Fingers Of Sound For Supporting ISS Based Studies On ISS

Space-DRUMS™

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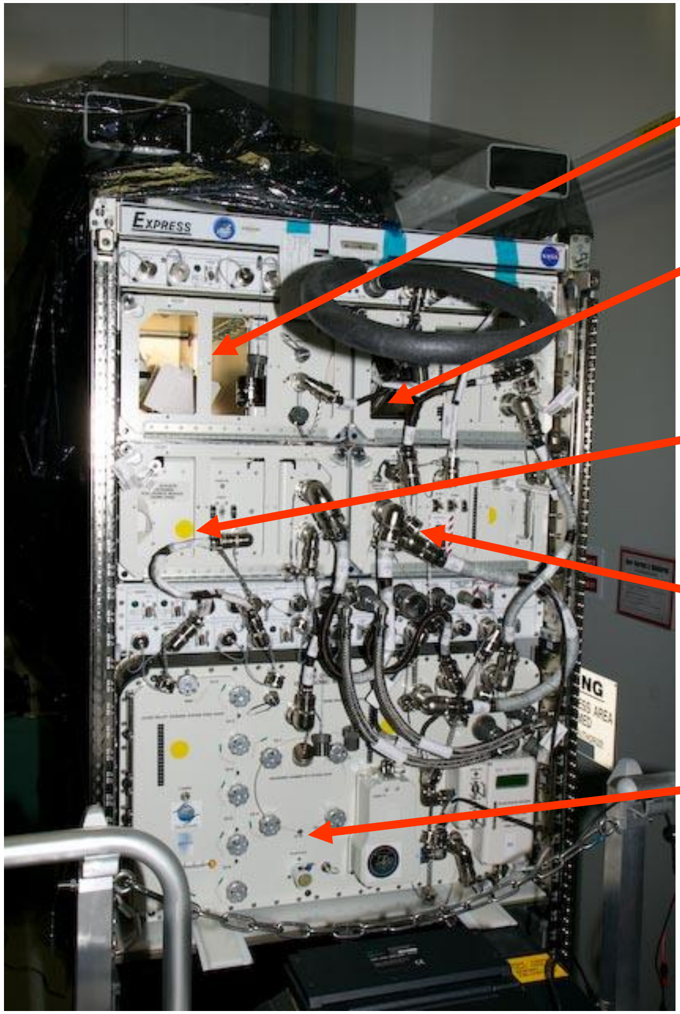
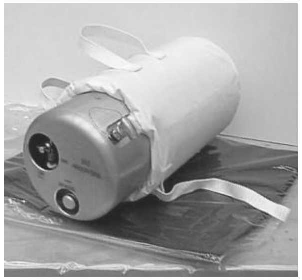
in association with Dr. D'Arcy Hart,
Dr. James Stacey and Mr. Bill Hunt, Mr. André Pant

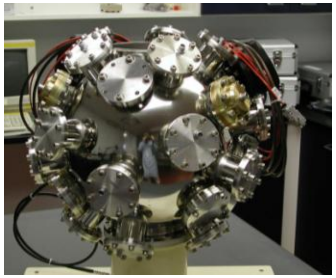
November 19, 2010 –NSAW Ottawa

The Space-DRUMS™ Facility



- **Argon Gas Module --**UHP argon to processing chamber
- **Ignition Power Module** – supplies high current, low voltage to ignition coil to start SHS
- **Acoustic Positioning Electronics Module** – supplies correct inputs to acoustic projectors
- **Payload Computer & Electronics Module** – automated software and electronics control for entire payload
- **Processing Module** – triple level containment for combustion synthesis inside sealed processing chamber





“…System ready for full ope

History

- Requirement for containerless processing of large samples
- Containerless prototype flown KC-135 1995
- Manifested in 1998 NASA Space Product Development Program
- NASA Center for Commercial Applications of Combustion in Space , CCACS, Colorado School of Mines
- Bioserve- University of Colorado, Boulder
- NASA Innovative Partnership Program, IPP
- Facility finished with ULF-2 and supplied by
- Located on the US Allocation of the JEM Module

Facility Specifically Engineered For The International Space Station(ISS)

- Designed to maximize the potential utilization and experimentation of long duration microgravity offered by the ISS environment for space sciences and in space manufacturing
- The research utilization plan focuses on advancing innovative advanced material designs in addition to handling physics applications
- Although target technologies were originally advanced materials based on metal-ceramics and glass-ceramics to produce stronger, lighter, higher temperature materials; the facility was specifically designed to be modular; designed for rapid adaptation and handling of a variety of physical science experiments

Current Priorities

- Manufacture in space using ISS as a base to explore techniques
- Conduct peer-reviewed science; physics and materials
- Provide for a hands-on educational vehicle for classroom demonstrations on micro-gravity sciences
- Contract for our services on lessons learned from our path to launching Space-DRUMS™
- Support NASA's space exploration mandate including verifying in-space repair concepts along with fabrication of essential replacement components such as ceramic filters

"….Learn from space to bring products to market faster"

Near term Potential On ISS For Education

- Space-DRUMS® provides a very flexible suite of opportunities
- Potential classes could be developed to engage students into understanding processing of materials in μg or low g
- Lessons on materials that could be developed from ISS could engage students with exercises using candidates for cutting tools, insulators, IR glasses, structural members for new spacecraft.
- Ideas related to containment and decontamination processing of foreign space materials could be actually demonstrated in simple forms
- Engaging students on how to create materials or components (like filters) in μg which could be manufactured in a future spacecraft enroute to Mars could be an exciting starting point

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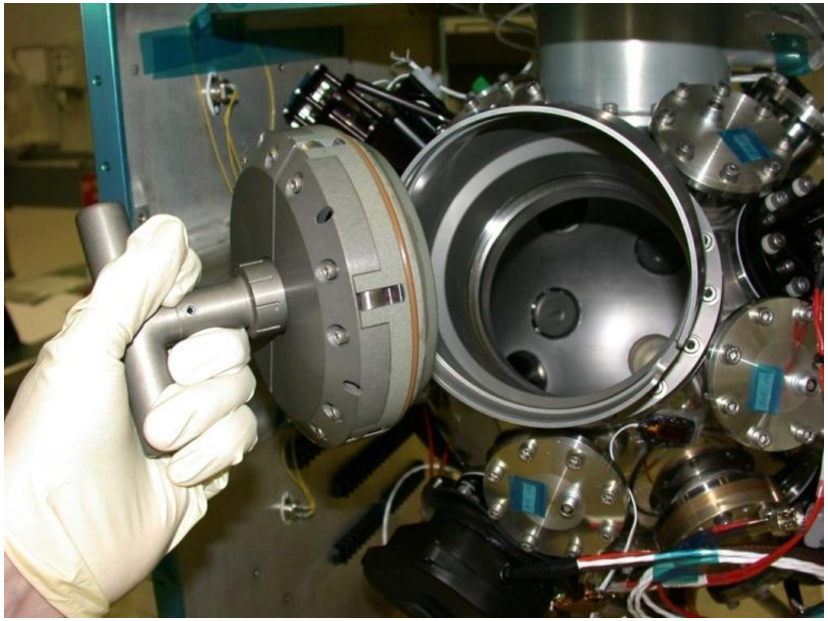
Complementary Advanced Student Processing Experimentations

- Available to students is a broad base of scientific container and containerless processing opportunities in μg
- Scientific processing in μg with high purity handling of materials within three containment levels and containerless could lead to graduate level research and thesis outputs
- Studying the long-term growth effects of chemical and biological mixtures in long duration μg is also possible
- Fluid physics studies in capillary flow, foam stability, diffusion coefficients as relates to enhanced oil recovery is a hands on way to connect students back to earth in a manner that is very pertinent
- With careful planning ripple turbulence studies could be organized to illustrate the cascading of energy (waves creating waves creating waves) and link this back to our knowledge to predicting hurricane paths and intensities

Student Dedicated Payload Utilization Opportunities



- Suitable student experiments could be inserted into chamber, for example an inflated ball to examine ripple turbulence caused by acoustic beams, or an insert designed for biological studies

"…Processing Module has access to Processing Chamber (round door) with additional hermetic door on chamber "

Student Engineered Small Payload Inserts

Argon Gas Module

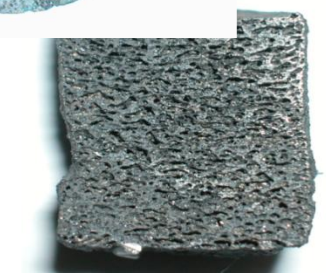
Ignition Power Module

- Ignition Power Module ORU can be removed and replaced with a student engineered experiment control electronics box, requiring only power connection to Rack or power through PCEM
- A simple fluid physics experiment is to perform capillary flow through a reservoir substrate with liquid level sensors to measure flow progress

" ….Both modules have available space to install fluid physics experiments which can be controlled by the payload computer through one simple electrical connection"

Examples Of Student Led Ceramics In A Containerless Micro-gravity Environment

- Porous ceramic materials based on metal-ceramic chemistries produced by Self Propagation High Temperature Synthesis (SHS)
- Glass ceramic materials based on metal-ceramic chemistries produced by SHS
- Infrared glasses produced by SHS
- Role of gravity in production of advanced materials
- Near net shaping
- High value semi-conductor candidate material production
- Stronger, lighter, higher temperature resistant materials for terrestrial use



Example Of An SHS- Produced Porous Ceramic

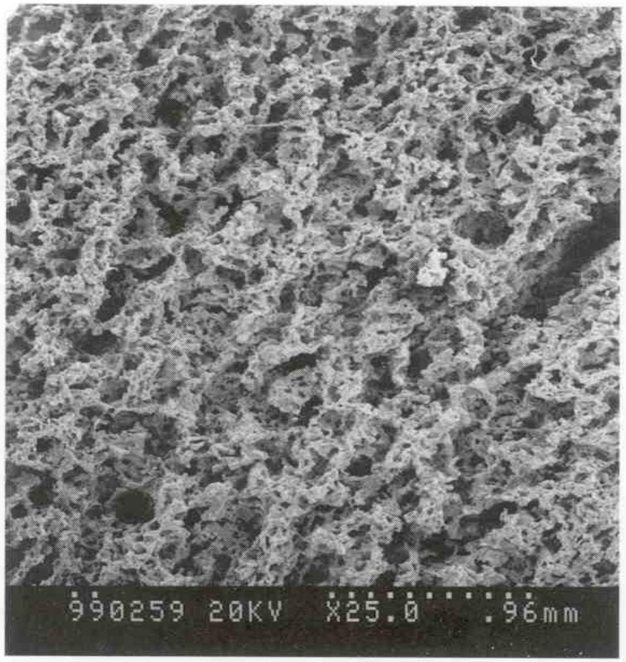
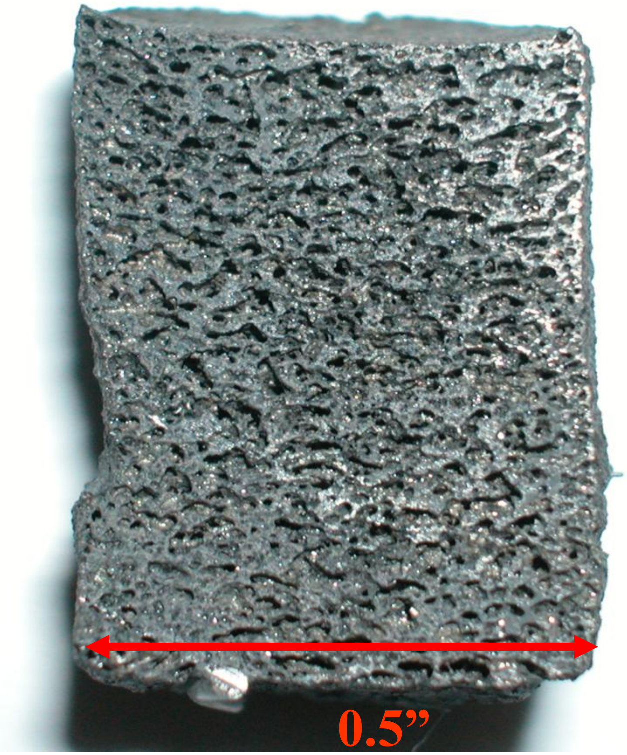


Figure 9. Surface morphology of a sample reacted from a green pellet of 35%, and degree of expansion of ~60% during combustion synthesis (Pa = 77%, Po = 84%).



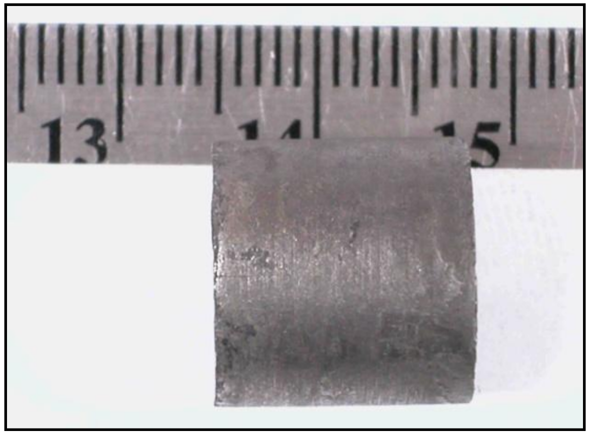
Porosity~80%

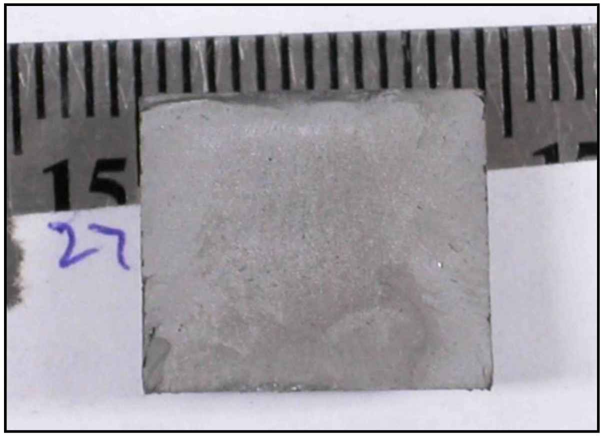
Porosity~60%

Example Of SHS-Produced Dense Metal-Ceramic Composites

As-Reacted Sample,

40-50% theoretical density typically





Dense, Pressed at ~70MPa

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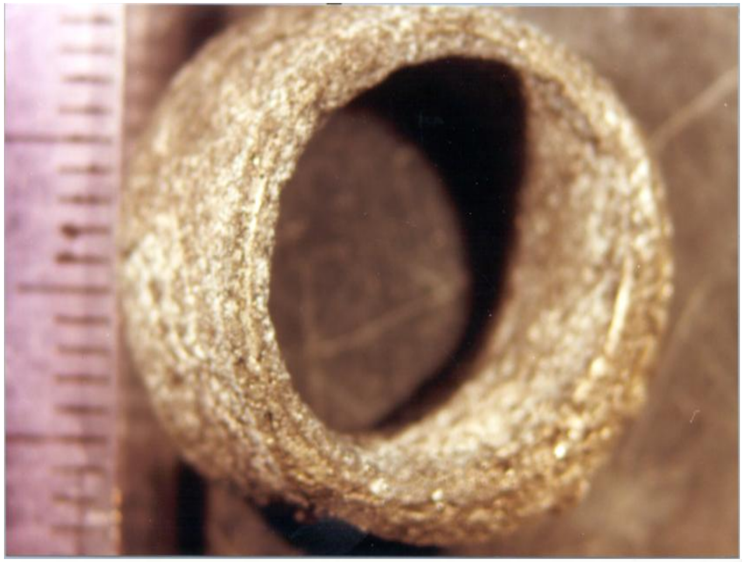
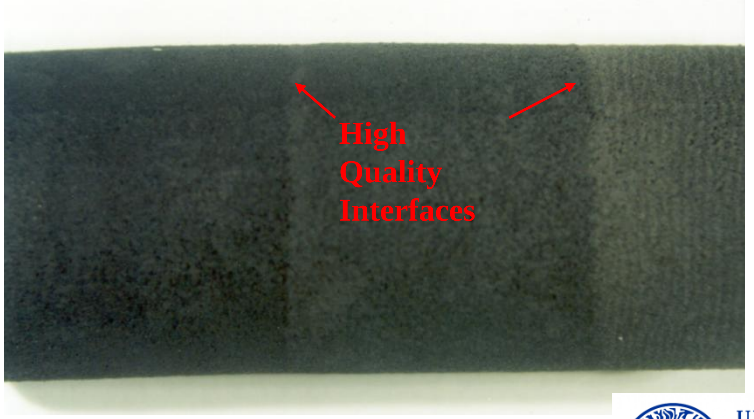
Example Of An SHS-Produced Net Shape Fabrication

Stronger Shell





Lessons On The Effects of Gravity On Phases

1-g, settling

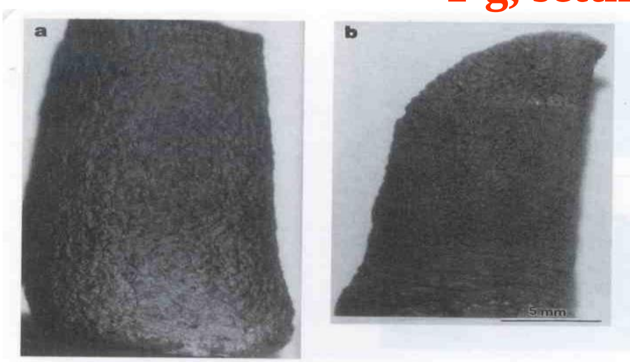
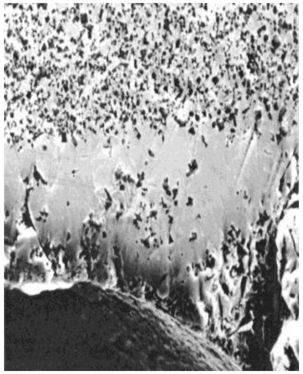
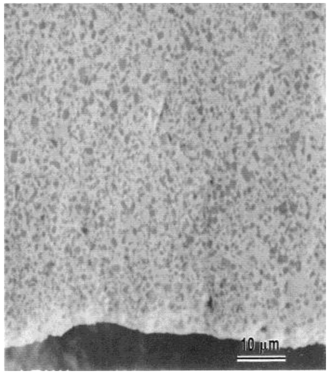
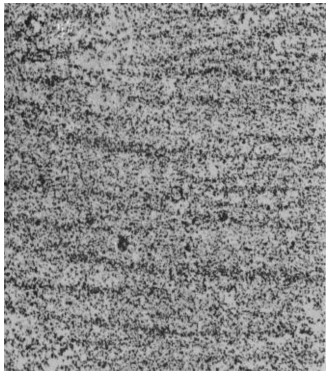


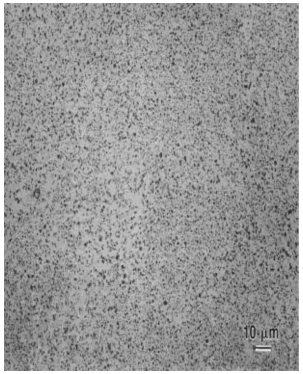
Fig. 3—Samples reacted under normal gravity: (*a*) 50 vol pct Ni_3Ti and (*b*) 70 vol pct Ni_3Ti.

Substantial sedimentation of ceramic phase in molten matrix, Yi, Moore, Guigné, (1997).









1-g **Low-g** **1-g** **Low-g**

Lessons On The Effects Of Gravity On Fluids

- Fluids (liquid and gas) are involved in the SHS Process
- Convective Flow of Fluids Induced by Gravity Affect Heat Transfer and SHS

COSYM™ Chamber

Wave Propagation

Yi, Moore and Guigné (1997).

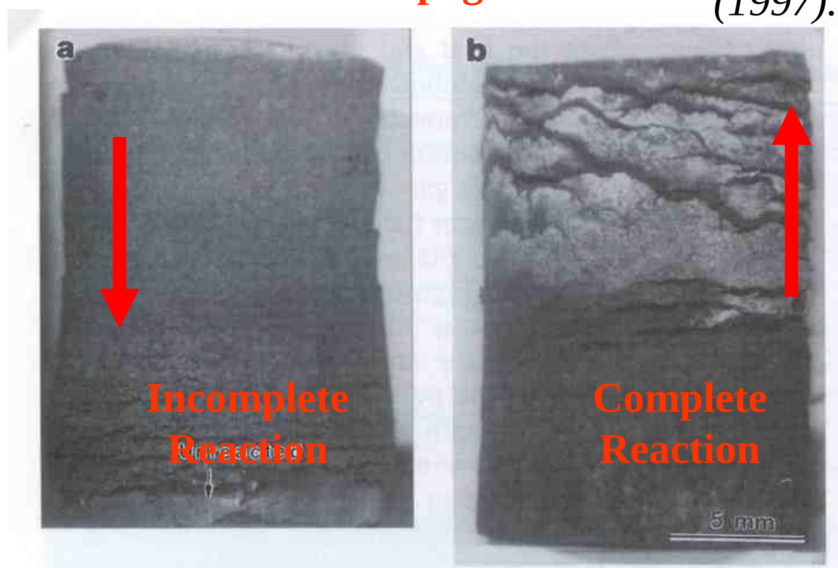


Fig. 7—Photographs of the 70 vol pct Al-HfB_2 samples ignited at the (*a*) top and (*b*) bottom of the pellets.

Students could access COSYM™ Ground And Parabolic SHS Facility

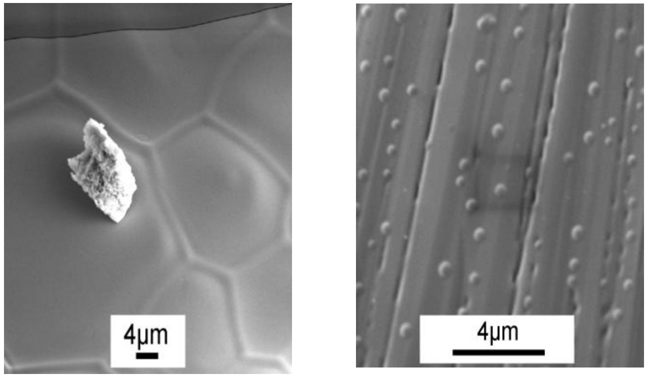
COSYM™

COSYM Parabolic Flight Payload
Conducted 15 Flight Campaigns in Collaboration with GIL, CSM, CCACS and UC-Davis

Developed a Series of Materials

Lessons On The Effects Of Gravity On Glasses

- **Promote Homogeneous Nucleation in µ-g**
  - Calcium Phosphate (Castillo and Moore, 2003).
  - ZBLAN Glass (Varma, 1992, Tucker, 1997)
  - CaO-Al_2O_3-SiO_2-BaO Glass (Yi, Moore, Guigné, 2000)
- **Affect Crystallization**
  - Zr_2O_3-Al_2O_3-Fe, more tetragonal Zirconia at low-g (Odawara et al., 1993)
  - ZnS, Lattice Parameter Closer to Ideal Value (Goroshin et al., 1994)

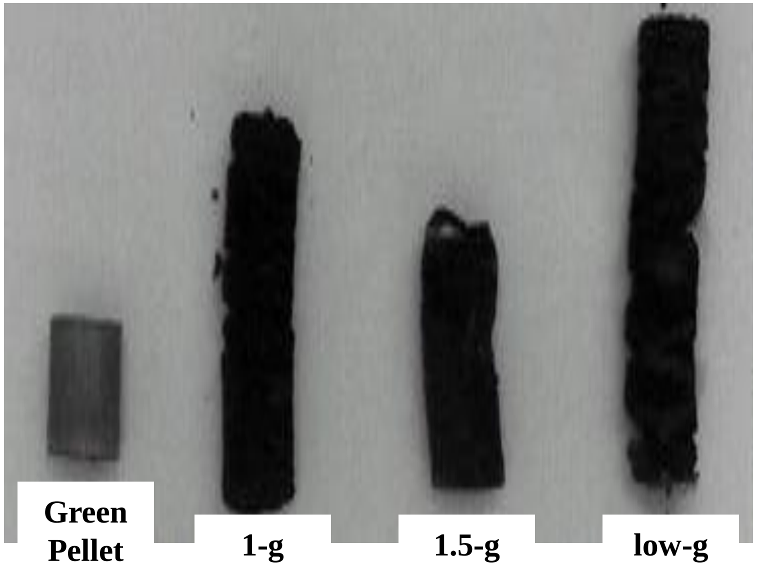


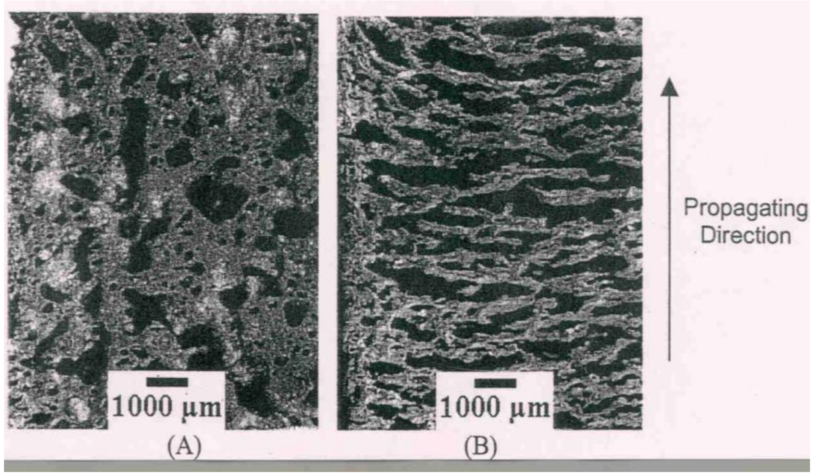
Low-g, more amorphous, less crystals

SEM images of $Ca_3(PO_4)_2$ produced at reduced gravity (left) and normal gravity (right)
(Castillo and Moore, 2003)

Lessons On The Effects of Gravity On Pore Size

- Porosity and pore size (Shteinberg etc, 1991, Moore, 1994)
- Morphology of pores (Zhang & Moore, 2003)



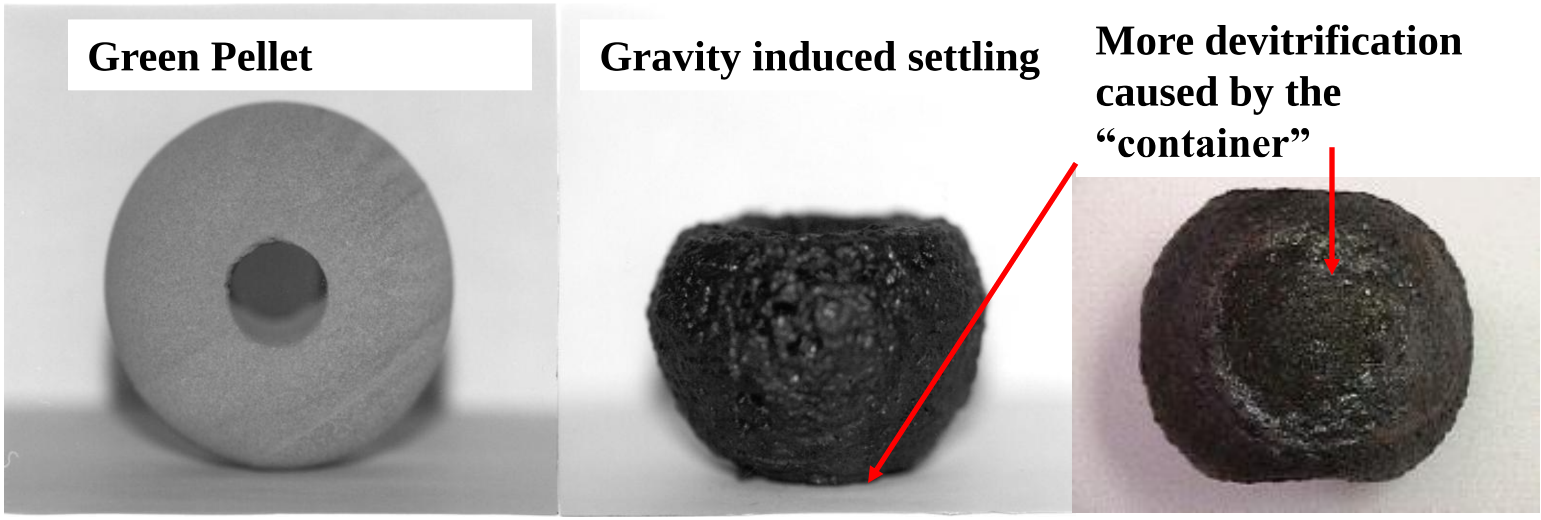


A) Low-g, more closed pores

(B) 1-g, more open pores

More closed pores in low-g

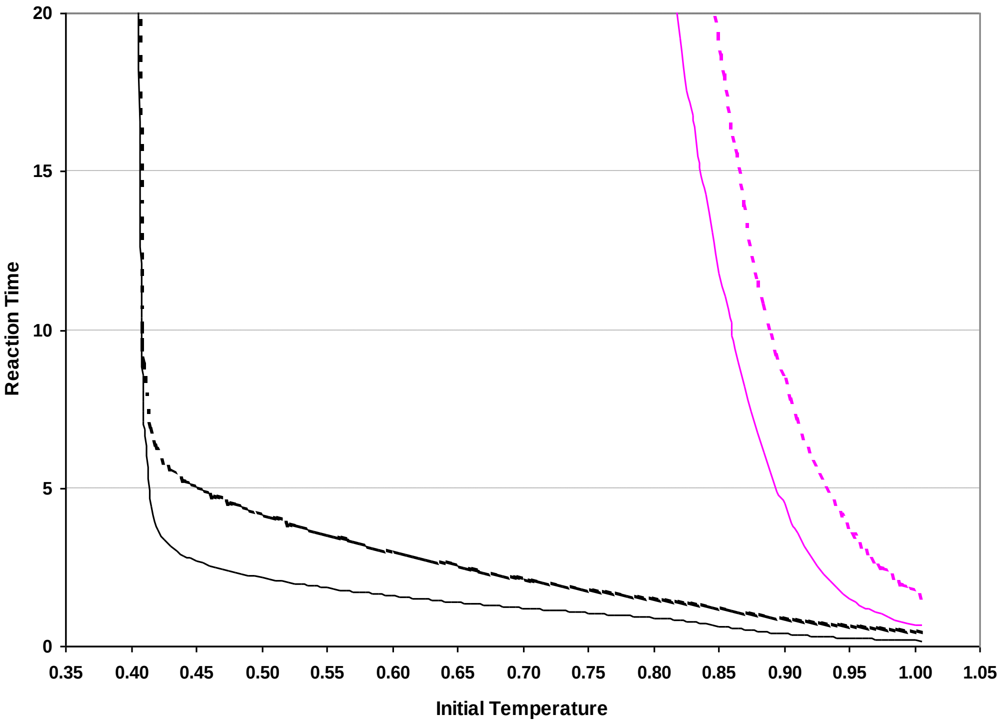
Lessons On The Effects Of Gravity And Container On The SHS Process



Photographs of a spherical green pellet and the same pellet after combustion synthesis. The green pellet had a density of 35%. The composition is $50Al_2O_3$-$30CaO$-$10SiO_2$-$10BaO$ (wt.%).

Lessons On The Effects Of A Container On The SHS Process

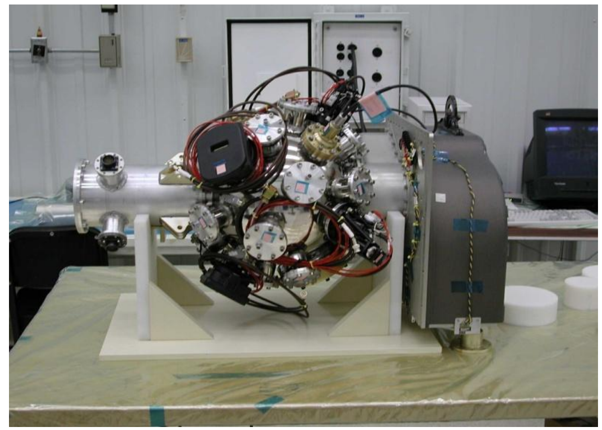
- Reaction rate is higher for adiabatic (no Heat loss) conditions
- Reaction rate is reduced by a container



Exposing The Physics Involved In Containerless Processing

ACOUSTIC BEAM CONTAINERLESS PROCESSING

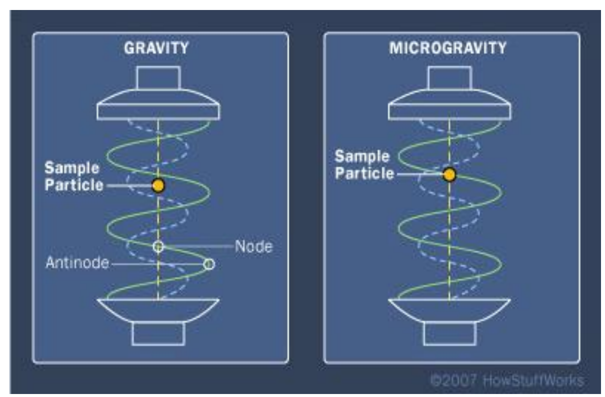
20 acoustic projectors generate individual acoustic beams as needed , to apply a direct force onto samples during their processing ,pushing them back to the chamber center, only when required …

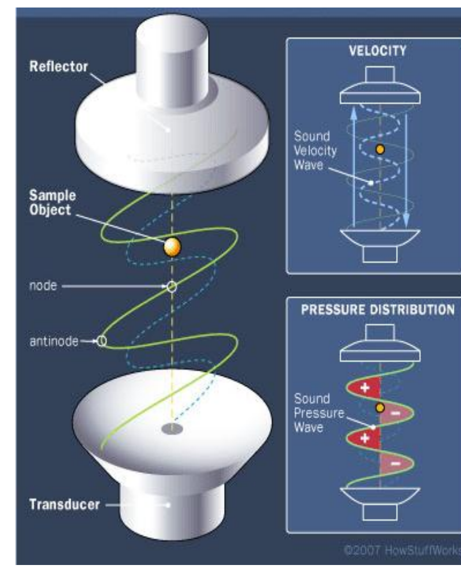


Acoustic Beam Projector

TRADITIONAL STANDING WAVE LEVITATOR

Samples held in nodes with no restoring forces available to restore positions





"…Fingers Of Sound Vs Standing Waves."

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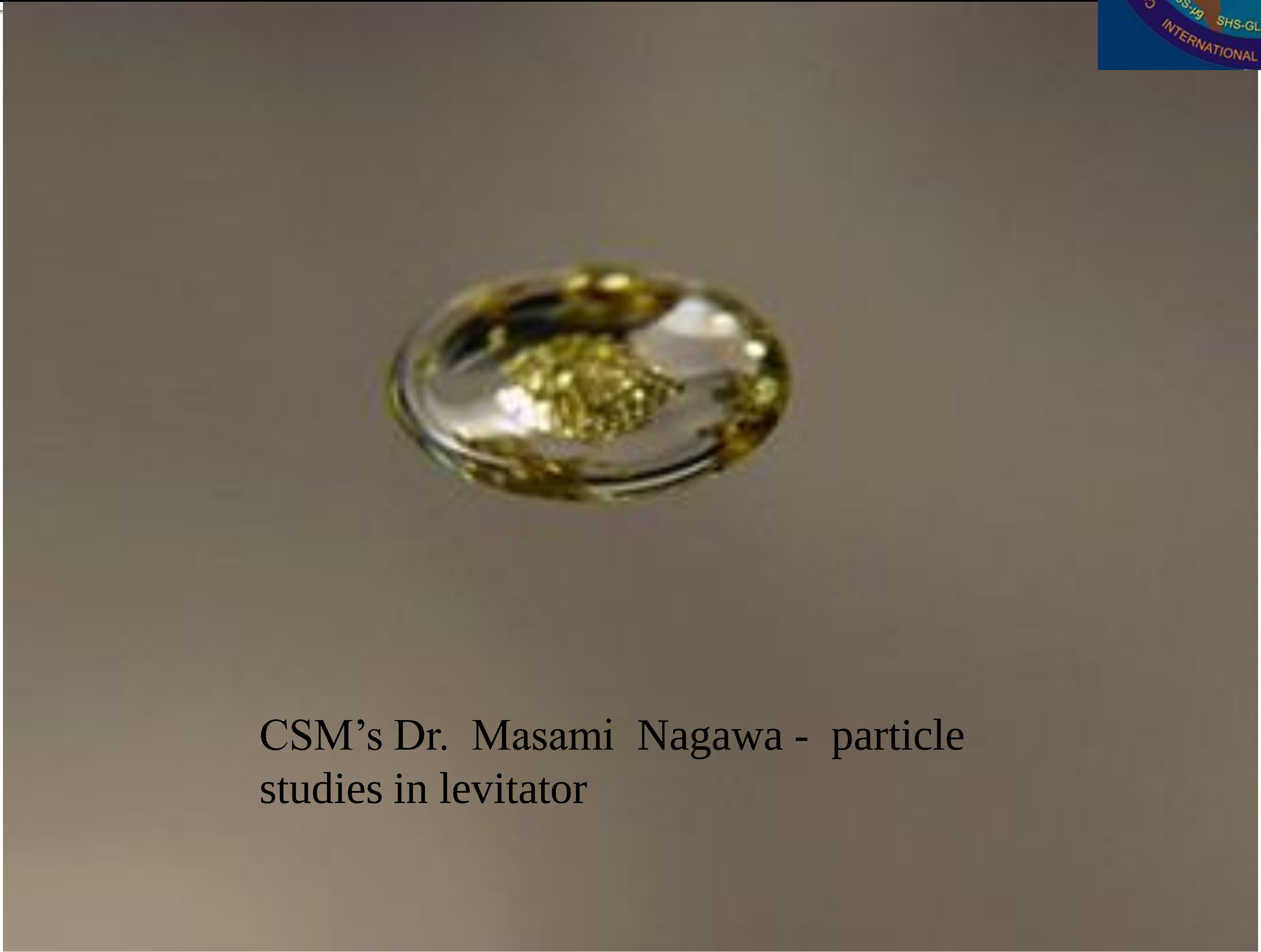
Suspended Droplet



CSM's Dr. Masami Nagawa - particle studies in levitator

Engaging Students Into Strategic Spacecraft Issues

REQUIREMENTS TO WITHSTAND SPACE CRAFT RE-ENTRY CONDITIONS

- T~3000K (1650 °C): High Tm, Oxid. Resistant
- Aerodynamic force: Mech. Strong
- Prevent Plasma Generation: low open pores

Firing a piece of foam at a shuttle wing section at the estimated impact speed that the foam debris hit Columbia on launch left a telling result. - *NASA image*

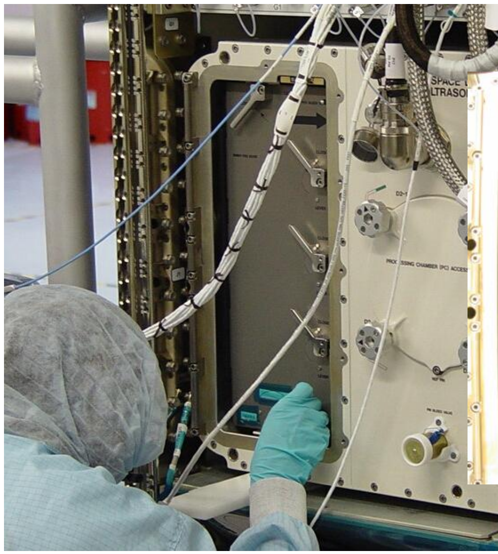
Issues to Engage Discussion : ie SiC Paste Tested on Discovery

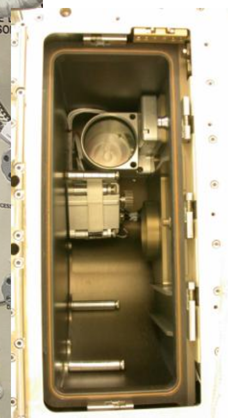
SiC

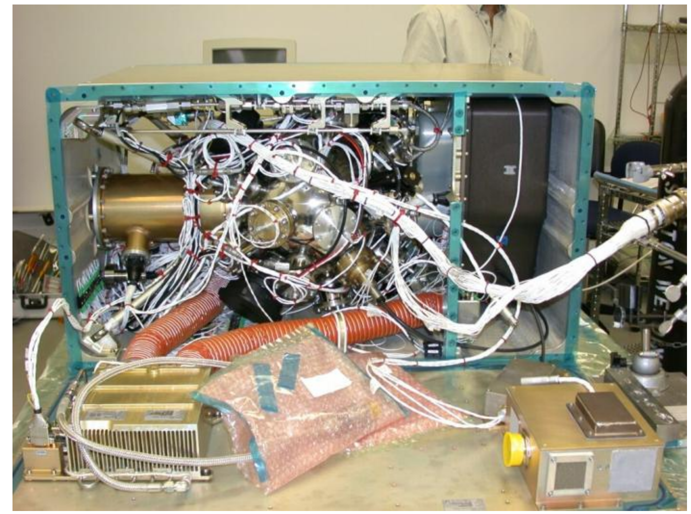
- High Tm, Oxidation-resistant
- Sintered at re-entry
- Mech. Strong? Density?
- For small cracks, holes?

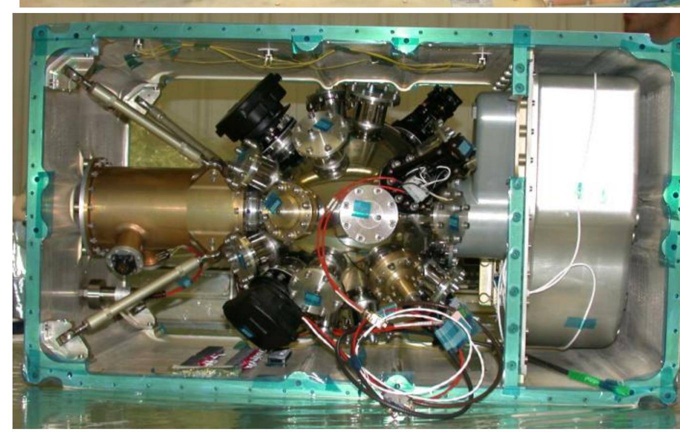
Clad in a U.S. spacesuit, STS-114 mission specialist astronaut Soichi Noguchi - of JAXA - participates in a dry run "cure in place ablator applicator" test aboard NASA's KC-135 aircraft as part of return to flight readiness program. *From: NASA/JSC.*

Whilst Using Space-DRUMS Initiate Engineering Exchanges
……on the making of the
Space-DRUMS™ Facility



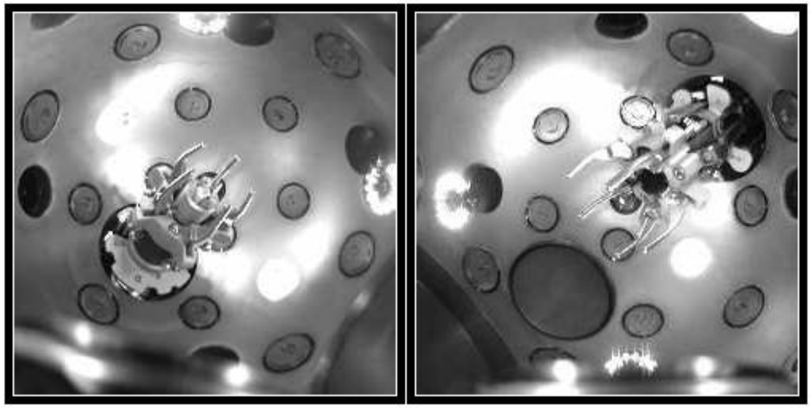






Core ISS Space-DRUMS™ Mission Team In Support of Student Projects

- Lead Scientist – Prof. Jacques Y. Guigné
- Program Operations and Re-Supply Coordinator – Mr. Ron Davidson
- Project Manager – Dr. D'Arcy Hart
- Ground Control Operators – Mr. André Pant and Dr. James Stacey
- Software Engineering Managers – Dr. James Stacey and Mr. Bill Hunt



Fully Automated Versatile Facility, Very Little Astronaut Involvement And Ground Support Needed

Inside imagery of actuator was taken on April 23rd,2010 at ~ 1830 GMT time; during on ISS Operations of the Material Handling System Checkout.

…..Ground Control TReK Station, Payload Engineering Support And Mission Utilization Paradise, Newfoundland , CANADA