used a failure rate risk based approach to develop vehicle reliability, but an analysis of the life support system doesn't always reveal all the contingencies to which the life support system should respond. Sometimes new functional capability is needed, but almost always life support needs to carry more consumables for the crew to survive an off-nominal event. Three of these types of events the project began to look at in RAC-1 are abort scenarios or other extended timelines, fire events, and a leak in the pressurized cabin. The life support system must be able to respond to all of these events, but not necessarily plan for them all in the same mission. Unique functions must be added where necessary, but a single worst case store of consumables can fulfill the needs of all the cases.

Emergencies that result in extending ascent timelines impact all vehicle systems, but especially life support, power, and thermal. A descent abort, or a need to leave the surface quickly could result in a less than ideal alignment between Altair and Orion. A loiter period many hours longer than the nominal plan may be needed for the vehicles to come together. Life support must provide oxygen to the crew in this period, but also provide water to the sublimators that provide heat rejection on the ascent stage. The life of the ascent stage batteries must be extended, so power rationing is important. Power rationing also helps extend the duration that the sublimator water can support. In an emergency like this the life support system will only operate critical suit loop functions. The cabin fan, any habitability equipment like waste or food systems, and many health sensors are shut down for power rationing. These choices extend the life of the overall vehicle until the rendezvous with Orion.

A second kind of emergency the life support system must respond to is commonly called "Feed the Leak". A strike by a micrometeorite or piece of orbital debris (MMOD) or a seal or small structural failure could create an unrepairable hole in the cabin wall. Altair must meet the same requirements as Orion in this case. The life support system must provide gas at the same rate that it is leaking out to maintain a minimum pressure of 55kPa (8 psia). The system must maintain pressure long enough for the crew to access their space suits, don them, and safely connect to the suit loop for life support. Before the suit pressure can be safely reduced, the suit loop must be purged to 95% O2 concentration, and the crew must perform any necessary prebreathe. The spacesuits can support the pressure difference between a cabin at vacuum and a 55 kPa (8 psia) internal pressure. But the crew would have significantly reduced dexterity during this period. Since the cabin can never be pressurized after this point, and there is no gas transfer to Orion available, it makes sense to maintain pressure with any available nitrogen (not

oxygen) as long as possible. Sizing regulator flow rates and providing consumable gas to “feed the leak” allows the crew to survive what would have been a catastrophic depressurization.

A special case combines the threat of extended timelines and feed the leak in a unique way. The Orion vehicle is expected to provide a “feed the leak” capability for the up to 21 days with crewmembers present. It seems reasonable to assume that an MMOD strike or leak is also a threat during the 6 month loiter in lunar orbit for crew missions to the lunar Outpost. If Altair returns from the lunar surface to an Orion that cannot hold pressure, several steps must be taken. The crew, wearing spacesuits configured for surface exploration, must depressurize the Altair ascent module to access Orion. Components for the launch and entry suit configuration must be retrieved and passed to the Altair volume. The Altair ascent module must be repressurized so that the crew can reconfigure their suits. The Altair vehicle must be depressurized again so that the crew can transfer to Orion for the uncomfortable trip home in a depressurized vehicle. This results in an extended timeline with more oxygen use, but also requires nitrogen for the repressurization.

Another contingency Altair must be prepared for is a fire in the cabin. Altair has requirements to detect and suppress a fire. Cabin air quality monitors will be needed and a water-mist fire extinguisher has been added to the vehicle in previous design cycles to suppress fires. But the crew also needs a way to recover the atmosphere quality. In RAC-1, the Altair project began to recognize the complexity of this problem, but did not yet come to a clear conclusion. Several items of forward work are necessary to resolve it. The community needs to be able to define some kind of assumed fire to design for. A “Class A” type fire burning normal combustible materials is the most likely fire. But the details of the fuel, the size of the fire and temperature, and other factors can impact what gets released into the cabin. The Altair team must also develop a more detailed concept of operations for fighting fires. The next questions are whether the cabin air is cleaned, or whether the crew transfers to spacesuits so that the cabin can be depressurized and refilled with clean nitrogen and oxygen. The life support community must address these questions for all Constellation vehicles, not just Altair.

The most critical contingencies the life support system must respond to cause a loss of a breathable atmosphere. Some require unique functions to meet. All of the unique functions must be provided in the vehicle, but the team is not planning to support all the contingencies in the same mission. After each scenario is studied, a store of contingency gas to support the worst case need in any category will be provided. The vehicle design will protect for any one of the major contingencies to occur during a mission.

F. RAC-1 Conclusion

Overall the RAC-1 tasks allowed the life support team to evaluate the impact of decisions made at the Constellation program level. Contingencies, dormancies, and performing in microgravity or especially dirty environments are all challenges that the life support system must meet to ensure the crew completes a safe and effective mission.

III. Requirements Analysis Cycle 2

In RAC-2, the Altair team continued analysis of CARD (Constellation Architecture Requirements Document) requirements, but also expanded to include several other documents. Interface Requirements Documents (IRDs) including Orion and EVA. Most critically for life support, the team began to evaluate in detail the Human Systems Integration Requirements. Outside the requirements documents, the vehicle team also started some major architectural decisions including propellant selection and propellant scavenging after landing. As the requirements set was developed in more detail, the vehicle mass estimate increased as capability was added. The team focused RAC-2 on requirements with important mass impacts or that drive unique functionality.

A. Important HSIR Issues

The Altair project chose to approach the HSIR somewhat differently from other Constellation projects. Instead of calling out all of the requirements marked for Altair in the HSIR allocation table in one group, Altair is defining top level functional requirements for the SRD. Each of these functional requirements, like “provide potable water to the crew”, or “maintain air quality”, is linked to several in the HSIR that provide more details. In most cases, a set of requirements from the HSIR must be considered together to truly understand the proposed impact to the vehicle.

1. Air Quality

Most of the functional requirements related to air quality are already included in the Altair life support conceptual design at some level. Oxygen and nitrogen can be introduced to the vehicle and controlled.

Contaminants like CO₂, CO, HCl, and HCN will be monitored, though the full suite of sensors was not added to the vehicle until DAC-4.

Several issues still remain with the air quality requirements. The first issue is Altair's ability to maintain CO₂ and humidity levels in the air during crew exercise. In the small volume of the Altair vehicle, humidity can accumulate quickly at high metabolic rates. The Altair team initially assumed that a crewmember who performed an EVA would not have to exercise. Under nominal conditions Altair assumes that 2 crewmembers perform an EVA every day. Therefore, exercise could be performed when only 2 crewmembers are left in the ascent module. But discussion with the Human Systems Integration Group revealed that they expected even crewmembers who performed EVA to do exercise. This issue would have to be worked in more detail to prepare for SRR. A final issue left unresolved is the ability to control particulate contamination. The life support design does include HEPA filters. But the true impact won't be known until the quantity of lunar dust that will enter the vehicle due to EVA activities can be predicted. Since the major functional issues are addressed, the air quality requirements are not a new key driving requirement for the Altair life support system.

2. Temperature Control

Controlling air temperature is a requirement allocated to the life support system, though it has significant impacts on the thermal system as well. Altair functionally accomplishes air temperature control with a heat exchanger downstream of the cabin fan. The fan would operate at constant flow, but a diverter allows flow to bypass the heat exchanger to control air temperature. This system appears to meet the HSIR functional requirement to cool the air. But there are also requirements that specify how large the steps between set points must be, how broad a range they must span, and how tight the control band around the set points may be. The HSIG team confirmed that the requirement was meant to drive a thermostat type control system. The manual control of the diverter included in the Altair minimum functionality design would not be sufficient. In the end, it's possible that thermostat control might be required for the air temperature control anyway. The vehicle design needs to expand to include global access to the entire lunar surface. This will significantly change the passive heat gain and loss through the shell. If the same vehicle design must meet requirements in all locations, a full flow through the heat exchanger would be too cold at the pole, and the max bypass would be too hot in a warm equatorial location. The crew could accidentally end up with a configuration that would be too cold or too hot during a period when they could not respond well, like sleep, or critical response to an emergency.

But even if automatic control is added to the life support system, the thermal system design changes still need to be assessed in future work. If the system did not have crew selectable set points, the Altair system could choose the high end of the range in a warm environment, or the cool end in a cold environment. More analysis in a range of environments is needed. If the mass impacts are large, Altair may need to argue for a relaxation of set point requirements in the HSIR. The team does not intend to exceed the range of air temperatures safe for the crew, only to examine whether selectability is truly worth the cost to Altair.

3. Potable Water

The potable water related requirements the life support system needs to meet are closely tied to the assumed food system. The DAC-3 Altair vehicle provided HSIR required quantities of potable water, gathered very clean water from the fuel cells, and included silver ion residual biocide to prevent microbial contamination. The HSIR also requires temperature control and precision. Together these capabilities would allow the crew members to rehydrate hot foods or cold beverages for maximum palatability. The requirement to provide hot and cold water is contentious. There is anecdotal support from Apollo astronauts that hot coffee is important to the crewmember's feeling of well being. Other people may counter with stories of camping trips, military exercises, or mountain climbing expeditions that survive on ambient temperature supplies. Even if Altair agrees to the requirement to provide hot or cold water, the availability of that service is important. Preparing a limited quantity of hot water for a meal period with time to recover before the next is more affordable than continuous availability. Accurately dispensing water at meal times prevents rehydrated foods from being too mushy or dry. But More work is needed to determine whether a system that reports what is being dispensed is sufficient, or whether a capability is needed to dial in the requested amount. These requirements will add complexity and new functionality to the life support system beyond simply having potable water available for the crew.

4. Conclusions on Requirements from the HSIR Document

In most cases, the HSIR does not introduce new functionality not anticipated or met in the Altair life support design. However, the subtleties of operations concepts like exercise timing or controllability of things like water or air temperature add complexity and cost beyond what would be captured in the Altair SRD functional requirements.

In many cases, the team can quickly bound the potential mass threat with Orion, ISS, or Shuttle hardware estimates. But More effort is still needed to clarify requirements and determine the most efficient way to meet each need.

B. Interface Requirements Documents

In RAC-2, the Altair team began to study two critical documents for the life support system: the Altair-Orion IRD, and Altair-EVA IRD. The team has not yet begun a thorough review of the Portable Equipment, Payloads, and Cargo (PEPC) IRD. When Altair began the minimum functional design process, the team imagined that anything that could be provided by Orion at the interface would be provided by Orion. The process also initially began without consideration of contingencies, which drive many EVA functions. It can be argued that functions added to the Altair ascent module are some of the most expensive in the Constellation architecture, because of the many locations and propulsion stages in the mission. But Orion and EVA have their own mass requirements to meet. Orion has a less capable launch vehicle (Ares I) than Altair (Ares V). EVA system designers are concerned with “on the back” mass for crewmembers exploring the lunar surface. Negotiation between the projects is required to create a functional integrated system.

In negotiating the Orion-Altair IRD, the basic position that Orion should provide most of the on-orbit life support was maintained. However, Altair did concede some functionality in nominal missions. Before descent to the lunar surface, the lander will carry consumables to for the global access loiter on its descent stage. After ascent from the moon, Altair is expected to be a dirtier vehicle than Orion. To prevent migration of lunar dust to Altair, filtered air should be passed to Orion, and cleaner air would return through the hatch to Altair. Altair already carries an filtered umbilical to ventilate the airlock by drawing air into the cabin fan. That umbilical could be used at the cabin fan outlet to push air into Orion. If the vehicle has a nominal ascent, there should be some power reserves for the additional pressure drop added to the fan system. This requirement was added to the IRD so that Altair would carry the umbilical during ascent. Altair might also provide pressure control after ascent if there are any consumable reserves left to preserve gases stored on Orion for the return trip to Earth. However, it’s not a good idea to make this an IRD requirement, because Orion still needs to be prepared for the off-nominal case when Altair does not have extra stored gases. Orion-Altair requirements for life support are relatively mature, since Orion had to begin developing them to do vehicle design. More work is required for Altair SRR, but a basic understanding between the teams is in place to design efficient solutions for crew support when the vehicles are docked.

EVA drives many functions in the Altair life support system, including the liquid cooling and low pressure oxygen umbilical support to suited crew members, and providing high pressure O₂. Initial work on the Altair-EVA IRD mostly focused on structuring and thoroughly documenting these functions. The design of the suit for surface exploration is not yet very mature. Significant analysis will still be needed to determine what quantitative performance requirements are needed in each functional area.

C. RAC-2 Conclusion

Review of some of the most critical requirements documents seemed to show that the Altair life support system design did a good job of providing required functions. Hardware estimates based on other vehicles can provide placeholders for the mass required to include each functional area. However, significant analysis efforts are still needed to quantify performance requirements and design optimal systems that can meet the true needs.

IV. Project Planning and Maturation to PDR

The primary focus of the Altair team has been preparation for SRR. But while SRR is the next major milestone, planning is required to work toward PDR and even eventually CDR. Altair also intended to award the “Altair Conceptual Design Contract” (ACDC) in the summer of 2009, but the contract was delayed until the window expired. This contract would add support from potential prime contractors working in teams with other contractors and NASA leadership in developing the conceptual design of the vehicle. The life support system team worked to layout critical tasks and plan team efforts for the future for contractors and civil servants alike.

The life support team identified several areas where extra effort or extra schedule would be required. Systems that integrated with EVA need to be worked early. Cross-project negotiation and integrated analysis must occur before detailed design for PDR should begin. Testing of these systems to validate designs after PDR may take longer than other systems because multiple projects are involved, and human test subjects are likely involved. This made EVA issues a higher priority than other systems to start early when resources were limited.

Systems with intimate connection to the crew, like waste collection, also need to be started early. Habitation systems are sometimes neglected in early system design. Everyone can think of an Earth analog for waste collection or food preparation, so the designs may seem trivial compared to other components. However, true evaluation of

these systems requires human evaluation. A formal evaluation conducted by the astronaut office would result in the generation of a Crew Consensus Report, and time must be allotted for the testing and the report for each iteration of the design until it is successful. These systems should not be neglected til late in the design process.

The third area that seemed to require special attention was the high pressure oxygen system. Significant safety issues are inherent to this system. The testing of oxygen systems requires specialized facilities. To prevent a disastrous test, the plans should be evaluated by oxygen safety specialists early in the process to ensure the design is sound.

The life support system was estimated to be one of the most expensive to develop in the vehicle. The diverse functions performed require a large staff to conquer each issue. The inclusion of humans in the system testing is necessary, but also complex, time consuming, and costly. The Altair team has started small, and did not expect to have resources for huge growth early. The life support team prioritized issues for early study and postponed others so that the team can efficiently meet SRR and PDR deadlines, to avoid being behind in preparing for CDR.

V. Conclusion

Beginning an organized review of program requirements is an important step in the maturation of the Altair life support system. For each requirement, the team must coordinate with stakeholders and requirement owners to clarify interpretation. After that, design choices can be made and mass threats established to determine whether the requirement is truly achievable in an affordable system. The Altair life support team has tackled important issues to begin building the vehicle SRD and prepare for SRR. But significant work still remains to thoroughly understand architecture decisions on contingencies, to perform detailed analysis of requirements that drive specifications from the HSIR, and begin to evaluate other documents like the PEPC IRD.

References

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