Summary for a paper for the 41st Aerospace Mechanism Symposium:

An Automated Sample Processing System for Planetary Exploration

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ABSTRACT:

An Automated Sample Processing System (ASPS) for wet chemistry processing of organic materials on the surface of Mars has been jointly developed by Ball Aerospace and the Jet Propulsion Laboratory. The mechanism has been built and tested to demonstrate TRL level 4. This paper describes the function of the system, mechanism design, lessons learned, and several challenges that were overcome.

SUMMARY:

The Automated Sample Processing System (ASPS) shown in Figure 1 uses traditional mechanical components such as gears, bearings, stepper motors, springs, heaters, o-rings, and encoders in a unique configuration to provide a re-usable soil sample processing mechanism to extract organic materials through solvent extraction, and processing the extract by removing non-organic soluble species and delivering samples to multiple instruments for analysis. The intent of this mechanism is to provide the planetary science community with a standard device that can be used in multiple instrument platforms.

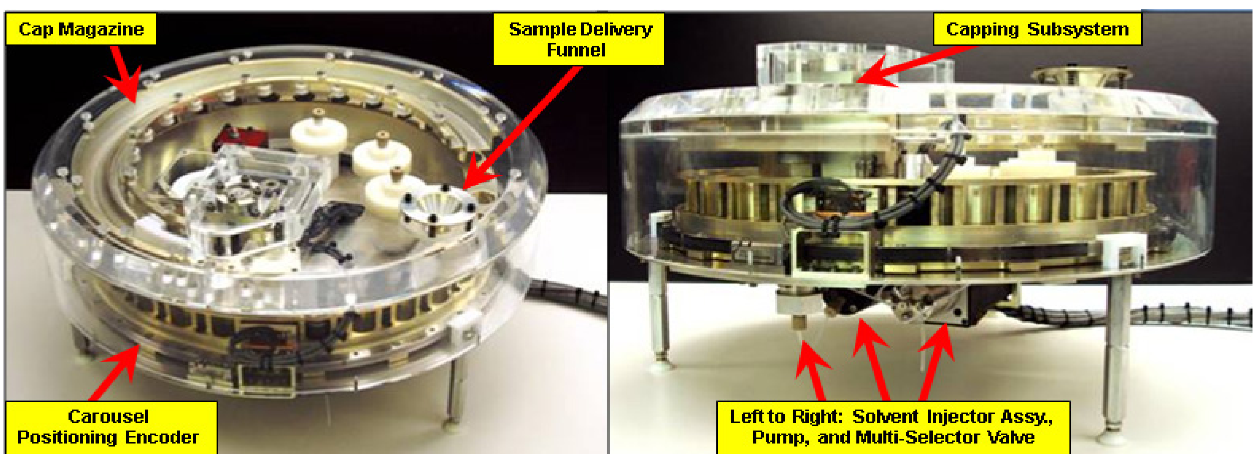


Figure 1 - ASPS with Clear Cover

Different sample processing apparatus have been designed and flown to Mars, and each time they have been redesigned and redeveloped for each specific mission. Yet, a standardized sample processing suite has not been developed for planetary science. Luther Beagle from JPL commissioned BATC a customer research and development study (CRAD) to develop such a mechanism to a technology readiness level 4, with plans to further develop it to TRL 6 by 2012; field testing has been proposed under an Astrobiology Science and Technology for Exploring Planets (ASTEP) project. Also, a paper has been recently written about the ASPS mechanism for an IEEE presentation focusing on the technical description and science capability of the mechanism (978-1-4244-7351-9/11/$26.00 IEEE, IEEEAC paper # 1602).

The basic requirement parameters were defined by JPL, requiring the use of as many COTS components as reasonable to minimize the cost impact, with the following five basic functions:

- Collect samples into a test cell
- Cap the test cell and seal the sample
- Allow a fluid to be injected into the test cell
- Heat the sample to a determined temperature and time period
- Extract the fluid and deliver it to an instrument suite

As a result, the ASPS mechanism consists of five subsystems: a test cell, that captures a soil sample fed through a funnel; a capping mechanism, that caps the test cell and seals it; a carousel, that moves and positions the test cells; a heating system, to process the sample under heat and pressure; and a fluid delivery system, which provides the solvent and manages the extract delivery.

The following details the design approach and functional process of the ASPS:

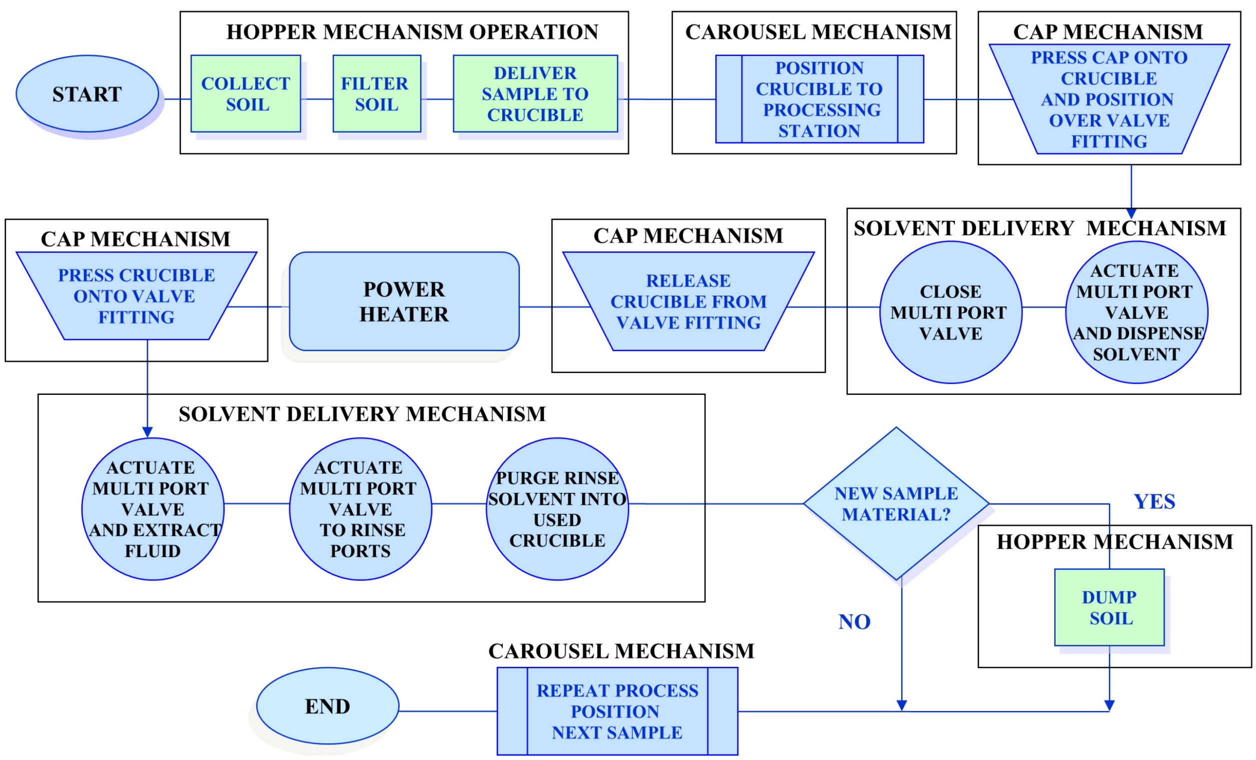
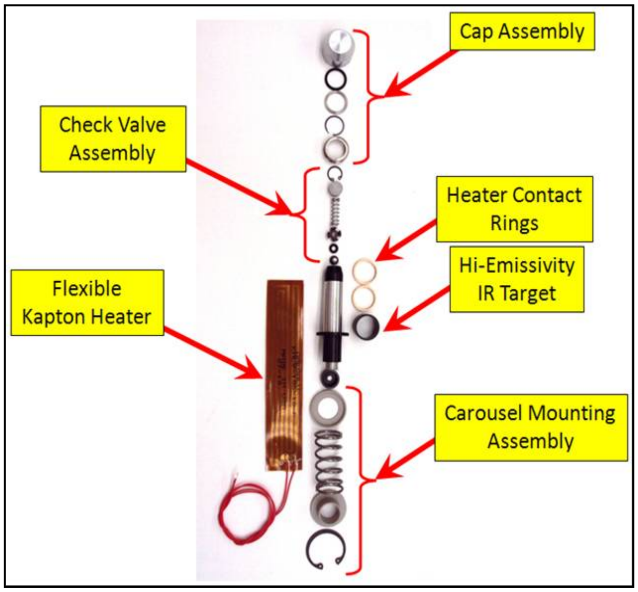


Figure 2 - Design Approach and Process Flowchart

The test cells (Figure 3) were developed to withstand over 2000 psi and seal fluids at over 200°C for various hours. Each cell is an individual laboratory capable of processing 2cc of solvent and 100mg of sample material. The cell design was focused to ensure sealing, minimize cross contamination, prevent clogging, improved seal life, and independent heating capability. To provide these features and overcome the challenges of sealing at high pressure and temperature for long periods, we paid close attention to the seal materials, surface finishes, coatings, tolerance stackups, and glad design. To facilitate ground testing and reduce refurbishment costs, the caps were designed to be manually removable from the test cells after use.



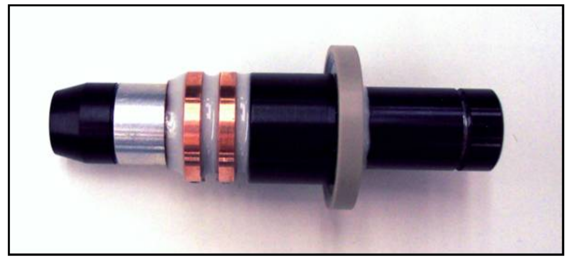


Figure 3 - Test Cell Assembly

The capping mechanism provides several functions to the ASPS. It controls the cap delivery, works as a capping driver, and connects the test cell to the fluid delivery system. This is achieved using a stepper motor in combination with a worm gear, a constant force spring, and a linear encoder to position the capping arm to perform the above functions. The cap magazine (figure 1) drives the caps with the constant force spring and positions them below the capping arm and above the test cell. Once the capping arm is actuated, it drives a cap onto the test cell, pushing it into the fluid injector needle until it hardstops; at which point it seats the cap until it snaps locked into place. Once the cap is installed, the capping mechanism is commanded to retract and allow the carousel to position the test cell into the next step of the process.

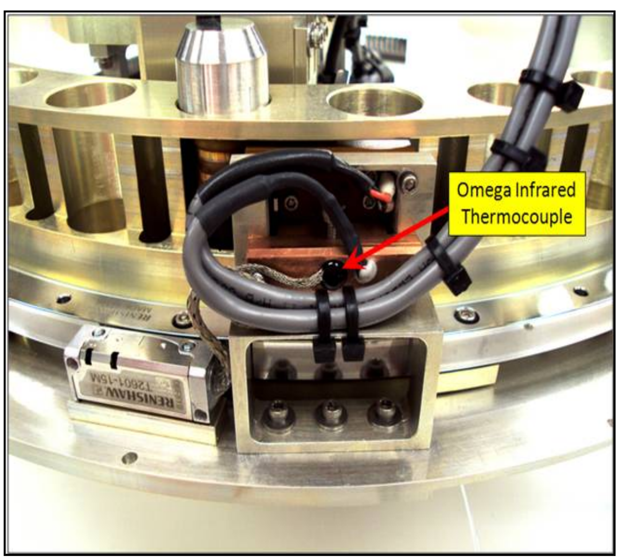


Figure 4 - Heating Assembly

The carousel holds 30 test cells, driven with a stepper motor and controlled with a circular optical encoder. The carousel is designed to precisely position and integrate with all other components in the ASPS mechanism. The carousel is capable of positioning the test cells within .003° to attain proper alignment between the test cell, the fluid injector and the capping mechanism. After capping, the carousel drives the test cell to the heating station.

Once positioned, the test cell makes contact with two electrical contacts that connect with the cell's heating element. At this point there are no powered loads on the mechanism and electrical power can be focused heating the element to achieve the desired programmed temperature for the sample. Temperature feedback is provided through an infrared sensor (Figure 4) and high-emissivity target bonded in the test cell. Once the sample has been processed for the desired time, it is positioned back above the injector needle by the carousel, and then lowered into it by the capping mechanism and ready to transfer the solvent.

The fluid delivery system consists of an injector interface/needle, three solvent reservoirs, a multiport valve, and a pump. Once the test cell has been positioned and driven into the injector needle, an internal valve in the test cell is opened to allow the solvent to flow. Sealing features in the test cell seal around the needle to prevent leakage of the solvent through transport. The multiport valve selects the desired solvent reservoir to inject into the cell, or selects the port to deliver the soluble. Once the multiport valve is positioned, the micro pump is actuated to extract or deliver the solvent as desired.

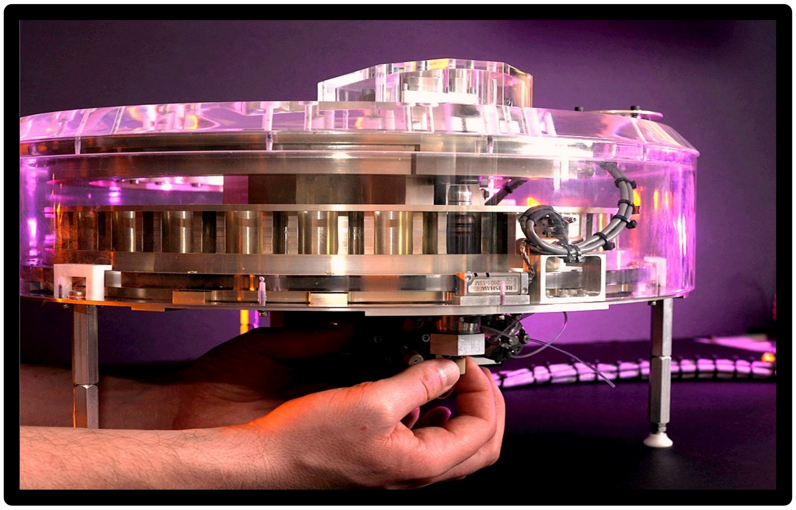


Figure 5 - Fluid Delivery

The ASPS software was developed using LabVIEW; allowing full control of each individual test cell for each processing parameter; such as temperature, processing time, solvent selection, etc. LabVIEW facilitated the coordination of a gamut of COTS components through the integration with National Electronics controller cards. The software allowed for a fully automated functioning mechanism.

This paper will summarize the design, fabrication, assembly and testing. Features such as component selection and troubleshooting process will be discussed. A 4 minute video of the functioning device will be shown.

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41st AEROSPACE MECHANISMS SYMPOSIUM

MAY 16 – 18, 2012
PASADENA, CA

Hosted by
Jet Propulsion Laboratory and Lockheed Martin Space Systems Company

Organized by the Mechanisms Education Association

SYMPOSIUM OBJECTIVES

This symposium is concerned with the problems of design, fabrication, test, and operational use of aerospace mechanisms. Emphasis is on hardware developments. The symposium provides both a social and technical forum for personnel active in the field of mechanisms technology. The symposium attracts papers and attendees internationally.

SUMMARIES AND PAPERS

Papers for presentation and publication are selected from summaries of approximately 1000 words plus figures (total of 4 pages maximum). Summaries are due September 1, 2011. The summary must include:

- A clear description of what is to be presented. Minimize non-essential design information and emphasize results and conclusions. Tell what is unique about the work and why your paper should be chosen.
- Identify the status of the work (concept, development, qualified, flown) and what data is available.
- Indicate whether the subject has been previously published.
- One or two figures, preferably containing test data that supports important findings and photographs to illustrate the maturity of the work.

Paper selection is based on the following criteria:

- Ability to educate with "lessons learned" from development difficulties, ground tests, or flight anomalies. First preference is given to papers that discuss fully-developed, tested and/or flown space or aircraft mechanisms. University student space project work is also highly encouraged.
- Unique and innovative characteristics of design solutions.
- Quality, general usefulness, and lasting value of the information to be presented.

Lessons learned are particularly important. Such papers are often more valuable than reports of purely successful efforts since they help others avoid similar problems in the future.

Authors are notified in October 2011. The final 14-page paper is due December 22, 2011. The paper is published in the symposium proceedings and the author makes a 25-minute presentation at the symposium (the written paper and presentation must be done in the English language). Paper acceptance is a commitment to present the paper at the symposium. Potential authors are advised to clear travel budget, security and export control issues prior to offering the paper. The committee may also choose poster papers, which are 6-page published papers and authors make a 10-minute presentation at the symposium and may also have a table/display at the supplier exhibits . The Dr. George Herzl Award is awarded to the author of the best paper.

TOPICS

- Mechanisms for commercial, military, government, or scientific spacecraft/aircraft, and related test and support facilities. Includes antenna, sensor, solar sail, solar array or instrument deployment; release & pointing mechanisms; steering mirrors & payload mechanisms; gimbals; EVA mechanisms; robotic systems; separation mechanisms; utility transfer; & momentum/reaction wheels.
- Space tribology, bearings, gears, or mechanism lubrication papers containing test data.

• Studies related to mechanism technology including:
  - new actuators, dampers, sensors, release devices
  - studies of reliability, redundancy, and lubrication
  - studies of thermal and space vacuum effects

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