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# Chapter 6
# Purposeful Ephemera: The Implications of Self-Destructing Space Technology for the Future Practice of Archaeology

**Justin St. P. Walsh**

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## Introduction

Recent trends in space mission design are likely to have serious consequences for future archaeological research on the development of technology. These trends, especially the introduction of new international standards governing the lifespans of equipment launched into Earth orbit, have resulted from the consequences of past and ongoing space missions as well as the foreseen impact of future activity by national, academic, and commercial participants in spaceflight. The new limits imposed on orbiting objects have been interpreted by the spacefaring community as requiring the destruction of those objects, to the extent (it is hoped) that no material trace of them will remain. AQ1

In the strictest sense, this paper is about problems that future archaeologists will face when they attempt to reconstruct the development of technology for the exploration and exploitation of space without direct access to examples of that technology. These problems are analogous to larger transformations in the contemporary world, however, as the objects we live with become increasingly (and purposely) ephemeral in the face of environmentalist efforts to promote recycling and corporate industrial design that favors "planned obsolescence" over long-term

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durability. The focus of archaeological observations on tangible, material remains of past human activities has precluded much work on ephemeral objects, but it is clear that new methods will have to be developed to study cultural goods that leave no direct evidence of their existence.

## The Problem of Space Debris

The definition of new space technology as ephemera was raised in April 2012, at a conference concerning "end-of-mission disposal and requirements" held by the American Institute of Aeronautics and Astronautics at the Jet Propulsion Laboratory. The attendees of this conference, all professionals with long-standing experience in the military and commercial space industries, were previously unaware of efforts by archaeologists to preserve in situ space heritage and of proposals that heritage management should be mandated for missions which are likely to be historic in nature (e.g., Darrin and O'Leary 2009; Capelotti 2010; Walsh 2012). The concerns of these professionals were governed instead by international treaties, national laws and policies, economic resources, mission requirements, and the legacy of past practices.

This last factor seemed, in fact, to dominate discussion, particularly as it was connected to the current problem of space debris. According to the US Air Force's Joint Space Operations Center, which monitors orbital space, as of 15 March 2013, there were roughly 22,000 objects larger than 10 cm in orbit; of these, only 5 % are functioning payloads or satellites, 8 % are rocket bodies or parts, and 87 % are debris or inactive satellites (Vandenburg 2012).

In fact, the actual number of objects in space is much larger, "if pieces smaller than ten centimeters are included, ranging from 500,000 into the many millions" (Chodas 2002). For example, in 1963, the US Air Force dispersed 480 million copper needles, each approximately 2 cm in length, at an orbit altitude of roughly 3,500–3,800 km (2,174–2,361 miles; by contrast, only 2 years earlier, there had only been 54 human-made objects in space (Overhage and Radford 1964). This launch was part of Project West Ford, which hoped to create a kind of reflective antenna for terrestrial radio signals in the days before widespread deployment of satellite communications (Wiedemann et al. 2001). Despite an initial prediction that the needles would have an orbital lifetime of 3–6 years, at least 46 clumps of these needles were still in orbit more than 50 years later.

The danger presented by orbital debris is significant. Many pieces are fragments, of widely varying sizes. One object, designated J002E3 upon its discovery in 2002, measured 10 m in length and was probably one stage of a Saturn V rocket [perhaps from Apollo 12 in November 1969 (Chodas 2002)].

Worse, the problem is growing due to events such as the Chinese test of an anti-satellite missile in January 2007, which led to the creation of over 2,000 trackable fragments and perhaps another 150,000 smaller pieces. A communications satellite, Iridium 33, was destroyed during a collision with a defunct Soviet military satellite,

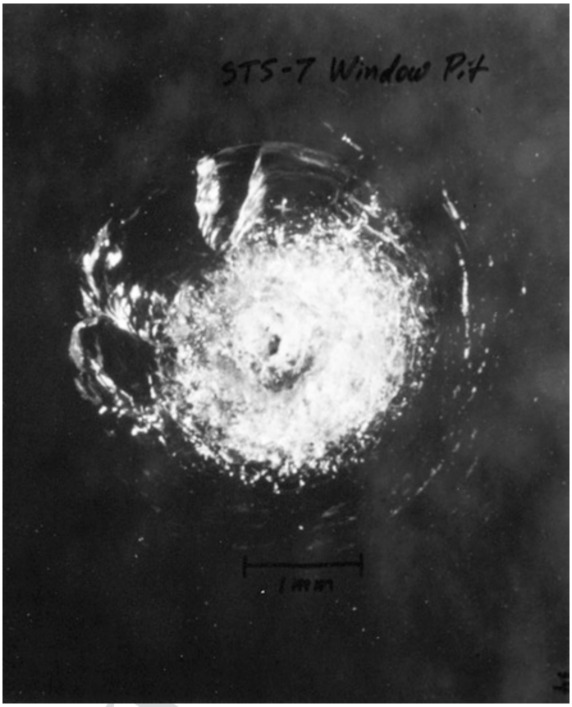


**Fig. 6.1** A crack in the windshield of the Space Shuttle orbiter *Challenger*. The crack was created by collision with a fleck of paint during STS-7 (18–24 June 1983) (NASA)

Kosmos-2251, in February 2009, creating yet more debris. A vice-president for Iridium was later quoted as saying that the company receives 400 close approach warnings every week for its fleet of 66 satellites (Weeden blog post).

The crew of the International Space Station has been forced to take cover on several occasions, on account of close encounters with other objects (Drew 2012). More worryingly, in 1983, the shuttle *Challenger* (STS-7) was struck in the windshield by a 0.2 mm fleck of paint traveling at roughly 28,000 kph (Fig. 6.1); the craft could have been depressurized as a result (Hyde et al. 2001: 191–196).

Defunct objects, of course, also pose a potential threat to life and property on the Earth's surface if they de-orbit. Kosmos-954 de-orbited unexpectedly in 1978, spreading radioactive material from its power supply across a 600-km stretch of north-central Canada, and NASA's Skylab showered southwestern Australia with debris in 1979. To date, only one person has actually been hit by deorbiting debris: a woman in Tulsa, Oklahoma, was struck by a piece of a Delta II rocket that re-entered the atmosphere in 1997, 1 year after its launch (Fig. 6.2).

At the same time that debris has been increasing, several developments are opening space up to a wide variety of new participants. For example, the Google Lunar X Prize is encouraging private groups to design a lunar rover and send it to the Moon. Some of these groups, such as Moon Express, see the competition as a stepping stone to exploitation of space resources, which will require much greater traffic.

**Fig. 6.2** Lottie Williams of Tulsa, Oklahoma, with the piece of a Delta II rocket which struck her upon re-entry in January 1997 (courtesy of *Tulsa World*, used by permission)



The spacefaring community has already increased its activity, especially in low-Earth orbit, with the development of nano-satellites, or "cube-sats" (Fig. 6.3). This class of equipment is designed to fit inside a standard metal cube which measures 10 cm on a side (or which is made of several such modules linked together). The miniaturization of electronics has made these tiny satellites feasible to construct and useful for research, while the lower cost of producing and launching them compared to traditional satellites is a strong incentive for their adoption by scientists. In one recent launch, NASA placed 29 such satellites into space simultaneously.

One direct consequence of this problem has been the development of new satellites which will themselves clear low-Earth orbital altitudes of debris. These satellites are being developed by scientists in Japan, Switzerland, the US, and likely elsewhere, too; they are still in the testing phase, but their developers hope to deploy them within the next few years (Kawamoto et al. n.d.; Gass and Grosse 2012; Chang 2012). These satellites are intended to "sweep up" debris, collecting it and destroying it by de-orbiting into the atmosphere with it.

Another consequence has been the institution of a new international standard by the Inter-Agency Space Debris Coordination Committee, which is made up of all of the major national and international space agencies. Its Mitigation Working


**Fig. 6.3** Recent developments in the miniaturization of electronics for communication have allowed satellites to become smaller and cheaper. One example of this phenomenon is the nano-satellite, or "cube-sat," which puts all of the hardware within a standard 10 cm cube (or multiple connected modules of this size), as shown here (NASA)

Group issued guidelines in September 2007 (also accepted by the UN through Committee on Peaceful Uses of Outer Space): A spacecraft or orbital stage should be left in an orbit in which, using an accepted nominal projection for solar activity, atmospheric drag will limit the orbital lifetime after completion of operations. A study on the effect of post-mission orbital lifetime limitation on collision rate and debris population growth has been performed by the IADC. This IADC and some other studies and a number of existing national guidelines [sic] have found 25 years to be a reasonable and appropriate lifetime limit. If a spacecraft or orbital stage is to be disposed of by re-entry into the atmosphere, debris that survives to reach the surface of the Earth should not pose an undue risk to people or property. This may be accomplished by limiting the amount of surviving debris or confining the debris to uninhabited regions, such as broad ocean areas (Inter-Agency Space Debris Coordination Committee 2007).

The IADC document was preceded in March 2007 by a UN Committee on the Peaceful Uses of Outer Space (COPUOS) policy which provided less-defined guidelines, specifically Guideline 6 in the Annex to the Report on the Sixty-Second Session of the General Assembly (United Nations 2007: 50): *Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission:* Spacecraft and launch vehicle orbital stages that have terminated their operational phases in orbits that pass through the LEO region should be removed from orbit in a controlled fashion. If this is not possible, they should be disposed of in orbits that avoid their long-term presence in the LEO region.

Although this standard is not widely known outside the space industry, it has now also been codified by the International Organization for Standardization for low-Earth orbit (LEO, below an altitude of 2,000 km (1,242 miles), in the area where most satellites have been placed) in a document put forth in February 2011 (ISO 2011). Section 6.1.1.2 of the ISO document reads: "Space debris released into Earth orbit as part of normal operations … shall remain outside the [geo-stationary orbit] protected region and limit their presence in the LEO protected region to a maximum of 25 years after their release." Anecdotal evidence indicates that the new standard appears to be broadly accepted by commercial industries for future missions. AQ2

Criticism can easily be made of the standard's anthropocentrism, given that it suggests that debris including toxic chemicals and radioactive substances should be directed into areas that are uninhabited by humans but are full of other forms of life, such as the world's oceans. In any event, a few scientists have begun to take up the challenges posed by these policies to mission design. For example, Aerospace Corporation's Center for Orbital and Reentry Debris Studies is working on a project based on the principle of "design for demise": creating space equipment from materials specifically chosen for their ability to burn up entirely in the atmosphere during de-orbit re-entry, so that nothing remains to fall to the Earth's surface (see the contributions in Ailor and Wilde 2013: 603–776). The group launches satellites made of different kinds of materials, noting which ones dissipate and which remain following descent. Future satellites will be designed to take advantage of this research and protect the public.

Current events in space mission design therefore pose a problem for future archaeologists who want to study the development of human technology. For, although the study of artifacts is not the only method available to archaeologists or used by them, direct observation of artifacts has long been at the core of archaeological practice—and would be the best way to learn about how the artifacts themselves changed over time.

How will we study the development of a society's technology when the evidence we would most like to have is not just largely vanished, but entirely absent? These problems seem similar to the ones faced by future archaeologists who will trace the development of bottles, cans, and other containers which have been subject to recycling since the 1970s, but the ubiquity of those objects seems to ensure that many will be discarded as garbage rather than recycled. Some direct traces of their existence will almost certainly survive.

The space technology considered here, by contrast, generally consists of unique objects (or very limited numbers of types or series of objects) designed for highly specific purposes. If these artifacts are designed to self-destruct completely, how will they later be identified or understood by future researchers as tools or as cultural objects? On one hand, future archaeologists would probably be able to read some significance into the lacuna. They may be able see that first, around the middle of the twentieth century, humans developed space satellites. Perhaps *Vanguard 1*, the oldest piece of manmade material in space (launched in March 1958), will remain in orbit.

But in studies of later periods, even though it will likely be known that people continued to engage with space, no satellites dating to the period 60 or 70 years after the earliest examples will be found. We don't know what future techniques might be developed to deal with these problems, or even what kinds of questions future archaeologists might be tempted to ask; any guesses quickly move us into the realm of science fiction. For example, one technique might include some form of sampling of the upper atmosphere and low-Earth orbital altitudes for chemical residues of the incinerated equipment, much as present-day archaeologists sample soils for evidence of human activities (or the way that cosmologists survey cosmic background radiation for evidence of the Big Bang).

## Space Technology as Ephemera

The study of purposeful ephemera has been quite limited in archaeology. This fact is perhaps surprising, given that the archaeological record is only a partial sample of the set of materials which once existed—in other words, material culture is, almost by definition, ephemeral. But most material culture is not *purposely* ephemeral. While humans generally have not expected most of the tools or structures that they create to last forever (at least prior to the introduction of the concept of "planned obsolescence" to modern industrial design (Slade 2006), they have produced many, if not most, of their creations with an eye towards their durability.

The ephemerality found in the archaeological record is largely a result of the effects of processes over time such as the "natural and cultural transforms" elucidated by Schiffer (e.g., 1972: 156–165, 1987). Therefore it can usually be seen as accidental, or at least unrelated to the design of objects, rather than intentional, and, indeed, some material *does* survive, giving us the record of material culture that forms the basis of much of archaeological research.

Human-made objects survive even in space—as the space debris problem described above suggests, some objects survive longer than their designers might want or in ways that are unexpected. Some objects on the Moon, such as the nylon American flags, will have disintegrated following more than 40 years of exposure to alternating extremes of heat and cold, not to mention radiation. NASA's online *Apollo Lunar Surface Journal* collects a variety of opinions on the present state of the flags, as well as remote sensing imagery that shows whether shadows are cast by flags at the various landing sites (Fincannon 2012).

According to astronaut Charles Duke, who took part in the Apollo 16 mission of 1972, the photographic portrait of his family which he left behind at the landing site showed signs of damage almost immediately from the heat of a lunar

**Fig. 6.4** Astronauts left some objects on the Moon not directly related to their missions, and yet form part of the material record of their activity there. This image shows a portrait of the family of Charles Duke (Apollo 16, 21–24 April 1972) in a small plastic bag which he placed on the surface. Duke noted that the photograph started to turn brown almost immediately in the heat of the lunar day (NASA)



day (Jacobs 2009; Fig. 6.4). But these objects were not intended from their very invention to be destroyed, and, in any case, archaeologists are used to working with objects on Earth that have broken or partially disintegrated.

Until our present era, though, it seems that there have been relatively few instances of humans creating objects which will be destroyed on purpose or even self-destruct. This is precisely the plan for orbital space equipment. The probability of any one example's survival, while not impossible, thus becomes extremely unlikely.

Consideration of other historical examples of objects that have been purposely constructed to be ephemeral or to destroy themselves seems to be a worthwhile means of trying to understand how ephemera can be studied and what lessons can be learned about what evidence might be the most useful for future scholars. In brief, it will become clear that two primary possibilities exist for preserving useful evidence: replicating the objects, and recording and documenting ephemeral objects and the activities associated with their creation and use (a third possibility, study of the sites where ephemeral space equipment was developed, produced, and launched, also exists, but it presents less direct access to the actual space equipment; see Donaldson, this volume).

The following discussion will explore these possibilities with a view towards the establishment of priorities. Would it be more useful to create and preserve replicas of ephemeral technology, or to emphasize their thorough documentation? In some ways, these approaches are intertwined and overlap, since recordings and documents can help to vet the accuracy of copies. There are, as will be seen, also significant problems with both approaches.

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## Documentary Evidence

Some of the greatest challenges to documenting and analyzing ephemera can be found in the world of performance—particularly the history of theater, dance, and associated arts. In drama, there has long been a widely-recognized tension between the importance of the authorial intention and the text, and the interpretation of the text by actors, directors, and stage crew—the reconstruction of performances, especially in the far-distant past is highly problematic.

For example, the only known example of stage notes from the sixteenth or seventeenth centuries (Dulwich MSS 1, Article 138, folio 8r) records the lines for the lead character in the play *Orlando Furioso*, probably by Robert Greene, who died in 1592 (Greg 1922; an image of the part can be viewed online at http://www.henslowe-alleyn.org.uk/images/MSS-1/Article-138/08r.html). The notes have been identified as probably by or for the actor Edward Alleyne in a production of 1591 or 1592. It is clear from what remains of this document that there are variations, some significant, between the notes and the same passage in the published first quarto edition of 1594 (Foakes 2005–2013). Lines were added or removed, and their order is altered.

These differences reflect the gap between an artist's conception and the reality of performance, where the same actor will deliver lines differently on different nights, different actors will play the same role differently, and of course, an actor fumbling for a line might even invent new dialogue or skip material in the text. Likewise, the text could be seen as a record only of one specific performance, as opposed to a guide for all performances. In other words, it is important to be wary of treating documents as "ur-texts" encoded with definitive truth.

Contemporary art can draw our attention to similar challenges associated with documenting ephemera. The artist Tino Sehgal calls his art "constructed situations." They are not performance art (according to Sehgal) because they require audience participation and they happen in museums, not theaters. In his pieces, which have taken place in major venues including the Solomon R. Guggenheim Museum in New York and the Tate Modern in London, visitors interact with performers who ask scripted questions or make statements (called "prompts") and converse with them. There are no objects associated with the artworks except costumes and accessories (like umbrellas) held by the participants.

Moreover, Seghal "forbids the creation of any of the by-products—photographs, videos, catalogues, wall text—that normally derive from a work. His pieces leave no physical residue…. He believes that mementos of his work would threaten its purity, which could weaken its effect" (Collins 2012). Even the contracts for his work are oral, rather than written (there are not even any notes taken; later disputes over the contracts are understood to be resolved through the development of consensus among those who were present at the negotiations about what they remembered having occurred). Each time a piece is performed, it will necessarily be different.

The only recordings which exist to document Seghal's works are "tertiary reports," which is to say critical published reviews in newspapers and journals, as

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well as descriptions such as blog posts by other visitors, and photographs which are illicitly made (visitors are forbidden from making photographs, but in practice it has been impossible to stop them from doing so with cameras on cell-phones; Collins 2012). The lack of detailed documentation makes it practically impossible to study the individual works. Researchers' attention must be directed only towards Seghal's methods instead, but even these are only accessible through the documentation of the few interviews in which he has participated.

## Replication as Evidence

One might think that copies of purposeful ephemera would be the most direct way to understand the missing original, but there are complications here as well. The most important Shinto shrine in Japan—the one associated with the *kami*, or spirits, of the Imperial Household, which is located at Ise in southern Honshu—is an especially interesting example of ephemera that has been replicated.

There are two shrines, an inner one and an outer one, at the site. These were first built, according to tradition, in 672 CE (Isozaki 2006). The buildings associated with the two shrines were constructed in a simple fashion from cypress wood and *miscanthus* grass, with copper and gold fittings. The plant-based materials decompose relatively quickly; as a result, a system called *shikinen-sengū* (or *shikinen-zōkan*) has emerged by which, every 20 years, the shrines are totally rebuilt using new materials. 2013 marks the completion of the sixty-second rebuilding.

All of the items dedicated by the imperial family over the centuries (hundreds of sacred treasures and vestments, spinning and weaving tools, military arms and wear, horse equipment, musical instruments, writing implements and daily goods) are also replaced with new versions, the gods are moved in a ritual known as *sengyo*, and the old buildings are dismantled. The former site of the each building becomes a vacant lot which awaits its rebuilding in 20 years.

The *shikinen-sengū* process is thought to preserve traditional Japanese building and religious practices (not to mention metalsmithing, weaving, etc.); in fact, the process of rebuilding became properly systematized by the tradition of cyclical replacement at Ise. The old materials get recycled, either into objects associated with veneration, or into building materials such as metal fittings which are then used at other shrines around Japan. In this case, the physical evidence which remains of the building's shape and function is only what purports to be a perfect, repeated reproduction of the original.

The word "purports" is important here, because it is clear from analysis of the documentary evidence (both photographs and written accounts) that the process has been revised throughout the centuries and not been carried out in the same way every time. It is generally difficult to assess the fidelity of the new structures at Ise to the old ones, since the public is not allowed to enter them, or even to approach them closely. Concentric fences block access and even close views of the shrines.

These fences, however, have themselves increased in number since the nineteenth century, from two to four. Photographs from the earlier period also indicate that the fences were not as tall as they are today (Isozaki 2006: 134). Moreover, the shape and orientation of the buildings has changed, and some Japanese scholars have reconstructed yet more differences going back to the sixteenth century, with changes tending towards increased decoration and complexity as time went on.

More profound problems exist for understanding the original shapes and formats of the Ise shrine buildings, too. In particular, there was a 123-year period (1462–1585) in which no rebuildings happened due to national unrest, and for the last 85 years of that era, there was no shrine at all because "the main precinct" collapsed in 1500 (more recently, the disruption caused by the Second World War caused a delay in rebuilding at Ise, with the date pushed back from 1947 to 1953, followed by a resumption of the traditional twenty-year period; for the information here and below, Fukuyama 1968: 41, quoted and translated in Isozaki 2006: 137). Hardly anyone still alive in 1585 could have remembered the shrine's design and decoration. The response of shrine officials, according to the shrine's own record of the 1586 rebuilding, was to collect information concerning detailed measurements of each structure and [give] it to the carpenters; when this data contradicted the master carpenter's records, officials and master carpenters settled on a compromise. They were forced to determine scale, structure, and form of the new main sanctuary by combining bits and pieces from old records and plans.

As Isozaki (2006) quickly noted, the plans in question could not have been precise even if the shrine had a simpler layout (as seems likely), given the documentation standards of the time. In fact, he suggested, based on the spirit of compromise and "guesswork" recorded in the shrine's document concerning the rebuilding, "a certain will to readjust the design toward a perceived authentic form … must constantly have been at work" (Isozaki 2006:138). Such a sentiment is a useful reminder of the bias inherent in archaeological reconstruction, too, when investigators make interpretations without extant direct evidence.

These interpretations are supported by (perhaps educated) intuition but also derived from expectations which are themselves generated by previous work, experience with similar situations, and personal attitudes. In any case, a constant process of replication without access to the original, or to the people involved in the creation of the original, is likely to problematic, as it will inevitably introduce variations that are dependent on the interests and personalities of the replicators.

The problems faced by conservators dealing with modern art show the value of recreations, though, even those which happen at a later date. The artist Eve Hesse's 1969 work *Expanded Expansion, today in the collection of the Guggenheim Museum in New York, was* made of reinforced fiberglass poles and rubberized cheesecloth, but it "has become brown and brittle" over time (McCoy 2012). Art conservator Tom Learner described an experimental exhibition during the symposium: "We showed sections of the original piece alongside a material mock-up of a segment that was made by Doug Johns, Hesse's assistant…. Walking past the mock-up was really extraordinary because the slightest air movement caused the latex-impregnated cheese cloth to sway and move—which most definitely did not occur with the embrittled original. You could also smell the materials in the air." He continued, "We're not trying to say that what we've done is the 'right way.' We're trying to explain the different approaches that could be taken, and—ultimately—ensure that the full variety of approaches still remain available to the artwork" (McCoy 2012).

## Combinations of Recording and Replication

So far in this discussion, media have been treated uncritically as a means of documenting ephemera—through photographs, drawings, and written descriptions—but media themselves are cultural creations, and they are also subject to the same kinds of ephemerality as other artifacts. Digital media have recently attracted the most attention for the problems associated with its ephemerality, since there are clear problems related to long-term storage, the need for legacy hardware for reading old digital media, and the viability of file formats. These issues direct our attention to the general difficulties associated with preserving any unstable (i.e., cutting-edge, rapidly developing) technology. Some historians (amateur as well as professional) and institutions have been collecting evidence for early software, including software languages (see, for example, the Museum for Computer History, or Paul McJones' *Dusty Decks* blog; http://www.mcjones.org/dustydecks).

The original website created by Tim Berners-Lee at CERN was recreated in 2013 to celebrate the twentieth anniversary of the World Wide Web (http://info.cern.ch/hypertext/WWW/TheProject.html). Many of the links beyond the first page are broken, however—a phenomenon with which most users of the Internet will be familiar when dealing with older, neglected, or incomplete websites. Other projects, such as 404 *page found* (http://www.404pagefound.com/), whose name refers the code used on the Web for an error related to internet resources that cannot be found, attempt to recognize or preserve old websites which still function.

The Internet Archive's so-called "Wayback Machine" (http://archive.org/web/) claims to provide access to 368 million old webpages. The Internet Archive was founded in 1996, specifically to provide "a mechanism and a memory" to allow web culture to learn from its successes and failures. It has affiliated with the Smithsonian Institution and other research organizations.

More recently, a remarkable project has begun to address the problem of reconstructing ephemeral media: sounds in the form of recorded audio. Although these media do not fall into the category of purposeful ephemera because they were intended to be durable, their intangible nature provides important insights to help us understand how it might be possible to work with other ephemera. Feaster (2012a) has examined the different means used by humans to record sounds, from manuscripts of musical notation to experimental scientific formats developed in the nineteenth century, and he has developed methods for playing some of these recordings.

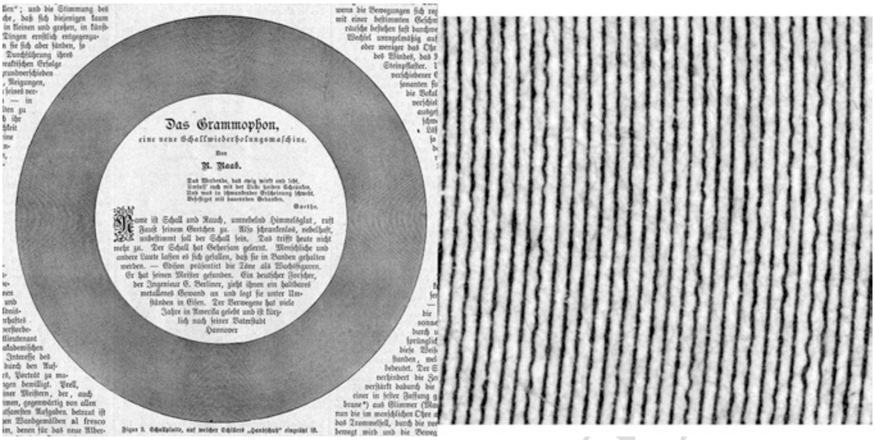


**Fig. 6.5** *Left* image of an early gramophone record containing a recording of “Der Handschuh” by Emile Berliner, from the February 1890 issue of the German magazine *Über Land und Meer*. A close-up of the image (*right*), showing the shape of the grooves on the record (courtesy of Patrick Feaster)

The most relevant examples of Feaster’s work are probably the recordings made by Emile Berliner, which were pressed onto gramophone records by 1889 and made available for sale beginning in 1890. Several of these records are known only from images of the discs which were printed in contemporary German magazines. Feaster took advantage of the very high image quality used in the printing, which reveals the shape of the recordings’ grooves, where the sound was encoded (the text which accompanied the image of the record in the magazine actually gave instructions to readers about how the recording could be recreated from the image, and then played using a homemade bamboo stylus; see Feaster 2012a: 65–66). In one example, the record was a recording of Berliner reading “Der Handschuh” (“The Glove”), a poem written in 1797 by Friedrich Schiller (Fig. 6.5).

As Feaster has described in a blog post (2012b, with playable audio), it was possible to use a computer to play back the sounds by scanning the image at high-resolution, converting the spiral grooves to straight lines, stitching them together, and converting them to a .WAV-format digital audio file by means of a program normally used for digitizing optical film soundtracks. The sounds of the reader’s voice in the resultant file are audible, if not clear. Without a copy of the text available for comparison, it is admittedly very difficult to understand the poem.

Even so, the reconstruction of a recording of any fidelity without access to the original matrix on which the recording was made is a remarkable achievement, arguably comparable to producing an accurate recreation of a painting’s colors, composition, and textures from a literary description alone. Even better, with the development and distribution of high-quality 3-D printing technology, it is becoming possible for individuals to produce their own playable analog records from raw materials (Ghassaei 2012, with video demonstration), so the possibility exists for a complete recreation of a usable piece of media in the correct physical format without ever having examined the original object.

## Conclusion

There are obviously problems associated with what can be learned about original ephemera in each of these cases. Our access is indirect, coming either through visual and literary description, or through the vagaries of copying (which can never be completely faithful) and the destruction and dispersal of the original. Both kinds of access will themselves probably require thoughtful attention to preservation in order to survive for study.

Documentation can describe or depict the original object; it can come in tangible forms (e.g., books or other printed material, photographs or drawings on paper) or intangible (i.e., digital). The examples described above, however, show that documents must be taken as partial and biased, created according to the intentions of the person or people who made the documentation, not with the interests of researchers in mind. Whatever documentation is made and preserved should capture the widest possible range of information relating to the ephemera. The documentation should also be produced in formats which are most likely to be usable in the future, a point which suggests that digital methods, while appealing for their ability to make infinite identical copies, should be used only sparingly until such technology stabilizes.

Copies seem on their face to be more useful than documents, since they can open up new avenues of personal experience with the original (as seen with the recreation of *Expanded Expansion*), but there can still be significant problems. Those that were created closer to the moment of the original's creation are likely more faithful than those created at a later date, or which are at a remove of several object-generations from the original. Just like documents, copies should be treated warily for the biases associated with their creation. Each approach has its own positive qualities, but the problems associated with using documentation or copies show that a combination of these approaches is preferable, and researchers should be aware that documents and copies might be used in innovative ways to gain access to the past (such as 125-year-old sounds).

We already lack access to many original objects related to space exploration, either because they have already been destroyed, or because they remain in remote contexts. For those that still exist, the hope remains that we will someday be able to study them both for themselves and as evidence for humanity's development. The importance of ensuring that such materials as exist in standardized formats likely to be readable by future interested researchers should also be recognized.

The spacefaring community should also be encouraged to preserve experimental versions, prototypes, or replicas of their equipment. Making contact with space scientists and working together with them on these archives thus should be a high priority. Finally, to the extent that a mission can be foreseen to be historic, we ought to promote the preservation of original equipment by boosting it to otherwise-unused higher orbital altitudes.



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