

FUSED DEPOSITION MODELING IN MICROGRAVITY

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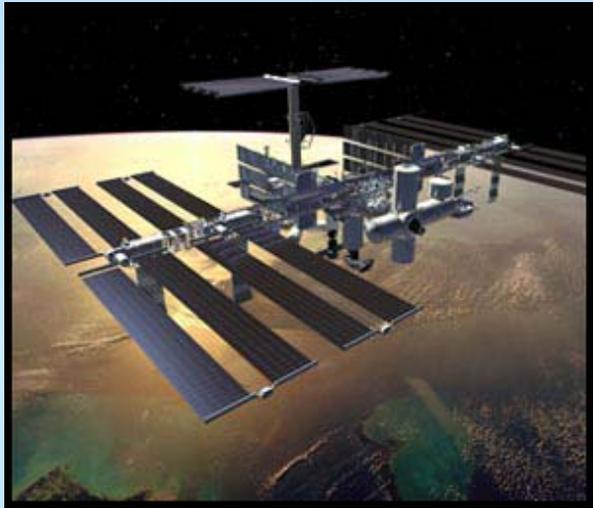
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What Happens if Things Break in Space?



Space Station:
1 week



Journey to
Mars:
12-18 months



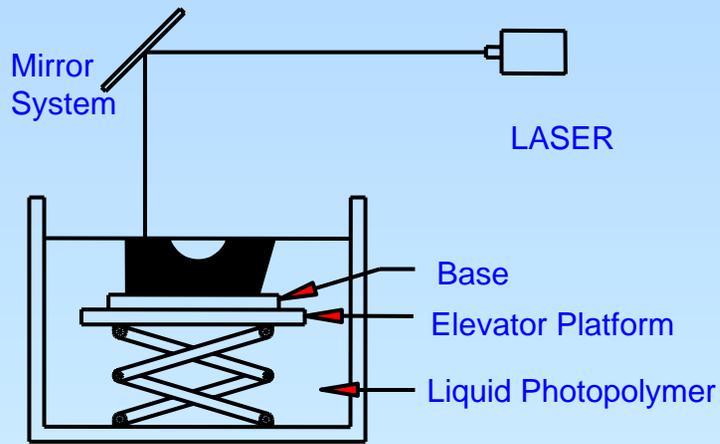
Mars Base:
12 months
minimum

Manufacturing in a Microgravity Environment

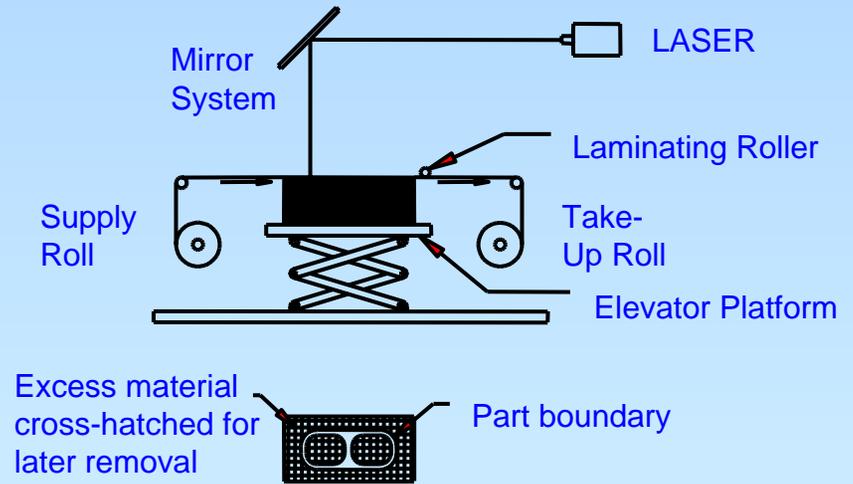
- *Things will break* during long duration missions (Mars).
 - Storage of large number of parts.
 - Sending replacement parts.
 - Becoming EXTREMELY handy with duct tape.
- **Additive Manufacturing (RP/SFF)** vs. **Subtractive Manufacturing (Machining)**.
 - Amount and form of feedstock materials.
 - Amount of waste / reprocessing.
 - Reduced manufacturing / assembly overhead.
 - Single machine for multiple materials & geometries.
- μ G imposes unique requirements on SFF systems.



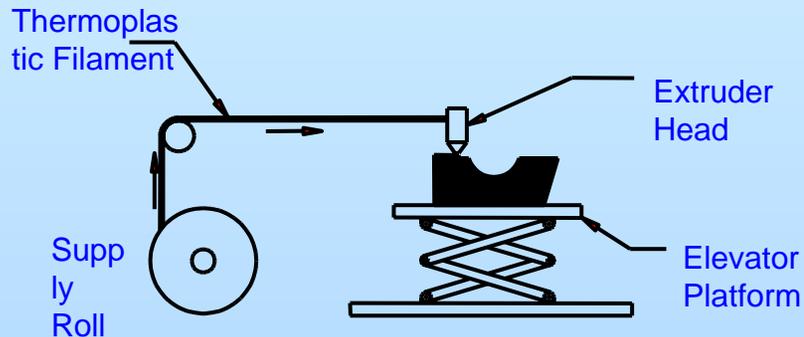
Rapid Prototyping Systems



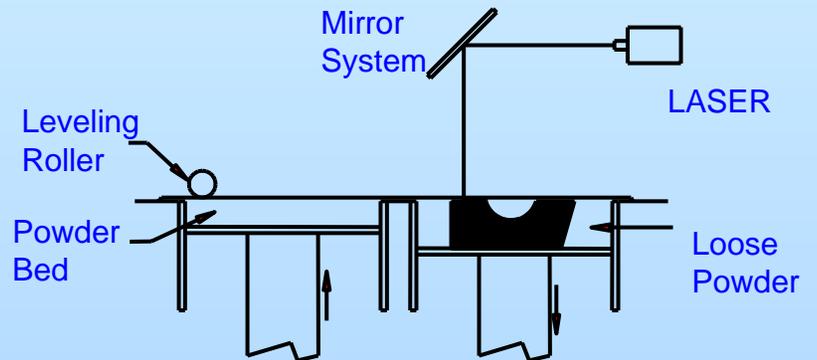
Stereolithography



Laminated Object Manufacturing



Fused Deposition Modeling



Selective Laser Sintering

Deposition Techniques

- FDM / FDC / FDMet / EFF / SDM / LENS / ...
- Variety of materials (metals).
- Commonality with robotic assembly systems.
- Reduced gravity material handling.
 - Small melt volume



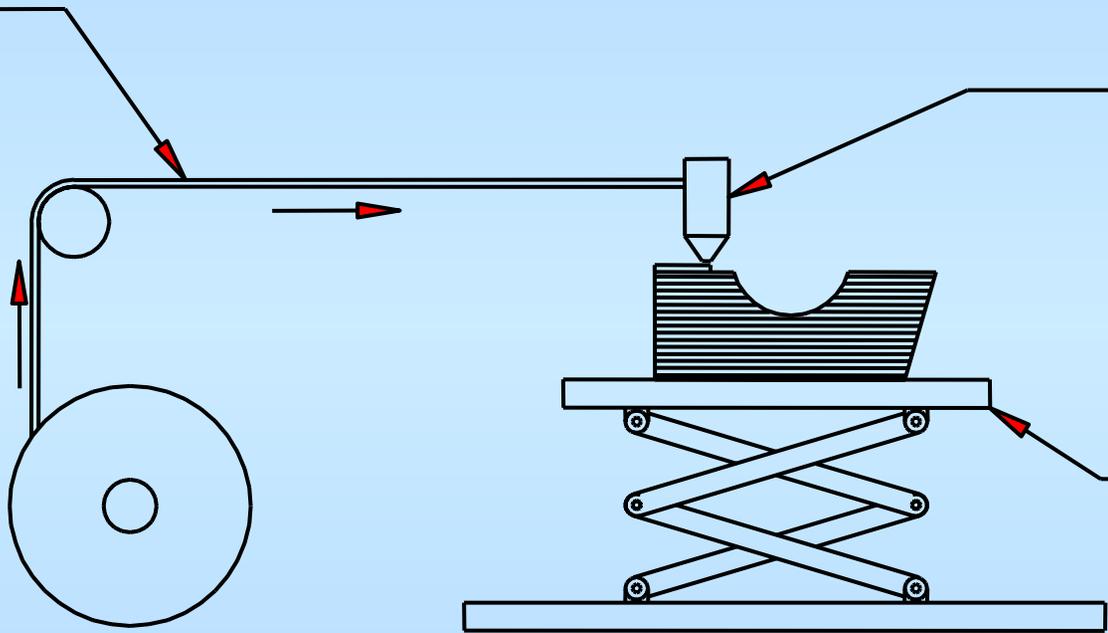
Fused Deposition Modeling

Thermoplastic
Filament

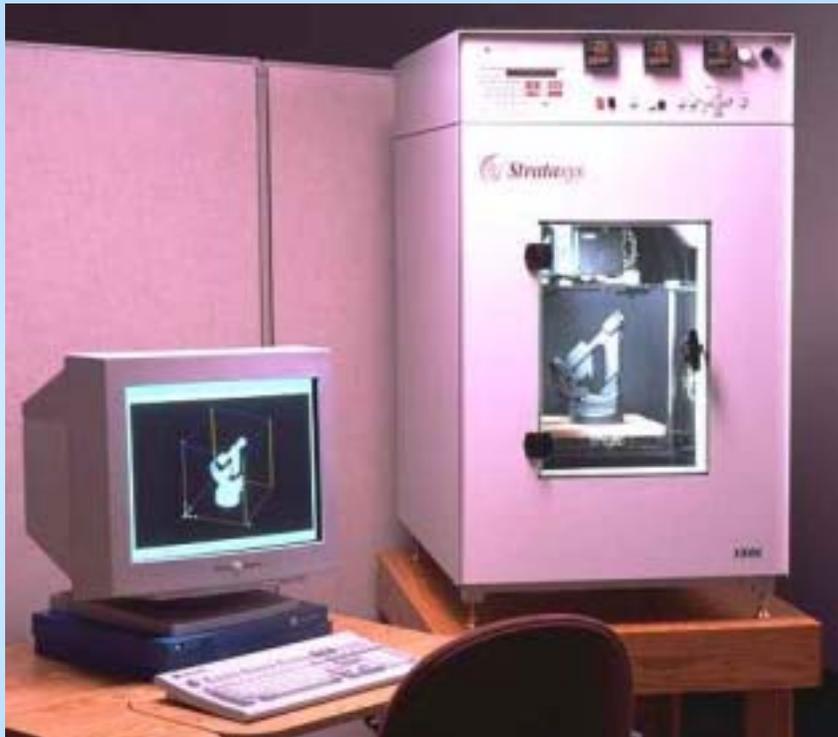
Extruder
Head

Supply
Roll

Elevator
Platform



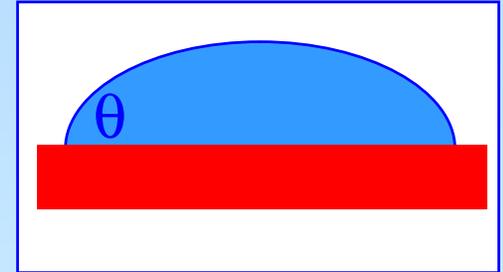
Fused Deposition Modeling



Liquid Handling in Microgravity

Young's Equation

$$\gamma_{SV} - \gamma_{LV} = \gamma_{LV} \cos \theta$$



Driving force for spreading

$$\gamma_{LV} (1 - \cos \theta)$$

Capillary limit

$$\kappa^{-1} = \left(\frac{\gamma_{LV}}{\rho \bullet g} \right)^{\frac{1}{2}}$$

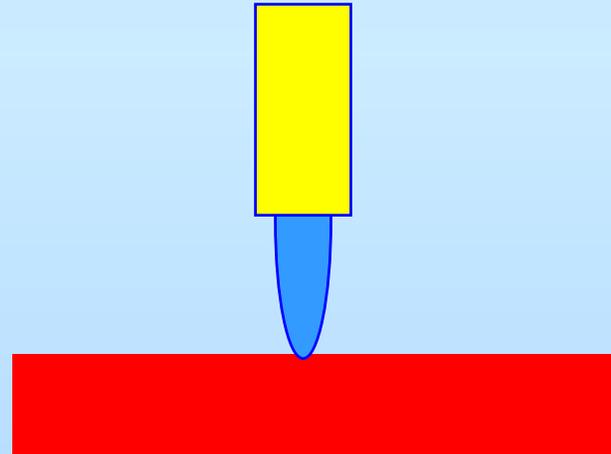
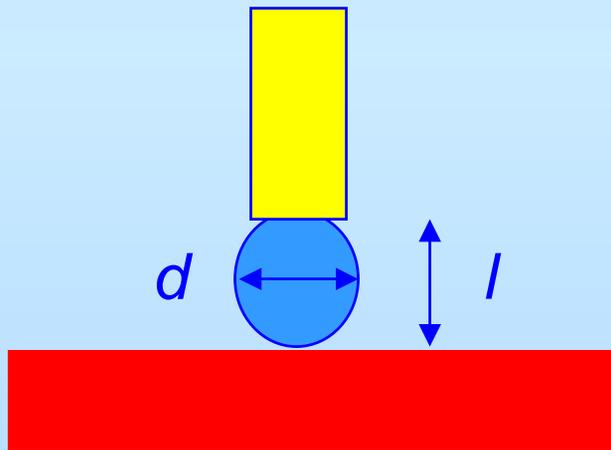
Ground-Based Testing



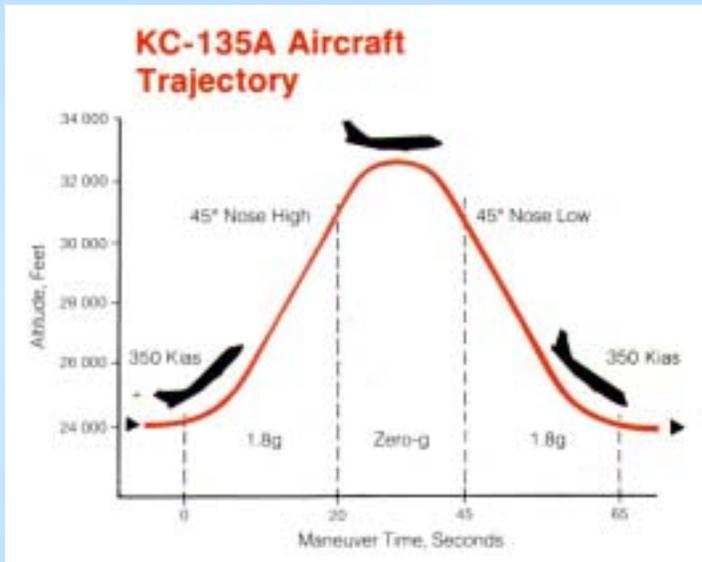
Critical Issue: Continuous Substrate

- Condition for Bead stability:

$$l < \pi d$$

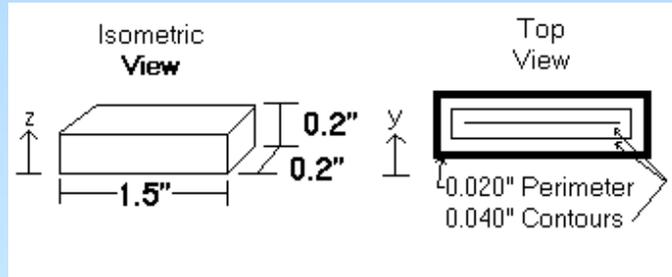


KC-135 Reduced Gravity Aircraft

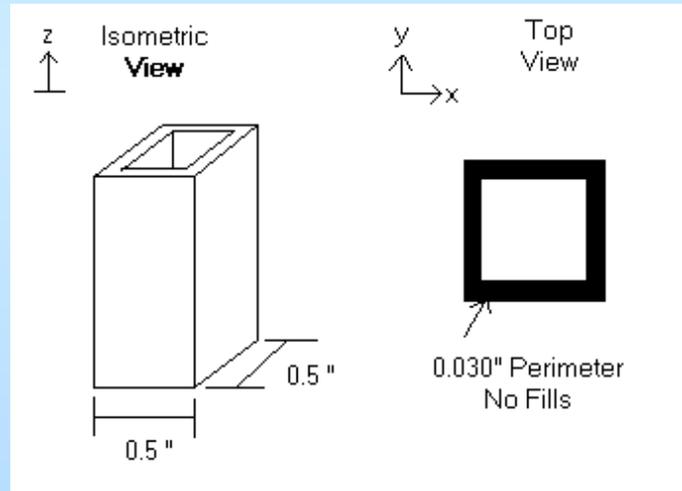


Experiment Set 1: Continuous Substrate

Horizontal Bars

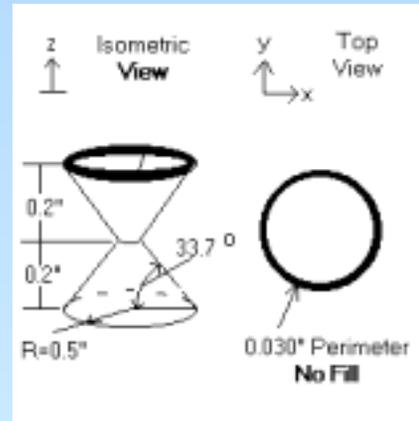


Vertical Columns

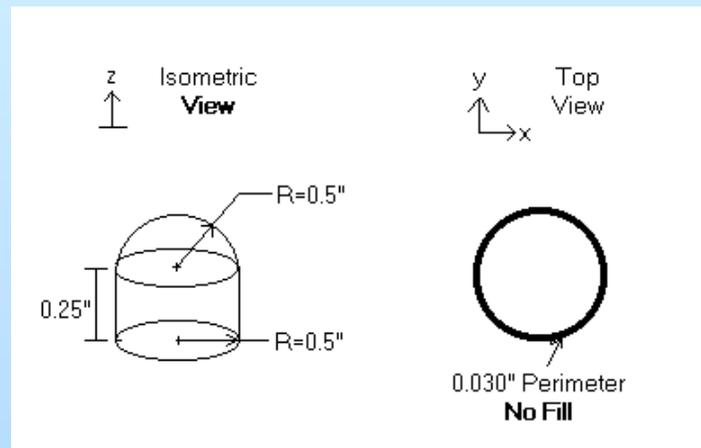


Experiment Set 2: Reduced Substrate

Hourglass

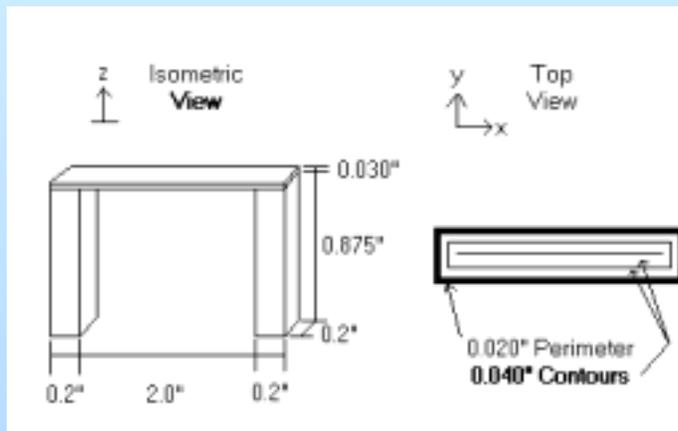
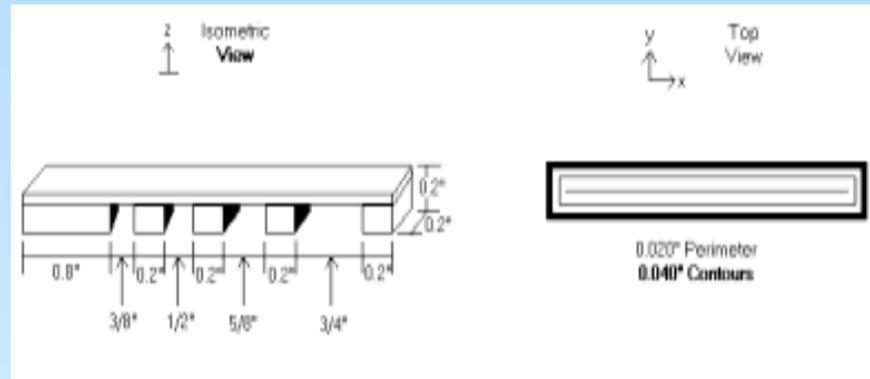


Domed
Cylinder



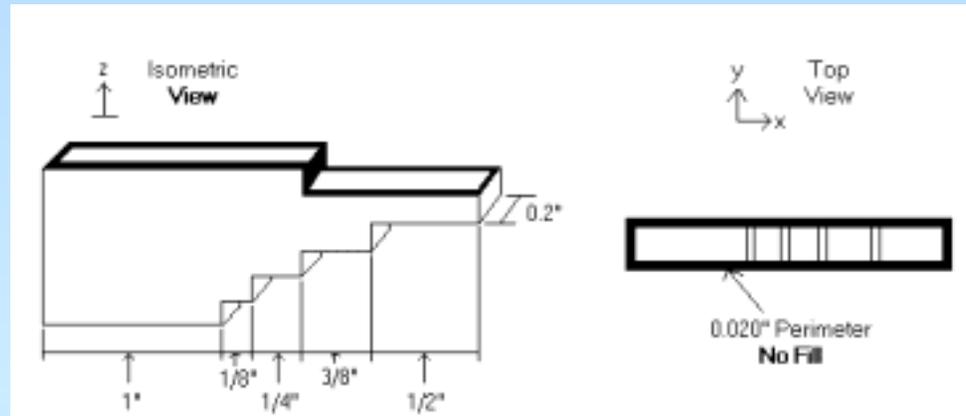
Experiment Set 3: No Substrate

Bridges

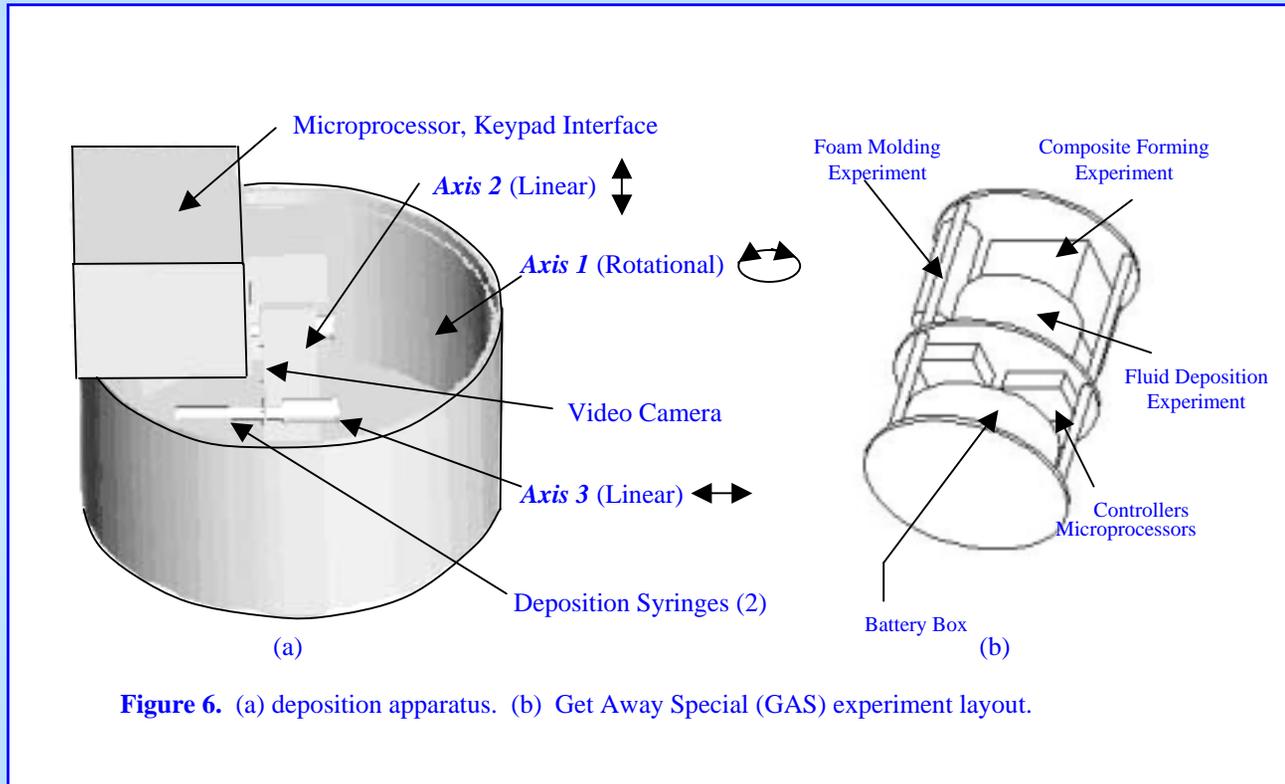


Experiment Set 3: No Substrate

Cantilevers



Space Shuttle "Get Away Special" Payload



Acknowledgements

NASA

National Science Foundation

MSOE Rapid Prototyping Consortium

Milwaukee Discovery World Museum

Gammex, Inc.

Danfoss Fluid Power, Inc.

