

# The Orion Air Monitor; an Optimized Analyzer for Environmental Control and Life Support

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## ABSTRACT

This paper describes the requirements for and design implementation of an air monitor for the Orion Crew Exploration Vehicle (CEV). The air monitor is specified to monitor oxygen, nitrogen, water vapor, and carbon dioxide, and participates with the Environmental Control Life Support System (ECLSS) pressure control system and Atmosphere Revitalization System (ARS) to help maintain a breathable and safe environment. The sensing requirements are similar to those delivered by the International Space Station (ISS) air monitor, the Major Constituent Analyzer or MCA (1-3), and the predecessors to that instrument, the Skylab Mass Spectrometer (4, 5), although with a shift in emphasis from extended operations to minimized weight.

The Orion emphasis on weight and power, and relatively simpler requirements on operating life, allow optimization of the instrument toward the mass of a sensor assembly. The Air Monitor is more integral with Orion's ARS, simplifying the sampling system relative to the MCA, the verification assembly has been greatly simplified, and the electronics have been redesigned around a simple controller, allowing the design to come in at under 15 pounds.

## INTRODUCTION

The Orion Crew Exploration Vehicle is specified to support six astronauts in missions to and from the International Space Station, and four astronauts in lunar missions, with crewed operations up to 20 days per mission and un-crewed operations – in ISS lifeboat or lunar loiter – of over 180 days per mission. The Orion spacecraft doubles as its own airlock, supporting the crew with breathable air through umbilicals to a suit loop, when required, though most operations are in a shirt-sleeve environment. The functions of breathing air supply and carbon dioxide and humidity removal are common to both cabin and suit-loop operations, and must therefore be maintained in the sealed plumbing associated with the suit-loop; under normal operations cabin air is maintained by the suit-loop with diffusers at the umbilical attachment points.

The air monitor is integral to the pneumatics of the suit-loop, drawing air from the return line coming from the astronauts or the cabin, and sampling that air for its principal constituents nitrogen, oxygen, water vapor, and carbon dioxide. The air monitored can be a fairly normal mix of nitrogen and oxygen, at pressures ranging from 9 to 15 psia, or it can be a largely oxygen mix as astronauts convert over to low pressure, suited operations. Additionally, the ARS includes a requirement to supply hyperbaric oxygen should one or more astronauts develop decompression sickness.

The spans of target analyte partial pressures that the analyzer must respond to and the tolerances on those concentrations are listed in Table 1. Key performance requirements imposed by the application are identified in Table 2.

Table 1. Orion Air Monitor Sensitivity Requirements.

| Analyte        | Pressure Range /psia | Accuracy at Nominal Concentration /psia | Response Time /sec |
|----------------|----------------------|-----------------------------------------|--------------------|
| Oxygen         | 0 – 24               | 0.1                                     | 10                 |
| Nitrogen       | 0 – 13               | 0.1                                     | 10                 |
| Carbon Dioxide | 0 – 1.5              | 0.005                                   | 10                 |
| Water Vap      | 0 – 1                | 0.005                                   | 15                 |

Table 2. Key Air Monitor Performance Requirements.

| Parameter      | Specification | Performance Target |
|----------------|---------------|--------------------|
| Weight         | 15.6 lbs      | 14 lbs             |
| Power          | 24V, 25 W     | 17 W nominal       |
| Communications | RS422         | 300kbps            |

The analyzer is based on a single focusing magnetic sector mass spectrometer with four fixed Faraday collectors at the exit slits. Figure 1 illustrates the analyzer core, an approximately 3 x 6 x 7 inch vacuum system that includes a sputter ion pump (right), an ion source (middle), and an array of Faraday collectors (left, top). Not shown is a 3700 gauss magnet mounted across the bend in the vacuum envelope that is responsible for separating ions formed in the ion source into the four detector channels.

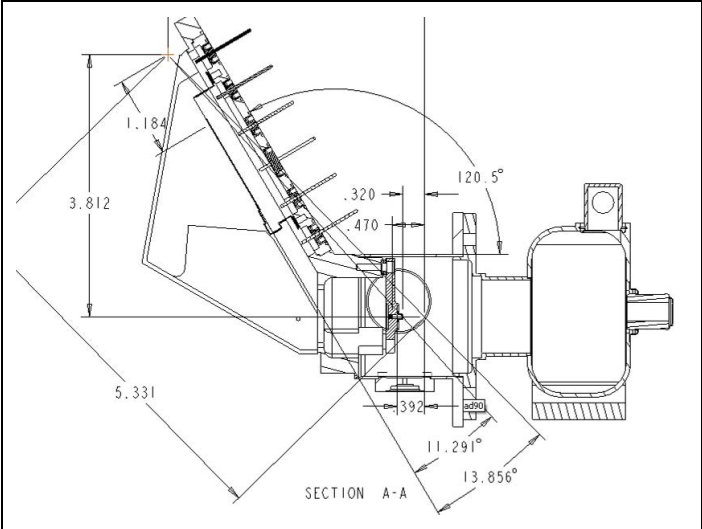


Figure 1. Single focusing mass spectrometer analytical engine in the Orion Air Monitor.

This analytical engine has been used in a number of applications, including the Skylab Mass Spectrometer, Gas Analysis Mass Spectrometer (GAMS), and most recently the Space Station Major Constituent Analyzer (MCA). The instruments as packaged for these applications are illustrated in Figure 2. There are a number of trade-offs that lead to the different instrument layouts associated with the three designs, including weight, power, mission duration, built-in test, and modularity; the challenge for the Orion Air Monitor (OAM) is to improve on the weight and simplicity of the Skylab instrument, while providing the built-in test and on-orbit calibration functionality of the ISS MCA.

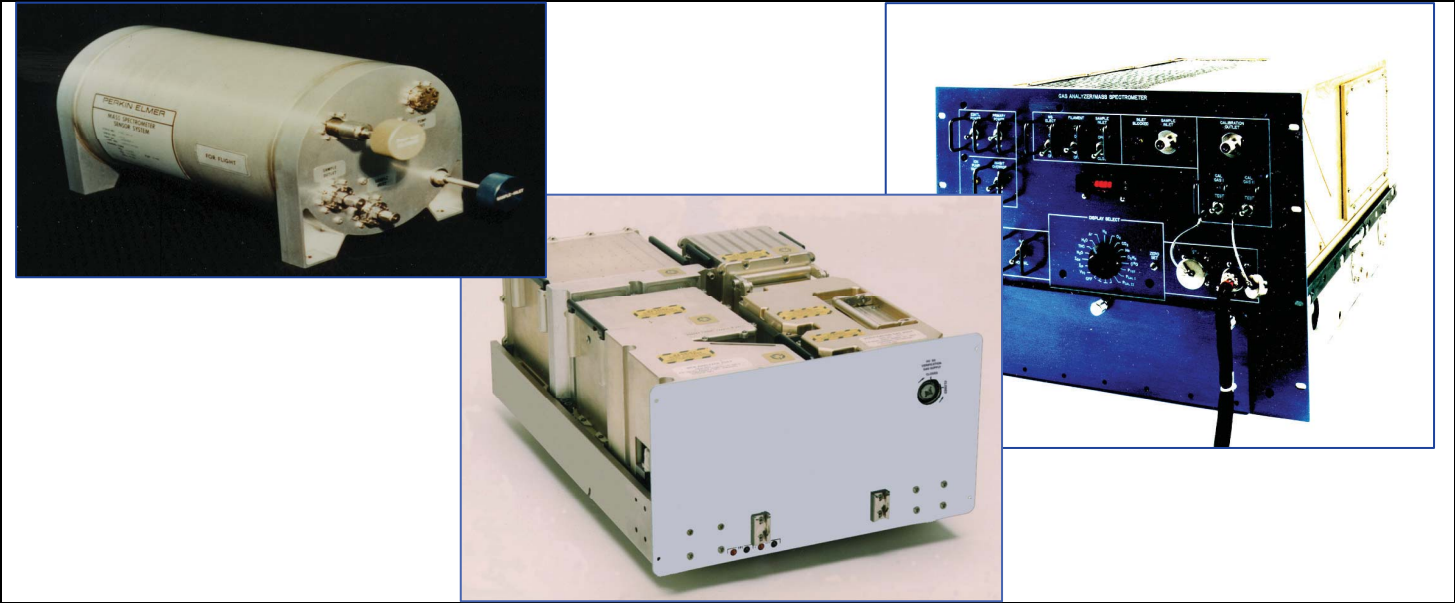


Figure 2. Flight predecessors of the Orion Air Monitor. The image at the top left is of a compact instrument used on Skylab, the top right image shows the Spacelab Gas Analysis Mass Spectrometer (GAMS), and the lower image is the current ISS Major Constituent Analyzer (MCA). The modular nature of the MCA segregates the air analyzer (the left front block) from other orbital replaceable units, allowing replacement on-orbit without replacing the entire MCA.