An Electrically Actuated Pin-Puller for Space Application using Nickel-Titanium Memory Alloy

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LionSat Program Objectives

Mission Statement

The LionSat mission will investigate the local ambient and perturbed plasma environments surrounding a small satellite in the Earth's ionosphere. LionSat will measure the ambient plasma environment and the satellite's ram and wake regions using a novel hybrid plasma probe instrument. LionSat will test a miniature RF ion thruster system that will augment the satellite spin, which is necessary for mapping the plasma environment surrounding the satellite.

Technology Demonstration

- LionSat will demonstrate the Hybrid Plasma Probe as a plasma diagnostic instrument.
- LionSat will also test *in situ* a miniature RF Ion Thruster as a satellite spin control device.

Science Mission Goals

Primary Objectives:

- P1. To map the ram and wake plasma structure surrounding a small satellite
- P2. To collect data on ionospheric plasma in a variety of geophysically interesting locations in low Earth orbit
- P3. To test, on orbit, a miniature RF ion thruster

Secondary Objective:

- S1. To test IP communications for uplink and downlink to a spacecraft in low Earth orbit

Spacecraft Technical Data

Dimensions

- **Diameter: 18.25 inches**
- **Length: 18.5 inches**
- **Shape: Octagon**

Mass Budget

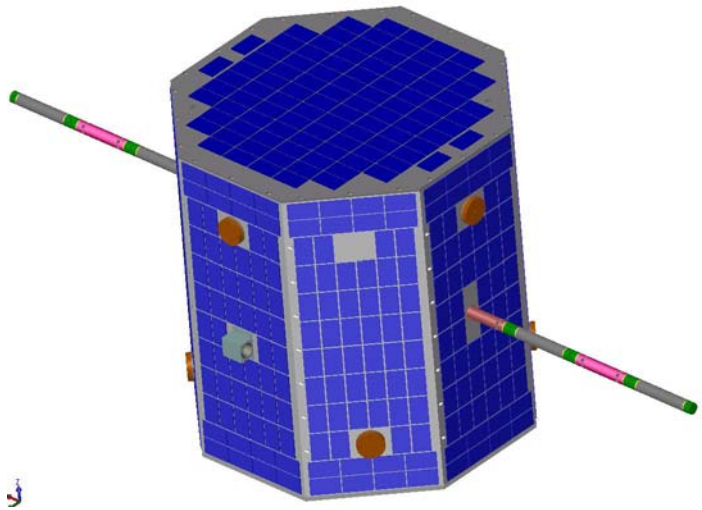
- **30 kg maximum**

Power Budget

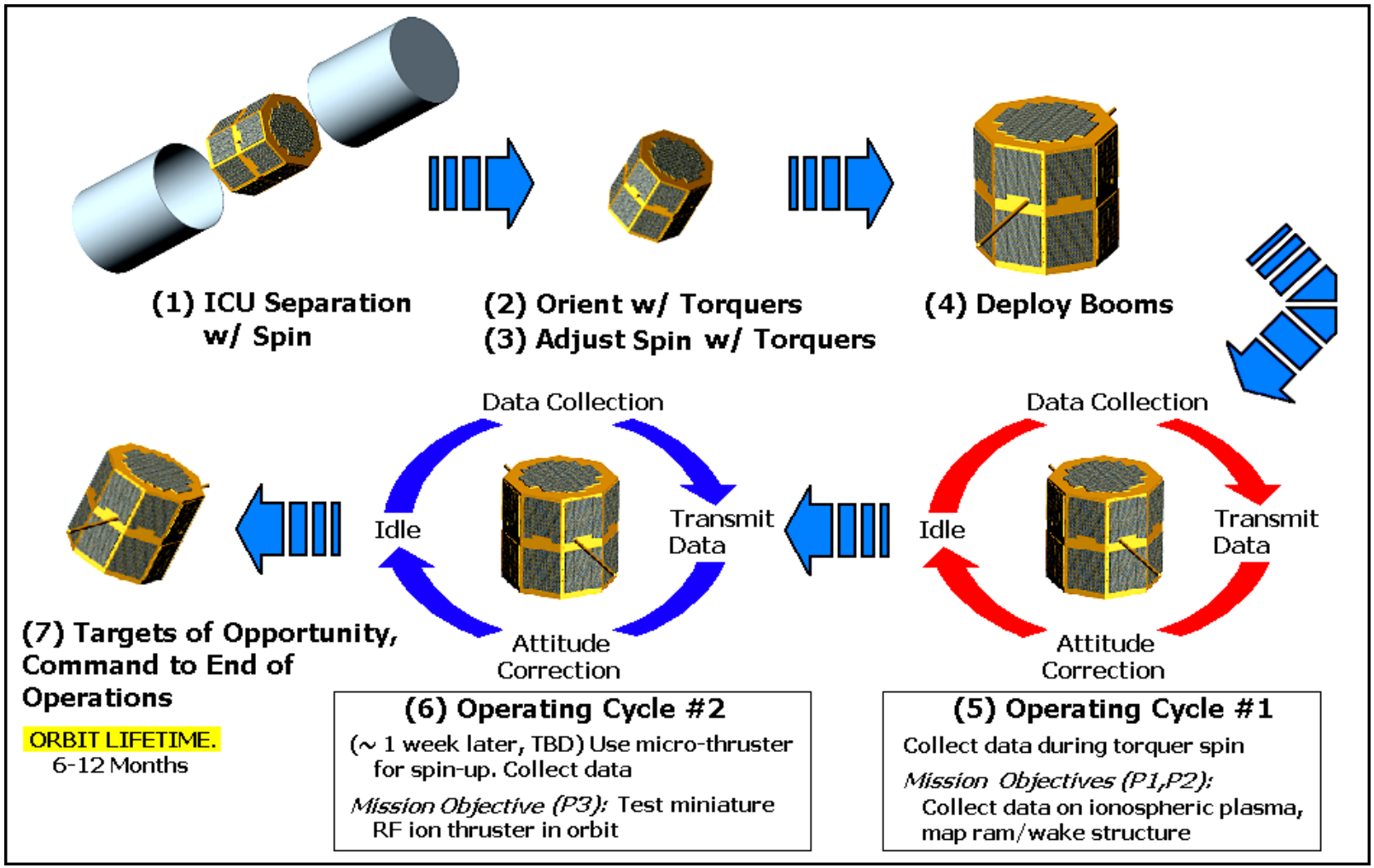
- **26.2 W**
- **12–20 V bus depending on load**

Cost

- **$100K from Air Force, “seed money”**

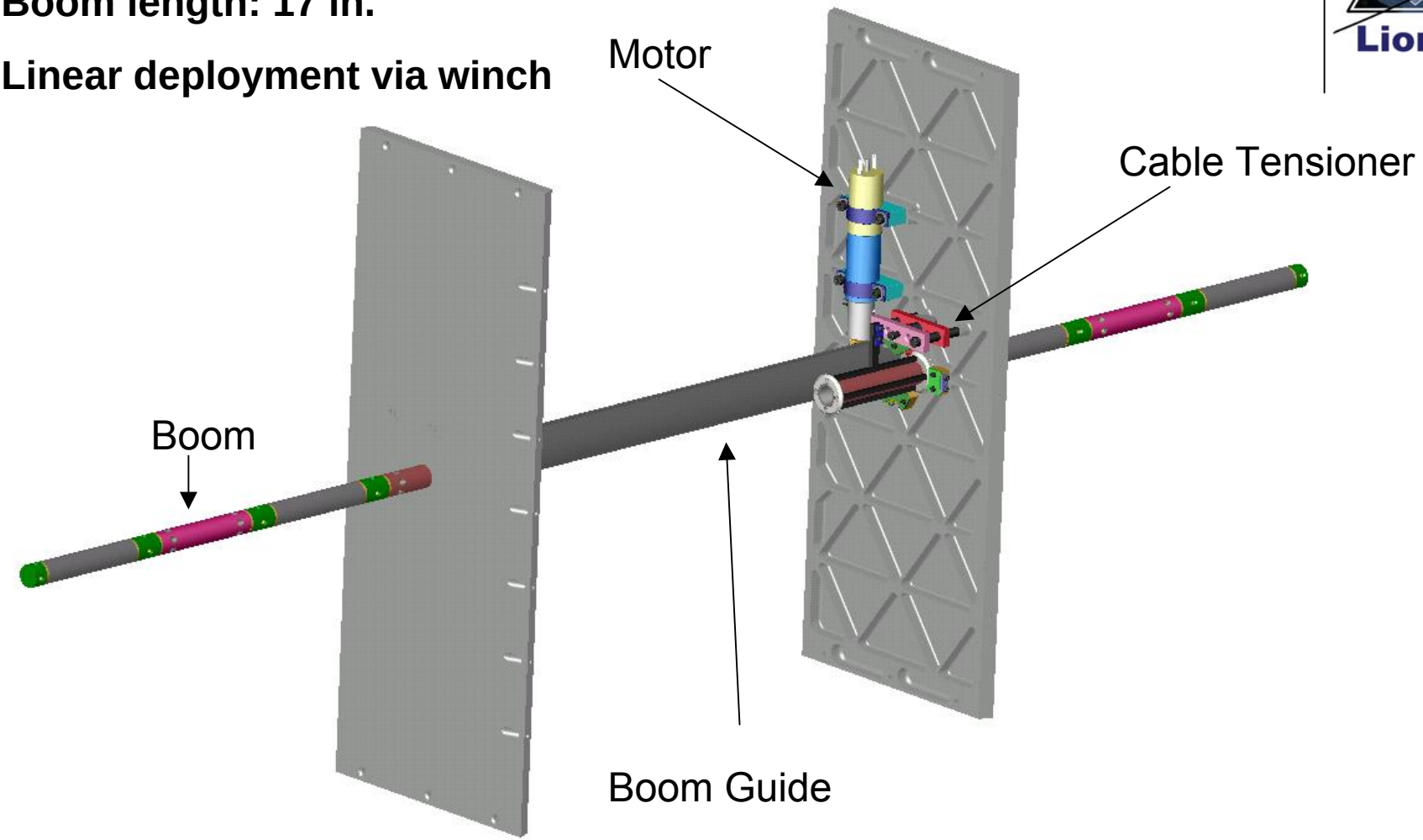


Mission Timeline



Hybrid Plasma Probes (HPP)

- **Boom length: 17 in.**
- **Linear deployment via winch**



HPP Inhibit Requirement

Requirement – **"Functions Resulting in Critical Hazards.** A function whose inadvertent operation could result in a critical hazard must be controlled by two independent inhibits, whenever the hazard potential exists." NSTS 1700.7B, section 201.2

Solution – a low cost, electrically actuated pin-puller that makes use of Nickel-Titanium (NiTi) memory alloy to be used as part of the boom deployment inhibit system.

Pin-Puller Criteria

- Low Mass - strict mass budget < 200 g
- Low Cost - COTS hardware where possible
- Reusable - must be able to cycle multiple times to reduce testing costs
- Remote Reset - not practical to disassemble satellite to reset device
- 12-V unregulated supply for operation, current draw ≤ 500 mA
- No magnetic parts
- No hazardous materials

Commercial Possibilities

- None could be found that meet all the criteria

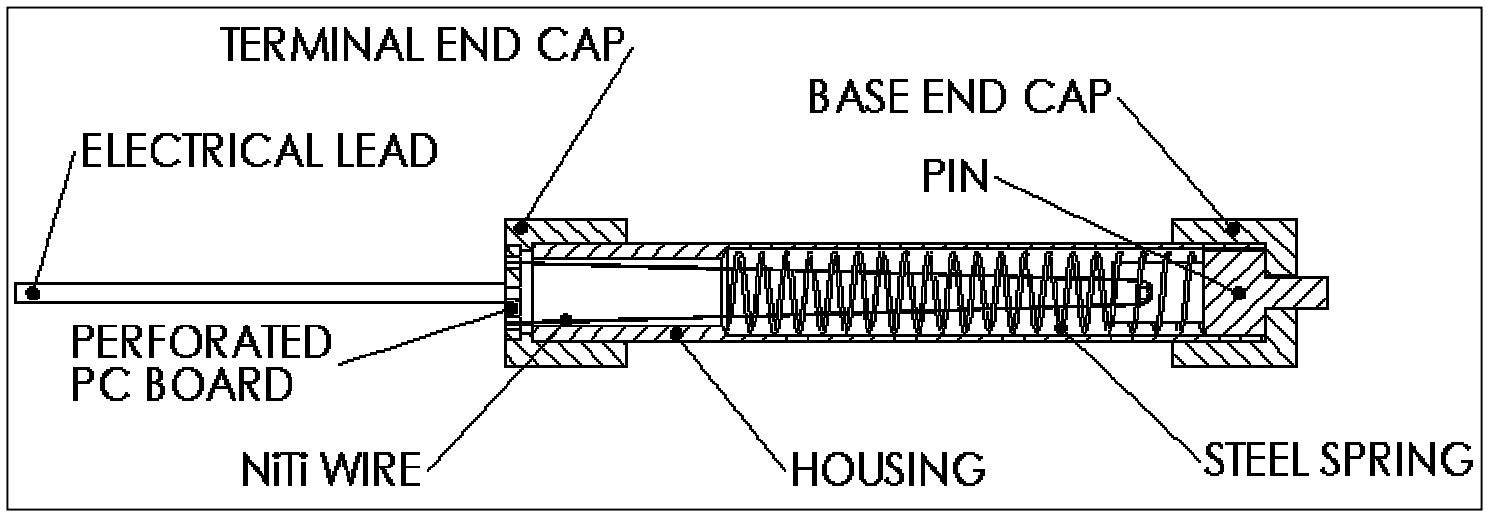
Pin-Puller Requirements	Technology		
	Pyrotechnic	Paraffin	Solenoid
Reusable		●	●
Remotely Resettable			●
Low Power Consumption	●	●	
Low Cost	●		
Low Mass	●	●	●
Non-Hazardous		●	●
Non-Magnetic	●	●	
Compact	●	●	●

NiTi Pin-Puller Design

- Low force linear actuator using NiTi shape memory alloy
- Low power
- Automatically resettable
- Reusable
- Nonmagnetic
- Nonhazardous
- Light weight
- Inexpensive

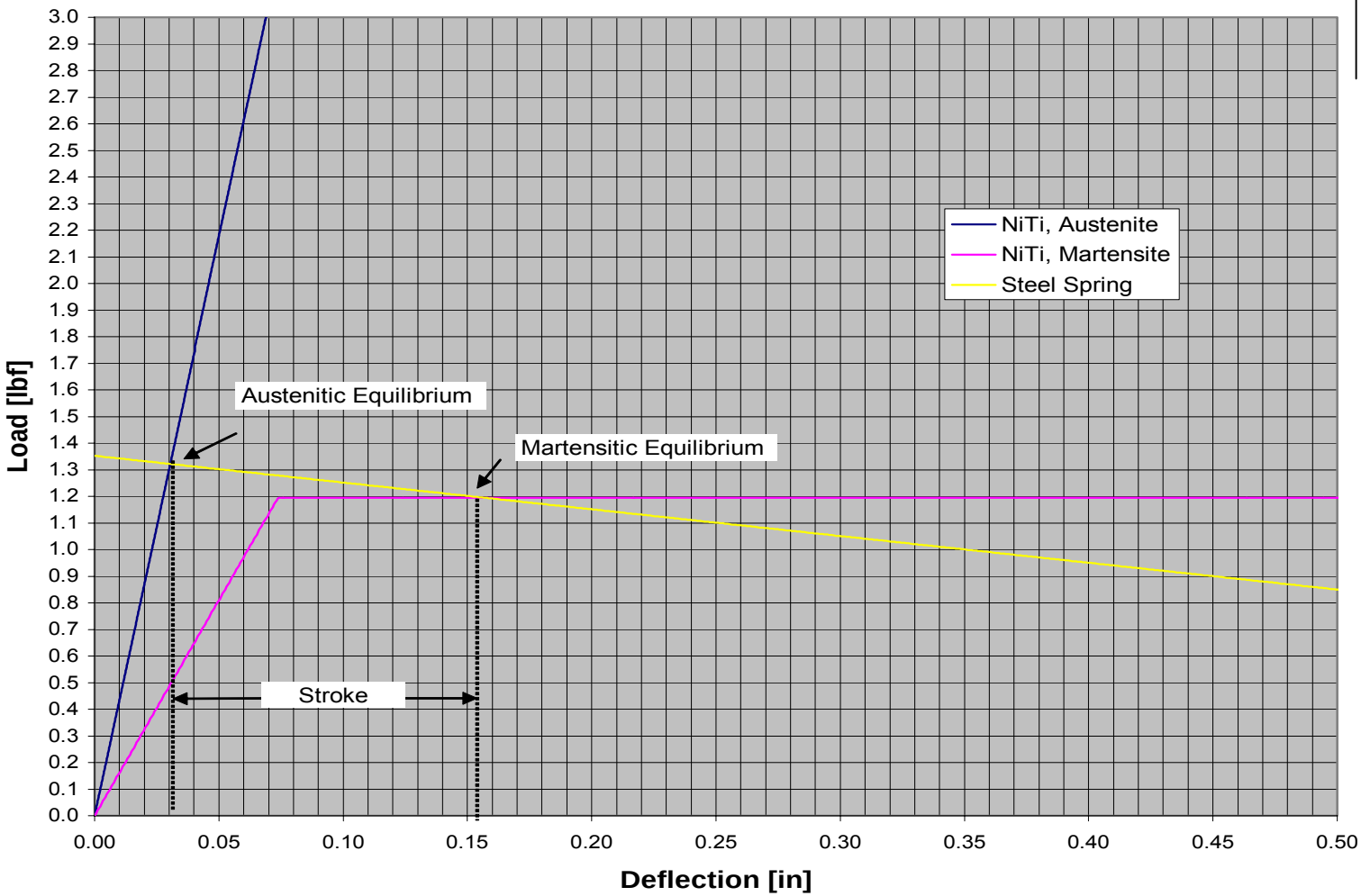
NiTi Pin-Puller Design Issues

- Anodized aluminum construction provides electrical insulation for NiTi wire
- Ø 0.004" NiTi shape memory alloy actuator provides the required displacements and forces
- Steel bias/reset spring keeps the pin engaged at >75 g acceleration
- Capacitive discharge circuit reduces the requirements on the power system
- 25 g mass (not including electronics)
- 0.125" stroke ensures pin is engaged
- 3.5" overall length
- 0.5" largest diameter



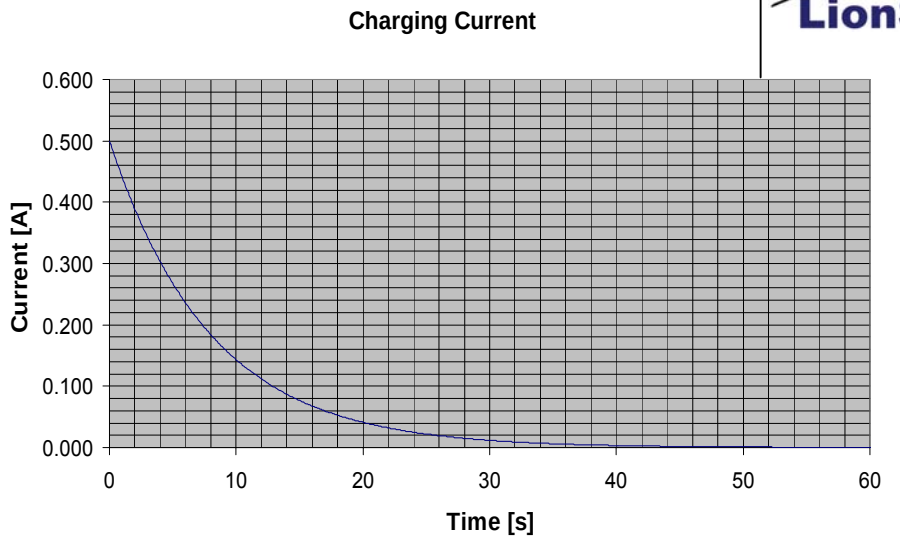
NiTi Mechanical Response

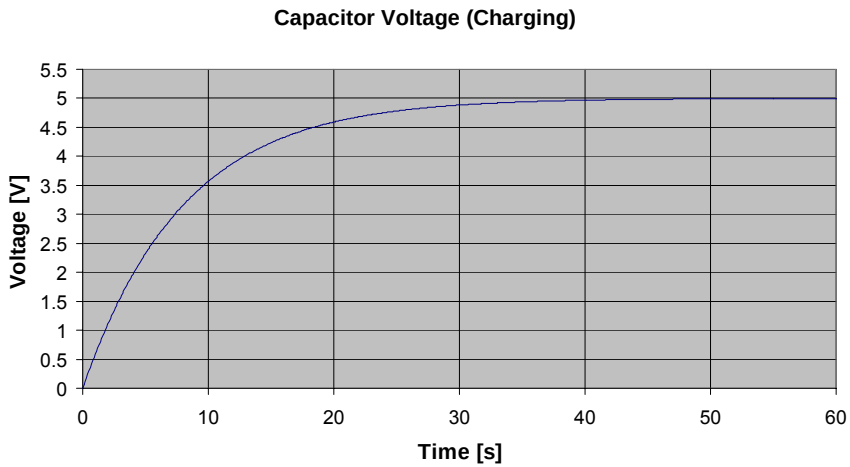
Mechanical Response of Ø0.004” NiTi Actuator Wire with Steel Bias Spring



NiTi Pin-Puller Charging Circuit Design Issues

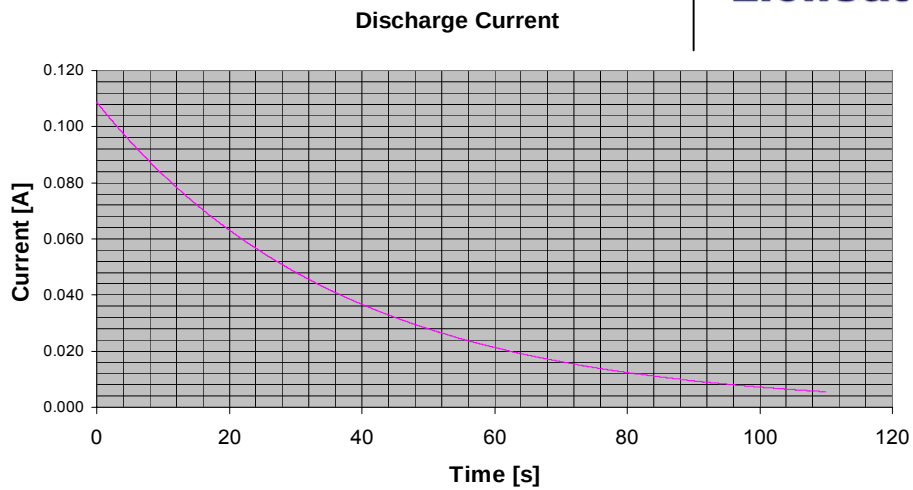
- 500-mA peak current draw at 5 V
- Capacitor is fully charged in <60 s
- 0.8-F capacitor chosen for energy capacity/favorable discharge time constant
- 10-Ω resistor in series with capacitor
  - reduces peak current draw without dropping excessive power

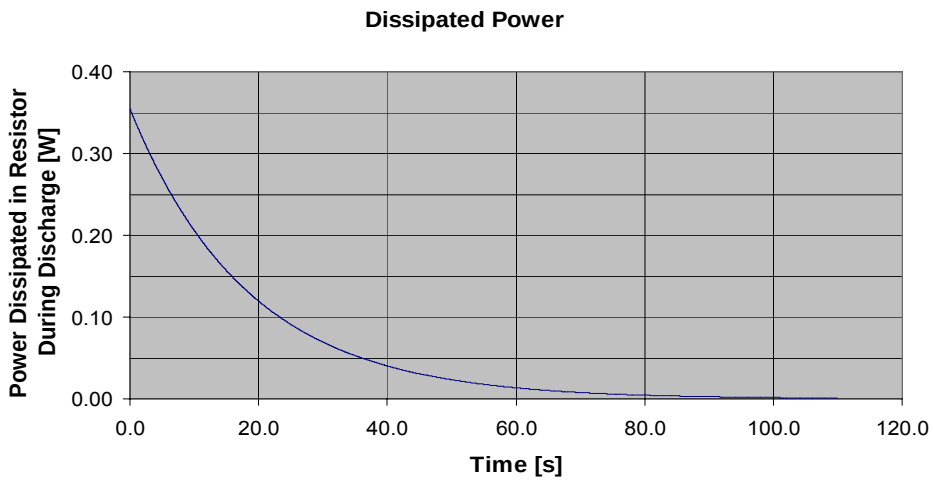




NiTi Pin-Puller Capacitive Discharge Circuit Design Issues

- 30-Ω power resistor in series with capacitor to achieve time constant
  - 0.35-W maximum power dissipation in resistor
- NiTi wire transitions from -55°C to 90°C in 38 s, holds above 90°C for minutes
- Discharge controlled by the flight computer
  - Allows precise coordination of components in the deployment system





NiTi Pin-Puller Status

Work Completed

- NiTi wire obtained for experimentation
- Alpha prototype designed and fabricated
  - Testing showed initial bias spring was too stiff and NiTi wire failed mechanically
- Steel spring selected for LionSat application
- Equipment developed for conditioning of NiTi wires
- Beta prototype designed
- Beta prototype fabricated

Testing Regimen

- Apply 200 mA to NiTi wire at 5% strain with bench supply
- Test pin-puller with capacitive discharge circuit
- Test pin-puller in thermal vacuum

Conclusion

- Inexpensive pin puller designed for LionSat mission
- Meets all LionSat requirements and NS-3 safety requirements
- Simple design should be applicable to other nanosat missions