Phase I Project Summary
Firm: Luminit, LLC
Contract Number: NNX-12-C-E38P
Project Title: Carbon Nanotube-based Supercapacitor (CANS)

To address NASA's need for low mass electrical energy storage devices for onboard long duration balloon flights at mid-latitudes and altitudes, Luminit, LLC, proposed to develop a new carbon nanotube-based supercapacitor (CANS) based on our mature sol-gel chemical solution deposition technology. This approach incorporates new CNT-sol-gel based electrode materials and alignment of CNT in the sol-gel, which increases the power energy density and decreases the mass by increasing the effective area accessed by electrolyte ions. In Phase I, Luminit demonstrated the CANS feasibility by fabricating unpackaged CNT-sol-gel based supercapacitors and comparing their performance to commercial rechargeable batteries, which reduced the development risk in Phase II. In Phase II, Luminit plans to optimize CNT-sol-gel electrodes and fabrication process, and fabricate a fully-functional prototype CANS to meet NASA requirements for 28 V DC, 0.1 to 1 kW power, and 1 to 12 kWh energy. CANS will operate at extreme temperatures and offer millions of charge/discharge cycles, rapid charge times, high efficiency (98%), and long cycle life (>15 years). The CANS was at TRL 2 at the beginning and TRL 3 at the end of Phase I. We expect CANS to reach TRL5 at the end of Phase II.

Technical Objectives and Work Plan:

The following specific objectives were established as steps to meet our Phase I goal.

Objective 1. Development of a preliminary CANS design including modeling the required voltage (28 V) and power levels (100 watts to 1000 watts).

Objective 2. Development of the CANS electrode material with high energy density, high power density, long life cycles, rapid charge and discharge times, high efficiencies, and stable performance in space environs.

Objective 3. Testing and demonstration of CANS feasibility by fabricating an unpackaged prototype CNT-sol-gel-based electrode and comparing its performance to that of commercially available rechargeable batteries.

Objective 4. Exploration of the Commercial Potential of CANS and CNT-sol-gel materials.

We accomplished the objectives of the phase I project through the performance of the following tasks.

Task 1. Design a CANS System (Objective 1)
Task 2. Develop CNT-Sol-Gel Composite Materials (Objective 2)
Task 3. Develop CNT-Sol-Gel-Based Electrode (Objective 2)
Task 4. Fabricate and Test CANS (Objective 3)
Task 5. Explore the Commercial Potential and Product Viability (Objective 4)
Task 6. Prepare and Submit Reports

Technical Accomplishments:

In Phase I, Luminit developed a CANS design and a model to achieve maximum power and energy efficiency by controlling the amount of CNT, type of CNT, pore size of sol-gel material, electrode thickness, and selection of electrolyte and separators. We

developed CNT-sol-gel composite materials via hydrolysis, polymerization, and cross-linking. We investigated optimum solvent ratios, temperature, and drying conditions and produced a homogenous matrix to disperse CNTs. We fabricated unpackaged CNT-sol-gel electrodes and proof-of-concept supercapacitors, which demonstrated ~10 times higher power density than commercial rechargeable batteries, and ~100 times higher energy density than conventional capacitors. The Phase I modeling and experimental test results met all the Phase I objectives and proved the feasibility of the proposed CANS for application in future NASA balloon systems.

NASA Application(s):
The proposed CANS will benefit the NASA Terrestrial and Planetary Balloons Mission and provide a low mass high power energy storage device to support night operations for future NASA balloon systems.

Non-NASA Commercial Application(s):
Because its competitive advantages such as lower cost, lower mass and higher power than rechargeable batteries, Luminit's CANS technology has huge market potentials and wide commercial applications in renewable solar energy storage, smart grids, electrical vehicles, as well as in consumer markets such as laptops, digital music players, toys, eBook readers, cell phones, iPod, iPhone, iPad, cameras, power generators, power conditioners, power tools, inverters, uninterruptible power supplies, cloud computer systems, and automobile regenerative braking systems.
Luminit's CANS technology has attracted the interest of potential commercial users and corporate investors, such as Armageddon Energy and Holonix International Inc. which has committed $250K for the Phase II development and commercialization of our CANS technology.

Name and Address of Principal Investigator: (Name, Organization, Street, City, State, Zip)
Jun Ai
Luminit, LLC
1850 W. 205th Street
Torrance, CA 90501-1526

Name and Address of Offeror: (Firm, Street, City, State, Zip)
Luminit, LLC
1850 W. 205th Street
Torrance, CA 90501-1526