

AUTOMATED SAMPLE PROCESSING FOR FUTURE MARTIAN ASTROBIOLOGY MISSIONS.

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Introduction: One theme of past and future martian exploration focuses on characterizing the aqueous history of Mars and determining the potential that Mars may have once had the capacity to support life. Martian surface morphology and mineralogy show clear signs of past flowing liquid water such as valley networks, outflow channels, gullies, and mineral deposits that could only have been formed under aqueous conditions [1,2]. The next step in the search for life will be to understand the chemistry of the surface and near surface. Understanding what the surface conditions were when liquid water was present is astrobiologically relevant because of the possibility of the independent origin of life on Mars. Laboratory investigations of organic material present in rock and soil samples collected from terrestrial environments inevitably include some form of solvent extraction for wet chemistry analysis.

For most biologically relevant molecules, solvent extraction gently removes organic molecules trapped inside rocks. Developing and demonstrating an automated process that can handle such laborious processing would make possible a complete wet chemistry laboratory as part of potential future astrobiology-themed missions to bodies such as Europa and Mars, and demonstrate great cost and risk savings on sample return. Once the system is complete it will have the following performance metrics 1) Number of samples: 30, 2) Quantity of solids to be analyzed per sample: 100 mg 3) Number of different solvent combinations: 3. 4) Maximum temperature and pressure: 200°C and 2000 PSI. 5) Minimal cross sample contamination. 6) Minimal cross instrument contamination. 7) Sample transfer to multiple instruments.

The Automated Sample Processing System (ASPS) consists of a sample inlet sub-system, carousel, sample cells, heaters, solvent reservoirs, post processing sys-

tem and a distribution sub-system that directs the liquid analyte to multiple different analytical instruments. The main solvent extraction system is discussed herein.

Carousel: The main structure and cell actuation mechanisms operate to move multiple sample cells through the system. It consists of a carousel, capping plunger positioning system, and encoders that ensure proper placement. A photo of the ASPS carousel is shown in Figure 1. The cover functions as a load-bearing structure--this is especially the case during the cap application sequence--and it also acts to suspend the auto-feed, multi-cap magazine in place. Two covers were fabricated: A light-weight aluminum cover (not pictured), and a clear, polycarbonate cover (pictured in Figure 1), which enables full view of all mechanical processes during normal operation. In order to meet structural requirements, the polycarbonate cover occupies a physically larger envelope and exhibits significantly greater mass than that of the aluminum cover. Two stepper motors are required to operate the ASPS system: One motor is used to position the sample carousel, and another motor acts to cap and engage the sample cells with the fluidics subsystem. The motors are manufactured by Empire Magnetics Inc. (Rohnert Park, Ca), who has extensive experience in both manned and unmanned space flight, as well as a background in dust mitigation for lunar and martian applications. Figure 2 shows a photograph of the ASPS without a cover, allowing for an unobstructed view of the capping mechanism.

Sample Cells: The cells were initially designed for one-time-use, but were later modified to be reusable in order to better facilitate development and field testing. The cap and sample cell pair can be seen in Figure 3. Sealing is handled by an O-ring, and the cap is held in place by a C-clip that engages with a radial groove

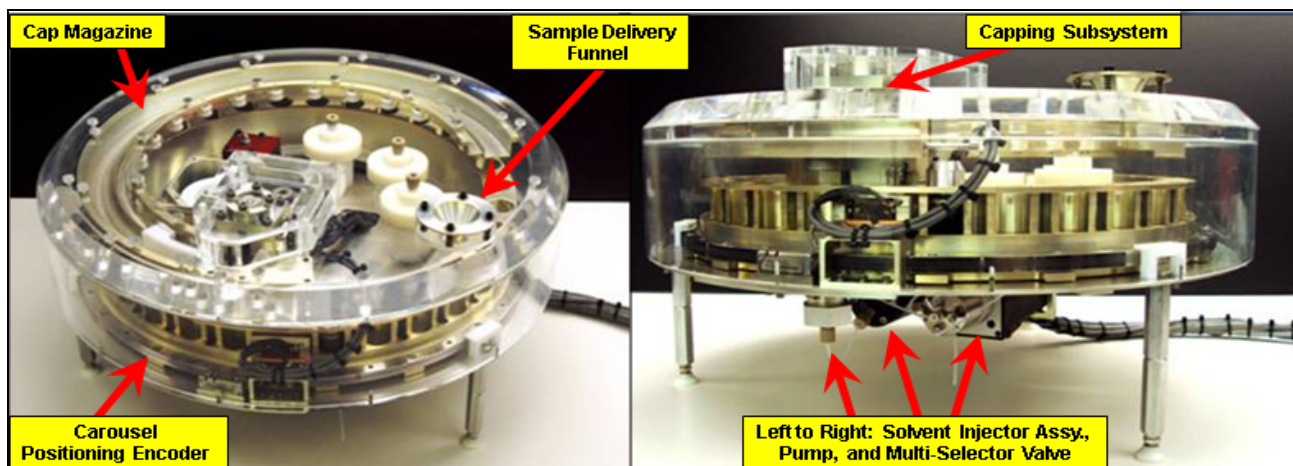


Figure 1 (Left to Right) Top and Side Views of the ASPS carousel with the transparent, polycarbonate cover installed.

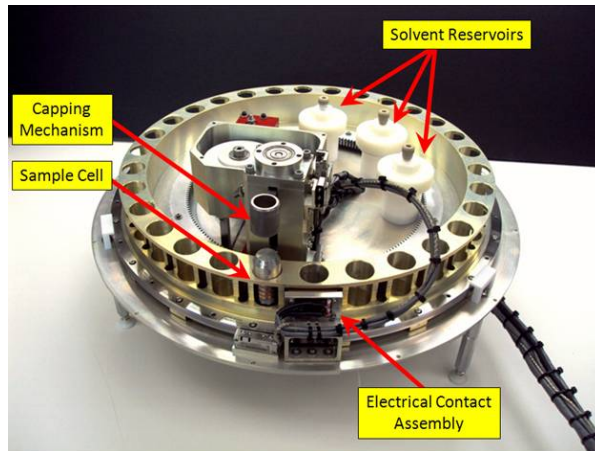


Figure 2 Top-view of the integrated ASPS (cover and cap magazine not pictured).

located near the top of the cell. The Cap and Test Cell are designed to be compatible with both rigid or elastomeric polymer O-ring seals, allowing for off the shelf components. The latest cap design incorporates a removable seal gland, which is the key element that allows non-destructive detachment and reuse of the press-on style caps and cells. The cells have been tested to 2000 psi and heated to 220°C. Heating of the test cell is achieved using a COTS 1" 30-watt Kapton heater, power to the heater is modulated using the LabVIEW interface, and temperature is monitored via an external infrared sensor. Testing was performed with 100% methanol as a solvent.

Once the cap is attached to the cell, solvent is delivered and directed using a single bidirectional pump and multi-port stream selector valve that were provided by VICI. Each cell incorporates a built-in sintered metal filter that prohibits small particles from being introduced into the solvent system, and a pinch valve that seals when solvent is not being introduced or extracted.

Capping: Once the sample is introduced into the sample cell (see Figure 3), the carousel system moves the cell into position so that a cap may be applied and the cell can be engaged/disengaged with the solvent delivery subsystem. A Renishaw LM10 miniature linear magnetic encoder system has been implemented to provide positioning telemetry for the capping plunger. The beveled design of the sample cell ensures that the capping occurs even if it is not perfectly aligned. A C-clip is integrated into the cap and becomes locked when it reaches the groove cut into the sample cell. An O-ring in the cap creates a hermetic seal as demonstrated through high pressure/temperature testing over 2 hours. This capping process occurs even if the cap is not introduced exactly perpendicular to the cell, and was demonstrated through testing.

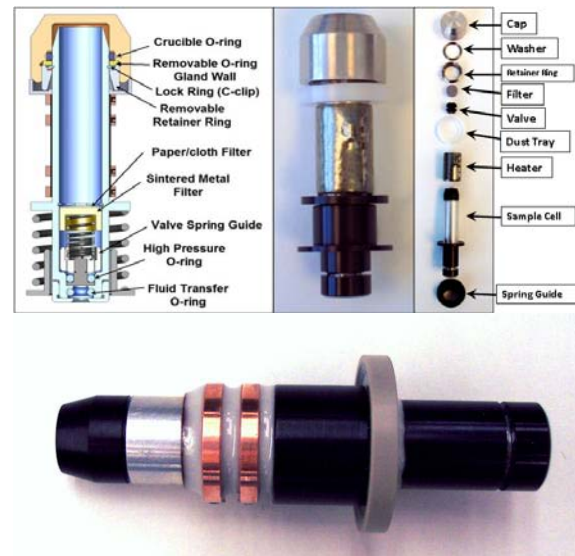


Figure 3 Sample cell cross section and hardware as-

The capping subsystem consists of a primary structural housing, to which the stepper motor, reduction gearing, capping plunger, encoder, emergency over-travel cut-off switches, and cap magazine spring box are currently attached. The capping mechanism has a 30:1 gearbox which minimizes capping time, and more importantly, provides the system with just enough torque to apply a cap while also ensuring that, in the unlikely event of motor control loss, the stall force exerted by the mechanism is far less than that which would result in a catastrophic failure. In other words, if the capping motor is in an open-loop runaway scenario, the system has been optimized such that the mechanism will bottom out, the motor will stall, and a software error will occur without resulting in permanent mechanical damage to the system.

Conclusions: The ASPS system with the aluminum cover—excluding sample cells and solvent—has a mass of 13.7kg (Figure 1 and Figure 2). A single sample cell has an average mass of 0.039 kg, therefore, the ASPS plus 30 sample cells has a total mass of 14.873kg, which is just shy of the 15 kg performance goal. Additionally, there are many non-load bearing structures that can undergo mass reduction for future flight designs, which could reduce the total mass of the system to below 10 kg and still maintain a 30 individual sample capability. Each sample above that would increase the mass on the order of 200 g due to the mass of a cell, cap, added carousel capacity, and solvents.

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References: [1] Squyres, S. W., et al. (2004). *Science* 306 (5702): 1709-1714; Beegle, L. W., et al. (2007).. *Astrobiology* 7 (4): 545-577. [2] Beegle et al. (2011) IEEE paper number 1602.