PERFORMANCE OF THE LINEAR ION TRAP MASS SPECTROMETER FOR THE MARS ORGANIC MOLECULE ANALYZER (MOMA) INVESTIGATION ON THE 2018 EXOMARS ROVER. Ricardo Arevalo Jr.[1], William B. Brinckerhoff[1], Veronica T. Pinnick[2], Friso H. W. van Amerom[3], Ryan M. Danell[4], Xiang Li[2], Stephanie Getty[1], Lars Hovmand[5], Martina Atanassova[2], Paul R. Mahaffy[1], Zhiping Chu[1], Fred Goesmann[6], Harald Steininger[6], and the MOMA Team[1-9], [1]NASA Goddard Space Flight Center, 8800 Greenbelt Rd., Greenbelt, MD 20771 (ricardo.d.arevalo@nasa.gov), [2]Center for Research and Exploration in Space Science and Technology (CRESST), University of Baltimore, Howard County, Baltimore, MD, [3]SRI International, Inc., St. Petersberg, FL, [4]Danell Consulting, Inc., Winterville, NC, [5]Linear Labs, LLC, Washington, DC, [6]Max Planck Institut für Sonnensystemforschung (MPS), Lindau, Germany, [6]Laboratoire Interuniversitaire des Systèms Atmosphériques (LISA), Univ. Paris-Est, Créteil, France, [7]Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS), Guyancourt, France, [8]Laboratoire de Génie des Procédés et Matériaux (LGPM), École Centrale Paris, Chatenay-Malabry, France, [9]Laser Zentrum Hannover e.V. (LZH), Hannover, Germany.

Introduction: The 2018 ExoMars rover mission includes the Mars Organic Molecule Analyzer (MOMA) investigation. MOMA will examine the chemical composition of samples acquired from depths of up to two meters below the martian surface, where organics may be protected from degradation derived from cosmic radiation (Pavlov et al. [1]) and/or oxidative chemical reactions (Quinn et al. [2]). When combined with the complement of instruments in the rover's Pasteur Payload, MOMA has the potential to reveal the presence of a wide range of organics preserved in a variety of mineralogical environments, and to begin to understand the structural character and potential origin of those compounds.

The MOMA investigation is led by the Max Planck Institute for Solar System Research (MPS) with the mass spectrometer subsystem provided by NASA GSFC. MOMA's linear ion trap mass spectrometer (ITMS) is designed to analyze molecular composition of: (i) gas evolved from pyrolyzed powder samples and separated in a gas chromatograph; and, (ii) ions directly desorbed from crushed solid samples at Mars ambient pressure, as enabled by a pulsed UV laser system, fast-actuating aperture valve and capillary ion inlet. Breadboard ITMS and associated electronics have been advanced to high end-to-end fidelity in preparation for flight hardware delivery to Germany in 2015.

Dual Source Mass Spectrometer: In addition to traditional pyrolysis evolved gas analysis (EGA), the MOMA instrument is capable of gas chromatography–mass spectrometry (GCMS) and laser desorption mass spectrometry (LDMS) operations. To achieve both GCMS and LDMS and remain within the limited mass, power, and volume resources available on the ExoMars rover, a dual source ITMS design was adopted. An open electron ionization source equipped with redundant electron gun filaments capable of emission between 10 – 100 μA (with an electron energy of 70 eV) enables the ionization (and consequently detection) of low abundance organic or inorganic compounds at high emission currents and while supporting the implemtnation of automatic gain control (AGC) to ensure maximum sensitivity and resolution during EGA and GCMS operations. During LDMS operations, a solid-state laser source that generates UV light (266 nm wavelength) with a 1 ns pulse width, repetition rate up to 100 Hz and adjustable output energy (250 μJ maximum) produces ions directly from solid samples that have been crushed by the rover's sample processing and delivery system (SPDS) and delivered on a refillable tray. Ions generated during laser processing at Mars ambient pressures are injected into the ITMS via gas flow and electrostatic voltages through a solenoid-driven check ball aperture valve and capillary ion inlet based on the discontinuous atmospheric pressure ionization (DAPI) concept of Gao et al. [3]. The requirements on the ITMS in each of the operating modes are summarized in **Table 1**. These must be met across a range of Mars surface/rover ambient conditions (pressures between 4 to 8 Torr, temperatures from -40°C to +20°C) to ensure the full science return over the 180 sol operational lifetime of the mission.

Table 1. Summary of MOMA Performance Requirements

Specification	pyr/GCMS mode	LDMS mode
Target Analytes	Volatile organics	Refractory organics/ inorganic mineralogy
Mass range	50 – 500 Da	50 – 1,000 Da
Resolution (m/Δm; FWHM)	≥ 500	≥ 500
Sensitivity	≤1 pmol (SNR ≥ 10)	≤1 pmol mm^{-2} (SNR ≥ 3)
Accuracy	≤ 0.4 Da	
Drift	≤ 0.4 Da per experiment	

Instrument Performance: A flight-like breadboard of the MOMA ITMS has been tested against performance specifications within mission resource and schedule constraints. The technical requirements on the ITMS (**Table 1**) have been met with margin, and the subsystem has passed its NASA Technical

Readiness Review (Nov. 2012) and Preliminary Design Review (PDR; Dec. 2012); the Critical Design Review (CDR) for this subsystem is scheduled currently for summer, 2014. A 3D solid model of the ITMS, as well as hardware photos of the hyperbolic rod subassembly and vacuum housing for the MOMA Engineering Test Unit (ETU), are shown in **Fig. 1**.

The ITMS is similar to a highly-miniaturized version of the Thermo LTQ ion trap and serves as the core of the MOMA investigation; this subsystem has been shown to detect effectively both volatile and nonvolatile organic compounds after separation in a prototype of the French MOMA GC (see Arnaud Buch et al. poster), as well as refractory organics hosted in powdered analog samples via LDMS, even in the presence of wt.%-levels of perchlorate (**Fig. 2**). Perchlorates, which have been observed throughout the martian surface (Archer et al. [4]), promote the combustion of organics during high-temperature pyrolysis analytical techniques (Hecht et al. [5]). Thus, perchlorates may have hampered attempts to detect organics directly on previous missions such as Viking (Biemann [6]) and Mars Phoenix (Ming et al. [7]), and on the currently-operating Sample Analysis at Mars (SAM) instrument on the Mars Science Laboratory (Glavin et al. [8]). The capacity of the MOMA ITMS to detect organics embedded in perchlorate-rich geological samples, coupled with the drilling capability (down to 2 m depth) offered by the ExoMars rover, provides for a unique and compelling science capability. ExoMars is on track to launch in 2018 with the integrated MOMA instrument incorporated into the Pasteur Payload module.

Technical Readiness and Next Steps: Vibrational qualifications of ITMS subassemblies have already begun, with successful test results acquired for the aperture valve, micropirani pressure sensor and channel electron multiplier (CEM) detectors; a full subsystem-level vibe test of the ETU will be conducted in February 2014, followed by instrument tuning and the subsequent integration of electronics subsystems over the course of the spring of 2014. The build of the flight model is scheduled to begin shortly after the MOMA CDR. Following full integration at MPS in 2015, the full MOMA suite goes to Italy for complete payload-level integration and testing at Thales Alenia Space – Italy (TAS-I) well in advance of the 2018 launch from the Bikonaur Cosmosdrome in Kazakhstan on a Proton launch vehicle.

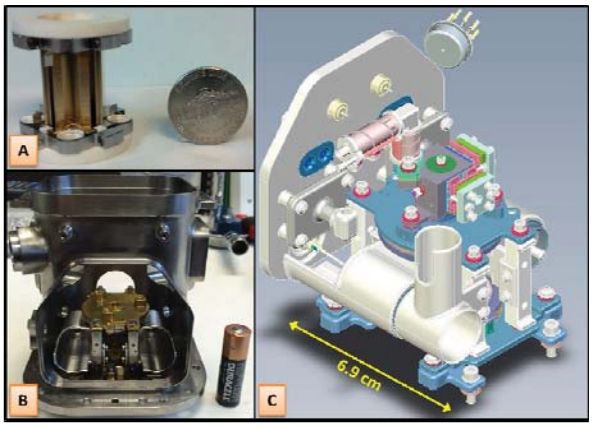

Fig. 1. (A and B) Photos of the MOMA ETU hyperbolic rod subassembly and vacuum housing. (C) 3D model of the ITMS, including dual-gun EI source, hyperbolic rods, detector shields, and discrete dynodes.

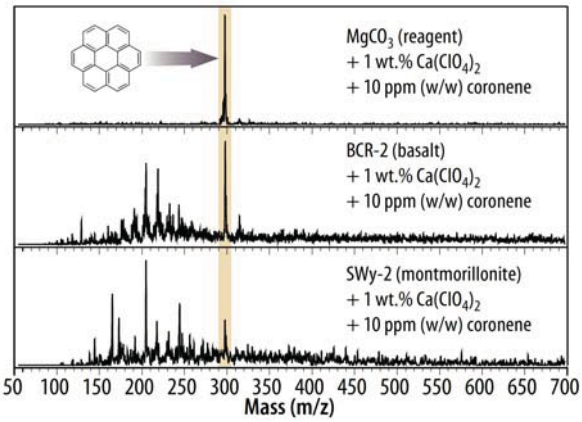

Fig. 2. Coronene is identified using a MOMA prototype using LDMS on a variety of mineral and rock matrices doped with organics along with wt.%-levels of Ca-perchlorate salts.

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Acknowledgments: The MOMA mass spectrometer development is supported by NASA's Mars Exploration Program (Program Executive, George Tahu).