

Pumped Vapor Chambers
Liquid Systems Loop Heat Pipes

Integrated Thermal Solutions

Heat Pipes Radar Electronics Cooling

Military/Aerospace

Nano Scale Cooling Solutions
Wicks

Satellite Thermal Control

Energy Conversion

Computer CPU/GPU Cooling

Heat Exchangers Ammonia Heat Pipes

AS9100 ISO 9001 ISO 14001
ITAR Registered



Self Deploying Nitinol LHP Radiator for Small Spacecraft

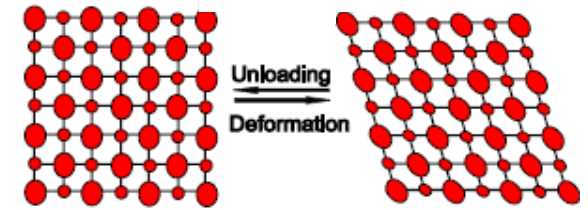
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Presented at
23rd Annual AIAA/USU Conference
on Small Satellites
August 11, 2009

Nitinol - Shape Memory Alloy

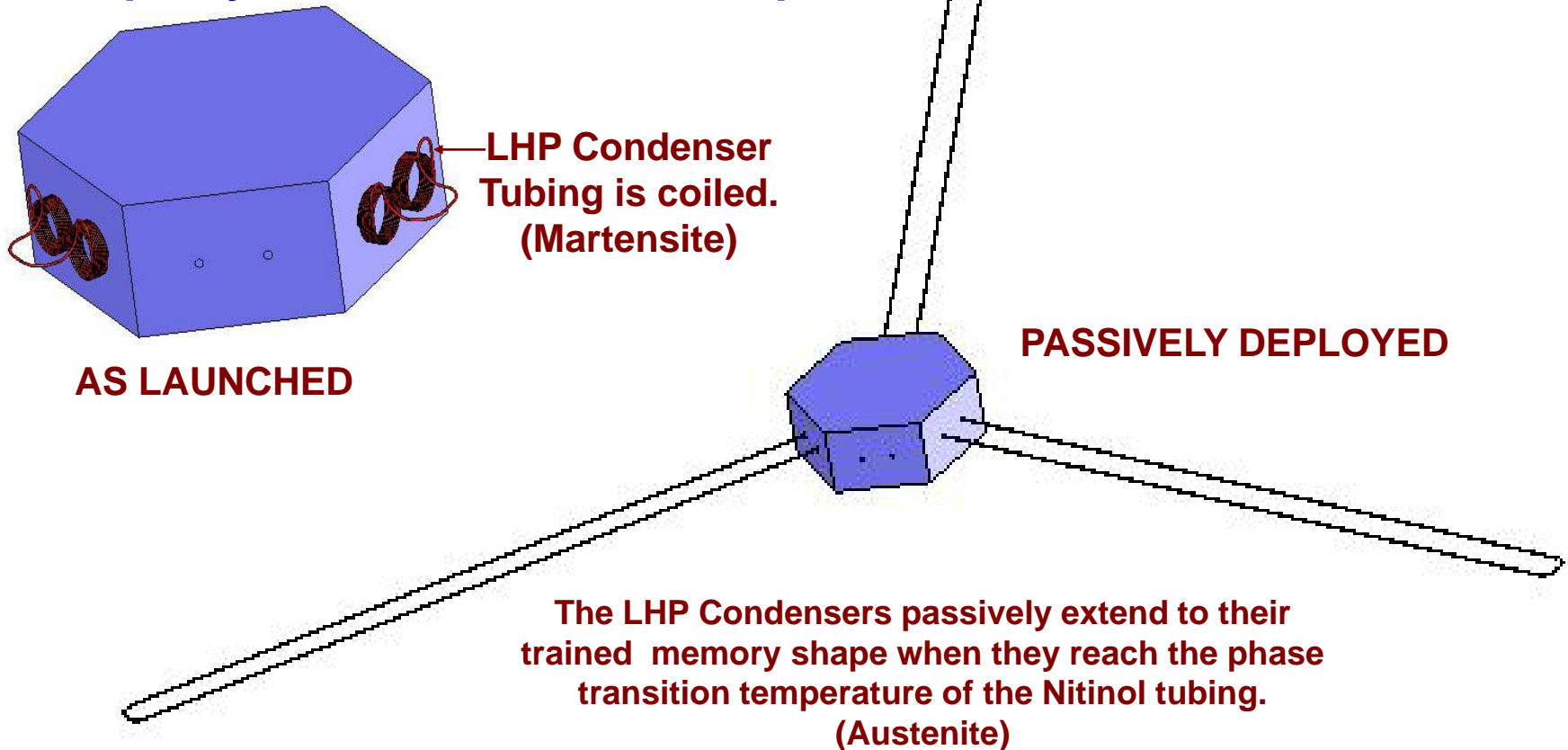
- Nickel Titanium Intermetallic Compound
 - Near Equi-Atomic (49.0-50.7 at% Ti)
- Low Temperature - Martensite
 - Twinned monoclinic structure
 - Very flexible - 8% elastic limit
- High Temperature - Austenite
 - Cubic B2 structure
- Shape Memory
 - Temperature or Stress



Memory-Metalle GmbH

Concept – Self Deploying

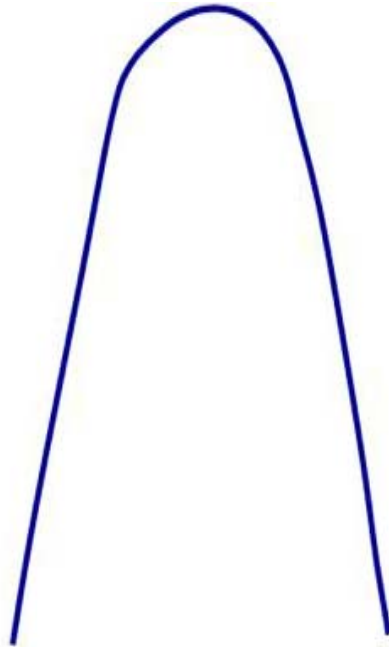
- LHP condenser tubing is Nitinol so it self deploys as it warms up.



Coiling Constraints

- LHP Ends are Constrained

Memory Shape



Roll it Up



Ends don't move

- $\text{Radius}_{\min} \approx 7 \times \text{Dia.}_{\text{tube}}$

Coiling

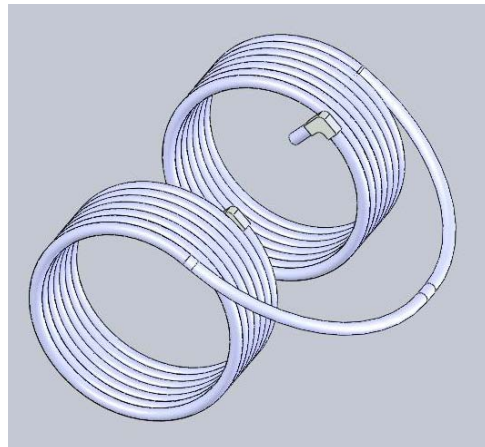
- Two Shapes were tried



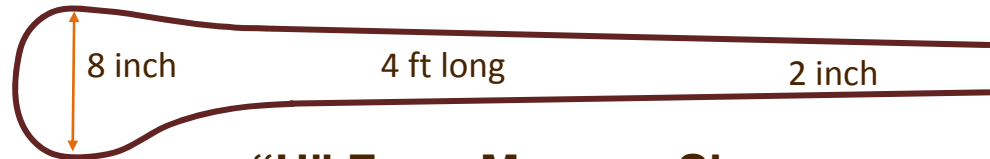
"V" Form Memory Shape



V Form Coil as Received



"U"-Form Nitinol Coil



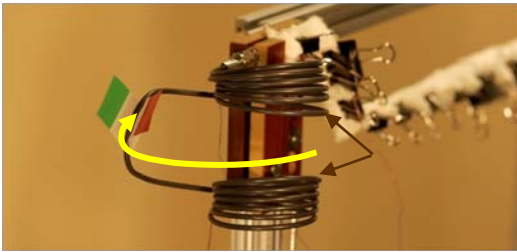
"U" Form Memory Shape

Deployment Tests

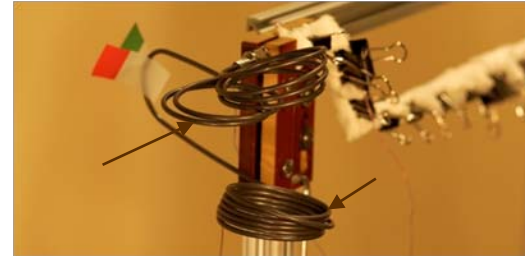
- Learn how SMA works when Heated by Internal Vapor Condensation
 - Water Loop Thermosyphon (LTS)
 - Safety while learning
 - Ammonia Loop Heat Pipe (LHP)
 - Proof of Concept
- Try Different Coil and Mechanical Arrangements

Deployment Tests

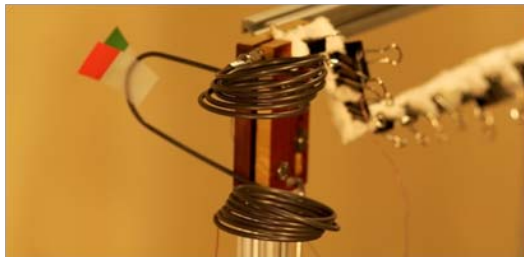
- First Test
 - Water LTS
 - Surface Mount



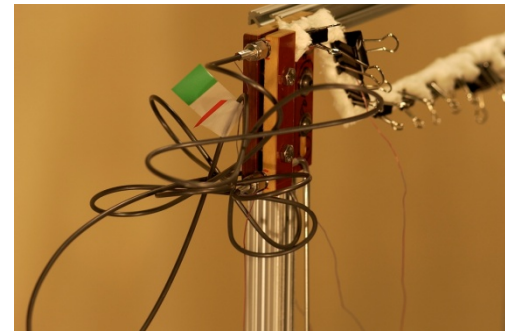
1. Center Curve Moves First



3. With ends constrained, upper coil moves in haphazard directions
Lower Coil has not reached transition temperature



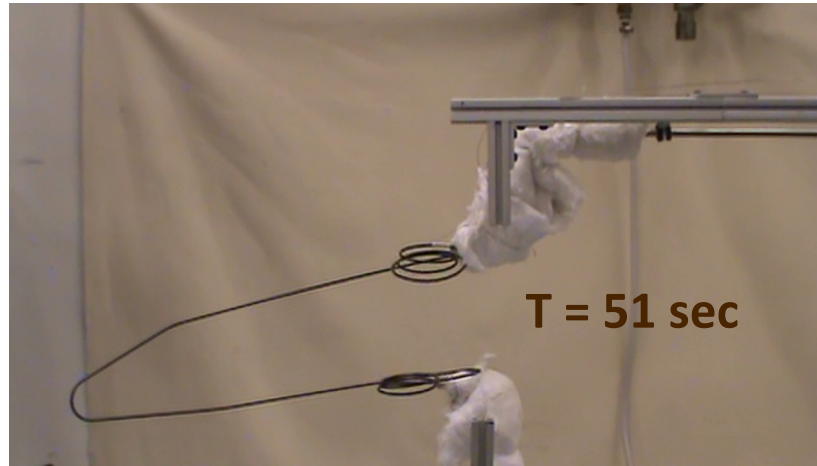
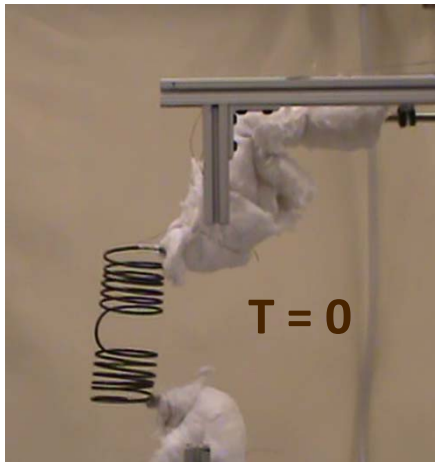
2. Center Curve runs into support
Upper Coil begins to change



4. Final Shape

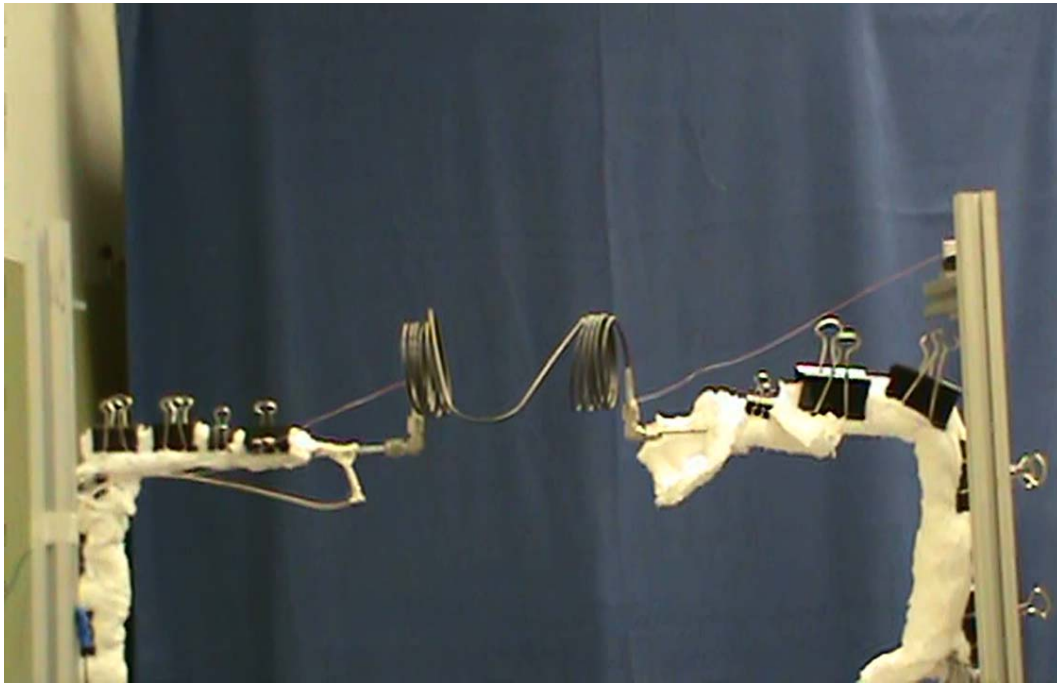
Deployment Tests

- Test of 6/4/09 (Rebuilt water LTS)

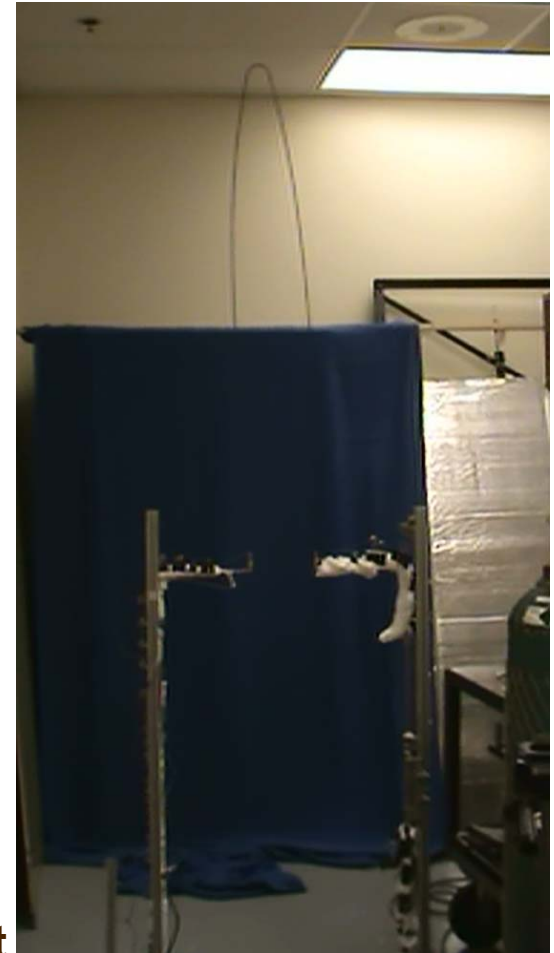


Deployment Tests

- Test of 6/22/09 (Ammonia Loop Heat Pipe)



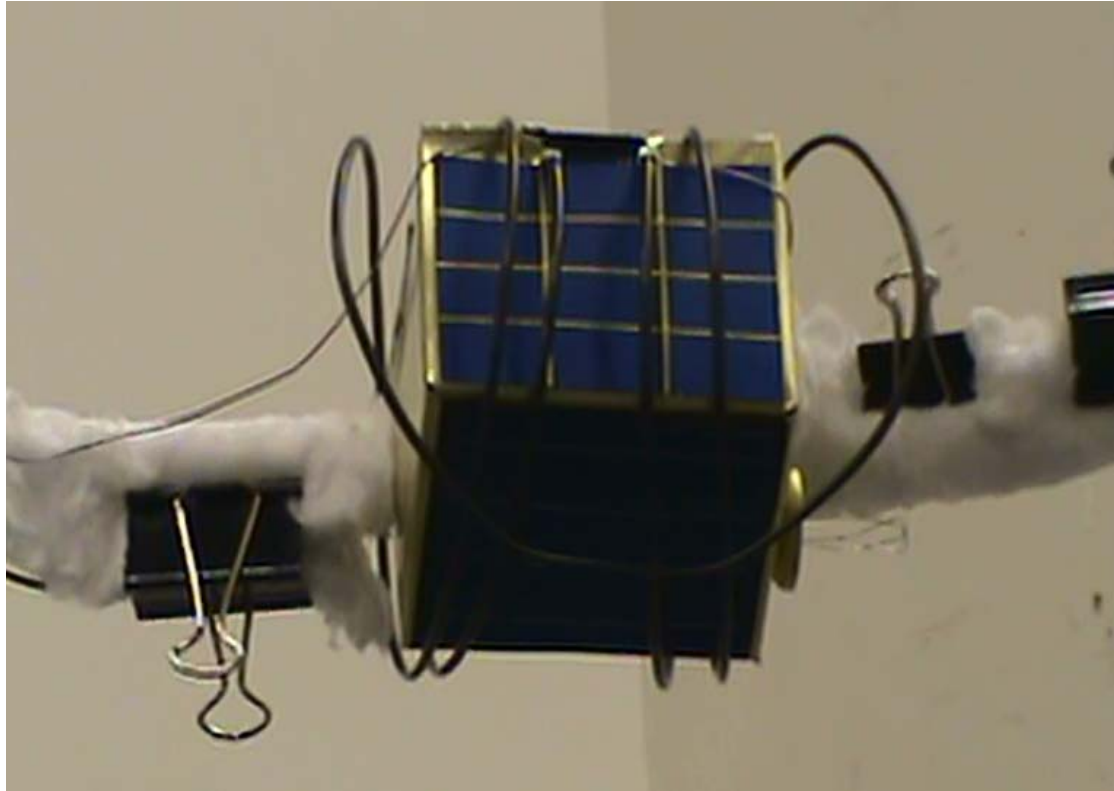
At start of Test



Full Deployment

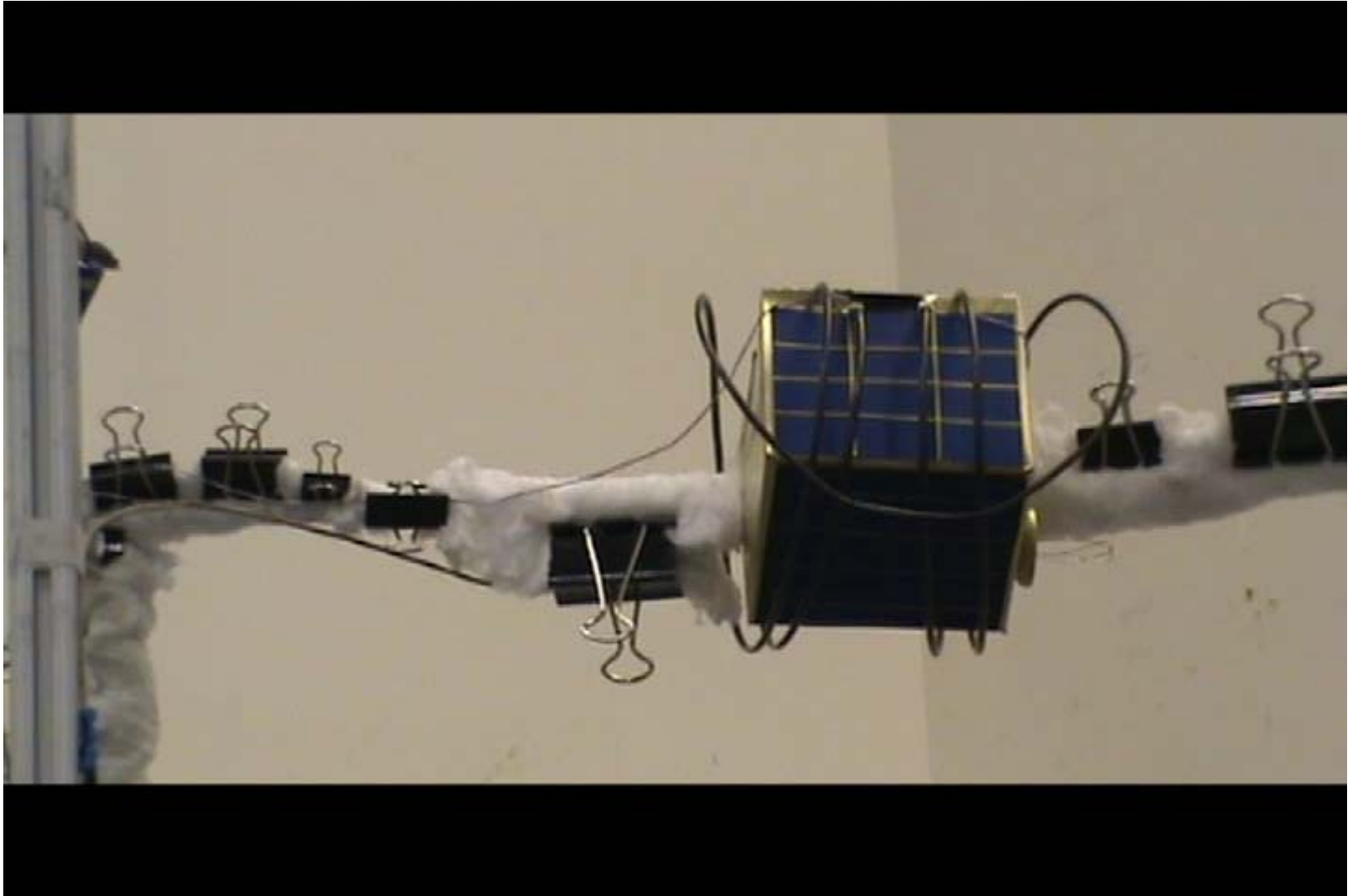
Deployment Tests

- Demonstration 7/7/09

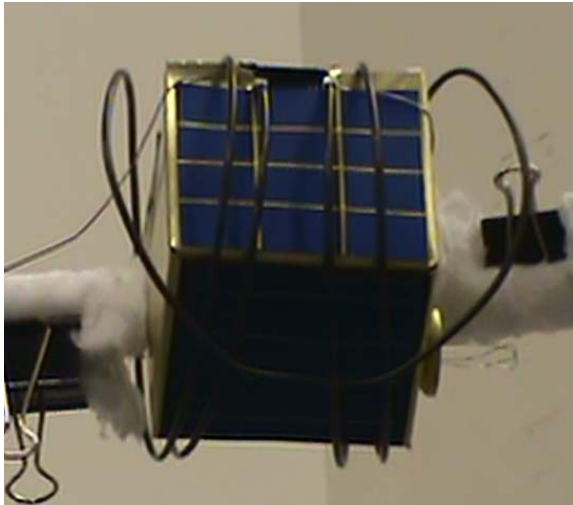


“U” Form Coil around AeroCube-Style Nanosat (4 inch cube)

Video



Conclusions



- Phase 1 Demonstrated Feasibility
- Need Mission Application for Phase 2