

# Sample Handling and Processing on Mars for Future Astrobiology Missions

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*Abstract*— In most analytical investigations, there is a need to process complex field samples for the unique detection of analytes especially when detecting low concentration organic molecules that may identify extraterrestrial life. Sample processing for analytical instruments is time, resource and manpower consuming in terrestrial laboratories. Every step in this laborious process will have to be automated for *in situ* life detection. We have developed, and are currently demonstrating, an automated wet chemistry preparation system that can operate autonomously on Earth and is designed to operate under Martian ambient conditions. This will enable a complete wet chemistry laboratory as part of future missions. Our system, namely the Automated Sample Processing System (ASPS) receives fines, extracts organics through solvent extraction, processes the extract by removing non-organic soluble species and delivers sample to multiple instruments for analysis (including for non-organic soluble species).

One of the main goals of NASA in the exploration of the Solar System is to determine if life exists on any planet beyond earth. To over simplify, life on the Earth consists of water and a collection of ever complex organic molecules that range from the simple carbon bearing species amino acids to DNA a highly complex macromolecule. If one was targeting identification of DNA like macromolecules, simple detection maybe enough to identify biosignatures, assuming they can be distinguished from terrestrial contamination. For smaller molecules, i.e. amino acids, quantification is vital so that potential biosignatures can be distinguished from ones abiotically synthesized [1]. Our system is inherently flexible and better enables both detection and quantification of these types of molecules.

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## 1. 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. The Mars Exploration Rovers (MER) found ample evidence in geomorphological, mineralogical, and elemental signatures that water existed at both Gusev and Meridiani landing sites [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. If life did not originate in Mars, discovering the reasons that it did not would also elucidate concepts of the origin of life here. If life was once present but no longer exists, it may have left detectable traces of its existence in the form of morphology, chemical signatures (such as the chirality and structure of organic molecules) or isotopic ratios not found in abiotic processes. If life still exists, the discovery would be the proverbial “Origin-of-life Rosetta Stone”, and many far reaching questions about life throughout the universe could be answered. Finding evidence of extinct or extant life is the key to future astrobiological investigations on Mars.

Strategies are being developed to pursue Astrobiological objectives for Mars exploration such as determining the abundance and distribution of biogenic elements and organic compounds, detecting evidence of ancient biota and determining whether indigenous organisms exist (or existed) anywhere on Mars. There are two paths Mars exploration might take in the next decade, sample return or *in situ* investigations. While sample return is currently in the next decadal plan, it would very expensive and is inherently high risk. If current *in situ* technologies are developed that have sensitivities approaching terrestrial laboratories a compelling case can be made for lower risk *in situ* investigations. Therefore, developing state-of-the-art

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detection techniques with very high sensitivity would play a major role in determining the pathway for Mars exploration over the coming decades. On these potential future Mars astrobiology focused missions, samples would be identified, acquired and analyzed by instrumentation to determine if they contain signs of biological activity (i.e. biosignatures) [3].

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. After this step, filtering particulates and removing soluble ions that can mask biological samples, is necessary to gain both detection and quantification of organic molecules. Solvent extraction has the following advantages over other techniques:

- Solvent extraction leaves organics intact (i.e. no fragmentation) which is crucial when attempting to determine the difference between biotic and abiotic organic material by avoiding degradation of heat-sensitive functional groups
- Quantitative results tend to be more reproducible and less dependent on the matrix material of the bulk field sample as is the case with pyrolysis
- Lower limits-of-detection of organics are possible through the concentrating of samples in solution by removing solvent before analysis.
- Direct interface into conventional instruments is easily achievable, which is in contrast to alternative techniques such as supercritical fluid extractions with CO<sub>2</sub>.

When each instrument is designed with its own processing unit, many of the same functions are duplicated and more mass is required than if duplicate functions are consolidated. A centralized processing station that provides several instruments with the type of sample that they require would result in analytical instruments being developed that have lower mass as a group than they would have individually (i.e. the whole suite would weigh less than the sum of the individual independent instruments).

Laboratory analysis of material for organic content can be costly in manpower. Samples need to be crushed, organics extracted using solvents or heat, the extract processed and then fed into an analytical instrument [4]. 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. Future complex landed missions that would include

chemistry and biological processing assume some kind of wet chemistry as the heart of the analytical laboratory and this instrument would help reduce the overall spacecraft mass [4]. Our development could be fully integrated with several analytical techniques such as electro(and nano)spray ionization, capillary electrophoresis, immunological based assays, and ion selective electrodes (ISE) investigations.

Our system consists of a sample inlet sub-system, carousel, sample cells, heaters, solvent reservoirs, post processing system and distribution sub-system to multiple different analytical instruments. Once the system is complete it will have the following performing metric

- **Number of samples: 30.** On future flight missions the number of samples to be analyzed would be developed given total mission constraints but is expected to be able to be between 20-100 samples.
- **Quantity of sample to be analyzed: 100 mg.** The AFL-Science Steering Group (AFL-SSG) designated a precision sample processing station which would create ~150 mg of material. This processing and transfer would be done at ambient Martian pressures (5 Torr).
- **Number of different solvent combinations: 3.**
- **Maximum temperature and pressure: 200°C and 2000 PSI.** The ASPS is fully programmable, so any parameters from room temperature to the maximum can be programmable.
- **Minimal cross sample contamination.** Samples would flow into the system from the same distribution point delivered there by an arm, and solvent + organic have to flow out of the ASPS and into the analytical instrumentation. The allowable percentage of cross sample talk has to be well below the percentage from the main sample acquisition apparatus.
- **Minimal cross instrument contamination.** The fluid used in this apparatus could not contaminate the rover environment. The cells need to stay sealed after use, with minimal fluid escape.
- **Sample transfer to multiple instruments.** In order for a facility instrument to be mass effective, fluid must be able to be transferred into multiple instruments.
- **Planetary Protection, ATLO and Cruise.** For a flight mission, the ASPS would have to undergo sterilization to meet planetary protection requirements. Future missions would have different cleaning requirements placed on them, and the system has to be designed to still function after this cleaning regardless if it is DHMR, or some other procedure currently being developed under planetary protection research.

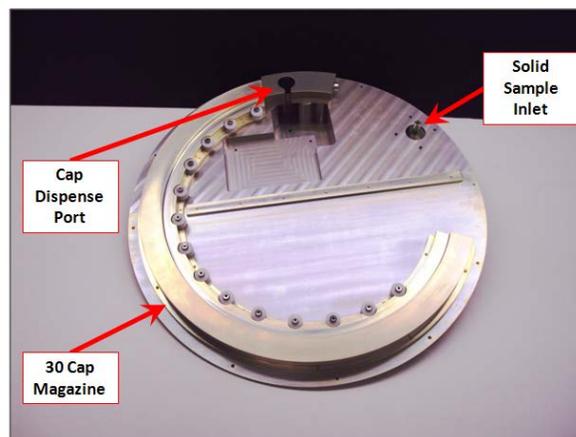
## 2. SAMPLE INTRODUCTION

It may be simplistic to say, but with any analytical system, the accuracy of sample analysis is only as good as the sample that is delivered to the analytical instrument. With any system, it is imperative to make sure that minimal cross-sample contamination and sampling biases is limited. Triboelectric charging is a well-known effect on Earth that occurs when two particles come into contact with each other (i.e., rubbing) and would be present as dry samples are moved into the ASPS on Mars. This effect can lead to pronounced effects that can greatly alter the analysis of samples and is something that we are attempting to mitigate.

There are two distinct forms of this effect that can present itself on Mars. One is when dissimilar materials interact with one particle gaining electrons from the other material resulting in a negative and positive final state for the different materials. The exact nature of the charge transfer depends on where the materials are located on the triboelectric series, and the physical nature of the samples including oxidation of surfaces, surface roughness, temperature, and relative humidity.

The other, less understood, case occurs when similar materials rub against each other; the larger particles tend to lose high-energy electrons to the smaller particles which become negatively charged [5,6]. Each of these phenomena occurs under martian simulated conditions and is expected to occur on Mars during sample distribution. The cold and dry nature of the ambient environment, along with no true ground (the surface is insulating and the rover is “grounded” to the atmosphere, an inefficient process) can result in adhesion that lasts for weeks or months.

Triboelectric charging would greatly increase cross sample contamination and might even remove specific samples from being delivered to the instruments through adhesion to the surfaces of the sampling delivery mechanisms [5]. In testing of flight hardware, we have identified adhesion as an effect



**Figure 1 ASPS cap magazine, which is attached to the underside of the carousel cover. The cap dispense port, sample inlet and the magazine are annotated.**

that readily occurs under martian ambient conditions. This adhesion has been shown to last for weeks on Mars, and could lead to limited sample distribution and severely alter analysis. Small mineral inclusions that are biologic in origin could easily become electrostatically attached to material already collecting on the hardware. Additionally, sorting based upon particle size could take place before the sample is present to the instrument, and might result in non-analysis of sample predisposed to make small particle size in creation/crushing. These scenarios could result in the organic concentrations would not be consistent with what is actually on the surface.

It is important to note that moving dry fines and powders is something that the trillion dollar a year pharmaceutical industry does every day. This process is still more of an art than a science. In this industry, when creating a new product or package, they design the manufacturing hardware nearly from scratch because their experience is that moving powders and fines is non-trivial and can result in unforeseen phenomena for references please see virtually any edition of the Journal of Pharmaceutical research or the Journal of



**Figure 2 ASPS carousel assembled without a cover (left) and with the acrylic cover (right). The stepper motor, encoder ring and read-head components are annotated.**

Electrostatics]. On robotic platforms we don't have the luxury of knowing, *a priori*, the chemical makeup of samples, the particle size/shape distribution and charge state of the processing hardware, so the hope would be to minimize these effects whenever possible.

In the design of the sample inlet funnel, we have taken into account this effect, and are working on mitigation strategies. Since the drill will preferentially create fines with different size distributions, finding a mitigation strategy that is workable over a large range of conditions and potential scenarios is vital.

### 3. CAROUSEL

Once samples are delivered to the funnel they are introduced into the main ASPS system. The sample carousel is the system that allows for multiple samples to be analyzed in individual pre-sterilized cells. After the samples are introduced into the cells, the sample cell is capped, and solvents are introduced which solubilize organic species and in-organic ionic compounds. After the analyte is distributed to the post sample processing system, the carousel system stores the cells and the solvent in a manner that minimizes contamination of the environment.

The main structure and cell actuator system operates to move multiple sample cells through the system. It consists of a carousel, capping plunger positioning system, and encoders to ensure proper placement. A photo of the ASPS carousel cover is shown in figure 1. This cover acts as a critical load-bearing structure, and the cover must be installed/fastened during normal operation to ensure proper function. During system integration and calibration, however, there exists a strong desire—if not absolute necessity—to have unobstructed visual access to the internal layout of the carousel for debugging purposes. To satisfy this need, we have an additional cover consisting of a clear polycarbonate cover. In order to meet structural requirements, the polycarbonate cover occupies a physically larger envelope and will exhibit significantly greater mass than that of an aluminum cover. Figure 2 tangentially illustrates the use of the ASPS cover as a load-bearing structure, where fasteners are used to support both the spring box and the capping plunger assembly. Also shown in figure 2 are the support legs that have been added to the ASPS base.

Two motors are required to operate the ASPS system: One motor is used to position the sample carousel, and another motor is needed to cap, and then engage the sample cells with the fluidics subsystem. The motors are manufactured by Empire Magnetics Inc., who has extensive experience in both manned and unmanned space flight, as well as a background in dust mitigation for lunar and Martian applications. Therefore, there is ample justification to make

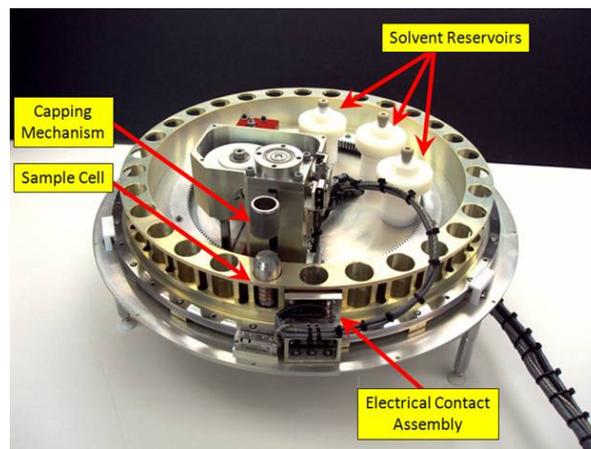
the assertion that these Empire Magnetics motors would easily translate to a flight design.

There are 1,199,995 micro-steps per revolution of the carousel, and the maximum overshoot/undershoot observed during testing thus far has been 5 micro-steps, which translates to a positioning uncertainty of 0.3 millidegrees, or  $8.3 \times 10^{-7}\%$  of full-scale. Given the high degree of positioning repeatability & accuracy, in addition to the maturity of the associated LabVIEW control subroutines, there is very little remaining risk associated with the integration of the carousel subsystem.

The sample cell carousel has been integrated to its associated base-plate, bearings, reduction gearing, stepper motor, micro-stepping driver and ring encoder. Furthermore, versatile LabVIEW subroutines (or sub-VIs) have been developed and fully tested in conjunction with the carousel and are capable of performing all the automated functions.

A sub-VI to locate and halt movement at the carousel ring-encoder's singular home index position has been developed and tested. The subroutine then resets the carousel encoder position that is stored in memory to "0". This routine will be used to initialize the system each time it is powered up. Finding the ring-encoder home index position is critical to finding and positioning the carousel at sample cell index #1; all 29 remaining sample cell indices will be located relative to cell index #1.

A sub-VI has been developed and tested that can position the carousel relative to the "zero-position" set by the home index sub-VI. The user can specify the carousel position, acceleration, deceleration and angular velocity. This sub-VI also provides continuous carousel position feedback to the user. This routine will be utilized to position the carousel at the sample cell index of the user's choosing.



**Figure 3:** Top-view photograph of the integrated ASPS (cover and capping magazine not shown).

## Capping

Once the sample is introduced into the sample cell (see figure 4), the carousel system moves the cell into position so that it can be sealed before solvent is introduced. A Renishaw LM10 miniature linear magnetic encoder system has been implemented to provide positioning telemetry for the capping plunger. The Renishaw LM10 exhibits a 1 $\mu$ m positioning resolution and incorporates a similar electronic interface that delivers digital quadrature telemetry identical to that of the Renishaw ring encoder that will be utilized for carousel positioning and is completely compatible with labview control software. The cells are rotated into position as determined by the encoder, and a mechanical actuator presses the cap on. 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. The design of the capping system ensures a hermetic seal even if the cap is not introduced exactly perpendicular to the cell, as is demonstrated by successful pressure and temperature testing as described below.

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, to provide the system with just enough torque to apply a cap while also ensuring that the mechanism does not have enough available torque to cause any damage in the unlikely event that there is loss of motor control. If the capping motor is in an open-loop runaway scenario, the system has been optimized such

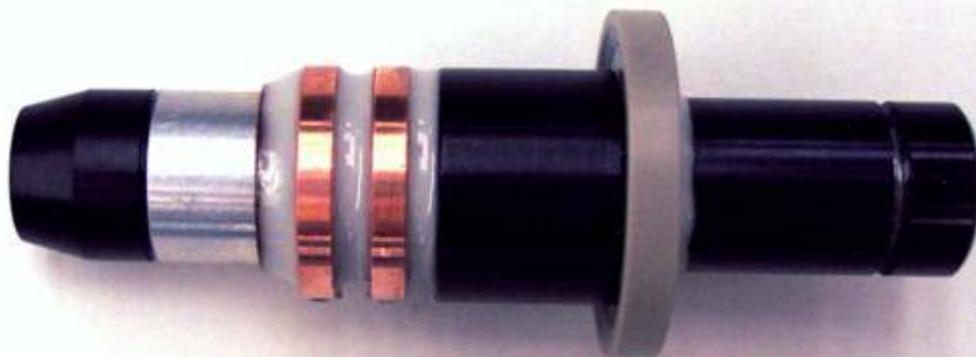


Figure 4 Cell design and capping system.

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. We are currently integrating the capping subsystem motor, micro-stepping driver and encoder with the National Instruments/LabVIEW control system. However, given that setup and operation of the capping subsystem motion control components are nearly identical to those utilized by the carousel, which is currently fully functional, the risk of encountering serious issues with respect to setting up capping motion control have been greatly diminished.

Figure 3 (top) depicts the CAD design of the capping subsystem in its current stages of integration. The cap magazine is attached to the underside ASPS cover. A C-Clamp is integrated into the cap below an O-ring.

### 3. CELL DESCRIPTION

The cells were designed as individual-one-time-only use, but with the potential to be modified into multiple use cells in a later incarnation of the ASPS. The cap and sample cell pair can be seen in figure 4. The pair is designed to be fully compatible with both rigid-polymer O-ring seal materials. A Custom, 20-watt, clamp-on mica heater with embedded thermistors mimic a flight-like device and allows for heating of the cell from any temperature to 200°C. Testing was performed with 100% methanol as a solvent. During the test, heat was provided by wrapping a thin, 1"-wide Kapton heater around the sample cell body. Temperature was monitored by taping a T-type thermocouple to the cell body beneath the heater. A temperature controller was used to maintain the operating temperature, demonstrating feasibility and stability up to 200°C.

Once the cap is placed on the cell solvent is introduced through a pump and utilizing a multiport valve both provided by VICI. PEEK entrance-only check-valves were installed atop the Teflon solvent reservoirs. Each cell has a built in sintermetal filter which prohibits small particulates from being introduced into the solvent system, and a pinch valve that seals when solvent is not being introduced or extracted into the cell.

Both of these systems are controlled with the same control software as the carousel. This "drag-&-drop" LabVIEW subroutine has been developed that reliably controls the VICI pump/valve pair, which will be used in multiplicity within the main ASPS state machine. \

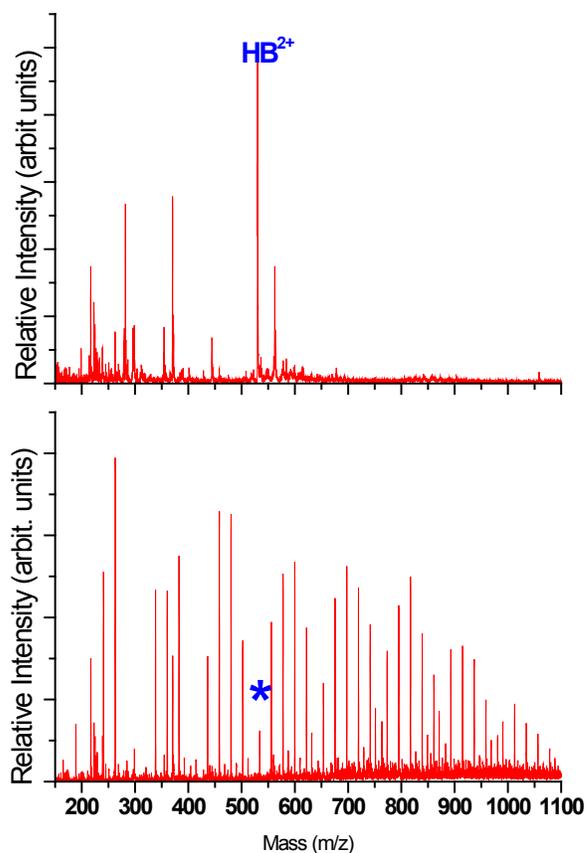
ASPS extraction sample cell was designed to accommodate 100 mg of sample, and 2 mL of solvent. Thus it was designed to accept up to 3ml of a solid/solvent mixture, plus some margin. Additionally, there are three all-Teflon solvent reservoirs that the user may select from, each of which are capable of holding a maximum of 47.5 ml of solvent.

The system as designed can contain up to 30 sample cells although it is capable of expanding to larger values. Sealed sample cells containing methanol have been successfully tested both in a standalone setting as well as integrated with the carousel at temperatures exceeding 220°C over multiple cycles. Extensive multi-cycle performance testing is planned with sample cells installed within the carousel in order to demonstrate long-term reliability.

For a detailed overview of the capping subsystem and each of its components, please refer to earlier ASPS progress reports.

#### Solvent

A set of sub-VIs that control the VICI pump and multi-position valve have been developed and tested. The pump/valve control sub-VI allows the user to choose between 4 selectable valve positions as well as a selection of pump parameters, such as flow direction (dispense vs. aspirate), flow rate (ul/min), total dispense/aspirate volume (ul), and pump slew rate (ul/s). In addition to the pump and valve, Teflon solvent storage reservoirs and the solvent



**Figure 5. Mass spectra of Bradykinin obtained with an electrospray ionization, ion trap mass spectrometer. Top spectra contains no salt, the bottom contains ~5mM, corresponding to 1/100 of the sea water present in the ocean on earth.**

injector assembly have also been fabricated. Given that the sub-VIs used to control the pump and valve have already been developed and rigorously tested, the highest risk associated with this subsystem will be engaging the sample cell check-valve with the injector needle.

### *Integration*

All that remains with respect to sample cell subsystem integration is the attachment of the thermistor, flexible Kapton heater and electrical contact rings. We currently have enough components to build 3 fully-functional ASPS sample cells. Given the extensive design refinements and performance testing of the sample cell subsystem, integration of the cells is currently viewed as a relatively low risk activity. Although, given that the check-valve-side of the sample cells have only been tested for their ability hold pressure, actuate, and then successfully re-seat, they have not been tested for ability to functionally interact with the solvent injector, thus there remains some fundamental risk associated with this aspect of the integration.

## 5. POST PROCESSING

Many different analytical techniques require the cleaning of sample of ions that interfere with the detection of low concentration biomolecules, especially in samples containing high salt concentration. Figure 5 shows what occurs when a binary mixture is introduced into a mass spectrometer through electrospray ionization. The top spectrum is of 5  $\mu\text{M}$  of the peptide Bradykinin. The mass of Bradykinin is 1060, and the peak shown at 531 is representative of the doubly protonated ion. The peak at  $\sim 522$  a.m.u is of the doubly protonated ion that has either lost an  $\text{H}_2\text{O}$  or an  $\text{NH}_3$ . The bottom spectra is that same mixture but with 5 mM standard table salt, NaCl. Each peak corresponds to a  $\text{Na}_x(\text{NaCl})_y$  cluster. The peak identified by the blue \* is most likely due to the doubly protonated Bradykinin. In order to understand this type of complex spectra, it is obvious that as much of the salt needs to be removed.

We have developed a system to test automated processing, and that system is shown in figure 6. The process has excellent reproducibility and demonstrated unit recovery of tyrosine test samples. We are in the process of designed and constructed a portable system that can perform automated desalting. We currently use Bio RAD resin as the bed to store amino acids. When processing by hand, the bed is primed with 2N NaOH followed by 2N HCl and a wash with deionized water. Samples are then introduced onto the resin bed. 0.1 M oxalic acid (adjusted with  $\text{NH}_4\text{OH}$ ), is introduced as chelating reagent to bring out ions that would otherwise interfere with amino acid analysis. The amino acids were eluted using 2.5 M  $\text{NH}_4\text{OH}$  ( $5 \times 1$  mL). This current set of protocols is the best method for retaining 100% of amino acids, without any ion interference, but is



**Figure 6 Image of system used in preparing samples.**

most likely overly complicated [7, 8], as demonstrated by the valve/pump schematic in figure 7 to re-do the hand processing methods. The typical handheld process is laborious, employing as many as 6 reagents and 10 steps in the overall process. We have revised this process and are demonstrating that isolation of amino acids can be accomplished with 3 reagents (water, oxalic acid, and ammonia) in a simplified series of protocols [7].

Results of our system indicate little cross sample contamination and the ability to concentrate samples, if needed. We are currently working on other methods including the use of zip tips and other in line filters that reduce the complexity, while still retaining a significant amount of organics.

A simplified sample preparation method for extraction and desalting of amino acids from complex matrices is presented. The process requires 3 reagents, water, oxalic acid and ammonia. By adjusting the pH of the extraction medium to  $\sim 1$  with oxalic acid three key steps if the process are achieved, protonation of the carboxylic acid group of the amino acid, protonation of the amine group and the amine group of the amino acid, and mitigation of interference by metal ions by metal complex formation with oxalate. The process is reproducible, and enables automation of sample processing by eliminating the number of steps required in the overall process. Initial experiments focus on extraction and desalting of tyrosine solutions.

## 6. CONCLUSIONS.

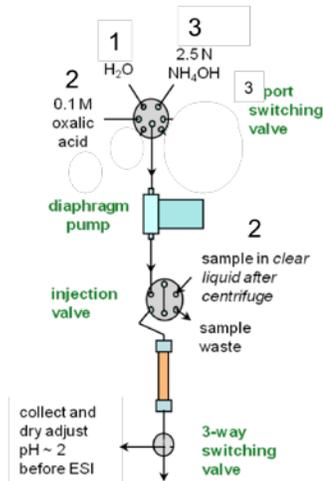
The ASPS system with the aluminum cover—excluding sample cells and solvent—has a mass of 13.7kg. Each of 30 sample cells has an estimated mass of 0.039 kg. Therefore, the ASPS plus 30 sample cells has a mass of 14.873kg, which is just shy of the 15 kg performance goal. Additionally, there are many non-load bearing structures that can undergo mass reduction if mass minimization for future flight designs, which could reduce the total mass of the system to below 10 kg for a flight model that can do 30 individual samples. Each Sample above that would increase the mass on the order of 200 gr due to mass of cell, cap and carousel. The post-sample processing unit, which is still in

## 7. ACKNOWLEDGEMENTS

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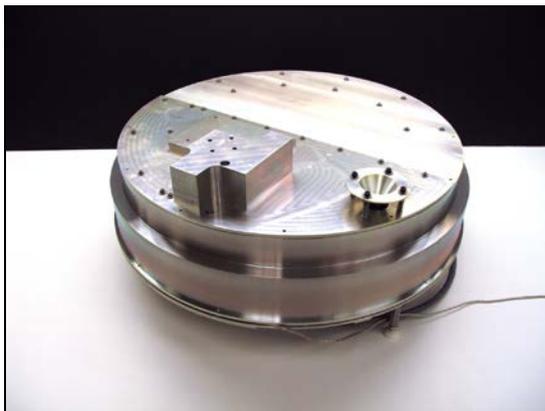
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**Figure 7 Schematic of the post-processing unit.**

the process of miniaturization and testing, is expected to have a mass on the order of 5 kg including redundant exchange columns, solvent reservoirs and waste containers, resulting in a full system below 20kg.

While the original plan was to test this system under as close to ambient conditions as possible, we plan to demonstrate the system in local desert environments in conjunction with a small portable mass spectrometer that has been developed at Purdue University in conjunction with JPL [9]. Between the first design of the system, and the construction of the system, the Mars program has been drifting away from in situ analytical missions and moving toward a very costly Mars Sample Return campaign. It is hoped that using this instrument and doing automated field analysis, we will be able show that the best method for looking for signs of extraterrestrial life would be through in situ analysis of sample.



**Figure 8: ASPS carousel with aluminum cover installed. When debugging is complete, the transparent acrylic cover may be replaced with the lower-mass aluminum cover.**

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## BIOGRAPHY



**Luther Beegle** is a Research Scientist at the Jet Propulsion Laboratory where he has been employed since 2001 after spending 4 years at JPL and the California Institute of Technology as a Post Doctoral Researcher. He

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**James Patrick "J.P." Kirby** is a Research Technologist and a member of the Planetary Chemistry and Astrobiology Group in the Planetary Science Section of NASA's Jet Propulsion Laboratory in Pasadena. He received a BS in chemistry at Ithaca College in 1990, and a PhD in inorganic and organic

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**Anita Fisher** is a Research Technologist at the Jet Propulsion Laboratory in the Analytical Instruments Group. She has an educational background in biological sciences, B.S (Univ Leeds, UK), Ph.D (Univ Sheffield, UK) and worked in University research before coming to JPL in

2002. Since joining JPL, she has worked on research

projects related to biosensors based on nanostructures, rapid detection assays, organic biomarker extraction and in-situ chemistry instrumentation for planetary exploration. In addition, she supports flight and pre-flight projects, and recently served as the analytical chemist for the wet chemistry lab (WCL) instrument on the Phoenix spacecraft that landed on Mars in 2008.



**Robert Hodyss** is a Scientist at the Jet Propulsion Laboratory where he has been employed since 2006. Dr. Hodyss received his BS in Chemistry from the University of Florida in 1999, and his PhD in Chemistry from the California Institute of Technology in 2006, and spent 2 years at JPL as a

Postdoctoral Researcher. Dr. Hodyss has designed and developed several devices for chemical sensing and analysis, including systems to detect amine vapors, explosives, and for the determination of enantiomeric excess. He is currently developing laser ablation mass spectrometry technologies for Martian organic analysis, as well as techniques for the extraction of peptides from complex matrices.



**Allison Saltzman** is a senior at the California Institute of Technology (Caltech) in Pasadena, CA. She plans to receive her B.S. in Mechanical Engineering in June 2011. In addition to engineering, Allison has a strong interest and background in Chemistry. She has been working in the Planetary Chemistry and Astrobiology group at JPL since

April 2010 and plans to continue her work on the Mars Instrument Development Program (MIDP) until graduation.

Prior to working at JPL, Allison has been involved in other significant chemistry and engineering-related research projects at Caltech and Columbia University in New York City.



**Shane Roark** is a Systems Engineer at Ball Aerospace & Technologies Corp., where he has been employed since 2004. He currently is a Co-Investigator on the Automated Sample Processing System project, which is funded under NASA's Mars Instrument

Development Program (MIDP). He also was the Principal Investigator for development of a passive wind sensor under NASA's Instrument Incubator Program (IIP), and has been a Systems Engineer on other NASA MIDP, Planetary Instrument Definition & Development Program (PIDDP), and Astrobiology Science & Technology Instrument Development (ASTID) projects. Prior to joining Ball, he was a Senior Scientist at Eltron Research, where he focused on development of optical sensors, gas purification

membranes, and catalysts for mitigating organic contaminants. He received a BS in Chemistry from San Jose State University in 1989, and a PhD in Analytical Chemistry from the University of Colorado, Boulder in 1995.



**James Lasnik** is a Systems Engineer at Ball Aerospace & Technologies Corp, where he has been employed since 2001. While at Ball, James has pursued a diverse breadth of technology development interests that include hydrogen & direct-methanol fuel cell systems, low-light imaging,

hyperspectral imaging spectroscopy and microbolometry. He has also been a contributing systems engineer on a number of planetary instrument development endeavors funded under the NASA Planetary Instrument Definition and Development Program (PIDDP), Astrobiology Instrument Development Program (ASTID) and Mars Instrument Development Program (MIDP), which include an Automated Sample Processing System, an Ion Mobility Spectrometer, a Mars Acoustic Anemometer and a Mars Pyrolysis Oven. He received a B.S. in Chemical Engineering from Colorado State University in 2001. Prior to working at Ball, James was employed as a student research associate at CSU as well as the Center for Engineering in Medicine, Harvard Medical School.



**Juancarlos Soto** is a Senior Mechanical Design Engineer at Ball Aerospace & Technologies Corp., where he has been employed since 2004. He currently is a Co-Investigator on the Automated Sample

Processing System project, which is funded under NASA's Mars Instrument Development Program (MIDP). He also was a co-developer/designer for the MECA instrument in the Phoenix Mars Mission when working at Starsys Research. During his employment at Starsys, he also designed and developed the cover systems for the XRT and UVOT instruments for Penn-State University, for the SWIFT spacecraft for NASA. Through his career he has had extensive experience in aerospace mechanical design, specializing in deployable systems and experimental mechanical components. He received an AA at Pasadena City College in 1985, and his BS in mechanical engineering from the University of Colorado, Denver in 1990.

