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Liberty Bell 7 Recovery Evaluation and Nondestructive Testing

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December 1999

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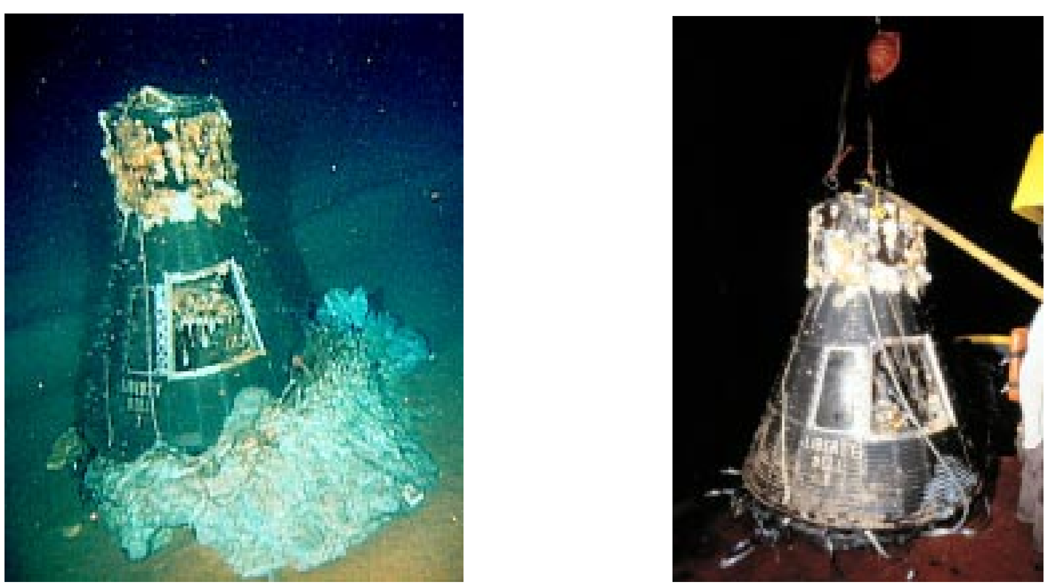
Abstract

An inspection of the Mercury capsule, Liberty Bell 7, and its contents was made on September 1 and 2, 1999. The condition of the capsule and its contents was consistent with long-term exposure to salt water and high pressures at the bottom of the ocean. Many of the metallic materials suffered corrosion, whereas the polymer-based materials seem to have survived remarkably well. No identifiable items or structures were found that appeared to have any scientific value. At this time, no further nondestructive evaluation appears to be justified.

Introduction

On April 16, 1999, an expedition funded by Discovery Communications Inc. left Cape Canaveral, FL, to search for the Mercury capsule, *Liberty Bell 7*, which sank to the bottom of the Atlantic Ocean on July 21, 1961. During that expedition, the expeditionary crew successfully located the *Liberty Bell 7* by using recently developed sonar maps and a remotely operated vehicle. Recovery took place on a subsequent expedition, and the space capsule was returned to port on July 21, 1999, exactly 38 years after its historic flight. Figure 1 shows the capsule as it was viewed on the bottom of the ocean (fig. 1(a)) and after being brought to the surface prior to being placed into a transportation/storage vessel (fig. 1(b)).

With the recovery of *Liberty Bell 7*, NASA had an opportunity to evaluate nondestructively the condition of the capsule. The Langley Research Center (LaRC) was tasked by the NASA Office of Space Flight to lead an Agency effort to inspect and conduct nondestructive analysis if warranted on the *Liberty Bell 7* capsule in accordance with a memorandum of understanding (MOU) between NASA and Discovery Communications Inc. The *Liberty Bell 7* capsule, which had been in salt water for 38 years, was recovered by an effort sponsored by Discovery Communications Inc. Langley Research Center formed a team including a member from the Johnson Space Center (JSC) to exercise the terms and conditions of the MOU where practical; this team was called the NASA *Liberty Bell 7* Recovery Team.



(a) View on bottom of ocean.

(b) View after being brought to surface.

Figure 1. *Liberty Bell 7* capsule. Photographs courtesy of Discovery Communications Inc.

For more information about the recovery and condition of the *Liberty Bell 7*, see the bibliography.

Charter and Team

Langley Research Center was tasked by the NASA Office of Space Flight to lead an Agency effort at the advent of the recovery of the Mercury capsule, that was sponsored by Discovery Communication Inc. to exercise the limited rights for the inspection and nondestructive evaluation (NDE) of the capsule which had been in salt water for 38 years.

The following table shows the NASA *Liberty Bell 7* Recovery Team formed by LaRC to conduct the inspection and evaluation:

Member	Expertise	Role/Center
William L. Smith	Human and robotic space systems design, development, and flight operations	Lead/LaRC
Michael P. Finneran	Public affairs	Public Affairs Officer/LaRC
John B. Hall	Human spacecraft systems and subsystems	Technical/LaRC
Robert D. Legler	Human Space Flight Historian	Historian/JSC
Eric I. Madaras	Systems NDE testing analyses	Technical/LaRC
Kenneth G. Wilson	Legal	Legal/LaRC

Assumptions

The first task was to try to identify elements of the capsule whose testing could provide scientific value. Inquiries with material scientists and engineers at JSC and LaRC confirmed that the materials and structures used on this capsule were obsolete and of little modern value. An additional complication was the fact that after being submerged in the Atlantic Ocean for nearly 38 years, many of the materials would undoubtedly be compromised. One specific item that was discussed was the possible condition of the thermal protection system (TPS). Initially the committee thought that the TPS on the *Liberty Bell 7* was of a phenolic variety. Although phenolic TPS is an old style of TPS, systems like this are occasionally revisited from time to time. Data on this TPS could be added to the database obtained from the other Mercury flights. In general, though, it was difficult to foresee what specific scientific tests should be done on the capsule without a preliminary investigation.

With this guidance, a few methods for tests that could be undertaken to acquire a preliminary view of the *Liberty Bell 7* and to archive the state of the capsule for further consideration are as follows:

1. With respect to the TPS, ultrasound might possibly be used to test such a structure. Thiokol Corporation experimented with this technology in reference to solid rocket motor nozzle throat erosion (private communication with Lee Pearson of Thiokol Corp.), and it might be possible to document the char thickness, if any, and the remaining thickness of the ablator.

2. Undertaking a complete photographic study of the capsule for NASA and public use would seem rather straightforward. This study could include close-ups as well as comprehensive views of the capsule.

3. A unique technology that could actually view the inside of the structure is x-ray computed tomography (CT). Because of the size of the capsule, only a few systems are probably available that could accomplish this task. For example, a large CT system at Hill Air Force Base (AFB)

outside Salt Lake City, UT, can scan objects up to approximately 2.4 meters in diameter. Also, the U.S. Navy has several systems that can scan objects with diameters of approximately 2.2 meters. If arrangements could be made, this system could actually scan an appropriately sized container accommodating both the capsule and its water bath to provide a three-dimensional view of the capsule, including structures within and behind the walls. Then this computer database would be available to engineers and scientists in the future. In addition, this information could be used to address the TPS dimensions.

For each of these methods, the cost, risks, and potential benefits were reviewed. First, the ultrasonic study of the TPS would have only taken a week or two and would not have involved much manpower. The potential risks were related to the uncertainty on several points with this measurement. The first point dealt with the condition of the TPS and knowledge of the ultrasonic properties of the material. To measure the thickness of the material, the ultrasonic velocity needed to be known. Sitting on the ocean floor for many years may have allowed some unknown material changes to take place in the TPS that could not be anticipated. Therefore, the velocity values for the ultrasound in the TPS might be only an estimate in this material and would require some sort of calibration to acquire; calibration might not be possible. Also the surface of the TPS might be partially charred with the rest intact; this would greatly complicate the measurement. Having burned and unburned components would require additional information to ascertain the relative thickness if it was possible. The second point touches on the geometry and access. How easy the access to the TPS would be is not clear, and data acquisition could be limited. Also, the surface might be so uneven that it would hamper the accuracy of the data.

The second suggested method, photographic evaluation, like the first method would have only taken a week or two and would not have involved much manpower. The costs for film processing were not expected to be exorbitant. The risk in obtaining these data was mostly related to geometry and access to the surfaces of the capsule. Another issue was duplication of effort because much of this information might be available from the organizations that recovered the *Liberty Bell 7*. Because they were also interested in documenting the capsule, they would probably have taken many photographs making this effort redundant.

The third method suggested would be the most costly. It would involve transporting the capsule to the CT site, making the measurements, and then transporting the capsule back to its original site; this would take about 2 to 3 weeks. In addition, the amount of data taken would be enormous and would require a few weeks to process. If more sophisticated processing was required, manpower needs could approach 6 months. The cost would encompass transportation, handling, facility usage expenses, and analysis manpower. The risks for this effort were related to several uncertainties. The first uncertainty again deals with geometry. The whole object could be scanned provided it is less than 2.44 meters in diameter. (See fig. 2.) Scanning the capsule and container together would require careful planning. Could the capsule be removed from its container or would it be in a correctly sized container? Also, at Hill AFB and the Navy bases, the operations are configured and designed to handle various large missiles with equipment to lift and handle these missiles. How that equipment and handling procedures could be adapted to handling the capsule and container would also require careful planning. Finally, some sort of agreement between the Air Force or the Navy and NASA would be necessary to utilize their facilities. The facility operators were supportive of this type of project, but they were unsure of the procedure for working with nonmilitary organizations. Additional risks would be involved in transporting the capsule to another site, including potential damage caused by truck vibrations or a possible truck accident.

(a) One CT system scanning a missile.

(b) Large CT system where capsule and container would have to fit between the two large gantries (on left) on large turntable (in center).

Figure 2. CT systems at Hill AFB. Photographs courtesy of Advanced Research & Applied Applications Corporation (ARACOR).

Preliminary Inspection

Based on these foregoing ideas, the decision was made that a visit to the site where the capsule was being stored, the Kansas Cosmosphere and Space Center, Hutchinson, KS, and to a site where CT could be performed would be the best way to evaluate the various opportunities. At Cosmosphere, the capsule was contained in a special steel transportation/storage vessel where it was being continuously bathed with fresh water. The fresh water served two purposes: (1) flush out the brine solution, which had penetrated every element of the capsule, and (2) keep the capsule wet so that the corrosion products would tend to stay soft and be easier to handle. Some corrosion materials can turn to a rock-hard compound that is hard to remove, which would make refurbishment difficult. Unfortunately, in this first trip to the Cosmosphere, the capsule could not be viewed directly because it was inside the transportation/storage vessel and there were no viewing ports. The drawings for the steel transportation/storage vessel were studied to see what physical constraints might be placed upon measuring with CT and to see how other inspections could be made. Because the capsule was housed in the closed container, no direct visual evaluation was made at this time. The rest of the trip was made to Hill AFB where a large CT system was available for evaluation. The Navy's CT system was unavailable for inspection at this time. At Hill AFB, it was discovered that several physical limitations did exist. First, the storage vessel of the capsule had external lifting and tie-down structures that exceeded the maximum allowable diameter of the CT systems by several centimeters. Second, the door to the facility, which was designed for their trucks and loads, was nearly 0.5 meter too short for the storage vessel to go through. These two limitations would force the additional handling complications of opening the storage vessel and transferring the capsule to the inside of the building and then into another holding tank that was less then 2.44 meters in diameter and about 2.5 meters tall where it could be submerged in fresh water again.

Reality

We learned after these initial visits in subsequent talks with people who had been present during the recovery of the capsule that the TPS heat shield was not a phenolic TPS material. Instead, the first two flights had a beryllium heat shield for its TPS, which in the case of *Liberty Bell 7* had completely corroded and was not recovered with the capsule. This fact, added to the complications of doing a CT scan at Hill AFB, removed most of the incentive of trying to perform CT and ultrasonic nondestructive evaluation on the *Liberty Bell 7*. The decision was made that a few individuals should visit the Cosmosphere at the time the storage vessel was opened and make a visual inspection to determine if any NDE was warranted.

Results of Inspection

On September 1, 1999, James Lewis of JSC and Eric Madaras of LaRC visited the Cosmosphere to be on hand for the removal of the *Liberty Bell 7* capsule from its storage vessel. The storage tank was opened at about 8:30 a.m., and the capsule was moved from the storage tank into an open viewing facility designed for the refurbishment of the capsule and simultaneous public viewing. The move took approximately 3 hours. After that, removal and cataloging of the contents of the capsule commenced.

The external structure was in surprisingly good condition. (See fig. 3.) The black object at the bottom of the capsule is a skirt that provided ballast support. The heat shield would have been below the skirt, but the heat shield was missing and had not been recovered. The bottom structures included the

Figure 3. *Liberty Bell 7* capsule being removed from its transportation/storage vessel. Photograph courtesy of Kansas Cosmosphere and Science Center.

flexible skirt and various metal strips and springs, a covering that appeared to be a polymer-based material, and the capsule base behind that; all looked to be in good condition. The external covering of the cone-shaped sides of the capsule consisted of small sheet-metal corrugated panels approximately 0.031 inch thick, which showed no signs of corrosion. Even the paint was still attached; although in some locations, it was loose. An electronic thickness gauge indicated that the sheet metal was a consistent thickness; this implied no corrosion. The upper portion of the capsule, which was made of thick aluminum plates, experienced significant material loss caused by corrosion. Although some areas measured full thickness of approximately 0.220 inch, most regions were less, including several areas where the material was completely lost. Attached to these aluminum plates were large nodules of corrosion products.

The internal structure was far from pristine. The right instrument panel was almost corroded away with the gauges and switches sitting on the astronaut's seat but still attached to the wiring harnesses. In addition, the forward part of the periscope pedestal and the central console were also totally corroded away. Two cameras were recovered, but their film reels were in very poor condition. A few additional instruments and gauges such as the "eight-ball" and the pitch, roll, and yaw gauges were lying on the couch. The other panels seemed to still be intact. Some electronic equipment mounted on the sides of the capsule was badly corroded. (See fig. 4.) The oxygen tank looked to be intact, whereas a helium tank appeared to have ruptured. Many of the gauges showed signs of implosion at the glass covers. Most of the polymer-based materials such as the seat, the harness, and the flashlight appeared to have survived the long-term exposure of the seawater intact. All material and structural degradations were consistent with the effects of high pressure at deep ocean depths and long exposure to salt water.

Items of historical note that were recovered on the first afternoon included the astronaut's flight notebook, four mercury dimes, a survival knife, and the cover for the door detonation switch. (See figs. 4, 5, and 6.) On the second day of investigation, an additional 35 mercury dimes were discovered.

Figure 4. Retrieval of astronaut's flight notebook; numerous electronic gauges, switches, and wiring harnesses are visible. Photograph courtesy of Kansas Cosmosphere and Science Center.

Figure 5. One of numerous mercury dimes recovered from debris and muck at bottom of capsule that were reportedly carried on board as souvenirs to commemorate the mercury flight. Photograph courtesy of Kansas Cosmosphere and Science Center.

(a) Knife encrusted in mud and muck from bottom of capsule.

(b) Knife after renovation work.

Figure 6. Recovered survival knife reportedly left in capsule. Photographs courtesy of Kansas Cosmosphere and Science Center.

Figure 7. *Liberty Bell 7* capsule with skin, insulation, and much of interior instrumentation removed. Video camera image courtesy of Kansas Cosmosphere and Science Center.

Refurbishment of the capsule is now well underway. Most of the internal components have been removed and much of the skin has been taken off. (See fig. 7.) The aluminum plates on the recovery tower were so badly corroded that they are probably beyond recovery. The small sheet-metal corrugated panels for the skin were indeed in excellent condition.

Concluding Remarks

The condition of the *Liberty Bell 7* capsule and its contents was consistent with long-term exposure to salt water and high pressures at the bottom of the ocean. No identifiable items were found that appeared to have any scientific value. At this time, no further nondestructive evaluation appears to be justified.

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