

Design Status of the Closed-Loop Air Revitalization System ARES for Accommodation on the ISS

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1 Abstract

The Closed-Loop Air REvitalisation System **ARES** is a proof of technology Payload. The objective of ARES is to demonstrate with regenerative processes:

- the provision of the capability for carbon dioxide removal from the module atmosphere,
- the return supply of breathable oxygen within a closed-loop process,
- the conversion of the hydrogen, resulting from the oxygen generation via electrolysis, to water.

The ARES Payload is foreseen to be installed - in 2012 - onboard the ISS in the Columbus Module. The operation of ARES - in a representative manned microgravity environment - will produce valuable operational data on a system which is based on technologies which are different from other air revitalization systems presently in use.

The ARES Technology Demonstrator Payload development started in 2003 with a Phase B, see references [1] to [4]. ARES is presently in Phase C1 and a PDR is scheduled for the beginning of 2009. This paper summarizes the design development work performed in present phase C1 and comprises an outlook on near-term development tasks in support of the ARES PDR in early 2009.

2 Introduction

During the last years there has always been a paper on the development progress of ARES on the ICES conferences, see references [1] to [4]. For the new reader the introduction summarizes the background behind ARES. In addition an ARES Payload requirements outline is presented.

2.1 ARES Functional Description

ARES is a system which can recycle oxygen from the CO₂ that is produced by astronauts in manned space vehicles. Such recycling technology can reduce the re-supply to the ISS significantly. On longer duration missions like a lunar base or a manned mission to Mars closed loop (regenerative) systems will be essential to make such missions feasible.

ARES has three major functions:

- (1) The **CO₂ Concentration Assembly (CCA)** concentrates the CO₂ from the cabin and thus controls the CO₂ level to acceptable levels;
- (2) In the **CO₂ Reduction Assembly (CRA)** or Sabatier reactor, hydrogen and CO₂ react over a catalyst to form water and Methane. The water is condensed and separated from the product gas stream and fed back to the electrolyser;

- (3) The **Oxygen Generation Assembly (OGA)** is an electrolyser which splits water into its constituents: oxygen and hydrogen.

Methane is vented overboard. In this way about 50% of the water needed for oxygen production can be produced onboard from the CO_2 which is exhaled by the astronauts. The remaining water needs to be uploaded from ground.

Similar systems, albeit based on different technologies, have been in use onboard MIR and the ISS. They require a constant re-supply of water for oxygen production, while CO_2 and hydrogen are vented overboard.

At assembly complete ISS will inhabit a crew of six. In order to produce Oxygen for this crew more than 2 tons of water is needed per year. This will put an important strain on logistics flight especially once the Space Shuttle is retired in 2010. Sized for a crew of 3, ARES will save about 450 kg of water upload per year.

The ARES cycle is shown in below Figure 1.

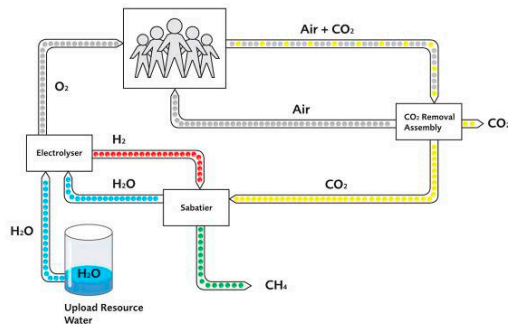


Figure 1: Closed Loop System with ARES

The Sabatier reactor is the key element for closing the oxygen loop. The Sabatier is a catalytic reactor which reacts H_2 and CO_2 at elevated temperatures to water and methane (CH_4). The water is fed into the electrolyser for reclaiming the O_2 and closing the oxygen loop. At this stage the by-product methane (CH_4) is of no further use and is vented overboard. Closing the H_2 loop will become a future development step of ARES, see reference [5].

2.2 ARES Perspectives

Although ARES is designed and will be operated on board the ISS as a Proof of Technology Payload its function will back up the CO_2 removal provided by the US CDRA and the Russian VOZDUKH CO_2 removal systems as well as the oxygen generation of the Russian ELEKTRON electrolyser and of the US OGS.

ARES relevant processes outlined in the previous chapter are not limited to life support applications. Complementing the ARES key technologies of CO_2 removal, CO_2 reduction and oxygen generation e.g. by methane Pyrolysis and fuel cells may once allow for

- the generation of H_2/O_2 from lunar ice to be used as propellant for rockets or as fuel for fuel cells;
- mobile energy storage and supply for robots and lunar exploration equipment by a Regenerative Fuel Cell System (RFCS) in which the electrolyser is one key element;
- the generation of O_2/CH_4 propellant from the Martian CO_2 atmosphere and in combination with the Methane Pyrolysis Technology, the generation of O_2 and H_2 as propellant or fuel for fuel cells;
- and bares the potential of RFCS as a future energy supply system for GEO satellites.

2.3 ARES P/L Requirements Outline

The major i.e. design driving requirements that apply on the ARES Technology Demonstrator Payload are as follows:

- ARES shall be launched as a fully integrated (IHI) ISPR double rack in the pressurized compartment of HTV and then be installed and operated in the Columbus module at O2 Rack position;
- ARES shall have a design life of minimum 10 years through preventive and corrective maintenance; ARES life limited items shall be designed for an on-orbit operational lifetime of minimum 3 years;
- ARES shall be designed for in-orbit maintenance thus comprised of exchangeable Intermediate Maintenance Items (IMI) that shall be compatible with launch on ATV, HTV and Progress;
- the design case for ARES is to provide all three functions, see above chapter 2.1, for a 3-men crew - in continuous ops, whereas, at reduced performance, cyclic ops shall be possible;
- in continuous ops ARES shall generate at least 1.2 kg/day of liquid water from the reaction of Hydrogen and CO_2

- f) in continuous ops ARES shall generate at least 2.52 kg/day O₂ by electrolysis of water
- g) in continuous ops ARES shall remove at least 3 kg/day CO₂ from the cabin air at a nominal CO₂ level of 4 hPa
- h) in continuous ops ARES shall limit the loss of cabin air through the external ventline to ≤ 50 g/day;
- i) in continuous ops ARES shall limit the loss of water vapour through the external ventline to ≤ 100 g/day;
- j) in continuous ops ARES shall limit the feed water supply to ≤ 17 kg/d;
- k) ARES shall provide an interface to the Columbus condensate line for rejection of product water and supply of feed water;
- l) for the venting of waste gases ARES shall provide an interface to the Columbus P/L ventline that shall be permanently available to ARES during its operation;

3 ARES Design Status

In the previous phase B extensive testing was done with an Elegant Breadboard (EB) of the ARES, see Figure 2, covering all three functions i.e. CCA, CRA and OGA.



Figure 2: Photo of the ARES Elegant Breadboard (EB)

The EB test results evaluation, together with the newly baselined requirements, see previous chapter 2.3, serves as the valid input for ARES design development subject to present phase C1.

3.1 ARES in IHI ISPR Accommodation

ARES will be operated in the Columbus module at O2 Rack position (actually used for passive storage rack 'European Transport Carrier' ETC), see Figure 3;

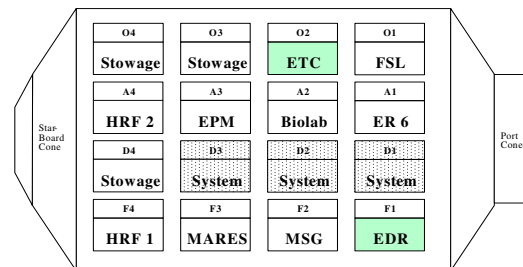


Figure 3: ARES Allocation in Columbus Module

ARES is accommodated for launch, as a fully integrated (IHI) ISPR double rack, see Figure 4, in the pressurized compartment of the Japanese HTV.

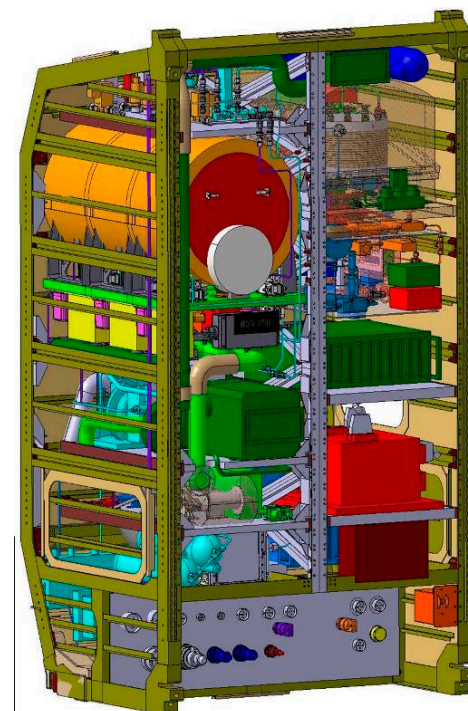


Figure 4: ARES in IHI ISPR Accommodation (w/o closure panels & OGA safety dome)

ARES is designed for in-orbit maintenance thus comprised of exchangeable Intermediate Maintenance Items (IMI) that are compatible with launch on ATV, HTV and Progress i.e. that fit through the Russian hatch. Reference is made to below Figure 5 to Figure 7.

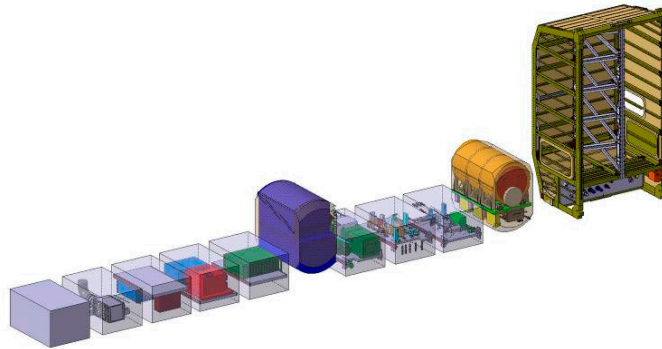


Figure 5: ARES Intermediate Maintenance Items (IMI's) compatible with ATV Cargo Transfer Bag (CTB) Shape



Figure 6: Cargo Transfer bags (CTB's) stowed in ATV



Figure 7: ATV Largest Bag CTB M01

The above outlined IMI concept may even allow for a modular launch of ARES - as a fall back possibility in case an integrated launch cannot be secured. The issue of a Pre-integrated Rack - IHI/ISPR standard - not fitting in CTB's nor through Russian hatch can be

overcome by a Foldable Rack design, see Figure 8 for initial design concept.

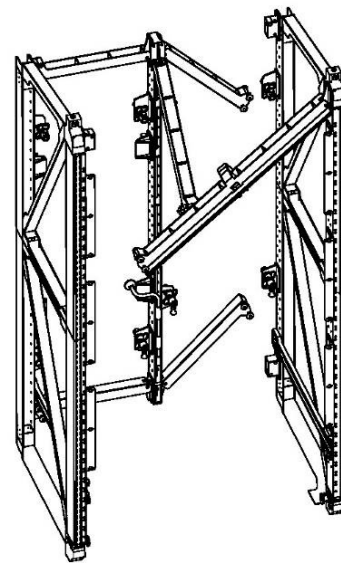


Figure 8: Foldable Rack Design Concept

3.2 ARES Subsystems

The ARES functional block diagram is given on Figure 9.

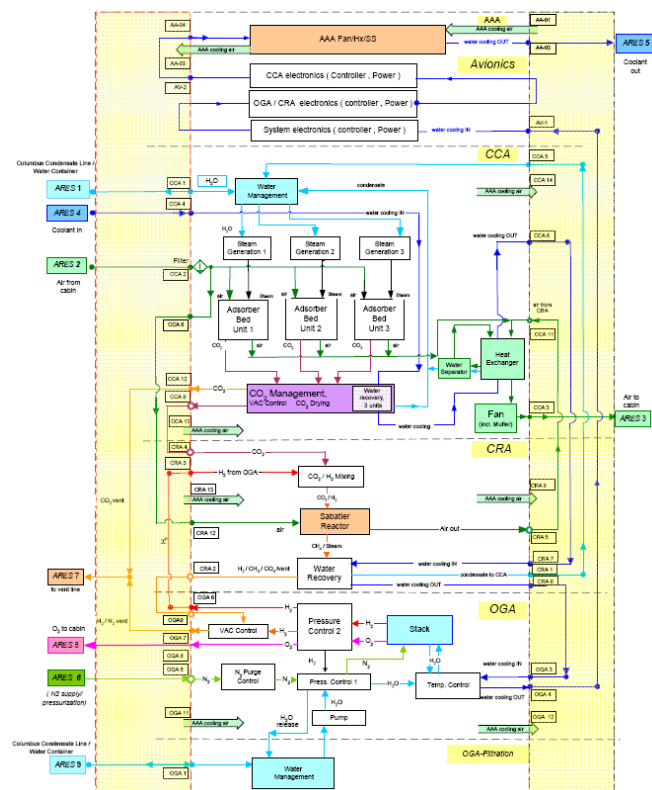


Figure 9: ARES Functional Block Diagram