G-38, 39 and 40

An Artist's Exploration of Space

Joseph W. McShane *
C. Daniel Coursen **

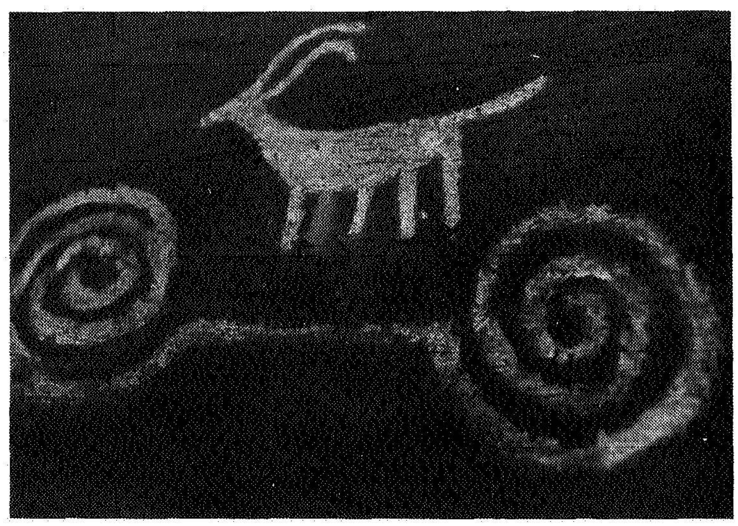
"Some say they see poetry in my painting: I see only science."
From the notebook of the pointillest painter Georges Seurat.

This paper is a tripartite exploration of (1) the human imagination in space, (2) a synopsis of the concepts expressed in Payloads G-38, 39 and 40 and (3) the systems of G-38 and technical lessons learned during the design and fabrication of the payload (sections 1 and 2 by Joseph W. McShane, section 3 by C. Daniel Coursen).

1

20,000 years ago, on the edge of the European ice sheet, in caves like Altamira in Spain, the visionary hunter/artist held brush in hand and sought understanding by creating an image of the animals that formed the basis of his culture. When that artist grasped the brush as an extension of his eye and hand he was using a tool on the cutting edge of his technology.

The computer on G-38 and the systems it interacts with are tools on the cutting edge of our technology. They form an extension of the artist's eye and hand as I seek to understand 20,000 years later the nature of the vacuum, weightlessness and scale of space that will become the basis of the next 20,000 years of man's future.



Anasazi pictograph, painted 1200 years ago.
Photographed in the Grand Gulch of the San Juan Basin, Utah by Charles Lyon.

The mathematician/philosopher Jacob Bronowski saw the cave painting as a sort of timelock. "For us, the cave paintings re-create the hunter's way

* Marshall-McShane, Prescott, Arizona
Sculptor/Payload Manager

** G.M. Vacuum Coating Laboratory, Newport Beach, California
Optical Design and Engineering/Payload Engineer

of life as a glimpse of history: we look through them into the past. But for the painter/hunter, I suggest, they were a peep-hole into the future: he looked ahead. In either direction, the cave paintings act as a kind of telescope tube of the imagination: they direct the mind from what is seen to what can be inferred or conjectured."

The analogy of a telescope of the imagination that Bronowski applied to the cave paintings also aptly applies to the sculptures that will be created by the technological experiments in space of payloads G-38, 39 and 40. For the first time since man first gazed at the stars and from an earth-bound, one-atmosphere, one-gravity perspective sought understanding of the unfathomable heavens through his art, the opportunity has been presented to make use of man's technology as an extension of the artist's eye and hand to venture forth directly into the vacuum and weightlessness of space, seeking understanding.

Until the opportunity was presented to work directly in space by the Small Self-Contained Payload Program, the artist has always been earth-bound, able to only create imaginary images of a space he could never know. The program offers the opportunity for the artist to develop and interact with a technology unique to space: to create new artistic concepts of space with new materials on a scale never before possible.

On a fall day in 1981, standing with astrophysicist Phillip Morrison at MIT's Steinbrenner Stadium, watching Japanese kites soar through the sky, Phillip said (and I quote as accurately as I remember), "The earth is flat. Please don't quote me out of context," he hurried on to say, "but the scale involved in the few kilometers distance between the bottom of the Mariana Trench and the top of Mt. Everest becomes relatively insignificant and flat when one looks to space and contemplates not only how far away the Andromeda Nebula is, but how may light years older the light reaching us from the far side is than that from the edge nearest to us. That is the scale man will have to come to terms with as he ventures off the face of the earth and into space."

Today, with certain significant exceptions, sculpture remains fastened to earth somewhere between Mt. Everest and the Mariana Trench and to interact with it one walks slowly around its base observing a form constructed in such a way as to support itself in a one-gravity environment.

——— 2 ———

The intent of payload G-39 is to explore space with sculptural concepts: creating art on a scale never befor accessible, using materials and processes in a way specific to, and possible only in, the vacuum and weightlessness of orbit.

For a number of years, in addition to solid sculpture, I have created a series of sculptures out of bubbles, free for brief moments to flow as a diaphanous form with the breeze. On earth, due to gravity, the largest size any of these sculptures have attained is less than three feet in diameter. I owe a special thank you to GAS pioneer Gilbert Moore for providing the inspiration that permits the extension of this sculpture series from earth to space.

G-39 will expand on this series by ejecting a canister that, when safely away from the shuttle, will inflate bubbles in orbit out of a plastic material that will cure and harden in orbit. The absence of gravity will enable the bubbles to attain a size not possible on earth and clearly visible in the night sky from earth.

Looking to create a subtle reordering, of at least my own sense of scale and place, the sculpture becomes not the bubbles themselves, but conceptually the 30,000 mile circumference of the orbit they travel, creating a sculpture on a scale never before achieved. The earth will form the center of this art work and instead of walking around the sculpture, the orbit/sculpture would surround us and we will exist inside of, and look out at, it.

G-39 will be a peaceful celebration of man's venture into space, an art work possessed by no one and equally accessible to all.

As I first began to dream of using new technology to create art in space most thoughts centered on projects that would be ejected from the GAS can and placed in orbit, helping the mind make the transition from the one-gravity, one-atmosphere, horizon limited preconceptions that man has evolved with since his beginnings on an African plain, to the zero-gravity, vacuum, unlimited scale of space where man seems destined to venture. Each time I envisioned returning a payload to earth it became enmeshed in these innate earth-bound preconceptions. Since the operable lid was not scheduled for use on GAS containers until 1985, it became apparent that if I wanted to orbit an early experiment the payload would have to be processed in orbit and returned to earth. G-38 evolved to meet that condition.

G-38 is an interrelated group of nine glass spheres, blown for the experiment by the Schott Glass Works in Germany and modified for use in G-38. Eight of the spheres, ranging in size from 500ml to 3,000ml, will go into orbit as clear glass and while exposed to the unlimited vacuum of space be coated using two separate vacuum deposition techniques, with gold, platinum, aluminum and multi-layered coatings, creating eight lustrous sculptures formed in space.

Dan Coursen and Joseph McShane inspecting completed gold vapor deposition test at G.M. Vacuum Coating Laboratory.

Photographer: R. James Hills

The ninth and largest sphere is the simplest in concept, but the one that, for me at least, provides the greatest play of the human imagination. This 22,000ml sphere will ride into orbit containing a 15psi earth atmosphere. Once in orbit the Eptak 210 controller will direct a valve to open, linking the sphere directly to the vacuum of space. Over a three day period the sphere will attain an equilibrium with the vacuum of the orbit, becoming one with space. The valve will close and the sphere will return with the vacuum of space. A copper tube connecting the sphere to the valve will be cold welded, permanently sealing the sphere. Attached to the sphere is a 31GCH5-10 Baratron Capasitance Manometer, a vacuum gauge capable of a very exact digital reading of the vacuum in the sphere, expected to be in the $1x10^{-5}$ torr range.

The sculpture then is not the glass, but the outer space contained within. The sphere serves only to keep the one-g earth atmosphere from intruding on the space within, creating an anomaly of our common experience.

I would hope that this piece of sculpture, created using the tools of our technology, would find a place where one might view it as a "telescope of the imagination": observe, wonder about the nature and meaning of space, touch and know that only 1/8" of glass separates us from the purest outer space, a proximity to space heretofore reserved for only those few privileged to be astronauts.

"To see a World in a Grain of Sand
And Heaven in a Wild Flower
Hold Infinity in the palm of your hand
And Eternity in an hour."

William Blake
Auguries of Innocence

Joseph McShane inspecting an iridescent multi-layered coating on a 3,000 ml test sphere.

Photographer: Charles Lyon

The principle of vacuum thin film deposition (evaporation) is based on two concepts. First, some material is raised to a high enough temperature that it becomes a gas. Second, most of the gas must travel directly to the object being coated, the substrate, without first striking another molecule. This is, in effect, governed by "mean free path" conditions. If most molècules of evaporant reach the substrate unimpeded the coating will be reasonably dense and adherent.

The most common example of vacuum deposition is the dark coating in a light bulb that forms as the filament slowly evaporates itself. If that filament had been impregnated with aluminum, for example, the lamp would have become a shiny opaque ball the instant it was turned on.

By working at short distances in a clean vacuum of less than 1×10^{-5} torr, about 1/10,000,000 of an atmosphere, we expect to produce excellent coatings, in spite of some restrictions in the pumping speed caused by the restricted openings in the NASA lid and thermal cover. Extensive tests of the filaments and evaporation equipment have been run at G.M. Vacuum Coating Laboratory to verify the system's performance.

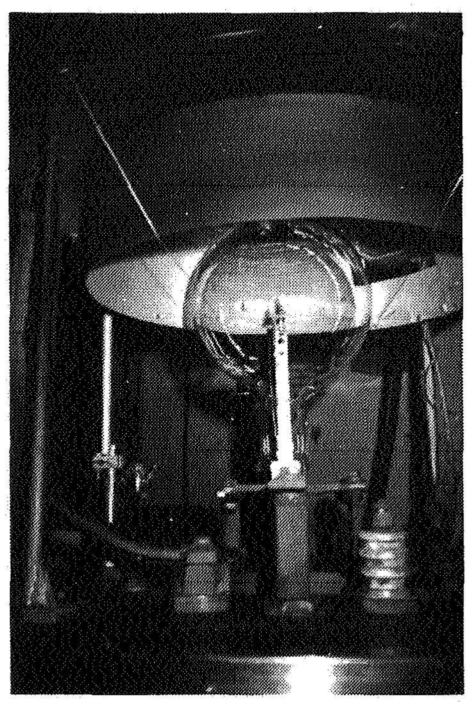
Sputtering is a unique type of vacuum deposition related to evaporation. In this case, molecules of the material to be deposited are mechanically knocked loose from a relatively cold source called the target. This is done by ionizing an inert gas at as low a pressure as practical and by charging the target negative, excellerating a positively charged gas, usually argon ions, into its surface. The reaction is similar to billiard ball behavior and target molecules are ejected by the impact of the ions at a high rate toward the substrate. In this type of system, the substrate is usually much closer to the source than in vapor deposition. This is why we elected to sputter the smaller spheres and evaporate in the larger ones.

It is our hope to use the space environment to our advantage. We can pump for several days without using power or adding contamination from organic oils often used in conventional vacuum pumps. We can also evapoate materials from filaments which normally tend to drip off during heat up and melt phase. In space the weightlessness should eliminate much of the risk of a droplet falling into the sphere.

The methods and results of G-38 will help supply useful data for simplified coatings of large antennas and heat shields in space where vacuum chamber size is unlimited. This device could have been made, for example, as a free floating module to coat rather large devices, such as bubbles, in space.

G-38 had three basic objectives. First, we were to design a sampling system to evacuate a large glass sphere with a vacuum gauge attached, seal it and return it in permanently sealed condition, allowing us to measure our working vacuum. Second, we were to perform eight depositions of thin films attempting to make best use of the space environment: vacuum, wightlessness and freedom from organic oil. The third task was to operate within budget limitations, using as much commercial technology as possible.

Several major areas of difficulty soon became apparent and we feel that in general they must apply to many GAS projects. Temperature swings in the experiment are a serious design challenge. If power were not limited, simple solutions would exist. We elected to use a cool option in designing the payload: insulate the experiment (with a few select thermal leaks where needed) and run a low density 6-watt heater to prevent battery freezing. It was in most cases easier to find materials to survive brief overheating in certain locations than it was to provide enough battery power to heat and cool the system. Some components, high current relays and evaporation filaments, generate up to 300-watts of heat for one or two minutes and then slowly leak it through polyimide foam to the rest of the system.



3 liter sphere with tungston filament in center, prepared for vacuum coating test.

Photographer: R. James Hills

The Eagle controller was selected for its E^2Prom memory, needing no backup power to retain program and current status inputs. Should battery power decline due to low temperature, the device merely waits for a warm cycle in the orbit and then continues. The same shutdown and continue mode occurs if over temperature sensors temporarily disconnect power and let the system cool down.

Location of space worthy materials was a major hurdle to overcome. Selection of excellent polymers to replace heavier metallic components was aided dramatically by the NASA Outgassing Data Compilation of Spacecraft Materials Publication 1014. An unusual example of plastic in place of more breakable ceramic is in the evapoation hardware. A piece of VR1040PPS is used to hold the filament and glow discharge cleaning electrodes. Only short manganese nickel leads isolate the hot tungston from the polymer support which has a working temperature above 500°F. Viton and TFE shrink tubing have eliminated many clamps and fittings in the system. The project would have been almost impossible without NASA's list of suppliers. Even so, obtaining specialized materials was a time consuming and frustrating challenge. Delivery times and prices can be shocking.

The power budget controls most final decisions in an experiment of this type. Our system needs both long term power for control and servo functions and high short term (1 minute/40amp) output for performing thermal evaporation and medium (2 hour/3amp) power for the sputtering tests. Since much of our experiment consists of light polyimide foam and empty glass spheres, battery weight was not the main problem. YUASA Captured Electrolite Calcium Lead Acid Batteries (sealed) were selected to meet the requirement and lab tests have been very encouraging. In spite of good batteries, we had to add a very low drain sleep cycle to our controller or it would have used too much power over seven days. At preset points in the program the controller turns itself completely off for six hours and then reactivates. During the off cycle current drain is about 12 micro amps. The E^2Prom memory retains currernt status of all valves and relays. The use of miniature filaments, from the R.D. Mathis Corporation, coated with the intended evaporant, allows short low power evaporation in three large spheres. A high fequency DC to DC converter drives the sputtering targets for a two hour coating cycle with metals tolerant to possible poor vacuum conditions, should all not go as well as expected. Globe gear motors and Swagelok plug valves running in a sealed nitrogen environment control the vacuum process and use power only when changing states.

Housing fabrication proved to be a challenging stumbling block. The most important lesson learned from this phase of the project is to select a single machine and welding shop that has helium leak test equipment and experience. Coordinating the difficulties of separate machining, welding and testing facilities is almost impossible. We found that stainless steel was so much more reliable to weld and fabricate that the weight and cost benefits of aluminum were negated. Of course, this may not be true for other experiments.

If all goes well, we will soon have a beautiful group of gold, platinum, chrome, aluminum and multi-layered spheres. But whether the experiment performs perfectly or not, it has been a challenging experience that none of us will forget.

As Jacob Bronowski said, "Man is unique not because he does science and he is unique not because he does art, but because science and art equally are expressions of his marvellous plasticity of mind."

The Greek root of Technology, Technical and Technique is TECHNĒ, meaning man's ART, CRAFT and SKILL.

From the cave as man first explored and strove to perfect his technē and continuing forth wherever he ventures, man leaves the imprint of his technē, saying: 'This is my mark. This is man.'

The hand of Anasazi man, painted 1200 years ago.

Photographed in the Grand Gulch of the San Juan Basin, Utah by Charles Lyon, Photographer for G-38, 39 and 40.