

International Space Station (ISS) Major Constituent Analyzer (MCA) On-Orbit Performance

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ABSTRACT

This paper summarizes the first seven plus years of on-orbit operation for the Major Constituent Analyzer (MCA). The MCA is an essential part of the International Space Station (ISS) Environmental Control and Life Support System (ECLSS). The MCA is a mass spectrometer instrument in the US Destiny Laboratory Module, which provides critical monitoring of six major atmospheric constituents (nitrogen (N_2), oxygen (O_2), hydrogen (H_2), carbon dioxide (CO_2), methane (CH_4), and water vapor (H_2O)). These gases are sampled continuously and automatically in all United States On-Orbit Segment (USOS) modules via the ISS Sample Delivery System (SDS). Continuous readout of the partial pressures of these gases is critical to verifying safe operation of the Atmosphere Re-vitalization (AR) system, Atmosphere Control System (ACS), and crew safety for Airlock Extravehicular Activity (EVA) preparation. The system also supports dedicated rapid sampling of any one location, a feature used primarily to support Joint Airlock atmosphere sampling during crew preparations for EVAs and module atmosphere sampling during re-pressurizations of the ISS atmosphere with oxygen or nitrogen.

The performance of the MCA is discussed; in particular, the sample pump life, accuracy tolerances, and calibration gas consumption. We will also discuss a study conducted to identify design changes to the MCA that would extend its life and operability. The operational life of the mass spectrometer assembly of the MCA will be presented in the Reference 1 paper.

INTRODUCTION TO THE MCA

MCA FUNCTIONS

The MCA continuously and autonomously monitors six major constituents of the ISS atmosphere:

1. Oxygen
2. Nitrogen
3. Carbon Dioxide
4. Water vapor
5. Methane
6. Hydrogen

The specified accuracy for each gas is listed in Table 1.

Table 1. MCA Gas Measurement

Accuracy Requirements			
Measured Gas	Torr ¹ full scale	Percent accuracy	Accuracy band ²
N_2	800	±2% full scale	±16.00 Torr
O_2	300	±2% full scale	±6.00 Torr
H_2	50	±5% full scale	±2.50 Torr
CH_4	25	±5% full scale	±1.25 Torr
H_2O	25	N/A	N/A
CO_2	15	±3% full scale	±0.45 Torr

¹760Torr=14.7psia

² in the range 719 – 786 Torr (13.9 – 15.2 psia)

This atmospheric monitoring is performed throughout the US segment of the ISS via a network of sample lines and valves known as the Sample Delivery System (SDS) shown in Figure 1.

This selection is done external to the MCA and the SDS is connected to two dedicated sample ports on the MCA. The MCA has its own internal sample delivery system (SDS) contained in ORU 06 (refer to Figure 4) that provides for five more (total of 7) sample ports.

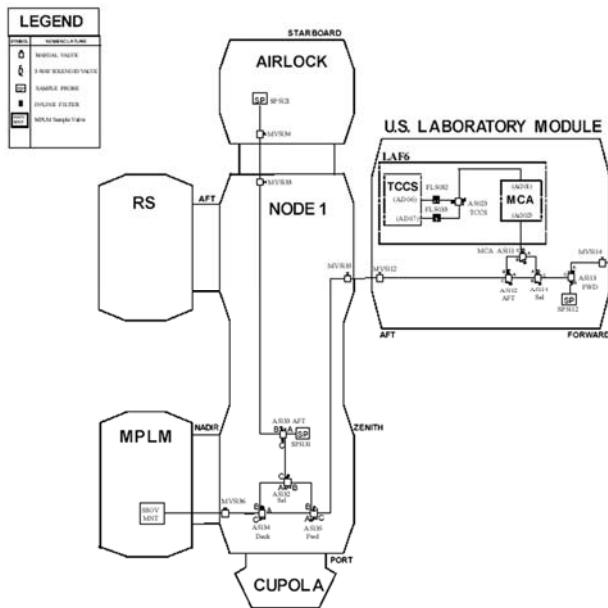


Figure 1. Segment of the Sample Delivery System (not shown Node 2 Columbus and JLP)

The Sample Delivery System (SDS), shown in Figure 1, provides the capability for the MCA to sample air from the various U.S. segment modules. The MCA Series Sample Pump Assembly draws air from U.S. segment modules through filtered sample probes (labeled “SP”) in Figure 1. Manual valves (labeled “MVxxxx”) provide access to or isolation of the various modules. Three-way latching solenoid valves (labeled “Axxxx”) controlled by ISS software allow sampling of the various modules. ISS software allows selection of which modules may be sampled and in which sequence.

The MCA also has an extensive Built-In-Test (BIT) and Fault Isolation capability. The BIT function can be performed on demand (Active BIT, or ABIT) or may run continuously in the background (Passive BIT, or PBIT) during normal operations. The MCA also has a fully self-contained Calibration capability with its own on-board supply of an accurately known gas mixture.

VITAL MCA ROLES

The MCA is essential for Environment Control and Life Support (ECLS). In this capacity, it serves the following vital roles:

- Monitor oxygen content in atmosphere throughout ISS
- Ensure Carbon Dioxide Removal is being maintained at acceptable CO₂ levels [Vozdukh also removes CO₂]
- Monitor for controlling Airlock oxygen partial for EVA pre-breath
- Ensure no buildup of flammable gases
- Monitor O₂, Air Represses
- Leak Detection by direct measurement of N₂ provides most timely indication of cabin leakage overboard

MCA ARCHITECTURE

The MCA has a modular architecture consisting of a number of Orbital Replaceable Units (ORUs) that are installed into a common baseplate/chassis. This architecture facilitates easy Removal and Replacement (R&R) of ORUs as limited life components reach the end of their service life, consumables (Calibration Gas) are depleted or if a failure should occur.

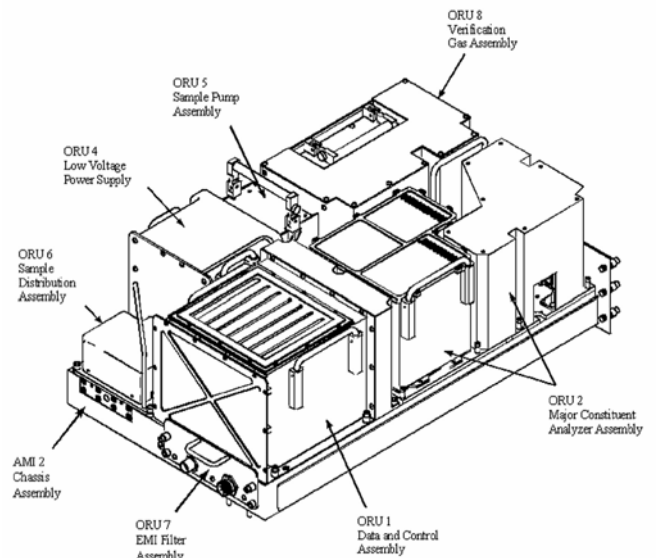


Figure 2. Major Constituents Analyzer

Figure 2 illustrates how the MCA is comprised of a chassis into which Orbital Replacement Units (ORU) are inserted. These ORUs are:

- ORU 01 Data and Control Assembly: The main computer for control and data acquisition. It consists of a series of Circuit Card Assemblies (CCAs), including an Embedded Data Processor CCA and memory CCA where the MCA controlling software, the Computer Software Configuration Item (CSCI) is programmed.
- ORU 02 Mass Spectrometer Assembly: The Mass Spectrometer that takes the actual measurements. It consists of an ion source, ion pump, analyzer magnet, various electrostatic lenses, and electrometers.
- ORU 04 Low Voltage Power Supply: The regulated, output-protected power supply for all MCA voltages (+5V, ±15V, +28V analog and +28V electromechanical).
- ORU 05 Series Sample Pump Assembly: There are two redundant pumps here that pull the sample air through the external sample lines and then through the MCA.
- ORU 06 Sample Distribution Assembly: Performs valve selection function for the seven external Sample Ports where the sample lines come in from the different parts of the ISS.
- ORU 07 EMI / Filter Assembly: Provides for EMI filtering of external 120VDC power and dual redundant MIL-STD-1553 databus lines.
- ORU 08 Verification Gas Assembly: On-board highly pressurized supply of accurately known calibration gas used for the MCA self-calibration.
- AMI 02 (Additional Maintenance Item), the chassis into which the ORUs plug, contains an integral pneumatic distribution system, electrical harness with interface connectors and a forced-air cooling plenum.

MASS SPECTROMETER (MS) PRINCIPLE OF OPERATION

The sample air passes through a line in the ORU 02, shown in Figure 3. A portion of this gas is directed into the mass spectrometer, where it collides with electrons produced in the ion source. This collision ionizes the gas molecules giving them an electric charge. Using electrostatic focusing, accelerating electrodes, and the analyzer magnet, the six main constituents of air that are ionized, are directed into dedicated electrometers. These signals are then read using highly sensitive electrometer circuits, and partial pressures for each gas are calculated. The mass spec is maintained at vacuum with the ion pump after initially being pumped down using space vacuum in the U.S. Laboratory.

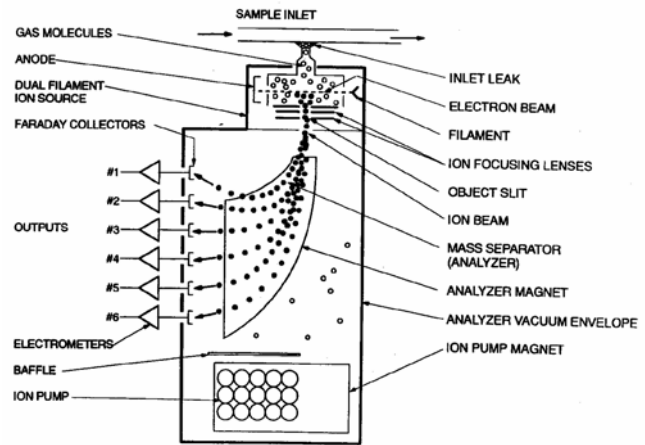


Figure 3. Principle of Operation of the Mass Spectrometer

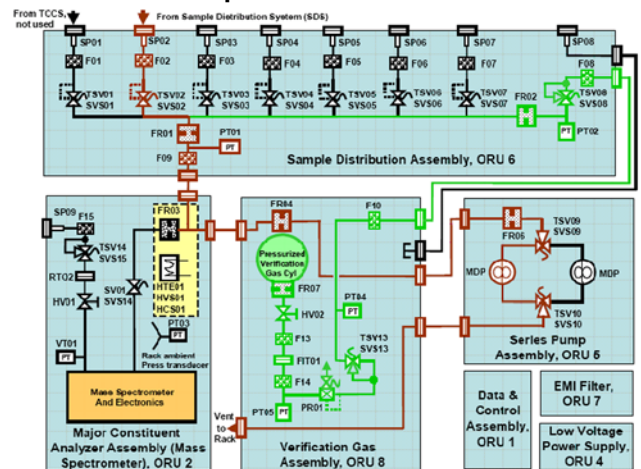


Figure 4. MCA Pneumatic diagram

Figure 4 illustrates the MCA pneumatic system. This provides a system of solenoid valves, manual valves, filters and restrictors with interconnect lines that perform the various pneumatic functions of the MCA, including:

- Sample port selection
- Standby/Operate mode selection
- Sample introduction to Mass spectrometer
- Selection of dual redundant sample pumps
- Sample pump Built-In-Test
- Calibration gas introduction
- Mass spectrometer initial vacuum pump down