Cold Hibernated Elastic Memory (CHEM) Self-Deployable Structures

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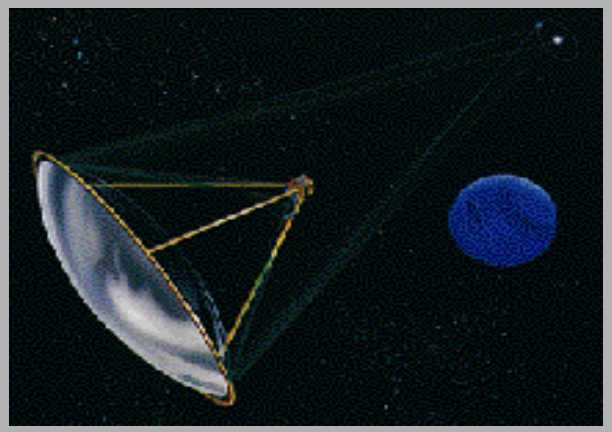
Contents

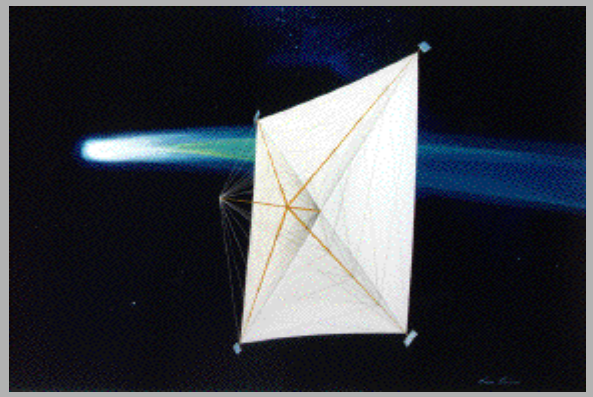
Introduction

- *New spacecraft architecture*

  - small at launch but deploys large apertures and appendages in space



- *Major efforts to develop low mass and small launch volume expandable structures*



- *Results:*

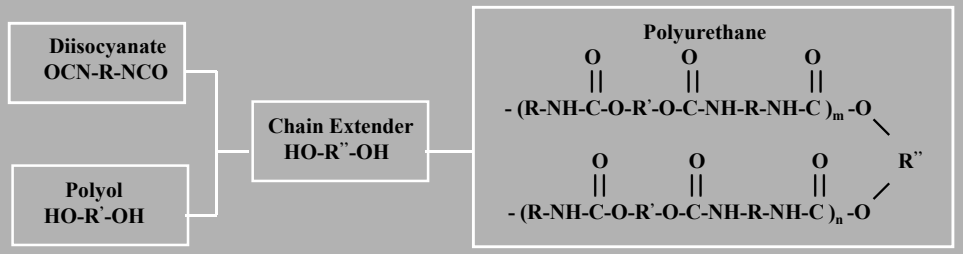
  - space inflatables

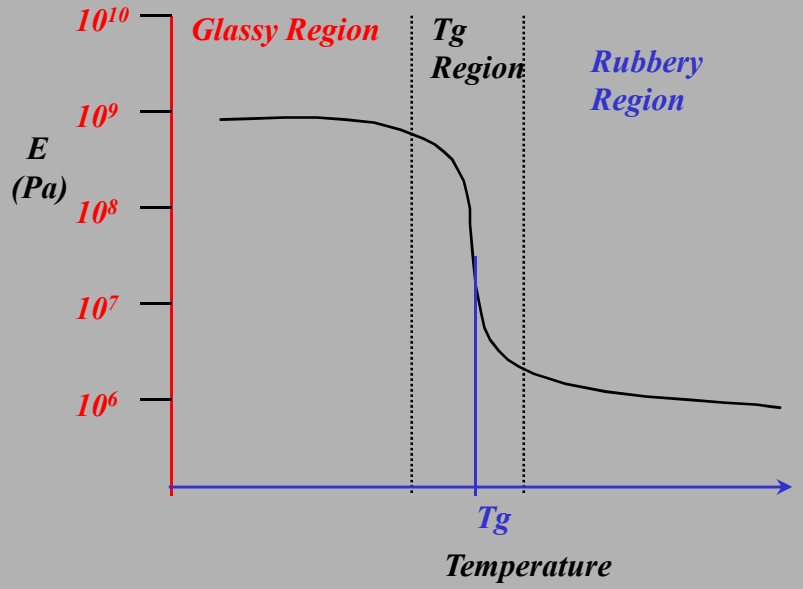
  - CHEM self-deployable structures

Shape Memory Polymers

.Description

- Polyurethane-based thermoplastics developed by Mitsubishi Heavy Industry
- Polymerization:





- Required molar ratio:

$$\frac{\text{mole of NCO group}}{\text{total mole of OH group}} \leq 1$$

Properties*	MM - 4500
Density (g/cm^3)	1.15
Tg (^{0}C)	45
E below Tg (MPa)	1102
E above Tg (MPa)	3.8
Recovery force (MPa)	up to 4.1

*from Virginia Tech

• Characteristics

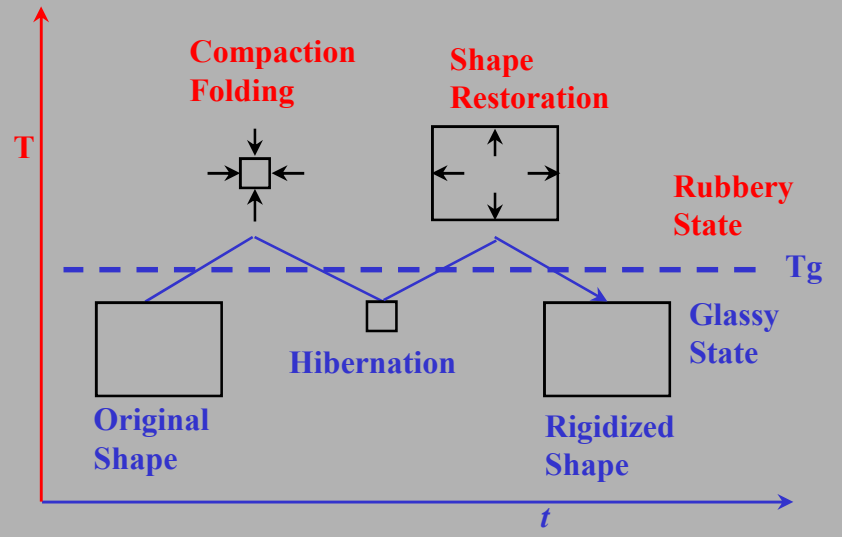
- Light weight
- Recover up to 400% of plastic strain
- Wide range of glass-transition temperature Tg
- Large reversible changes of properties
- Low recovery force
- Easy processing
- Low cost

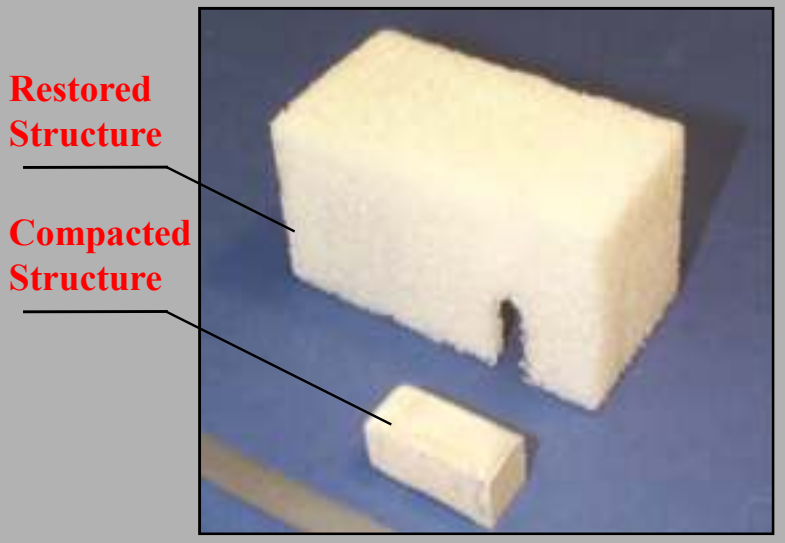
CHEM Description

• Characteristics

- Utilizes shape memory polymer (SMP) in foam structures.
- Precision deployment by elastic recovery and shape memory effect.
- Reversible compaction/deployment/ rigidization cycle.
- High full/stowed volume ratio.
- Wide range of glass-transition temperature Tg: from -70^{0}C to +100^{0}C.
- High ratio of E below Tg to E above Tg.
- Heat effective deployment: small transition range.
- Cold hibernation allows long-term unconstrained stowage.

• CHEM Processing Cycle





Benefits

- *Low mass*
- *Low stowage volume*
- *High reliability*
- *Low cost / quick technology development*
- *Self-deployable*
- *Very simple*
- *High dynamic damping*
- *Clean deployment and rigidization*
- *None long-term stowage effects*
- *Ease of fabrication*
- *Impact and radiation resistant*
- *Good thermal and electrical insulator*

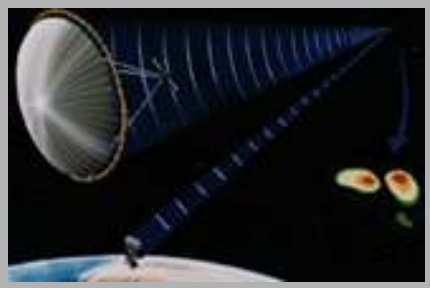
Disadvantage:

- *Heat energy is needed for deployment.*
  Natural heat sources are considered to be utilized

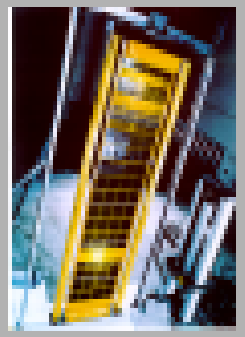
Potential Space Applications

• Support Structures

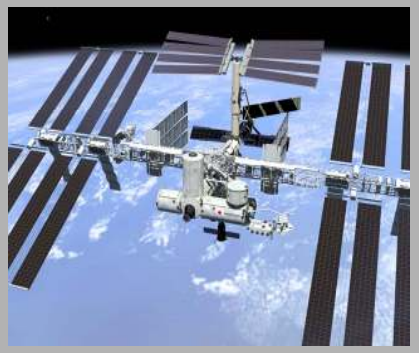
• Robotics



• Antennas



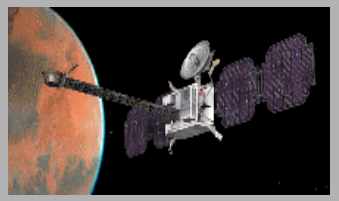
• Solar Array



• Trans Habs

• Space Habitats

• In-situ Propellant Production



• Radar

• Thermal Control

Potential Commercial Applications

• *Shelters, Hangars*

• *Coolers*

• *Camping tents*

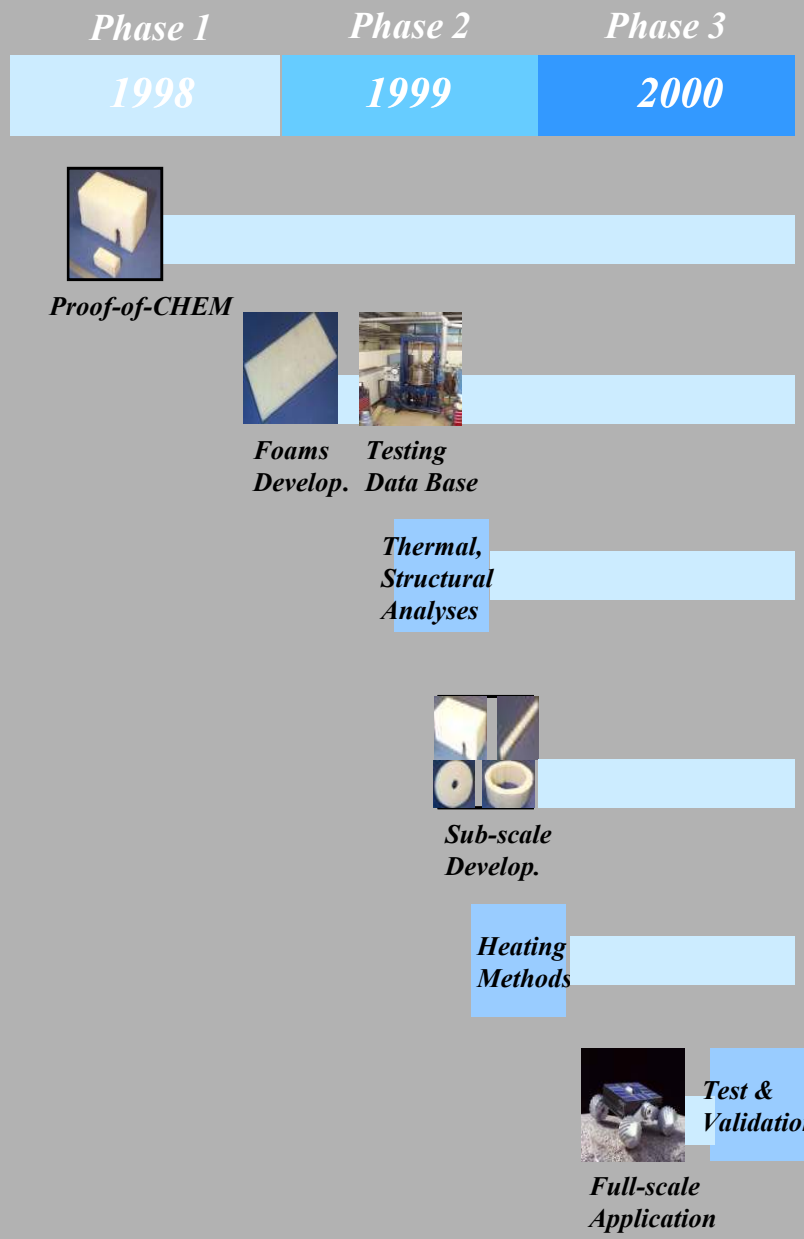
• *Tanks, Containers*

Thermos

• *Outdoor furniture*

CHEM Structures Development

• Roadmap



• Technology Team

JPL/NASA & MHI
+ Government/University/ Industry

• Objective

Develop & validate CHEM structure technology for space applications

• CHEM Program

FY '98 - Phase 1: Proof-of-Concept
FY '99 - Phase 2: Characterization & sub-scale development
FY '00 - Full-scale development & ground validation

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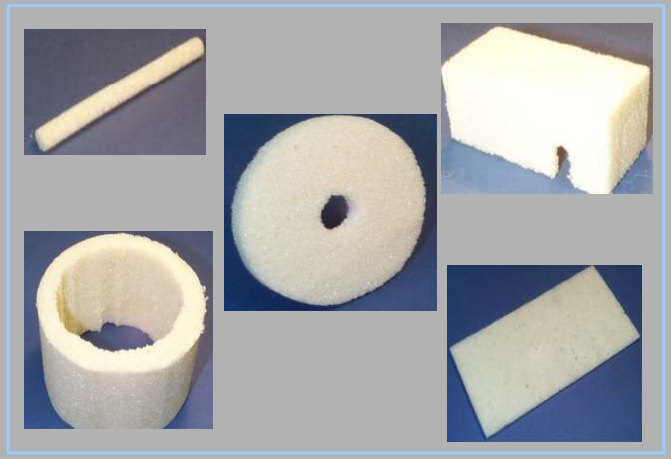
Proof-of-CHEM Concept

- ***Objective***

Build small models and demonstrate the basics of CHEM.



Properties	*M 5520*	*M-18G*
Density (g/cm^3)	*0.032*	*0.049*
Tg (^0C)	*63*	*-4*
E_g below Tg (MPa)	*2.69*	*7.44*
E_r above Tg (MPa)	*0.064*	*0.023*
E_G/E_r	*42*	*323*

- ***Results***

- High full/stowed volume ratios above Tg: up to 40.
- Long-term unconstrained stowage in hibernated state: over 1 year and continued.
- Deployment when heating above Tg.
- Precision shape restoration after long stowage.
- Rigidization of original shape when cooling below Tg.
- E modulus was increased 3 times by chopped fiber glass reinforcement

Summary

- *Experiments confirmed the feasibility of CHEM structures.*

- *CHEM structures will provide space and commercial users a revolutionary, next generation self-deployable light weight structure with high reliability, simplicity and low cost.*

- *Myriad CHEM applications are anticipated for space and terrestrial applications*