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

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Abstract: The Local Ionospheric Measurements Satellite (LionSat) is an ionospheric investigation nanosatellite that is being developed by an interdisciplinary team of students at The Pennsylvania State University. As part of its primary science mission, the satellite will be used to examine the plasma environment surrounding it via a set of plasma probes. These probes extend linearly on booms from the midsection of the satellite and must remain in a stowed, locked position during launch. This paper discusses the design and fabrication of an electrically actuated pin-puller used to secure the booms in the spacecraft that makes use of Nickel–Titanium (NiTi) memory alloy. The pin-puller design should be of particular interest to other low-cost small satellites.

1 Introduction

The Local Ionospheric Measurements Satellite (LionSat) is being developed as a student satellite under the Nanosat-3 (NS-3) program sponsored by the American Institute of Aeronautics and Astronautics (AIAA), the National Aeronautics and Space Administration Goddard Space Flight Center (NASA GSFC), the Air Force Office of Scientific Research (AFOSR), and the Air Force Research Laboratory Space Vehicles Directorate (AFRL/VS). The baseline launch vehicle for all Nanosat-3 participants will be the space shuttle; therefore, all participants must build their spacecraft to comply with the various safety and engineering standards for shuttle payloads. In our case—i.e., a deployment system resulting in spacecraft materials being released or extended beyond the spacecraft physical envelope)—a two-plus-one failure of the system inhibits must be tolerable without endangering the orbiter [1].

Part of the primary science mission for LionSat involves taking measurements of the plasma environment surrounding the spacecraft using two plasma sensors integrated into each of two deployable booms. The booms are rigid and deploy linearly from the "belly band" of the spacecraft to meet the science requirements. During launch, the booms are stored in parallel within the midsection of the spacecraft. Once on orbit, the flight computer deploys the booms using a winch system. Figure 1 shows the satellite with the booms in the deployed configuration.

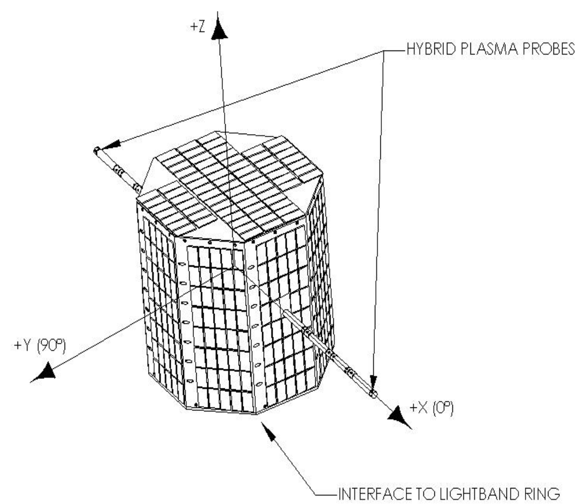

Figure 1 LionSat with booms extended

To ensure that the boom-deployment system complies with safety requirements, a locking mechanism had to be developed to keep the booms contained within the spacecraft during the severe vibrations that occur during launch. We determined that the best method for meeting this requirement was to use a pin-puller system that could be actuated by the flight computer and that could be easily reset without direct access to the system during ground testing. Several commercial systems were evaluated but were found to be infeasible due to high cost or power consumption. This forced the team into designing and fabricating a custom pin-puller that would be inexpensive and have low power consumption. The resulting design discussed in this paper takes advantage of the memory properties of Nickel–Titanium (NiTi) alloys to accomplish the mechanical action of moving a pin against a spring that can be used to secure the LionSat booms from undesired deployment.

2 Motivation for Custom Pin-Puller Development

2.1 Requirements

To design a small satellite on a strict mass budget with limited funding requires optimizing the designs of included systems in these two areas. To this end, a list of qualitative requirements was created to guide in the selection or design of a pin-puller for the purpose of retaining the plasma probe booms while the satellite is in the Internal Cargo Unit (ICU) of the Space Shuttle or similar launch vehicle.

The LionSat team determined that reusability of the pin-puller is critical in order to keep the cost of testing programs at a reasonable level. The device must be able to survive several dozen cycles without maintenance. In addition, another primary requirement is the ability of the pin-puller to be reset remotely during flight qualification of LionSat. Due to the small size of the satellite, components will occupy both inside and outside surfaces of the primary structure. It was decided that disassembling the spacecraft to reset the pin-pullers is to be avoided if at all possible.

LionSat has been designed to operate on a 12-V unregulated power system capable of producing a maximum power of 26.2 W. The pin-puller must be able to operate within these power constraints with as few modifications as possible to keep system complexity and mass to a minimum.

2.2 Existing Technology

Several pin-pullers already exist on the market that might be appropriate for use on LionSat. None of these technologies, however, are able to meet all of the design requirements for the retention of the booms used as part of the Hybrid Plasma Probe (HPP) experiment (more info on the HPP system may be found in an M.S. thesis by Rob Seigel, *Design of a Hybrid Probe System*, 2004.). Table 1 describes how three common technologies fail to meet all of the requirements for this mission.

Pyrotechnic devices have extensive flight history on spacecraft but have several characteristics that make them less than ideal for use on LionSat. In addition to requiring a replacement gas generator for each firing, a pyrotechnically actuated device must be installed by a trained technician, and increased safety procedures must be followed when handling and processing the satellite once the device has been installed.

Table 1 Current technologies and their ability to meet design requirements

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

Paraffin pin-pullers require a manual reset of the pin due to the nature of their design, but this also offers the added functionality of effectively latching in the open position without additional power requirements.

Many solenoid devices require a higher voltage than LionSat’s battery pack (i.e., unregulated power) is capable of producing, and a dedicated electronics support subsystem would be required to power either a standard or latching solenoid device. This would add additional mass and increased power consumption, and would also occupy valuable space in the interior of the satellite.

There are existing “smart material” pin-pullers and linear actuators available, but the high cost of these devices makes them impossible to use on LionSat without exceeding the current level of funding.

It is due to the inability of available technologies to meet LionSat’s requirements that development began an alternative design for a remotely resettable pin-puller device.

3 Shape Memory Alloys

3.1 Overview

Shape Memory Alloys (SMAs) are gaining in popularity among mechanism designers due to their superelasticity and remarkable ability to remember a trained shape. The two primary SMAs to gain commercial success are NiTi and copper-base alloys. While each type comes in many perturbations and are doped with different levels of trace metals to modify performance, in general NiTi alloys are capable of being strained to a greater degree and are more thermally stable than copper-base alloys. Copper-base alloys are less expensive and more ductile than NiTi alloys [2]. This paper focuses on the development of a pin-puller using NiTi SMA due to its large strain recovery potential and its higher resistivity compared to copper-base SMAs.

When nickel and titanium are combined in an equiatomic alloy, the resulting product has mechanical properties that are dependent on temperature. The exact temperature dependence of the material depends on many aspects, including the exact ratio of nickel to titanium [2]; the annealing temperature and post-processing mechanical treatments [3]; and the number of strain/recovery cycles the specimen has already undergone [4].

The temperature dependence can be attributed to the shift in the crystalline structure of the alloy from martensite at low temperatures to austenite at high temperatures. The microstructure of NiTi SMAs allows a high degree of freedom to exist in the metal, providing a non-linear and complex mechanical response [3]. The specific metallurgical processes are beyond the scope of this document and will not be discussed in further detail. The reader is referred to Ref. [3] for more information.

3.2 Strain Recovery

In their martensitic phase, memory alloys may be plastically deformed to leave permanent strain and internal stresses in the metal. The strain can later be recovered by raising the temperature of the alloy and causing the austenitic phase to express itself. Due to the stability of this process, stress–strain curves can be created for both the low temperature (martensitic) and high temperature (austenitic) phases to predict the behavior of the SMA.

Figure 2 shows that the path of the stress–strain curve is dependent on whether the specimen is being heated to the austenitic phase from the martensitic or *vice versa*. This process is normally known as hysteresis because the load paths are not identical. This type of hysteresis is expected and predictable by finite element techniques and a deeper study of the microstructure of the memory metal [7] and is not cause for concern. Note that each path has a "plateau" region where very small changes in stress yield very large changes in strain. This is the region of the curve that allows the properties of NiTi shape memory alloy to be exploited.

Another type of hysteresis occurs when the loading and strain recovery steps are repeated, and slight changes to the values that define the plateaus occur. This type of hysteresis is a concern, but studies have shown that the strain/recovery process becomes more

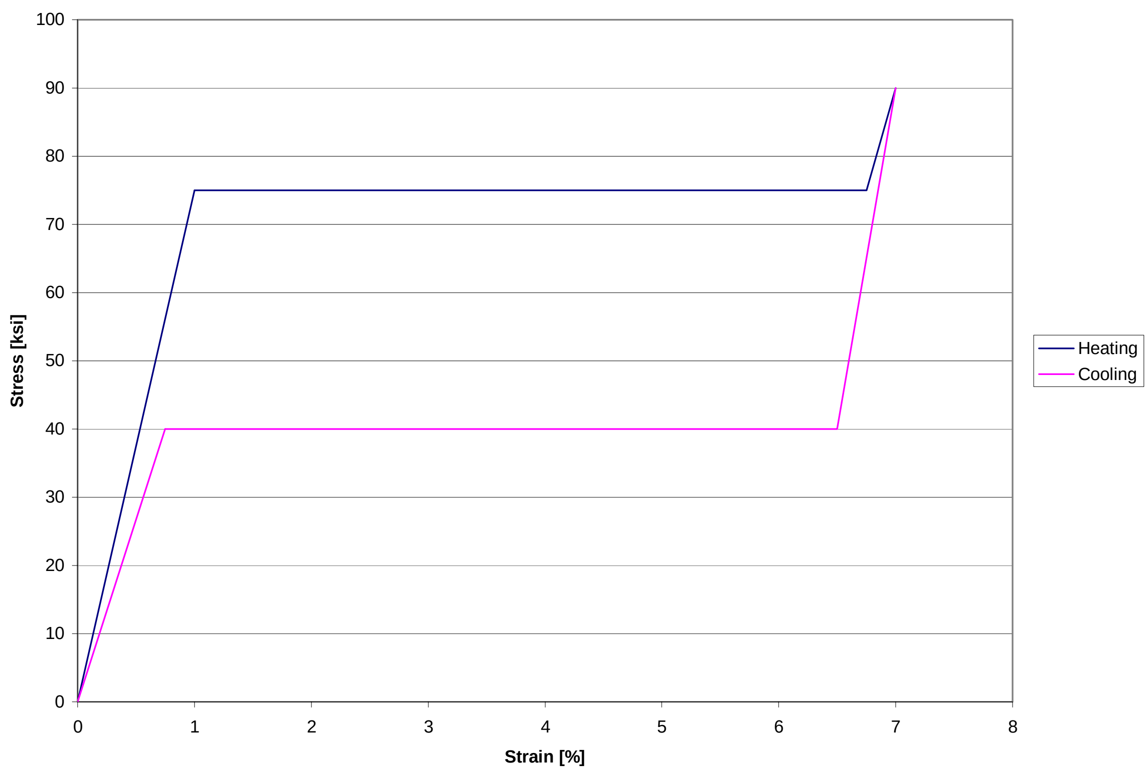

Figure 2 Approximate stress-vs.-strain curve for NiTi shape memory alloy

stable as the number of loading and strain recovery cycles on a particular specimen is increased [4, 5, 6], and changes to the loading plateaus after 20–30 cycles are negligible.

3.3 Strain Limits

The elongation before breaking of NiTi is dependent on the forming and thermo-mechanical treatment of the metal. The finished shape memory alloy must undergo a series of cold working and annealing treatments before its full potential is reached. Johnson Matthey is a leading producer of NiTi SMA products and lists the following as NiTi treatment conditions: cold worked, straight annealed, flat annealed, shape set annealed, prestrained, and hot worked. The cold worked condition of NiTi has not been heat treated and has an elongation at failure of ~7%. The same material in its fully annealed state has an elongation at failure of ~15%. These numbers vary depending on the exact alloy type, but all show the same trend between cold worked and fully annealed conditions. The term "straight" applies to wires that have been annealed without bends, and "flat" refers to sheets that have been annealed without ripples.

Among fully annealed NiTi elements, a design strain of 4–8% can be fully recovered without a large irreversible permanent deformation. It should be noted that a small residual strain may occur that cannot be recovered; residual strains are on the order of 0.25% and are not cumulative for repeated extension to the design strain [4].

3.4 Loading Method

To determine the most effective way of straining the shape memory alloy, several loading methods were considered: bending, compression, and tension.

Using the SMA as a cantilever or straining the member through bending produces an uneven stress distribution through the cross section of the beam. According to classical beam theory, one surface undergoes compression, one surface undergoes tension, and the stress along the neutral axis of the beam is zero. This method is capable of producing the maximum design strain of 5% along the top and bottom surfaces of the cantilever, but the interior cross section of the beam is under-strained, leading to a decrease in the efficiency when using this loading method.

Experimentation has shown that NiTi behaves differently in compression and tension, and that loading NiTi in tension is more energy efficient than loading NiTi in compression [8].

3.5 Geometry

NiTi shape memory alloy is commercially available in rods, ribbons, sheets, and wires. The pin-puller is a linear actuator, so films are quickly eliminated as a choice. Rods and ribbons are expensive, and have a large cross-sectional area that requires a large force to strain them. Due to the low force required to remove the pin, both of these shapes were also eliminated. Wires come in many varying diameters, are relatively low in cost, are small size, and are highly versatile.

Wires and ribbon have the added possibility of being wound into springs that maintain the shape-memory characteristics of NiTi. Springs are generally produced on a lathe or spring winding machine from cold worked NiTi material and then annealed either on their mandrel or free form in an oven. Although Penn State has facilities to produce springs such as these, the complexity and low repeatability of small batches of custom springs both argue against producing a custom NiTi spring for the LionSat pin-puller. Additionally, when the strain recovery phase occurs in a NiTi spring, the diameter of the spring can increase up to 25%. Since this deformation occurs along a different line than the applied tension load, there is a decrease in efficiency in this design. An increasing diameter means that the housing would also have to be designed with dimensions large enough to accommodate the spring in its austenite phase, which increases the total volume of the system.

4 Design of LionSat Pin-Puller

4.1 Selection of Materials

For the reasons discussed above in Section 3, the pin-puller design utilizes a fully straight, annealed NiTi wire to be loaded in tension at a strain of 5%. Straining the wire to 5% places the load case near the center of the loading plateau, but is still large enough to produce an appreciable change in length from the short length of NiTi wire.

Several options exist for the design of the reset device including a NiTi or steel spring in tension, a nested NiTi or steel spring in compression, a sealed pneumatic piston, a solenoid, or even an electric motor. The most predictable, lowest power usage, and most versatile method is to use a nested steel spring in compression.

To eliminate potential magnetic interference between the pin-puller and either the magnetometers, magnetic torque rods, or the Hybrid Plasma Probe experiment, a non-magnetic material must be chosen for the housing and major structural parts of the device. Due to its high machinability, extensive flight history, and commercial availability, 6061–T651 aluminum alloy was chosen to comprise the remaining sections of the device.

4.2 *Heating the NiTi Shape Memory Alloy*

The NiTi wires must be heated in order to produce the phase change from martensite to austenite, and there are three effective ways to institute this temperature change on orbit.

The first is to select a NiTi alloy with a transition temperature above room temperature but lower than the maximum expected stable temperature that the spacecraft will experience during launch or while in orbit. In this case, the heat of the spacecraft could be channeled to the device by means of a physical thermal path and would thus actuate the pin-puller passively. This method relies on accurate orbital modeling and thermal profiling of each component of the satellite. Since the exact orbit of our spacecraft is still unknown at this point, and the satellite has not been completed and tested to verify its thermal characteristics, designing a device that relies on this method is risky and very difficult to justify.

The second method is similar to the first, but rather than using the heat of the satellite, the entire device is heated by powering an active heating element. This method indirectly heats the NiTi wire through conduction to the housing and absorbing the thermal energy radiated from the inside of the housing. The efficiency of this method is low, because the entire device must be heated to the transition temperature to produce actuation. Since the NiTi wire represents a small fraction of the total thermal mass of the device, this method is extremely inefficient. Sealing the device with a fluid to assist in heat transfer is possible, but also presents significant challenges. There are no students working on the LionSat project with expertise in dynamic vacuum seals, and so sealing the device has been eliminated as a possibility. Sealed devices also represent an additional safety hazard.

The final method is to direct heat the NiTi wire by passing an electrical current through it. The resistance of the wire causes power to be dissipated in it, and the temperature rises as a function of the dissipated power. This "resistance" method requires that the wires be electrically isolated from other components that are connected to the power system's ground reference. The entire spacecraft's primary structure is grounded to the battery due to spacecraft charging concerns, and several sections of the hybrid plasma booms are grounded to assist in accurate data gathering. This requires the use of the resistance heating method, which requires that the wire be electrically isolated from the device, since the pin will contact a component that is grounded. Isolating the wire from the device also removes the possibility that current can flow through the housing and bypass the NiTi wire. This can be accomplished by anodizing the inside of the aluminum housing and attaching the NiTi wires to isolated electrical contacts. Anodizing produces an electrically non-conductive layer of oxides on the aluminum whose thickness can be controlled accurately to ensure the proper mating of parts. Anodizing produces no volatile compounds to be permanently deposited on the material, so it does not affect the outgassing properties of the aluminum.

The specific voltage and power requirements of direct resistance heating for the NiTi wire are discussed in greater detail below in Section 5.

4.3 *Pin Size and Required Linear Motion*

A reasonable design goal for the pin-puller is to have a 0.125″ diameter pin extend 0.125″ into a mate. When actuated, the pin would retract into the pin-puller completely for long enough duration to allow the winch system to deploy the booms.

The actual size of the pin and length of the pull are to be determined at a later point when several configurations are tested. Therefore, the design must allow for multiple configurations without significant redesign. To ensure that vibration is incapable of forcing the pin to retract during launch, the mass of the pin must be less than or equal to the force of the reset spring divided by 73.54 g. This requirement comes from the ICU User's Guide, which states that the device must not fail upon static loading of 20 g in three perpendicular directions simultaneously [1]. Since retraction of the pin would cause the device to fail, the ultimate load factor of safety of 2.6 is used, bringing the total potential static proof load to be 73.54 g. This value comes from the largest resultant of three 20-g loads multiplied by the ultimate load factor of safety.

4.4 *Wire Size and Length*

With the many parameters involved in this design, it is difficult to approach the problem analytically along one path to arrive at a solution. To reduce the unknown parameters and aid in the quantitative design of the device, a commercially available 0.004″ diameter NiTi shape memory alloy wire was chosen as the actuator. This particular wire was chosen because it has good resistance (~3 Ω/in) but is still large enough to work with without specialty tooling. A length of 3.15 inches was selected to provide 0.1575 inches of length change

Table 2 Selected properties of equiatomic NiTi

	Martensite	Austenite
Young's Modulus [ksi]	4,060	10,900
σ_y [ksi]	14.5	81.2
σ_u [ksi]	109	109
Density [g/cm^3]	6.45	
Resistivity [μΩ/cm]	~70	~100
Latent Heat of Transition [cal/g]	5.78	

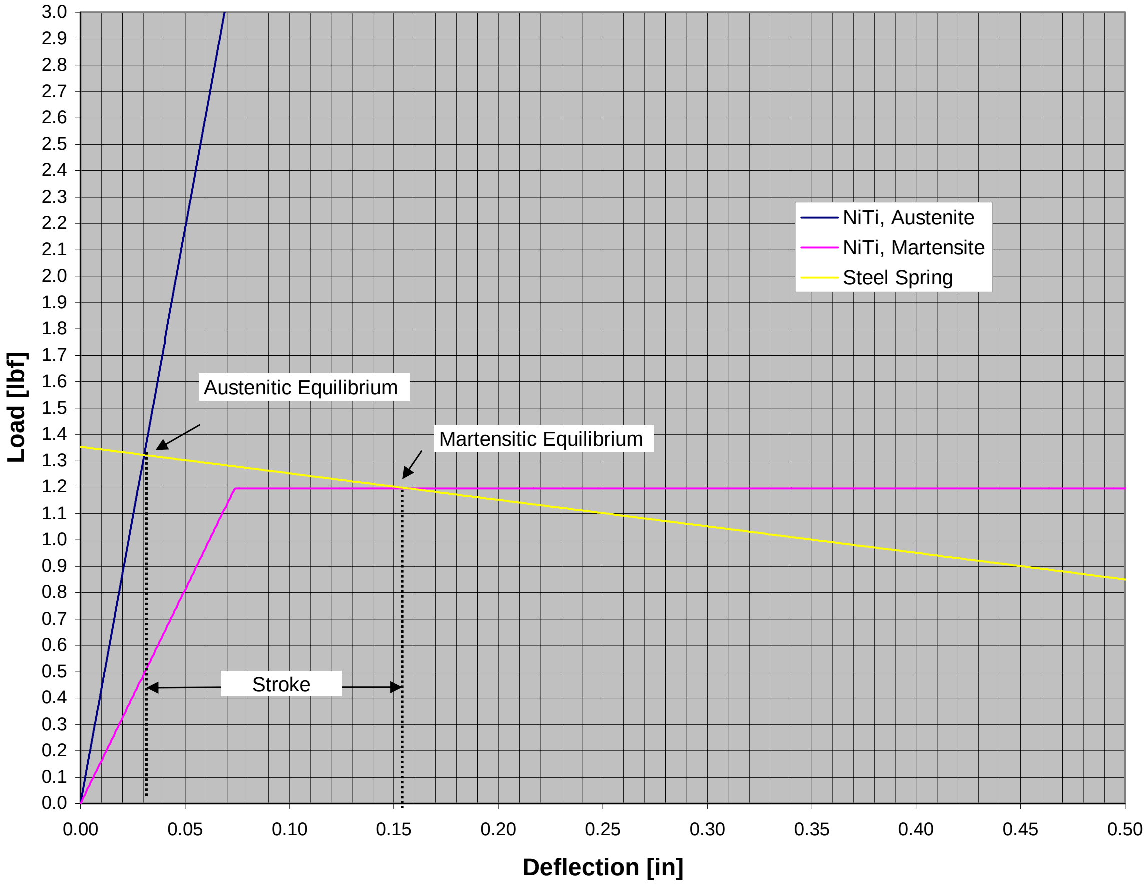

Figure 3 Mechanical response of LionSat pin-puller

when a 5% strain is applied.

The cross-sectional area of the wire is $A = \pi D/4 = 1.2566 \times 10^{-5}$ in^2. Johnson Matthey reports that several of their NiTi SMA materials have a load plateau around 95 ksi [9]. The load required by the reset spring to strain the wire to its load plateau is then $P_{\text{plateau}} = \sigma_{\text{plateau}} A = 1.1939$ lbs. Using published data that was confirmed in multiple sources [9, 10], a list of the properties of NiTi wire was compiled and can be found in Table 2. Using these values, the strain achieved just before the loading plateau is $P_{\text{plateau}} = \sigma_{\text{plateau}} / E_{\text{martensite}} = 0.0234$ in/in. Elongating the wire from this strain of 2.34% to a strain of 5% occurs without a large increase in strain due to the shape of the stress–strain curve for NiTi.

Based on this analysis, a spring capable of producing 1.2 lbf is capable of straining the NiTi wire 5% in the martensitic phase. In order to maximize the length of the pull, a spring with a low spring constant is critical. Figure 3 shows the equilibrium points for a NiTi wire with a steel reset spring that has a spring constant of 1.005 lb/in. The spring used in this example has been created by stacking two commercially available springs from McMaster Carr (P/N 9657K135). Each spring is made from steel music wire, has a spring constant of 2.01 lb/in, fits inside a 13/32″ diameter hole, has an as-ordered free length of 1.5″, and is capable of supporting a 1.92 lbf load at maximum deformation. The configuration used in Figure 3 is able to provide 0.129 inches of stroke.

Because NiTi alloys behave similar to most other metals during the first portion of their martensitic phase—i.e., linear proportion between stress and strain—the mechanical-response analysis used the values in Table 2 for the Young's Modulus to predict the first segment of the graph in Figure 3. The martensitic phase plateau occurs when the stress equals 95 ksi, and the low spring constant causes the high temperature equilibrium point to be on the linear portion of the austenitic phase plot. In this design case, a stress of 105.35 ksi is reached, which is below the yield stress of 109 ksi found in Table 2. Testing will need to be preformed on the system to ensure that yielding does not occur while the NiTi wire is in its austenitic phase.

4.5 Prototype Pin-Puller

A prototype pin-puller will be created to verify the analysis used to create Figure 3. This prototype will be based on the conceptual pin-puller design fabricated before an analysis was performed to match the reset springs to the 0.004″ diameter NiTi wire. The conceptual design utilizes an aluminum body bored to accept the reset spring's outer diameter. Another hole is drilled through the entire piece at approximately the inside diameter of the spring. Two aluminum caps were made for each end of the housing body. One cap has a hole drilled to allow the pin to slide into and out of the pin-puller. This cap is secured to the body by a steel set screw. The other cap has been counterbored to accept a disc of perforated fiberglass PC board. The PC board allows the contacts to be isolated from the body of the pin-puller to eliminate electrical shorts. The vias in the PC board also allow the NiTi wires to be firmly soldered in place, which greatly aids in the ease of assembly of the device. A picture of the conceptual design prototype is shown in Figure 4.

The conceptual design uses a single 6.3″ wire that runs from the terminal end cap down to the pin, around a small diameter pin affixed perpendicularly to the long axis of the device, and back to the terminal end cap. This design allows both terminals of the NiTi wire to be near each other, which simplifies the wire routing and device installation. Using a looped wire reduces the stress in each wire by half. This means that the load from the spring must be doubled to keep the strain in the wire at 5%. To accomplish this, only one 2.01-lb/in spring needs to be used instead of two in series. This again simplifies the design and reduces the overall length of the device by eliminating some spring length. A schematic of the pin-puller is shown in Figure 5.

The prototype model will be resized to accept the appropriate spring, and an attachment method will be built into the device to allow it to mate to the satellite.

Figure 4 Conceptual design prototype of NiTi pin puller

The specific attachment style, whether a thread, set screw, machine screw, or adhesive joint will be decided after development of the boom deployment mechanism is completed.

5 Electrical Support and Circuitry

5.1 Power System Design

Since the battery pack on LionSat is designed to operate at 12 V and 26.2 W, it was determined that the energy to heat the wire should come from a capacitive discharge circuit. The design for this circuit is similar to those recommended by the NASA Pyrotechnic Handbook, where a capacitor is charged to the required

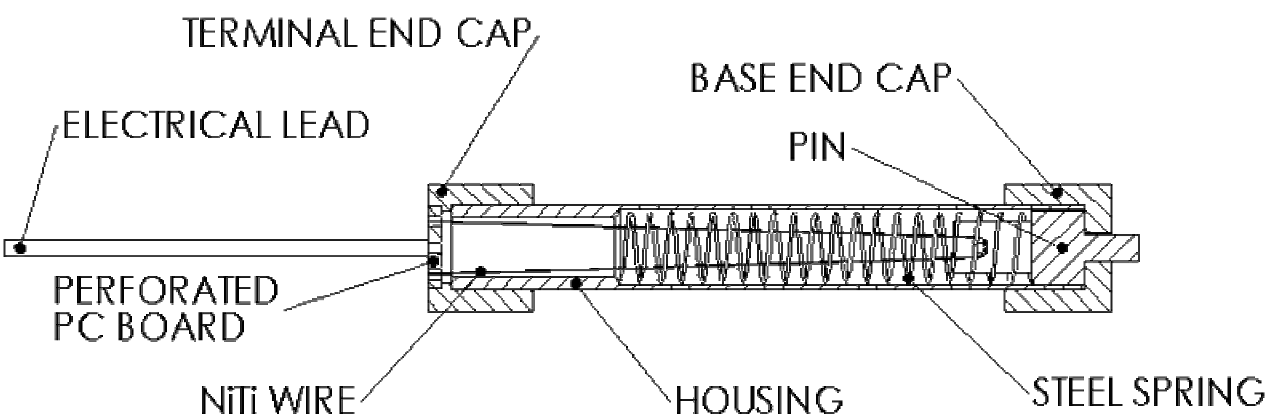

Figure 5 Conceptual design of NiTi pin puller

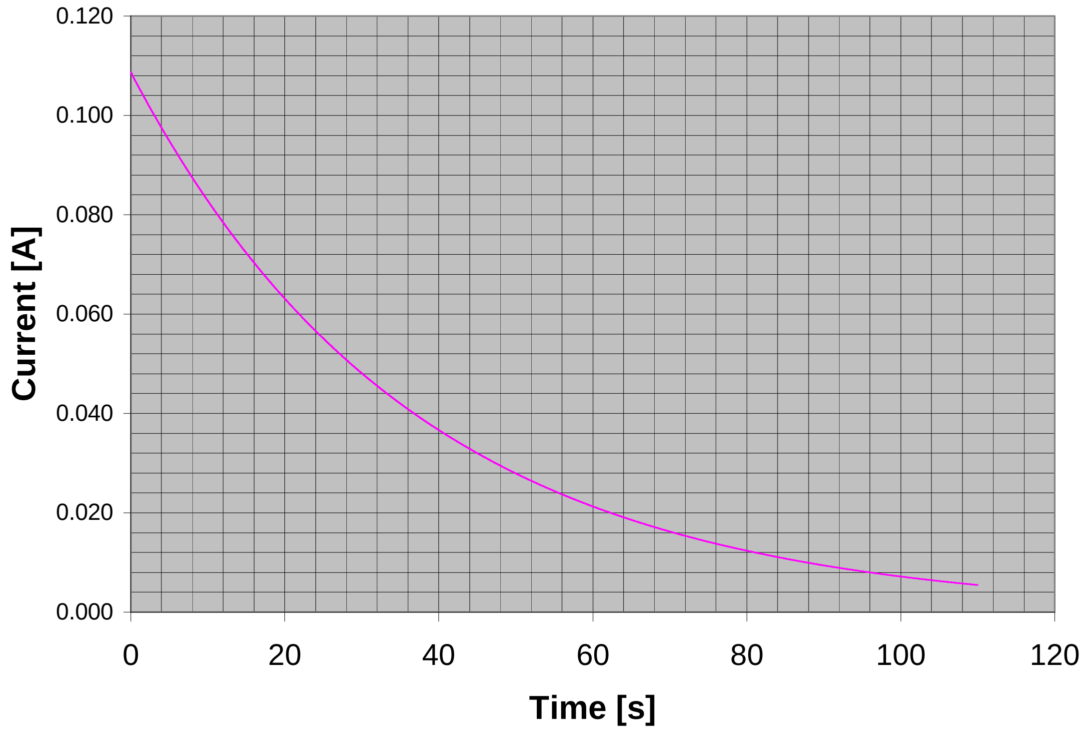

Figure 6 Discharge current for device

potential by the battery, a relay is then opened removing the capacitor from the main power supply, and another relay is closed on the device end to allow the current to flow from the capacitor to the device [11].

5.2 *Capacitive Discharge Circuit Simulation*

The capacitor chosen for the circuit has a nominal capacitance of 1.5 F and operates at 5.5 V. Using a 10-Ω resistor in the charging circuit, the capacitor will be at 99.8% of its maximum storage capacity after 50 seconds. The resistor will have a peak power surge through it of 2.5 W. To discharge the circuit, a 30-Ω resistor will be added in series to the 16-Ω of resistance from the NiTi wire. The resistor will have a peak power surge of 0.35 W. The peak current draw from the capacitor during the discharge is 109 mA [See Figure 6]. Assuming radiation is the primary source of heat dissipation on orbit, the NiTi wire will heat from –55 °C (218.15 K) to 90 °C (363.15 K) in 38 seconds and remain above 90 °C for several minutes. Note, that if the design requirements of a long actuation time are shortened, then the capacitive discharge circuit may not necessary.

The thermal calculations were performed numerically using published data for the heat capacity and latent heat of martensite transition for NiTi shape memory alloys. The total energy required to heat the metal from 218.15 K to 363.15 K and through the transformation is 0.591 J.

6 Assembly and Testing Procedure

6.1 *Preparing the NiTi Wire*

Before the first working prototype is created from NiTi wire, the wire must be strained and allowed to recover to reduce the hysteresis effects discussed in Section 3.2. In order to do this, a 10″ free length of 0.004″ diameter NiTi wire will be crimped into screw leads. Then, the terminals will be connected to different sections of a ball drive unit so that any rotation of the ball screw causes a translation of the ball nut and one terminal block. The ball screw will be rotated counterclockwise manually until a measured strain of 0.05 in/in is achieved. The wire will remain at 5% strain for 15 minutes. The ball screw will then be rotated clockwise to remove the stress from the wire. The wire section will then be moved to another fixture and each terminal end will be attached to a bench-top power supply. A current of 0.200 mA will be passed through the wires for 10 seconds to allow the austenitic phase change to recover the strain in the wire. The wire will then be measured and its length recorded. It will be placed back on the ball drive fixture and again strained to 5%. This process will repeat for 30 cycles for each NiTi wire section to be used in the fabrication of the pin-puller device.

6.2 Testing the Pin-Puller

A fixture has already been designed to accurately measure the spring constant of various springs. This device uses known masses and a calibrated measuring tool to record the displacement of the spring for different masses. These results are compiled to produce an accurate measurement of the spring constant of each spring being used.

After the spring properties have been specifically determined, the length of the housing will be machined to be an exact mate for that spring. Each aluminum component will then be anodized and become an electrical insulator. The pin-puller will be assembled, and the pin will be forced into the device. The NiTi wire ends will be pulled through the perforated PC board and soldered in place with no strain. The NiTi wires will also be soldered into an adjoining PC board via hole in order to hold the wire more securely and also to provide a contact point for the electrical leads. The electrical leads are then soldered into the second NiTi-occupied via hole. After the wires have been soldered, the pin is allowed to leave the device, straining the NiTi wire to the design strain of 5%.

During initial proof-of-concept testing, a constant current of 200 mA will be put through the electrical leads of the device until the pin retracts fully into the pin-puller. The speed of the actuation will be observed and any changes to the design will be made at this point. If any changes occur, the device will be retested on the bench-top power supply until the actuation behaves as expected.

Once the device has been shown to work with a constant current, the pin-puller will be tested with a potentiometer in the discharge circuit. The resistance will initially be 10 times greater than the design resistance, and will progress toward the design resistance in subsequent discharges if no actuation is observed to occur.

After the device has been shown to actuate repeatedly with the capacitive discharge circuit, it will be placed in a thermal–vacuum chamber and tested again; first with a bench-top power supply, and then with the capacitive-discharge circuit. After the design has been proven in thermal–vacuum testing, it will be repeatedly actuated in the thermal–vacuum chamber with the capacitive discharge circuit until failure, with any decrease in performance being noted as it occurs. If the device's performance does not decrease significantly in over 20 cycles, then the design will be accepted for use on the LionSat mission.

Each subsequent pin-puller will be subjected to inspection by a Quality Assurance member of the team, and each new device must be actuated 5 times in a vacuum with a capacitive discharge circuit to be qualified for flight.

7 Author Biographies

Peter Cipollo received his B.S. in Aerospace Engineering from the Penn State University in Spring 2004. He led the Mechanisms, Pyrotechnics, and Deployments Team for the Student Projects Involving Rocket Investigation Techniques (S.P.I.R.I.T. II) from Spring 2001 until its successful launch in October 2003. Peter also leads the Structures Team for the LionSat student satellite being developed at Penn State. Peter will continue studying Aerospace Engineering in the masters program at Penn State in Fall 2004.

Brendan Surrusco is an M.S. graduate student in Electrical Engineering. He received his B.S. degree in Electrical Engineering from Penn State in Spring 2003. He was one of the Student Design Team Leaders for the S.P.I.R.I.T. II Sounding Rocket Payload. Currently, he serves as Student Project Manager and works on the Command and Data Handling Team for the Penn State University LionSat nanosatellite project.

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