N93-20522

Nickel Metal Hydride, A Flight Experiment

Presented at the NASA Aerospace Battery Workshop, Huntsville, Al., Nov.19,1992

Edward A. Fitzgerald

Senior Systems Engineer
Teledyne-Brown Engineering
Cummings Research Park
300 Sparkman Drive, NW
P.O. Box 070007 ; MS#70
Huntsville, Alabama 35807-7007

Dr. Francis C. Wessling

Professor of Mechanical Engineering
University of Alabama in Huntsville
Consortium for Materials Development in Space
Huntsville, Alabama 35899

Abstract

A Nickel Metal Hydride battery was discharged at high rate in a microgravity environment. Data from the flight is compared to data taken on the earth's surface.

Introduction

The sounding rocket program at the Consortium for Materials Development in Space (CMDS) at the University of Alabama in Huntsville (UAH) needed to improve the power system used to support experiments. Also SEDSAT, a small satellite program at UAH needed new battery technology. Currently, commercial Nickel Cadmium (NiCd) "F" cells are used to power the Consort and Joust series of sounding rockets. The goal of this work is to reduce the weight and volume of the battery packs and, thereby, allow more payload (experiments).

Trade studies quickly limited the choices of new batteries due to the budget constraints of these programs. The new batteries had to be functionally equivalent to NiCd in cost and performance. Nickel Metal Hydride (NiMH) promised a weight reduction of 20% and a volume reduction of 30% over commercial NiCd. NiMH has a specific energy of 50 watt-hrs per kilogram compared to 25 for aerospace NiCd and 40 for commercial NiCd. NiMH has an energy density of 2.4 watt-hrs per cubic inch compared to 1.2 - 1.7 for NiCd. [1&2]

NiMH is a low pressure Nickel Hydrogen technology which lacks the volumetric inefficiencies attendant with the storage of hydrogen in the gaseous state. This emerging technology has seen some success in cellular phones and laptop computers. NiMH meets or exceeds NiCd performance in all areas except peak discharge current. NiMH is capable of 5 "C" continuous current and NiCd is capable of 10 to 20 "C" continuous current where a "C" is the one hour current. The NiMH performance should improve as the process matures. In the commercial market NiMH is twice the cost of NiCd but is expected to be equal in the future. In the aerospace market NiMH is expected to cost less than NiCd. Pending OSHA decisions may in the near future make the domestic manufacture of NiCd unattractive and cause its cost to rise.

The only significant environmental parameter which can not be adequately simulated on earth is the absence of gravity. Gravity causes convection and without convection the behavior of liquids and gasses is changed dramatically. Due to the lack of experience with this couple in space, a simple experiment was devised to test its performance so we could gain the confidence necessary to allow it to power the experiments. The proof of performance would be launched on the Consort IV rocket from White Sands Missile Range in New Mexico.

Six cells would be sufficient to prove performance while minimizing the size and weight of the experiment and, a "C" rate discharge would be initiated during the seven minutes of microgravity. One voltage and two temperature measurements were available from the on-board computer.

Lacking the time for a normal purchasing cycle, parts were procured in local stores and Bill Powellson, mechanical engineer, had to machine the parts he had designed. The establishment of a non-disclosure agreement with Gates Aerospace Batteries (GAB) and the procurement of a NiMH Materials Safety Data Sheet for White Sands range safety proved to be projects in themselves.

In order to have vibration qualification performed on the experiment , it was necessary to build two experiments. The first model was built in two weeks with NiCd cells and sent to vibration. The second or flight model was finished just as GAB delivered the samples. The 24 samples had been cycled 5 times before delivery and this data was used to select 6 cells with the same capacity and self discharge characteristics. The NiMH cells were installed in the flight experiment and 10 days of testing was performed, including four additional charge/discharge cycles, to characterize the battery and experiment.

The flight experiment was conceived on Aug. 8 ,1991, delivered to UAH on Sept.19,1991 and launched on Nov.16,1991. Sounding rockets do, indeed, allow rapid access for experiments to low gravity !

The Rocket

Consort launches and experiments are funded by a cooperative arrangement between the NASA Office of Commercial Programs (OCP), industries, universities, and other government agencies. The Consort program [3] is managed by the Consortium for Materials Development in Space (CMDS) at the University of Alabama in Huntsville. The Consortium is one of seventeen Centers for the Commercial Development of Space (CCDS) established by the NASA-OCP to promote commercial uses of space.

The launch vehicle for Consort IV was a Starfire sounding rocket (Fig 1). The two-stage solid-propellant launch vehicle was 52 feet tall and carried 1000 lbs of payload to 200 miles altitude. After achieving a ten micro-g environment for seven minutes the payload section re-entered the atmosphere and parachuted to the earth 50 miles from the launch site. It was recovered by helicopter and returned to the launch site within 2 hrs. The payload module was approximately 3.6 m in length and 0.44 m in diameter and contained nine experiments packages.

The Cell

Nickel Metal Hydride is a low pressure Nickel Hydrogen (NiH) technology. It is very economical compared to NiH. The specific energy is the same as NiH but it has double the energy density. The cell used in this experiment was a standard sub C size of cylindrical construction. The cell had a diameter of 0.87in. and a height of 1.66in. It was provided by Gates Aerospace Batteries and has an aerospace nickel plate, an Ovonic Metal Hydride plate and a Nylon 2538 separator. The average output voltage per cell is 1.2 volts and its capacity is 2 amp-hrs. All charging of the cell was done at the 20 hour rate with a current of 180 ma.

The Experiment

A battery of six cells was housed in a Delrin honeycomb with a chamber for the electronics. The experiment had a height of 2.5in., a depth of 1.5in. and a width of 14.5in. Its weight was 2.6 lbs. The electronics were designed to connect a resistive "C" rate load (2 amps) to the battery whenever the microgravity signal was present. The microgravity signal was available from the sounding rocket which contained the facility to record the voltage and the two temperatures every second. The sounding rocket also recorded its internal ambient temperature.

Figure 2 is a schematic of the experiment. The discharge is initiated when the signal "MICROG" goes high. This forward biases the photodiode (U1) and causes the phototransistor (U1) to conduct. The current flow through the phototransistor (U1) forward biases the darlington transistor (Q1) which turns on the electromechanical relay (K1) and connects a wire wound resistive load of 3.9 ohms to the battery. The voltage is now present on connector P1-pins 7&8 , and is proportional to the battery voltage. The relationship between the true battery voltage and the voltage measured was characterized during testing to correct for wire and relay contact resistance. Thermisters were in surface contact with two of the cells and measured their temperatures. Connector (P2) was used for battery charging which was performed on the ground only. Launch was specified to be accomplished within 72 hours of charging.

The Data

The launch occurred 25 hours after charging. Graphs have been included which characterize the discharge performance of NiMH in the lab and during the flight.

Figure 3 is a graph of discharge voltage vs. time (60 min) for the initial lab capacity discharge and is typical of this NiMH cell.

Figure 4 is a graph of the cell temperature vs. time for the lab discharge of figure 3. The experiment was in an air conditioned lab at 24 C.

Figure 5 is a graph of discharge voltage vs. time for the seven minute flight discharge. The lab data graphed for comparison was taken after the flight with an identical standtime of 25 hrs. The five volt full scale analog input had a resolution of 8 bits, therefore the flight data has a granularity of 20 millivolts.

Figure 6 is a graph of the cell temperature vs. time for the seven minute flight discharge. The data shows a higher rate of heating in flight (3.4 C in 7 min). The curve of figure 4 showed rates of heating that varied between 0.7 C and 2.1 C in 7 minutes. The rocket's internal ambient temperature was higher than the temperature of the battery at the beginning of discharge and is graphed to explain the source of this additional heating.

Figure 7 is a graph of discharge voltage vs. time (60 min) before and after the flight. It indicates that the 1 hour capacity was essentially unchanged by the flight.

Conclusions

1 . The graphs of battery voltage versus time (Fig 5) proved to be very similiar on earth and in space. The higher voltage at the beginning of flight discharge occurred because the flight battery was six degrees Celsius colder at the beginning of its discharge.[4]

2 . Capacity measurements before and after flight did not show any degradation (Fig 7). The slightly higher voltage in the "after" curve occurred because of small differences in the cells' internal temperature.

3 . The graphs of battery temperature versus time show a higher rate of heating in flight than in the lab but this is attributed to still air and conducted heat from the ambient. (Fig 6).

4 . The experiment was dissassembled and examined for anomalies. The cells did not exhibit any swelling or leakage. At this time, they had a total of fifteen charge/discharge cycles accrued.

The NiMH battery performed well in space during this test and appears suitable for powering the experiments in the sounding rockets. The sounding rocket has been the first test of this new battery technology in space and soon will become its first application in space.

Future Experiments

Teledyne-Brown is looking for a partner to participate in a new battery technology experiment that will fly on-board the shuttle in the near future. The experiment will consist of multiple charge and discharge cycles of a new battery technology. The experiment will demonstrate the practical use of the new technology as well as gathering scientific data. It will be among several Teledyne Brown material science experiments to be flown on a GAS can (Get Away Special can) (Fig. 8). The new technology will be either Nickel Metal Hydride or Silver Metal Hydride. Twelve charge and discharge cycles are planned on a 105 hr. timeline. The first ten cycles will use the other GAS can experiments as the load and then two cycles will be performed using fixed resistive loads.

The authors acknowledge the support given on this project by the NASA Office of Commercial Programs under grant # NAGW-812.

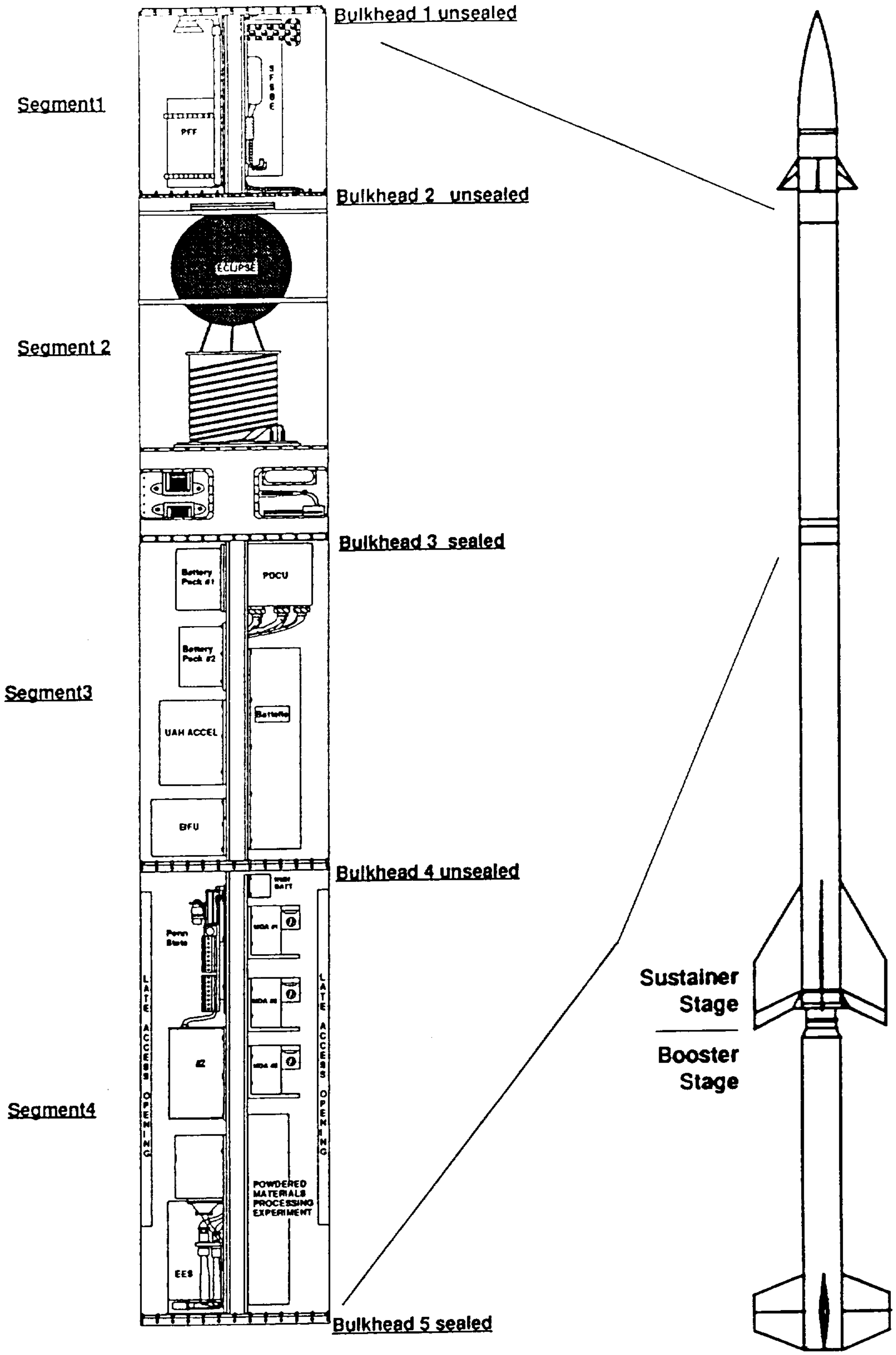
Bibliography

[1]. Gates Energy-Battery Application Manual, 1989

[2]. S. Bogner ; Hughes Advanced Nickel-Cadmium Batteries - An Update, Proc. of the Sixth Annual Battery Conference at Cal State, Long Beach, Ca. , Jan, 1991.

[3]. F.C.Wessling and G.W.Maybee ; Consort 3 Flight Experiments
Journal of Spacecraft and Rockets , Jan-Feb,1991, vol 28; pgs 100-108

[4]. D. Coates ; Sealed Aerospace Metal Hydride Batteries
NASA Aerospace Battery Workshop, Huntsville, Al. , Oct, 1991



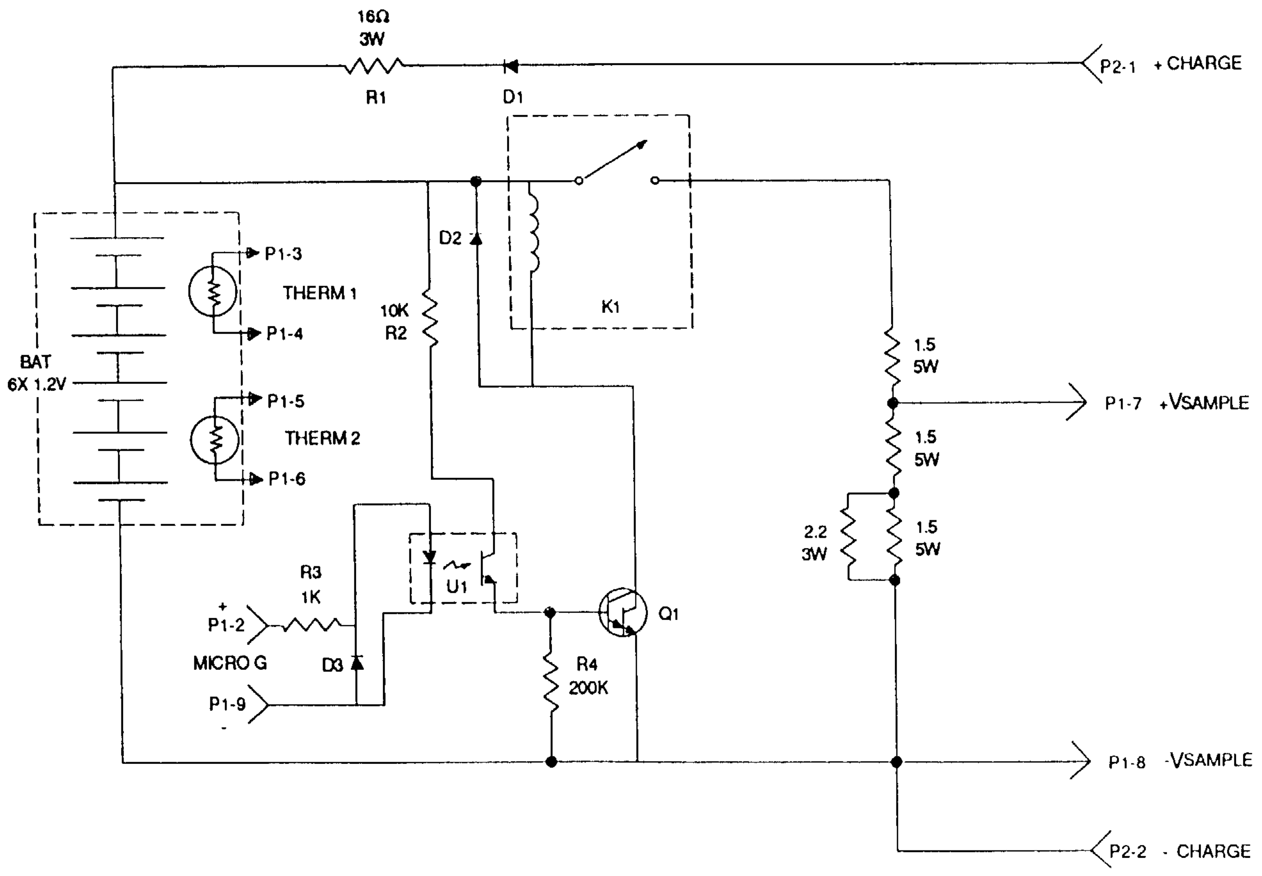
CONSORT IV

FIGURE 1

FIGURE 2

Nickel Metal Hydride, A Flight Experiment

Ed Fitzgerald



CONSORT BATTERY EXPERIMENT SCHEMATIC

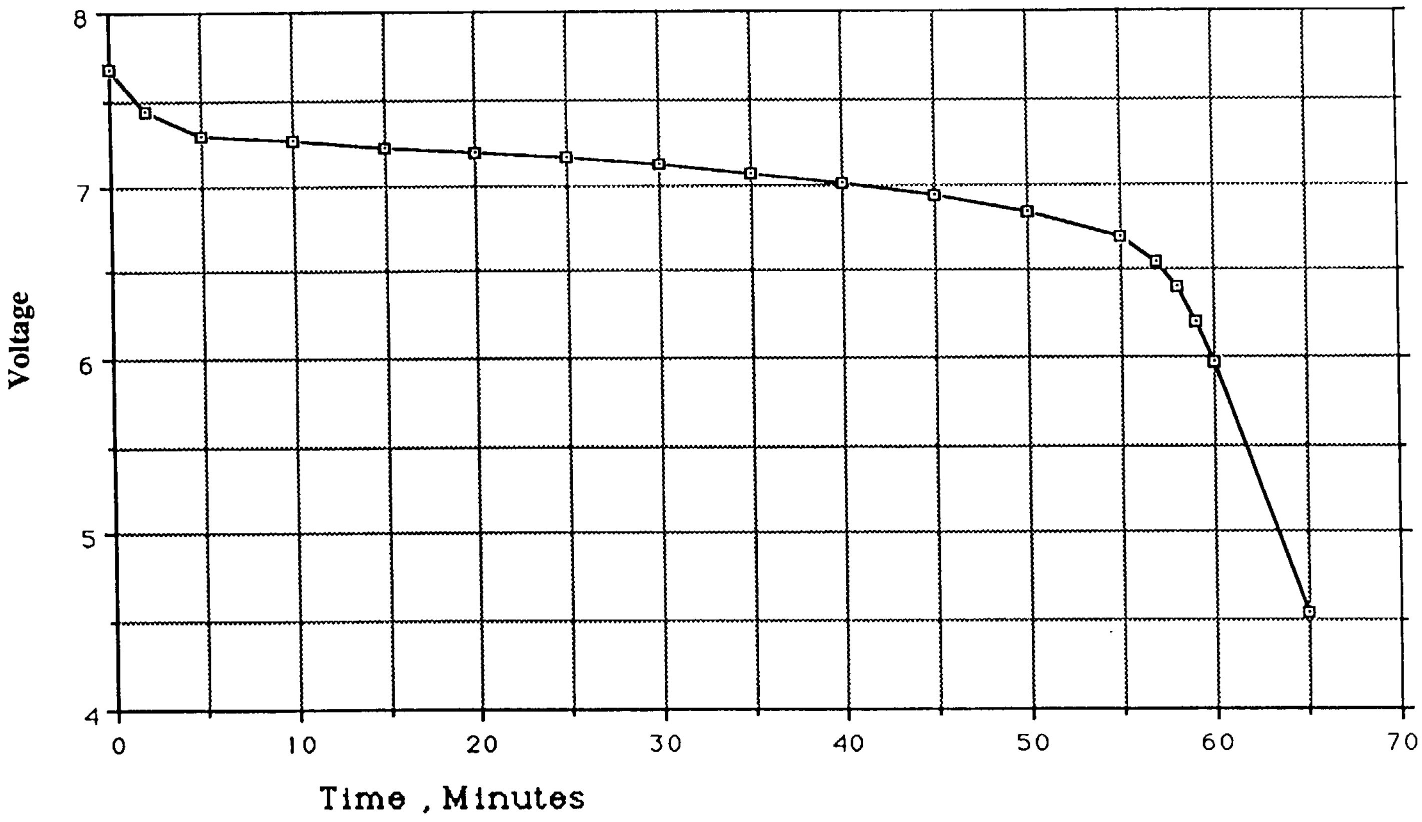
TELEDYNE
BROWN ENGINEERING

FIGURE 3

Nickel Metal Hydride , A Flight Experiment

Ed Fitzgerald

NiMH Battery , Discharge Voltage vs. Time



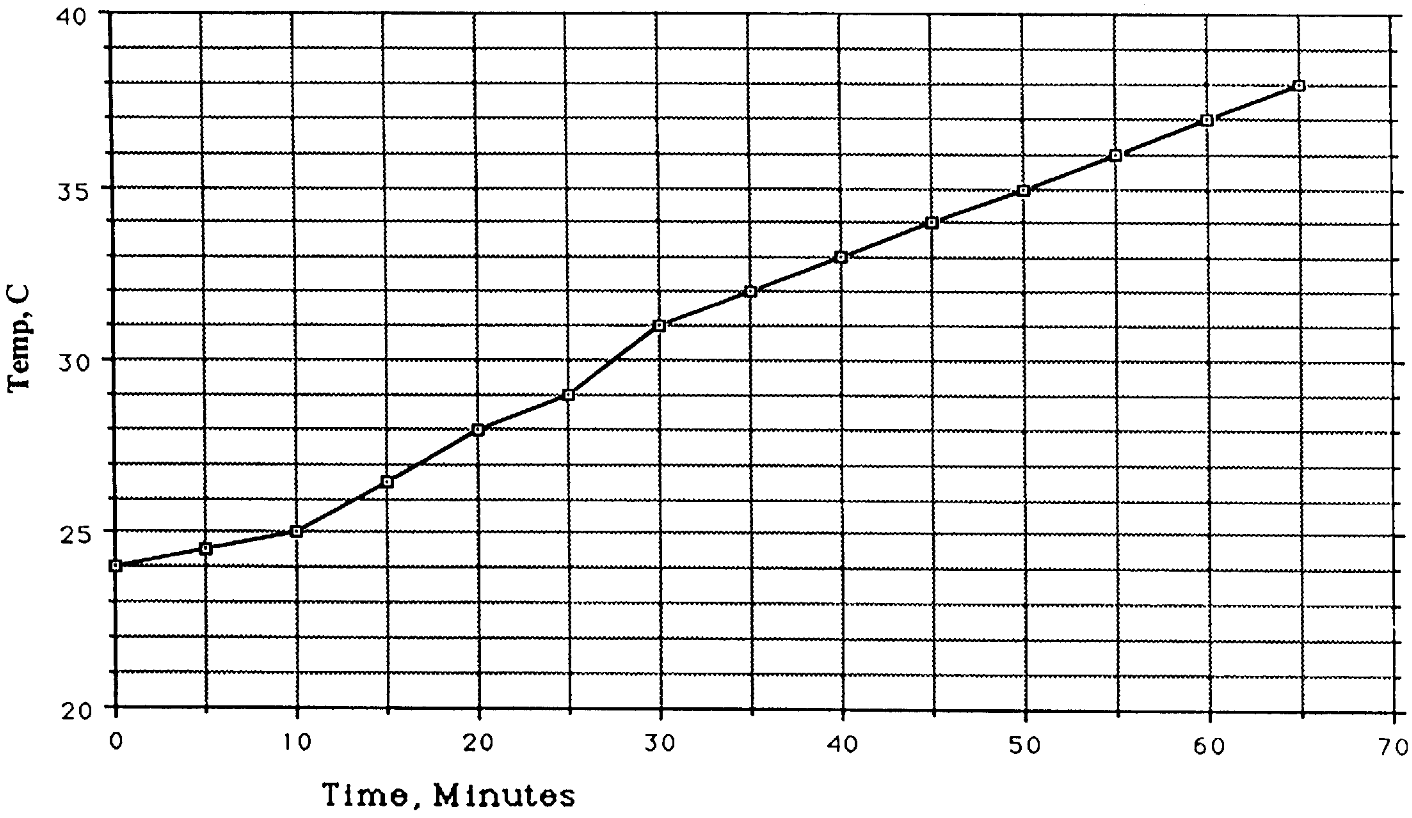
TELEDYNE
BROWN ENGINEERING

FIGURE 4

Nickel Metal Hydride , A Flight Experiment

Ed Fitzgerald

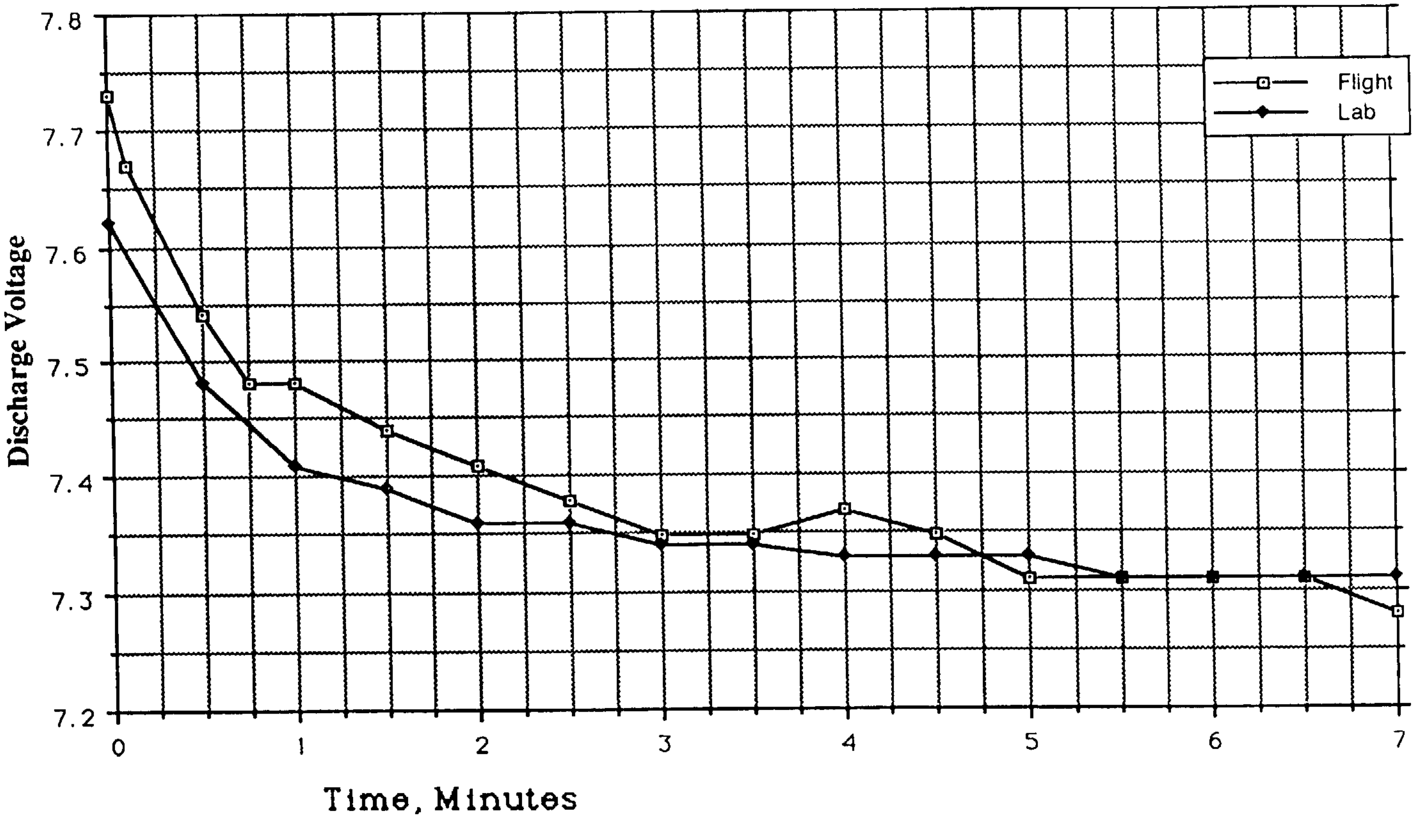
NiMH Battery, Discharge Temperature vs Time



TELEDYNE
BROWN ENGINEERING

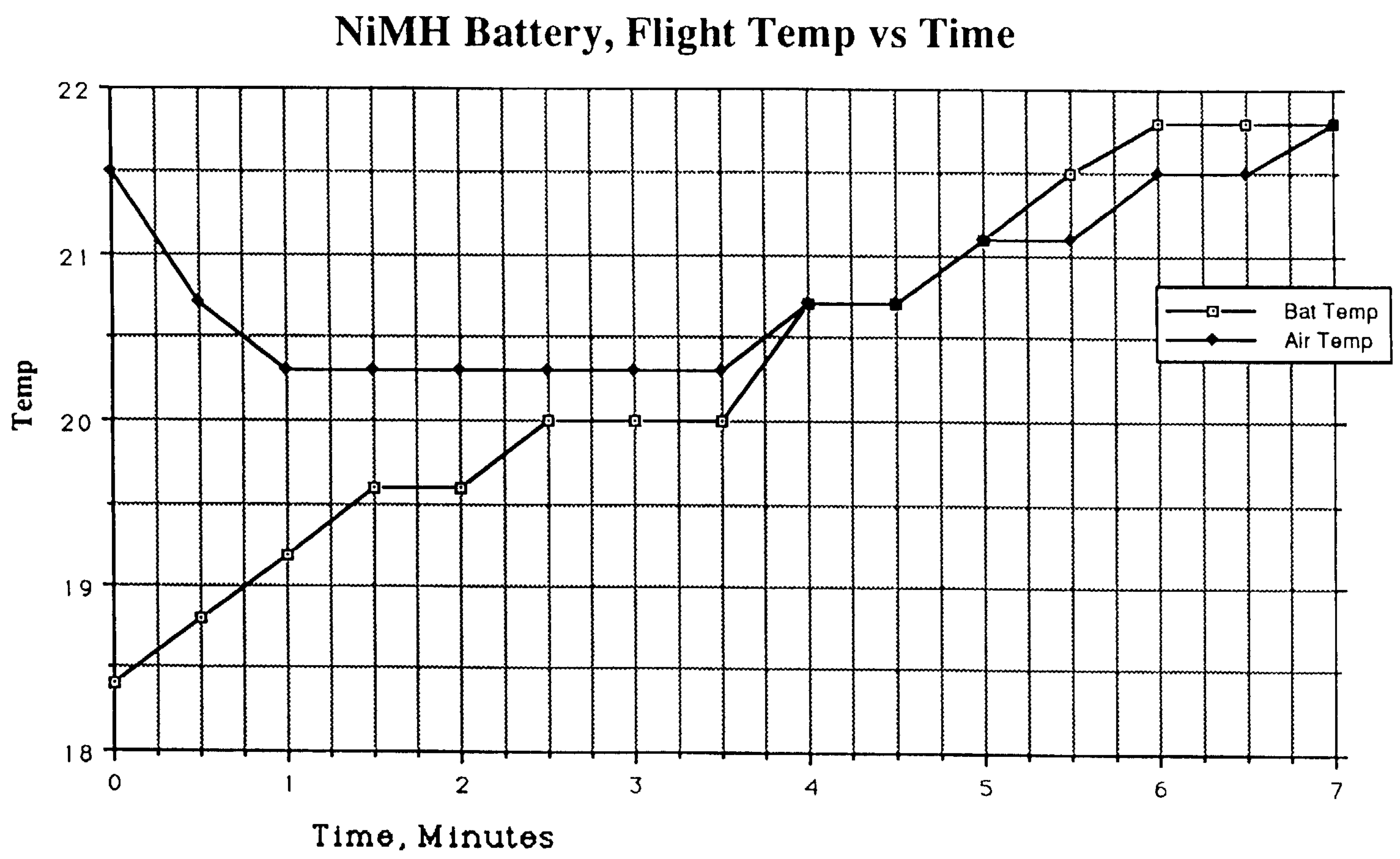
FIGURE 5 | Nickel Metal Hydride , A Flight Experiment | Ed Fitzgerald

NiMH Battery, Comparison Flt vs Lab



TELEDYNE
BROWN ENGINEERING

FIGURE 6 | **Nickel Metal Hydride , A Flight Experiment** | Ed Fitzgerald



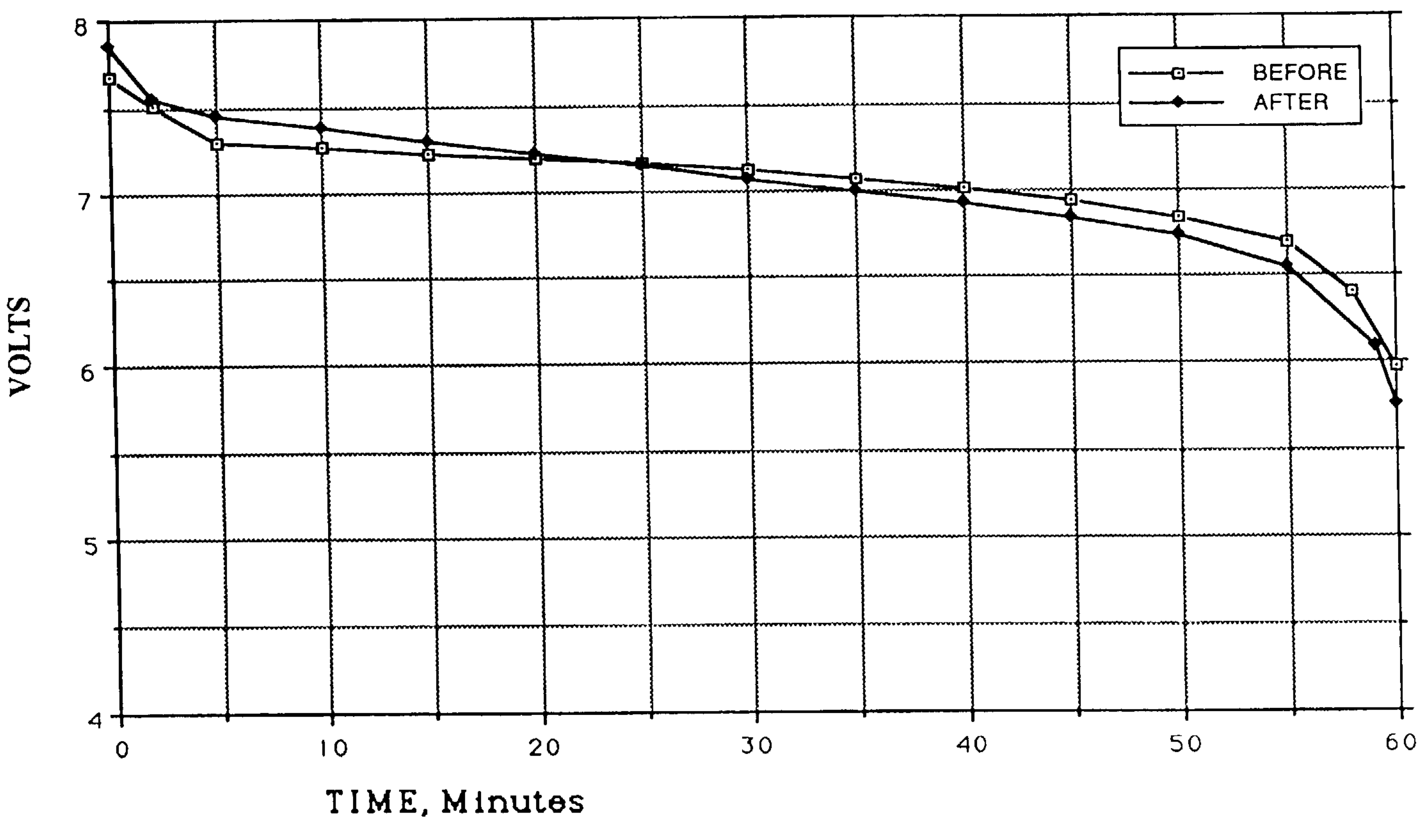
TELEDYNE
BROWN ENGINEERING

FIGURE 7

Nickel Metal Hydride , A Flight Experiment

Ed Fitzgerald

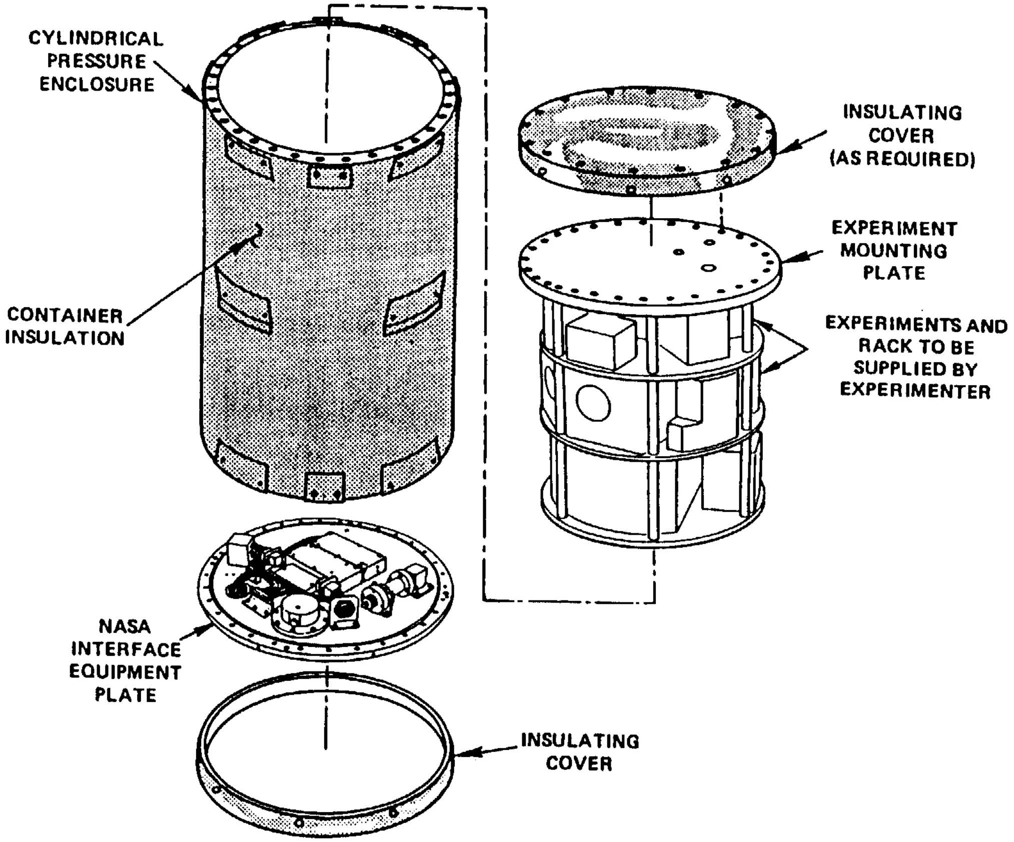
NiMH Battery, Capacity Before & After

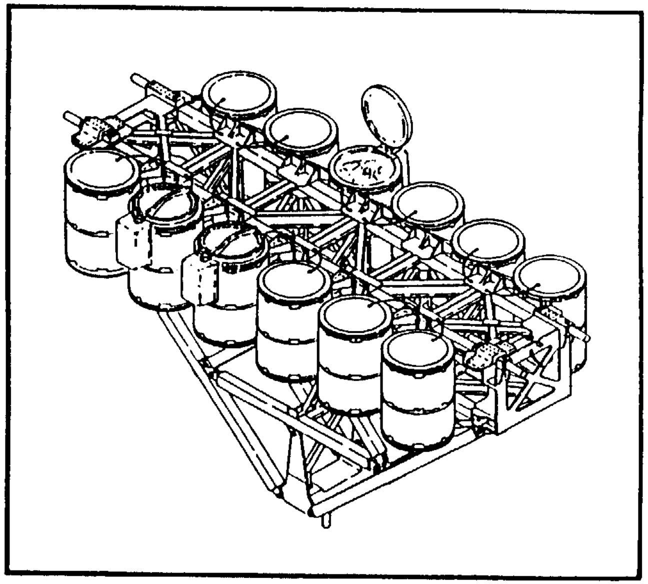


TELEDYNE
BROWN ENGINEERING

FIGURE 8 | Nickel Metal Hydride , A Flight Experiment | Ed Fitzgerald

GET AWAY SPECIAL
SMALL SELF-CONTAINED PAYLOADS
CONTAINER CONCEPT





GAS BRIDGE PAYLOAD

TELEDYNE
BROWN ENGINEERING