IAF SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations - IAF SPACE EXPLORATION SYMPOSIUM (IP)

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MINIATURE MODULAR MASS SPECTROMETER

Abstract

This paper describes the final outcomes of a project conducted for the European Space Agency aimed at the development of a miniaturized mass spectrometer tailored for space applications. The construction of the spectrometer relies on MEMS (Micro-Electro-Mechanical Systems) and 3D printing technology. It consists of modules responsible for: pressure measurement, gas sample ionization, separation and detection of ions. They are placed inside a 3D printed housing which is responsible for their positioning and alignment. The overall dimensions of the instrument are 10x2.5x2.5 cm3 with additional 1.5 U allocated for electronic system. Individual modules are designed for easy replacement to accommodate diverse requirements, particularly concerning the ion analyzer and detector. By applying quadrupole analyzer with 1.75 mm inter-electrode distance we can cover mass range from 1 to 80 atomic mass units (amu), with a resolution reaching 100. It is excellent for detection of most gases present in the atmosphere around Earth, in space station, planets and other objects in Lunar system. The quadrupole analyzer with 1.05 mm inter-electrode distance covers a much wider range of masses (up to 400 amu) and can by applied for detection of organic molecules. However, the resolution is reduced to about 50. The spectrometer works with a Faraday cup detector offering detection limit at the level of 1e-8 hPa of partial pressure. Additionally, integration with a Multichannel Plate (MCP) improves its sensitivity by at least few hundred times. Rigorous mechanical and thermal vacuum (TVAC) testing confirms spectrometer's resilience to sinusoidal vibrations up to 10 g (at frequencies ranging from 5 to 150 Hz), random vibrations from 20 – 2000 Hz with an ASD 0.05 g2/Hz and shocks up to 600 g. It operates directly in high vacuum environment, in wide temperature range from -40 up to 50 C. Short and long term stability were proven as well. In conclusion, the exceptional performance characteristics of the developed instrument position it as an optimal candidate for a diverse array of space missions.