Orion Multi-Purpose Crew Vehicle Active Thermal Control and Environmental Control and Life Support Development Status

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The Orion Multi Purpose Crew Vehicle (MPCV) is the first crew transport vehicle to be developed by the National Aeronautics and Space Administration (NASA) in the last thirty years. Orion is currently being developed to transport the crew safely beyond Earth orbit. This year, the vehicle focused on building the Exploration Flight Test 1 (EFT1) vehicle to be launched in September of 2014. The development of the Orion Active Thermal Conrtol (ATCS) and Environmental Control and Life Support (ECLS) System, focused on the integrating the components into the EFT1 vehicle and preparing them for launch. Work also has started on preliminary design reviews for the manned vehicle. Additional development work is underway to keep the remaining component progressing towards implementation on the flight tests of EM1 in 2017 and of EM2 in 2020. This paper covers the Orion ECLS development from April 2013 to April 2014.

I. Introduction

Development of the Orion spacecraft has continued this year assembling and testing the flight vehicle for EFT1, refining the vehicle level designs for next unmanned and manned lunar missions, and the continuing to develop the components needed for the manned missions. This paper encompasses changes to the Orion Active Thermal Control (ATCS) and Environmental Control and Life Support (ECLS) System since May 2013. This is the 9th in a series of ICES papers on Orion ECLS development status.[6-13]

This was a year of building, testing flight vehicle for EFT1, refining vehicle designs and developing hardware for the next missions.

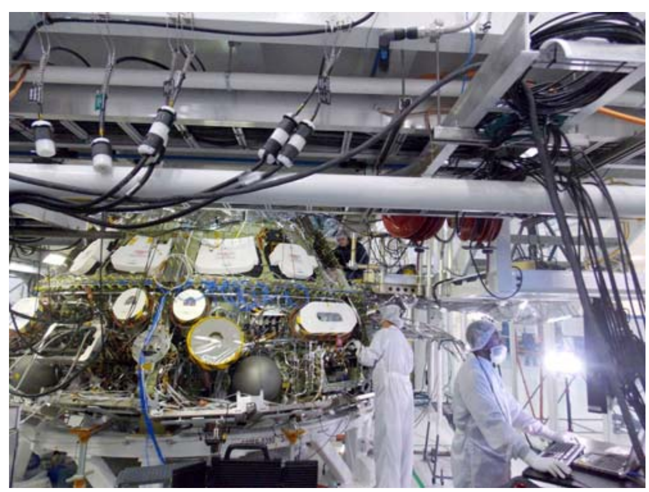

Figure 1: Orion Ground Test Article

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A. MPCV Development Manifest

EFT1 will test out the thermal protection system heat shield and parachute recovery systems. This flight launches an Orion capsule without crew for two orbits and performs a high-speed entry close to lunar return velocities. On EFT1, ECLS will have Active Thermal Control to provide cooling to the flight avionics and cabin pressure relief to protect the sealed volume. EFT1 launch is scheduled for 2014 on a Delta IV heavy from Launch Complex 37A at Cape Canaveral, Florida.

EM1 will launch an uncrewed Orion on a distant retrograde orbit (DRO) flight around the Moon on the first flight of the SLS launch vehicle. The DRO is what's being considered for an asteroid retrieval and rendezvous flight, so EM1 is being utilized to better characterize that approach. On this flight ECLS will add the external thermal loop with radiators to the EFT1 configuration to dissipate heat for the extended duration mission. EM1 launch is planned for December 2017 from Kennedy Space Center.

AA2 will be a launch abort test at maximum dynamic pressure. The flight launches and Orion capsule without crew to an altitude of 70,000 ft (21,336 m) where the launch abort system will pull the capsule from the launch vehicle to safety. The same capsule from EFT1 will be used for AA2, therefore the ECLS system will be the same as EFT1. It is still to be determined what ECLS hardware will be active for that flight depending on the avionics configuration and the duration of the mission. AA2 launch is scheduled for December 2018 on a Peacekeeper missile from Cape Canaveral, Florida.

EM2 will be the first crewed launch of Orion and is planned to orbit the Moon and return. On this flight, there will be a full ECLS system including atmospheric revitalization, pressure control, water storage, waste collection and emergency response. EM2 is planned for launch on the SLS from Kennedy Space Center in 2020.

An asteroid rendezvous where an unmanned craft would capture and bring a 7 to 10 meter asteroid to high earth orbit near the Moon continues to be investigated. This plan would have Orion rendezvous with the asteroid capture vehicle and the crew would perform EVAs to retrieve samples and return them back to Earth.

B. EFT1 Flight Preparation

The EFT1 flight vehicle was brought to the Operations and Control (O&C) building at Kennedy Space Center (KSC) to be assembled and readied for flight. For ATCS and ECLS, the activities of welding in tubing and installing components were completed. There were some issues with maintaining cleanliness during manufacturing which impacted schedule, but they were resolved. At the time of this writing, the ATCS system has been serviced with propylene glycol and water (PGW) coolant and vehicle level functional and vibration testing has been completed. Still to be completed before launch is ammonia evaporant servicing, ammonia boiler checkout, and vehicle level performance testing.

C. EM1 & EM2 Delta Preliminary Design Review (PDR)

With the development of EFT1 completed, work has started again to look at the fully capable Orion vehicle for EM2. To kick off that activity, a delta PDR from the PDR held in 2009. Since many changes, both technically and programmatically have happened since 2009, key areas are being reviewed and further analyzed to produce a preliminary design for the EM2 vehicle. Delta PDR will be in June of 2014.

D. European Service Module (ESM)

The Orion Program decided to utilize a European Space Agency (ESA) provided Service Module instead of one provided by Lockheed Martin. The Service Module is the unpressurized element that provides main propulsion, heat radiation, consumable storage, and solar array power generation to the Crew Module. For ATCS, ESA will provide the external thermal control loop and radiators and Lockheed will provide the internal thermal control loop component including heat exchangers and thermal capacitors. For ECLS, ESA will provide storage of water, oxygen, and nitrogen. This year is leading to the PDR for the ESA Service Module in currently underway.

E. ECLS Hardware Development Efforts

Work started investigating areas of performance or manufacturing risk along with approaches to reduce the cost of component manufacturing. Six different components were built and tested to reduce performance risks, three components were built and tested to investigate lower cost options for manufacturing, and four different processes were investigated to reduce both risk and cost of hardware development. The first round of development hardware is near completion and the next round is starting to get underway.

F. International Space Station (ISS) Collaboration

Work between the Orion and ISS Programs have been pursued to develop a common air monitor and universal waste management system.

ISS needs a replacement for its Major Constituent Analizer (MCA), which measures levels of Nitrogen, Oxygen, Carbon Dioxide, water, hydrogen, and methane. Since Orion is developing a unit with very similar requirements, building a common unit is being considered between the two programs. This work will continue through 2018.

The Universal Waste Management System (UWMS), which is now part of the baseline Orion system, is an evolution of the Shuttle Extended Duration Orbiter Waste Management System and Constellation Orion Waste Management System. Developing the UWMS for a Detailed Test Objective (DTO) on orbit test in ISS whose design and certification could be used in Orion is being pursued.

G. Pressure Integrated Suit Test (PIST)

The integration between the crew pressure suit and the life support system is hard to model due to flows and pressure drops being affected by crew motion and the changing volume of the suit. The NASA Orion ECLS team used development hardware and an existing altitude chamber to produce an integrated MPCV flight suit to Orion ECLS test bed. An intermediate pressure test (IPIST) was performed at a reduced pressure of 10.2 psia last year using a development amine swing bed for CO2 and humidity control, high fidelity development suit loop fan, development suit loop regulator, trace contaminant control, and development suits to test an integrated configuration based on the Orion Suit Loop. The plan is to do un-manned vacuum testing to push the system to its design limits, and manned vacuum testing over the next year. Components from the affordability efforts will be integrated into this facility in successive tests. Status of this test will be covered in PAPERXXXX REF

II. System Status

A. Active Thermal Control

EFT1 Status: The Active Thermal Control Subsystem (ATCS) configuration includes a pump package of four pumps (redundant pumps on each of two loops), accumulators, Service Module isolation valves, ground support heat exchanger, eleven cold plates, two ammonia tanks, and two ammonia boilers. All ATCS components for EFT1 are integrated into the vehicle and in test.

ESA Service Module: The Active Thermal System in the Service Module has propylene glycol water (PGW) solution pumped from the Crew Module where it cools additional electronics boxes via cold plates. The heat in the PGW is transferred into the external radiator loop, which uses HFE7200 as a thermal working fluid via an interface heat exchanger. This working fluid allows lower radiator temperatures without the risk of freezing or viscosity changes of PGW. After the interface heat exchanger, phase change heat exchangers are on the PGW loop to provide topping to the radiators. ESA is responsible for the HFE7200 loops and radiators, and Lockheed Martin is responsible for the PGW loops including the interface and ground cooling heat exchangers. PDR for this system is currently underway.

Ammonia Boiler Heat Exchanger (ABHx) Developments: Continued testing to achieve necessary performance from the ABHx has been underway this year. The issue is with the PGW's response to cooling causing a "stalling" effect where you quickly lose performance. After quite a few investigations and test, an approach to meet the performance with the available mass and volume looks to be achievable, but the final design for that approach is still underway.

Liquid Cooling Garment (LCG) Loop Developments: Two development LCG pumps and one development LCG gas trap have been built and tested this year. The pumps proved predicted flow and pressure performance from the considered design and demonstrated lower risk and cost manufacturing approaches. The pump was tested for performance, dead head, gas inclusion, and normal and abort vibration tested and performed well. Also a commercial gas trap is being investigated to see if it is applicable for the LCG application.

Flow Control Valve: A development unit of the PGW flow control valve is being developed to test simpler manufacturing techniques and use of a commercial motor for actuation. Testing will follow when the unit is built.

B. Air Revitalization

EFT1 Configuration: Since there is no crew for the EFT1 flight test, the EFT vehicle does not include air revitalization or suit support.

CO_2 And Moisture Removal Assembly (CAMRAS) Flight Test on ISS: NASA launched one of the development CAMRAS units coupled with a moisture recuperator to be tested on the International Space Station (ISS). The unit completed testing onboard ISS. Results from the flight test are covered in PAPERXXXX REF

Development Suit Loop Fan: A high fidelity suit loop fan that incorporates the flight materials and motor was built and tested in the IPIST test. This fan incorporates the ceramic "canning" of the motor required for oxygen safety and is a development risk. Follow on acoustics testing will be performed on the fan to better design acoustics treatments for the vehicle design. The fan will continue to be used in the PST series.

Development Suit Loop Regulator: Development of a high fidelity suit loop pressure regulator was completed this year. This component provides the capability of having multiple pressure set points utilizing a motor settable regulation point. Development of the regulator was documented in PAPERXXXX REF. The suit loop regulator performed well in the IPIST test and will continue to be used in the PST series.

Development Swing bed: Development of the next design turn of the amine swing bed for CO2 and humidity control is underway. This unit will pursue proving system performance and manufacturability. Manufacture of this unit is currently underway.

Development Aluminum Air Heat Exchanger: Development of an aluminum heat exchanger using existing parts from aviation components is being investigated. Aluminum, because of its thermal conductivity, makes for a larger heat exchanger with little if any weigh savings, but using dies and parts from commercial aviation heat exchangers will provide for a lower cost unit. The unit has been built and testing is under way to determine its performance and acceptability to Orion's environments.

Development Cabin Fan: A development fan was produced to investigate the use of an alternative lower cost electric motor manufacturer and simplified manufacturing techniques. The fan performed well in performance and vibration testing. There were some thermal issues that required more heat syncing of the motor, but the fan performed well after the improvements were made. Follow on acoustics testing will be performed on the fan to better design acoustics treatments for the vehicle design.

Orion Air Monitor (OAM) Common with ISS Major Constituent Analyzer: UTAS through Boeing is developing an approach to produce a qualified air monitor design to monitor oxygen, carbon dioxide, nitrogen, humidity, hydrogen, and methane, that would be used for the Orion and also serve as an upgrade to the ISS MCA. The International Space Station (ISS) Program made an agreement with the Orion Program for ISS to fund the development of and qualification of an air monitor that will be common between ISS and Orion. The Systems Requirements Review is complete and initial design work is starting.

C. Pressure Control

EFT1 Configuration: The Pressure Control Subsystem (PCS) configuration includes a positive pressure relief valve (PPRV) and a negative pressure relief valve (NPRV). The components to provide oxygen and nitrogen to the cabin have been deferred from EFT1. The secondary locking feature on the NPRV failed shock testing and will need to be redesigned before EM2.

Delta PDR PCS Flow sizing: Analysis is being performed to size the PCS system to better define the integration with the ESA Service Module and to look at simplifying and making more components common to reduce cost. This activity will continue through summer.

Common Valve Investigation: The approach of making as many of the PCS and some of the ARS valves common is underway to reduce cost. This will continue through the year.

ESA Service Module: The Pressure Control Subsystem in the Service Module includes the tanks to store oxygen and nitrogen and the isolation, regulation, and relief devices to manage the delivery of the commodities. All of these components in the Service Module will be provided by ESA. A good deal of effort is underway to determine the right amount of stored oxygen and nitrogen to support crew needs and contingencies, and how to fit it in existing ESA tank designs for affordability.

D. Emergency Response

EFT1 Configuration: Since there is no crew for the EFT1 flight test, no emergency response equipment is in the EFT1 vehicle.

Contingency Gas Analyzer: Work is being pursued with advanced development groups in NASA to make a common contingency gas analyzer for fire/tox response and cleanup.

E. Potable Water & Waste Management

EFT1 Configuration: Since there are no crewmembers or active thermal control sublimators that require water for the EFT1 flight test, no potable water or waste management is included in the EFT1 vehicle.

ESA Service Module: The Potable Water Subsystem in the Service Module includes the tanks to store water and the isolation, regulation, and relief devices to manage the delivery of the commodities. All of these components in the Service Module will be provided by ESA. Like in pressure control, a good deal of effort is underway to determine what is the right amount of stored water to support crew needs and contingencies, and how to fit it in existing ESA tank designs for affordability.

Alternative Waste Collection: Orion ECLS is investigating use of a UTAS developed waste collection system that is based on the Space Shuttle Extended Duration Orbiter unit but has been simplified using fewer parts and rotating equipment. A flight experiment on the ISS is being pursued.

III. Conclusion

Assembly is complete and test of the EFT1 Active Thermal and ECLS hardware is well underway for the EFT1 mission. Plans are being made for the follow-on Orion flights that will ultimately put crews out past low Earth orbit. To meet that end, Orion ECLS is pursuing ways to reduce technical risk and costs and improve ease of manufacturing ECLS hardware.

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