

# 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 2014. The development of the Orion Environmental Control and Life Support (ECLS) System, focused on the completing the components which are on EFT1. Additional development work has been done to keep the remaining component progressing towards implementation for a flight tests in of EM1 in 2017 and in and EM2 in 2020. This paper covers the Orion ECLS development from April 2012 to April 2013.

#### I. Introduction

Development of the Orion spacecraft has continued this year building and certifying components and assembling the flight vehicle for EFT1, while starting to develop the components needed for the manned missions. This paper will encompass changes to the Orion Active Thermal Control (ATCS) and Environmental Control and Life Support (ECLS) System since May 2011. This is the 8th in a series of ICES papers on Orion ECLS development status.<sup>6-12</sup>

This was a year of building and test flight hardware and developing hardware for the missions past EFT1 for Orion.



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 free return flight around the Moon launched on the first flight of the SLS vehicle. 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 an 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. Since the same capsule from EFT1 will be used for AA2, 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.

Planning is being considered for an asteroid rendezvous where an unmanned craft would capture and bring a 7 to 10 meter asteroid to high earth orbit near the Moon. The plan would have Orion meet the asteroid and capture vehicle and crews would perform EVAs to recover samples and return them back to Earth.

## **B. European Service Module**

The Orion Program decided to utilize a European Space Agency provided Service Module instead of one provided by Lockheed Martin. The Service Module is an unpressurized element that provides main propulsion, heat radiation, consumable storage, and solar arrays to the Crew Module. For ATCS, ESA will provide the external thermal control loop and radiators and Lockheed will still provide the internal thermal control loop component including heat exchangers and thermal capacitors. For ECLS, ESA will provide storage of water, oxygen, and nitrogen.

## **C. Affordability Efforts**

Affordability efforts started by updating the schematics to bring them to a common starting point, to simplify them, and to apply more commonality in components to reduce cost of the system. The updated schematic was reviewed with the Safety, crew, life sciences, and operations community to gain consensus in the new schematic.

The ECLS and Active thermal team were funded this year to pursue build of 12 components and investigate 5 processes to reduce technical risks and lower manufacturing cost. There are some components like the ammonia boiler used to cool the vehicle when the radiators cannot, that new development work is being done to improve its performance to required levels. There are other components like the cabin fan that is investigating alternate sources of fan motors, which can drive costs substantially. And there are areas like the suit loop heat exchanger utilizing existing aviation parts. Manufacturing processes are also being reviewed to remove steps that from past experience have been unproductive.

Work has just started at the time writing this paper on the components and processes, and will continue through the calendar year. Planning for the follow on years is underway.

## **D. 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 a space suit to Orion ECLS test bed. An

ambient test was performed last year using a development amine swing bed for CO<sub>2</sub> and humidity control, development suit loop fan, trace contaminant control, and development suits to test in an integrated configuration based on the Orion Suit Loop. Work is underway to continue modifications of the test bed to upgrade the suit loop fan and pressure regulator to a more flight like version, and add a flight like liquid cooling loop. The plan is to do intermediate pressure testing around 8 to 10 psia this summer and perform full vacuum testing the following summer. Components from the affordability efforts will be integrated into this facility in successive tests.

## II. System Status

### A. Active Thermal Control

*EFT1 Status:* The Active Thermal Control Subsystem (ATCS) configuration includes the 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 built and are either delivered or in the last stages of testing before delivery.

*EM1/EM2 Sublimator Analysis:* Analysis has been performed on the EM1 and EM2 mission profiles to determine if a Sublimator is needed to augment the ammonia boiler, and phase change heat capacitors when the radiators cannot. Preliminary analysis is indicating that a sublimator should not be required. If Orion has to operate in low Earth orbit (LEO), the environment drives a supplemental cooling device. But, in LEO a phase change heat exchanger does not have enough cold environment to refreeze the phase change material, so a water sublimator trades better. For the highly elliptical Lunar orbit for EM2, adjusting the size of the phase change heat exchangers should work to provide supplemental cooling to the radiators without adding the weight and complexity of a sublimator.

*ESA Service Module:* The Active Thermal System in the Service Module has the 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 that PGW has. 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.

*Liquid Cooling Garment (LCG) Loop Developments:* NASA has developing a venting gas trap for the liquid cooling garment. During disconnects and reconnects of the suit to the vehicle systems, gas is entrained into the cooling water and has to be removed to assure pump operation. A development venting gas trap has been built and tested this year, and looks to be a good option for the Orion LCG loop.

*Affordability Efforts:* The components that are being worked on this year are the ammonia boiler performance improvement, accumulator sensors improvement and manufacturing simplification, phase change heat exchanger development, suit liquid cooling garment pump development and venting gas trap, and cold plate improvements. The processes for comparing helium to PGW leak rates and corrosion inhibiting sealing process will also be investigated.

### 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<sub>2</sub> And Moisture Removal Assembly (CAMRAS) Flight Test on ISS:* NASA launched one of the development CAMRAS unit coupled with a moisture recuperator to be tested on the International Space Station (ISS). The unit has been installed and is now under going testing onboard ISS..

*Development Suit Loop Fan:* NASA is pursuing thru United Technologies Aerospace Systems (UTAS) the development of a high fidelity suit loop fan that incorporates the flight materials and motor. This incorporates the ceramic “canning” of the motor required for oxygen safety and is a development risk. Currently the fan is in manufacturing. This fan will be used in the next integrated suit loop tests.

*Development Suit Loop Regulator:* NASA is pursuing thru Cobham PLC the development of a high fidelity suit loop pressure regulator. This component provides the capability of having multiple pressure set points utilizing a motor settable regulation point. Currently testing is under way on the development unit. This regulator is key integrated suit loop tests.

*Orion Air Monitor (OAM) Common with ISS Major Constituent Analyzer (MCA):* Hamilton Sunstrand is developing an approach to produce a qualified air monitor design to monitor oxygen, carbon dioxide, nitrogen, humidity, hydrogen, and methane, that could be used for the MPCV 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.

*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 what is the right amount of stored oxygen and nitrogen to support crew needs and contingencies, and how to fit it in existing ESA tank designs.

### **D. Emergency Response**

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

### **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.

## **III. Conclusion**

Manufacture and test of the Active Thermal and ECLS hardware have been well underway to meet the EFT1 mission and integration into the vehicle has begun. Plans are being made for the following Orion flights that will ultimately put crews out past low Earth orbit. To meet that end, Orion ECLS is pursuing ways to reduce risk and costs.

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