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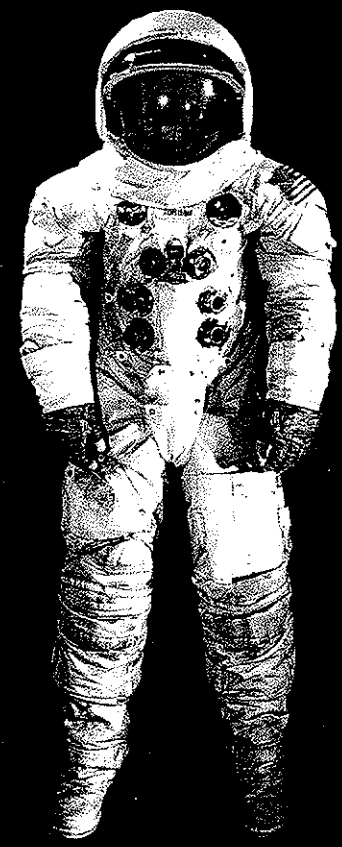

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Collecting a Spacesuit in the 21st Century

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Abstract In 1972, the Smithsonian Institution's National Air and Space Museum arranged to take possession of the remnants of the spacesuits that Neil Armstrong, Buzz Aldrin, and Michael Collins had worn during the 1969 Apollo 11 mission that landed the first humans on the moon. NASA had put aside these spacesuits and the components that the astronauts had returned to Earth for the express purpose of display to re-create the iconic images of the mission. For many years, the Air and Space Museum had complied with these intentions, but over the years, the deterioration of the suits and their materials led to a reconsideration of the rationale for collecting and displaying the suits. The new approach led to a revised collecting strategy that placed greater emphasis on the suits' point of creation and the negotiations that had occurred among those who built, designed, and wore the suits.

The twenty-first century has marked another shift in collecting spacesuits. NASA has initiated this shift through modifications in the construction, design, us, and disposal of spacesuits. New, modular spacesuits intended for reuse throughout the calculated life of their materials, do not lend themselves to iconic display; neither do they completely reveal the history of their points of creation and innovation because many components are missing, and few of the components were built at the same point in planning as the others. NASA's shift has caused the Air and Space Museum to reconsider a generation's expectations of collecting and exhibiting. Now the museum must focus on which particular stories we can and cannot tell with only a small part of the whole.

It might seem improbable, but the recent experiences of archeologists and art historians in Afghanistan have a great deal of information relevant to a discussion of spacesuits. In the spring of 2001, in an increasingly bold demonstration of the extent to which the Taliban was willing to impose its interpretation of Islam on the

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country, Mullah Mohammed Omar ordered the monumental statues of the sixth-century standing Buddhas that had been carved into the side of a cliff in the Bamiyan valley in the Hazarajat region of central Afghanistan to be destroyed. To him, they were idols that threatened the proper worship of Islam, despite the fact that historically, they represented the existence of Buddhist culture along the Silk Road that predated the spread of Islam. After the fall of the Taliban, an international group of historians and archeologists resolved to rebuild the Buddhas. In a National Public Radio interview discussing the controversies surrounding decisions as to how and if to restore the Bamiyam Buddahs, German art historian and sculptor, Bert Praxenthaler, spoke about the difficulty of rebuilding the Taliban-destroyed Buddhas of the Bamiyam Valley. In his interview, he referred to the archaeological technique of anastylosis.[1] The term, from the Ancient Greek meaning to erect a building, has the archeological meaning for the reconstruction technique whereby a ruined building or monument is restored using the original architectural elements to the greatest degree possible. It is also sometimes used to refer to a similar technique for restoring broken pottery and other small objects. Of course, there are critiques of this technique, both in the archeological community and among local officials in Bamiyam Province. By remaking the Buddhas to resemble their ancient history, restorers are deleting their more recent history of having fallen prey to the Taliban's dogma against idol worship in 2001. As the provincial governor, Habiba Sarabi, said in the same story about the Buddhas, "The Buddha was destroyed. If you made it, rebuilt it, that is not the history. The history is the broken Buddha."[2]

From the perspective of a curator, there is a similarity between the Bamiyan Buddhas and spacesuits. Both were manufactured for specific purposes, and over the years have taken on iconic imagery that transcended their original purposes. In each case, the objects were at least partially destroyed during the course of their histories, both through deliberate action and the long-term effects of the environment; the former as a deliberate political act, and the latter through the normal course of use. While architects and archeologists must come to terms about whether or not to reconstruct the Buddhas from the rubble, the decision has to be made. A curator must make a similar decision about collecting and displaying the parts of spacesuits that remain. The decisions that one makes, whether to re-construct these icons or not, have a significant impact on the historical interpretation of both objects.

In the case of spacesuits, the fundamental questions are: do we want to preserve the suits as they were constructed; as they were used; or as artifacts of the program for which they had been developed? Underlying those questions is the concern of whether an artifact or the individual components of an artifact can tell only one story, or can it tell many, or all, the stories of its existence. The answers to these questions are guided by the thoughts of two historians of material culture and science and technology, respectively—Brooke Hindle and Thomas Kuhn.

The spacesuits in the National Collection arrived at the Smithsonian during the most heated period of the Space Race. John Glenn's spacesuit and his Friend-

Figure 1. James Lovell's Gemini XII spacesuit wearing Thomas Stafford's Gemini VI gloves and training boots, as it was on display at the Air and Space Museum for over three decades. (Credit: Smithsonian Institution)

ship 7 spacecraft arrived at the National Air Museum immediately after they had concluded their world tour. The suit and capsules from Alan Shepard's missions and others soon followed. Visitors flowed into the museum to see these authentic pieces of history, fully aware of President Kennedy's pledge to send a man to the moon by the end of the decade.

During the 1970s, the overwhelming goal at the museum was to collect complete spacesuits that primarily identified with a single individual and re-created iconic images of historic activities. Among them were the re-creations of Ed White taking the first American spacewalk from the Gemini 4 space capsule and Neil Armstrong and Buzz Aldrin, whose steps on the moon were re-created not once but twice inside the museum's newly finished building. Faced with missing components, there was no second thought given to replace them with other components. The museum's staff rarely documented its informal acts of anastylosis. Frequently, staff would only discover it a generation later. For example, Jim Lovell's Gemini XII spacesuit stood wearing Thomas Stafford's Gemini VI gloves and a pair of training or test boots for 33 years on exhibit in a gallery inside the museum's building on the Mall (Figure 1).[3]

Clearly the curators and exhibit designers seeking to re-create the U.S. human spaceflight program sought anastylosis as the solution to shortcomings in the collection, as the original configurations of the spacesuits had been lost to the physics of rocketry, engineers of testing facilities, and property managers' understandings of space hardware. These re-creations, albeit not entirely historically accurate from the point of view of material culture, fulfilled what was, at the time, perceived to be an urgent need to "provide direct, three-dimensional evidence of individuals who otherwise exist only as abstractions in words, paintings, or monographs" or the grainy memories of black-and-white television broadcasts from the 1960s.[4] This alternative would drive staff to anastylosis, no matter the cost to the authenticity of the spacesuits. Visitors coming to see these re-creations had no concern over the extent to which substitutions had been made.

Soon, however, for reasons having little to do with the museum's historiographical approach, the process of re-creation ended. Conservation and preservation concerns turned curatorial concerns away from re-creating scenes towards

illustrating the fragility of the spacesuits and the circumstances under which they were created. This redirection shifted the goals of collecting and exhibiting towards an improved understanding of the point and place of invention.[5]

The History of Collection Spacesuits in the 20th Century

The National Spacesuit Collection came to the Air and Space Museum under a joint agreement with the National Aeronautics and Space Administration that granted the museum the right of first refusal to historic artifacts once NASA has finished programmatic use with them.[6] The term "programmatic use" is purposefully vaguely defined as programs can include the finite mission or long-term research projects that assess a mission for years or decades. NASA retained some spacesuits for years to be examined for continuing studies on materials and design. The agency transferred others almost immediately after the completed missions.

In order to understand how answering these questions plays out in an existing collection, the museum's spacesuit collection through the Apollo program is an appropriate case study. NASM has 287 pressure suits and/or suit components in the spacesuit collection. This number includes all flown, training, and prototype suits, but it also counts suit pressure layer assemblies, and cover layers separately in the cases, when NASA delivered them to the museum as separate components. Historically, these suits date from the 1950s, when the U.S. Air Force and Navy were designing suits for high-altitude spy planes and maximum performance fighter pilots, through NASA's advanced suit development in the 1980s, that utilized knowledge gained from the Apollo program and initiated the development of a suit for long-term expeditions to the moon or Mars. The count omits partial suit components in the cases of modular suits, like the shuttle's Enhanced Mobility Unit (EMU) and NASA Ames and Litton advanced suits, for which arms, torsos and legs were built independently. In order to be technically accurate, the museum cannot outfit an army of 287 astronauts with the collection, but there are 287 objects that represent a whole or significant portion of a space or flight suit excluding gloves, boots, connectors, carrying cases, etc.

Among the suits from the Apollo program, we have forty-six suits that have flown in space.[7] Among them are all twelve suits that walked on the moon; the remaining eighteen suits that orbited the moon without landing; all the Apollo suits that flew on the American Skylab Program (1973–1974) and the joint US–USSR human spaceflight mission, Apollo-Soyuz Test Project (July 1975). In addition to those flown suits, we have eighty Apollo-era spacesuits that never went into space. Among them are thirty-one training suits that the astronauts used to prepare for their flights; ten pieces of suits that NASA disassembled during the testing process; and a collection of thirty-nine competition and developmental suits. The competi-

tion suits are the ones that companies submitted to NASA as part of the competitive contract process. These developmental suits represent the technological negotiations between NASA and its contractors over requirements for the Apollo program. All the flown suits have distinct ties to historical moments in space exploration. The training suits demonstrate the complicated process of determining a comfortable fit and training the astronauts to adjust their suits and activities while in space. The competition and developmental suits are material artifacts of the technical conversations that space company engineers had with NASA technicians and engineers and the astronauts. Each type of suit tells a different part of the story of spacesuit concepts, contracting development, and use.

But listing these suits by category implies that NASM collected the Apollo suits in a systematic and chronological process in order to document development, training, and flight. Unfortunately, that was not the case. Starting in the early 1960s through the mid-1970s, NASM collected spacesuits and ancillary parts from NASA from the Mercury, Gemini, and Apollo programs at an astounding pace. Nearly as fast as NASA pronounced the pressure suits and their components to be excess property, the Air and Space Museum requested the hardware be shipped to Washington. Many training and backup suits arrived, often in odd lots of mismatched gloves, boots, and helmets, along with pressure suits labeled with sizes or the names of suit lab technicians. The demand for Apollo-era spacesuits for display at museums throughout the world was so great that there was little time to sort out the provenance of many of the suits that were not easily identifiable as belonging to specific Apollo missions.

On rare occasions, iconic suits, such as those from the crew of Apollo 11, came as complete sets. In 1972, the Smithsonian Institution's National Air and Space Museum arranged to take possession of the remnants of the spacesuits that Neil Armstrong, Buzz Aldrin, and Michael Collins had worn during the 1969 Apollo 11 moon mission that landed the first humans on the moon. This arrangement was different than what had been developing as the routine transfer of Apollo-era artifacts. NASA had immediately taken the suits into isolation inside the command module *Columbia*. In consultation with the Smithsonian's conservators, once they had ascertained the moon dust on the suits was not hazardous to humans, NASA sent the suits out for dry-cleaning. At the time, that was a standard procedure for preserving historic textiles. NASA then immediately sent the suits out on touring exhibitions, which continued through the time that the Air and Space Museum took title to the objects.[8]

By the time that the Apollo 11 suits went on exhibit at the museum, in its 1976 building on the National Mall, visitors came to see the true pieces of the Apollo program that they had witnesses on their televisions. Visitors to the new museum exceeded expectations, approaching 10 million in the first year.[9]

Michael Collins' suit was installed inside the *Columbia* command module and Armstrong and Aldrin's suits stood in a lunar diorama simulating the poses

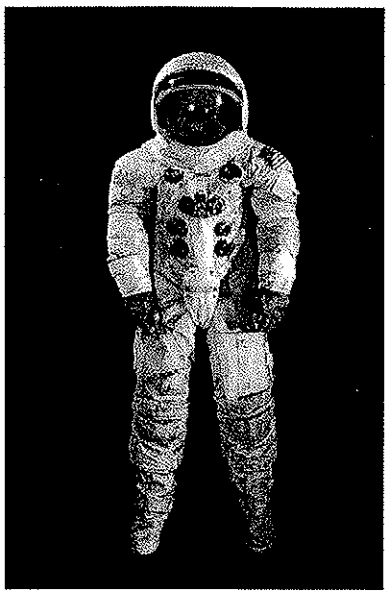

Figure 2. Neil Armstrong's Apollo 11 spacesuit as it was on display at the Air and Space Museum for over two decades. (Credit: Smithsonian Institution)

that the men had taken while on the surface of the moon (Figure 2).

However, displaying and preserving the spacesuit artifacts of the Apollo program was not the sole motivation for collecting. Imbedded in the NASA-NASM agreement was a mutual understanding that the museum would create a lending collection. The museum, NASA, and the United States Information Agency (USIA) loaned and displayed Apollo training suits and prototypes as approximations of the suits worn on the moon. In spite of the motivation to find artifacts to approximate the re-creation of the iconic image of Buzz Aldrin on the moon, that was not entirely possible. The suits that we received, even the ones that were put aside for the museum to collect immediately after their missions, were not complete suits. Imbedded in the history of the lunar missions is the fact that not everything came back from the moon. In the Apollo program, equipment was created to be disposable after use. All twelve moonwalking astronauts left their Personal Life Support System (PLSS) backpacks on the lunar surface. Armstrong and Aldrin opted to leave their bulky lunar overshoes to make room for lunar samples. All subsequent Apollo astronauts did the same with the exception of the last lunar excursion astronauts. Only the last pair of moon-walkers of *Apollo 17* brought their iconic lunar overshoes back from the moon. Eugene Cernan and Harrison Schmitt made their own decision to bring back the overshoes, while leaving their personal life support systems behind, as their predecessors had done. Despite initial efforts to re-create the iconic images of the astronauts on the surface of the moon in the form of a diorama, all museum attempts to do so are incomplete. Some of the museum's borrowers have cobbled together components, combining flown, training, test, and prototype and mock-up components, in order to assemble a complete astronaut kit.

Preserving National Treasures

During the course of lending, installing, and collecting spacesuits over a quarter of a century, it became clear to my predecessors that something was happening to the

spacesuits. The white Teflon and fiberglass of the beta cloth in the cover layers was turning yellow. The joints that had specifically been designed for ease of movement had grown stiff. Brown stains appeared on the surface of the cover layers where hoses were once attached. The anodized aluminum around the necks and wrists was corroding. And the brass zippers and rubber gaskets that formed the seals that kept precious oxygen inside the suits were either stuck open or closed. The materials had aged and in some cases, they were fighting against one another.[10] In 1999, spacesuit curator Amanda Young applied for and received a grant from "Save America's Treasures" to study the deterioration of these suits.[11] In conjunction with conservator Lisa Young, and in consultation with a number of spacesuit engineers and materials specialists, Amanda Young was able to uncover previously undocumented procedures from the manufacture of the suits. Among them was the decision to include an additive to the neoprene synthesis that increased the shelf life of the pressure layer of the suits.[12] Most significant was the consensus that the materials in the suits were deteriorating at differing rates and often causing cross-reactions that could not have been predicted. Short of disassembling the suits in order to isolate each material into its own optimal storage conditions, Young determined an optimal storage condition that was best for the overall integrity of the suit. Pressure suits, gloves, helmets, and boots, which might have differing materials, would be stored under different climate conditions.[13]

The effort to divide the suit components according to materials and conservation condition led her to re-document the components and realize that frequently gloves, boots, and helmets had previously been treated as if interchangeable. Upon determining the optimal storage and display conditions, it was decided that the best situation would be to separate all of the parts. The re-creation of iconic images in museum exhibits was no longer possible. And the curation of the separate objects was directed towards a focus on the creation and function of each individual component. Future exhibits of the spacesuits and their components from the Apollo era and prior now turn to focus on the place and purpose of creation.

The New Economy and New Curation of American Shuttle and the International Space Station Spacesuits

At the close of the 1960s, as the U.S. human spaceflight program shifted from the Apollo moon programs to the space shuttle orbiter, NASA's philosophy about the design, construction, and consignment of spacesuits changed. The Shuttle orbiter allowed for more room in the cabin, thus eliminating the necessity of having a single suit for launch, landing, and EVA. As a matter of economy, and following the reusable culture of the Shuttle program, NASA turned from the Apollo custom of having five suits made for each flight seat, to reusing suits for launch and entry, and EVA.[14]

The American extravehicular spacesuit is featured in the many photographs of astronauts assembling the International Space Station (ISS) and the repair of the Hubble Space Telescope. The Extravehicular Mobility Unit (EMU) consists of two major systems: The Space Suit Assembly (SSA) and the Life Support System (LSS). Unlike previous generations of spacesuits, the EMU is not custom made for individual astronauts. It consists of interchangeable and reusable components that each astronaut chooses to fit his or her body. Several sizes of each major component are manufactured and placed on the shelf for future use. The major components include a hard upper torso unit, arms, a waist assembly unit, and legs with attached boots. In 1974, NASA had dictated that the suit be "compact, reusable, robust, and cost-effective" with standardized sizing that would fit all astronaut candidates ranging from the 5th percentile among females and the 95th percentile among males. In human terms, that requirement meant that suits with their components could fit anyone from a five-foot tall, small-framed female to a six-foot-four tall man.[15] This decision that has saved NASA money and led to a more versatile and durable suit, but has made it impossible for a museum to collect and display a whole EMU to re-create the iconic images of the Shuttle and ISS eras. The difficulties are two-fold. First, the equation for determining what constitutes a complete spacesuit is open-ended. Second, the interchangeability of parts has led to an incongruent lifespan for the hard and soft goods contained in the suits.

The precise count of components in the Shuttle/ISS SSA/EMU is a difficult number to determine. That number includes fittings and braces that have changed over time, and vary from individual to individual. Glove components provide a good illustration of problems of counting all the components in a spacesuit. The changes in the way the gloves have been manufactured over the last thirty years makes pinning a finite number on parts very difficult. Gloves are the most technological difficult part of building a spacesuit; they remain the only part of the spacesuit that is semi-custom made for each astronaut. In order to maintain a tactile sense, the pressure bladder is molded first from a dip form, and a laser scan is taken from the astronaut and a fitted restraint layer prevents the urethane bladder from expanding while under pressure (Figure 3). Astronauts can choose to wear comfort layer(s) or not when suiting up for a spacewalk. In addition, astronauts can adjust fittings and straps on the restraint layer for their own personal comfort. They practice this as part of their ground prepa-

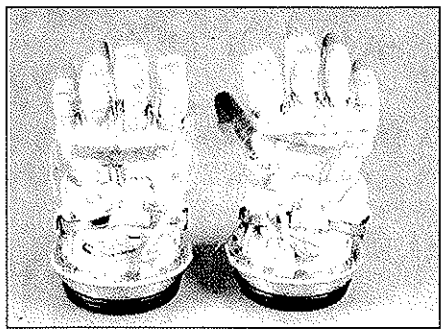

Figure 3. An example of the current series of spacesuit gloves, known as Phase VI gloves. The thermal layer is absent, revealing the details of the restraint layer, which keep the gloves fitting snugly under pressure. (Credit: Smithsonian Institution)

ration for spaceflight. If that were not enough, glove engineers have experimented with heaters and mittens to keep hands warm in the shadows of space.

The distinction between hard and soft goods was not a new concept to NASA spacesuit contractors. During the production of the suits for the Apollo program, ILC Dover had to accommodate the production and adhesion between the soft goods of neoprene, silicone, and the layers of DuPont-created textiles to the hardware of neck and wrist connects and restraint systems.[16] Hamilton Standard manufactured the Personal Life Support System and, as the primary contractor, was responsible for the systems integration of the spacesuits with the spacecraft. But in the 1960s and 1970s, the expectation was that once the suit components were assembled, each component would have a shelf life equal to that of the shortest-lived material in it. ILC Dover knew that the neoprene in the pressure layer of the suits had a shelf life of six months, which meant that the Apollo spacesuits had a shelf life of six months. NASA's requirement that the Shuttle/ISS EVA suits consist of reusable parts changed the calculus. Despite the improvement in the textiles available for creating the pressure and thermal layers of the suit, the soft goods could never match metal components in durability. NASA had made it incumbent on the suit manufacturer to create suits where hard goods could be extracted from soft goods ,and continue their operational life through several more generations of soft goods.

An imprecise knowledge as to what constitutes the whole and incongruent life expectancies of the hard and soft goods has led to an interesting sampling of artifacts that NASA has offered to museum and educational institutions.[17] Since the conclusion of the Space Shuttle program, NASA began to release components of the EMU to museums as artifacts; there is a distinct pattern in their offerings. In contrast to expectations in the early 1970s in the afterglow of the Apollo program; NASA is not in a rush to have completed EMUs on display in museums throughout the world. At no time has NASA offered a complete EMU. Even the availability of components has not been that of complete components.

NASA's administrative emphasis has been to get the most programmatic use out of each piece of hardware as possible. In the past year, the NASA-GSA screening outlet offered glove components most frequently to museums and educational institutions with occasional pieces of thermal micrometeoroid garment sprinkled throughout.[18] This is not surprising, as gloves remain the only semi-custom made components in the EMU. For the most part, they are based on a library of stored files of laser scans of 200 astronaut's hands.[19] Nothing that NASA has offered to date has flown in space; all have seen ground testing, and bear markings as not for flight. All are artifacts of the agency's demand for reusable and robust components—tested for durability that would exceed NASA's contractual expectations.[20] On the rare occasions when hard goods artifacts have become available, those objects have been old or obsolete hardware. For example, in one of the initial rounds of disposing of artifacts included a Hard Upper Torso Unit (HUT) from the EMU. The HUT is best described as a rigid sleeveless t-shirt. When it arrived at the Air and Space Museum,

it was obvious why this piece of hardware had made it to the list so early in the process. The joints that connect to the hardware for the arms of the suit are pivot joints. This was an obsolete, single point of failure that NASA abandoned during the 1980s in favor of a more rigorous planar joint (see Figure 4).[21]

Figure 4. STS-38 Mission Specialist Robert C. Springer dons extravehicular mobility unit (EMU) upper torso with technicians' assistance in JSC's Weightless Environment Training Facility (WETF). The entire suit, including parts not pictured here, weighs 275 pounds, so it is necessary to have help while putting it on in Earth's gravity. (Credit: NASA)

Conclusion

NASA's strategy on the disposition of Shuttle spacesuit components disappoints our Apollo-era expectations of full-up re-creations of shuttle history in museums. However, it does reveal significant underlying trends surrounding modern NASA spacesuit operations. In this century, spacesuits are no longer the products of Cold War cooperation between industry and NASA to complete a project as quickly as possible with the material at hand. The suits are no longer the outfits of distinct Cold War heroes. The EMU represents one of a multitude of tools and equipment that astronauts use in their routine Earth-orbiting space work. A modern story about NASA spacesuits might best be illustrated by incomplete spacesuits that tell the stories of reusability, sturdiness, and interchangeability.

So we are left with three alternatives for collection the Shuttle/ISS EMU. Each emphasizes a different story about the spacesuit. The first alternative is to continue the random, catch-as-catch-can collection that we are currently pursuing with the EMU. This plan continues to identify each component individually, unrelated to another. The result is a collection that emphasizes NASA's production and consumption of spacesuits as part of the Shuttle and ISS program. This plan deemphasizes the spacesuit development program as a whole, neglecting the experiments, prototypes, and technological detours along the way. The resulting collection does not resemble the findings of a unique archeological dig, but a documentation of the administrative character of the excess property process.

The second alternative is to assemble as much of an EMU as possible, connecting unrelated parts to each other for display. This emphasizes the engineering

of an interchangeable part suit, but deemphasizes the changes in technologies and engineering over the 30-year period during which the suits have been made.

The third alternative is to continue on, hoping to re-create the historic icon of John Grunsfeld repairing the Hubble Space Telescope. In recapturing a single moment with a single suit in the collection, we lose the NASA story during this period and how it is distinguished from the Apollo era. We also lose the engineering of the spacesuit over the course of a generation.

The solution is to acquire unique individual component and research its individual history and use. It is highly unlikely that a complete suit could ever be assembled from these components. The curatorial and exhibition focus will be on the individual stories of each component. The result is a series of histories of the design, materials and evolution of each body part instead of a complete suit.

During the last forty years, collecting spacesuits has changed dramatically at the Smithsonian Air and Space Museum. We are no longer collecting according to the Brooke Hindle or Thomas Kuhn models, or recapturing the real thing for display, or re-creating the environment of innovation. Collecting and exhibiting now has an odd component imbedded in both collecting and exhibition that might be leading us to a third alternative of collecting and exhibiting. Small components, such as gloves or sizing inserts, might tell stories that cut across the stories of iconography, construction, and use. But in this case, they will tell the smaller stories of spacesuits. They won't tell the stories of the conquest of the moon, but will tell stories of a tightening of a bolt or the change in the astronaut corps that accommodates women and men from the 5th to the 95th percentile.

Notes

1. Joanna Kakissis, "Bit by Bit, Afghanistan Rebuilds Buddhist Statues," NPR Morning Edition, accessed 07/27/2011, http://www.npr.org/2011/07/27/137304363/bit-by-bit-afghanistan-rebuilds-buddhist-statues.
2. Ibid.
3. Smithsonian Institution National Air and Space Museum Accession Record #001866, catalogue number A19680449000, Identification note dated March 29, 2012.
4. Brooke Hindle, "How Much Is a Piece of the True Cross Worth?" in *Material Culture and the Study of American Life*, ed. Ian M. G. Quimby (New York: W. W. Norton & Company, 1978), 5-20.
5. Thomas S. Kuhn, *The Structure of Scientific Revolutions*. (Chicago: University of Chicago Press, 1996), 1-9.
6. "The Agreement Between the National Aeronautics And Space Administration and The Smithsonian Institution Concerning The Transfer And Management of NASA Historical Artifacts," was originally ratified between the Secretary of the Smithsonian and Administrator of NASA in 1968. It has been renewed periodically thereafter, most recently in 2008.
7. The 46 flown suits include those worn by astronauts Borman, Anders, Lovell, Conrad*, Gordon, Bean*, Shepard*, Mitchell*, Eisele, Lovell, Armstrong*, Aldrin*, Collins, Worden, Schirra, Schweickart, Scott, McDivitt, Cernan, Young, Swigert, Haise, Irwin*, Cernan*, Roosa, Evans,

Young*, Duke*, Mattingly, Schmitt*, Scott*, Stafford, Lousma, Conrad, Bean, Garriott, Kerwin, Weitz, Carr, Pogue, Gibson, Stafford, Slayton, Brand and Cunningham. An * indicates that the suits are the twelve that walked on the moon.

8. Douglas N. Lantry, "Dress for Egress: The Smithsonian National Air and Space Museum's Apollo Spacesuit Collection," *Journal of Design History* 14 (2001): 343—359.
9. In 1976, visits to the museum exceeded expectations to the extent that museum security occasionally had to close the doors when attendance exceeded building codes. Within six months of opening, the museum greeted its 5 millionth visitor. Michael J. Neufeld and Alex M. Spencer, eds., *Smithsonian National Air and Space Museum: An Autobiography* (Washington, DC: National Geographic Society, 2010), 270-274.
10. Mary T. Baker and Ed McManus, "History, Care, and Handling of America's Spacesuits: Problems in Modern Materials," *Journal of the American Institute for Conservation* 31(1992): 7785.
11. The grant was for the program "Threatened Artifacts of the Apollo Program." The initial project was on the preservation of the Apollo spacesuits. Hamilton Substrand matched the SAT grant for the spacesuit project. HS was the systems integration contractor for the Apollo suits and manufacturer of the life support backpacks. The total budget for the spacesuit project was $100,000. The second half was for the preservation of the Saturn V launch vehicle at Johnson Space center in Houston Texas.
12. Lisa A. Young and Amanda J. Young, *The Preservation, Storage and Display of Spacesuits* (Washington, DC: Smithsonian National Air and Space Museum, 2001).
13. Lisa A. Young, "Saving America's Treasures: Threatened Artifacts from the Apollo Era," *Polymer Preprints* 41 (2000): 1798—1799.
14. The Apollo suits contract required a training, flight and backup suit for the primary crew and a training and flight for each of the backup crew. After Apollo 17, NASA reused training and backup suits for the Skylab and ASTP crews.
15. N. C. Jordan, J. H. Saleh, and D. J. Newman, "The Extravehicular Mobility Unit: A Review of Environment, Requirements, and Design Changes in the U.S. Spacesuit," *Acta astronautica* 59 (2006): 1135—1145.
16. Douglas N. Lantry, *From the Moon to the Museum: A Material History of Apollo Space Suits*, Ph.D. Dissertation, University of Delaware, 2010.
17. NASA has chosen to release objects from the Shuttle program through a modified General Services Administration excess property system. Once NASA program officers deem objects ready for distribution, the objects' availability is released to a limited number of pre-qualified organizations. Each organization must submit a proposal to the NASA Property Office describing the use of the selected object. In the case of multiple requests, NASA rates the proposals on a number of criteria, including potential audiences.
18. R. A. Opperman et al., "Probability of Spacesuit-Induced Fingernail Trauma Is Associated with Hand Circumference," *Aviation Space and Environmental Medicine* 81 (2010): 907—913.
19. David A. Graziosi "ILC Dover Spacesuit Glove History," http://spacecraft.ssl.umd.edu/design_lib\ICES01-2163.phaseVI_glove.pdf.
20. Jordan, Saleh, and Newman.
21. David Graziosi, Jinny Ferl, and Keith Splawn, "Development of a Space Suit Soft Upper Torso Mobility/Sizing Actuation System," (2004), accessed June 22, 2011, https://imageserv5.team-logic.com/mediaLibrary/93/Development_of_a_Space_Suit_Soft_Upper_Torso_Mobility_Sizing_Actuation_System.pdf . Robert Jones and others, "Development of a Space Suit Soft Upper Torso Mobility/Sizing Actuation System with Focus on Prototype Development and Manned Testing," (2007), accessed June 22, 2011, https://imageserv5.team-logic.com/mediaLibrary/93/Development_of_a_Space_Suit_Soft_Upper_Torso_Mobility_Sizing_Actuation_System_with_Focus_on_Prototype_Development_and_Manned_Testing.pdf.