ABSTRACT

Recent technological developments have accelerated the pace of space conquest. Nonetheless, while there have been a few timid efforts to innovate, traditional design and manufacturing techniques largely remain in use. We believe, however, that it is possible to partly overcome the misconception of space as a harsh environment simply by developing tailored design and manufacturing techniques. In the long term, with the strengthening of our presence in space through projects such as space mining or settlements on the Moon and Mars, this idea will increasingly impose itself. The sooner we embrace it, the more rapidly we will increase the ability to realize space projects. The art community could play a central role as an accelerator of space-appropriate novel techniques and technologies.

In this paper, we first articulate the idea of design and manufacturing techniques dedicated to space applications, while giving a few examples of early attempts in this direction. We then provide a practical example through an artwork we have jointly developed, entitled *S.A.D. Astronaut, Loneliest Man on the Moon* (Fig. 1). This conceptual project clearly illustrates how shape-memory polymers (SMP) can be used to generate objects tailored for the lunar surface.

ADAPTING TO THE SPACE ENVIRONMENT

Space [1] is considered a harsh environment. It is important, however, to explicitly state what is implicit in that proposition: Space is harsh for human beings. The machines we send all over the solar system are a good demonstration of our ability to design, manufacture and operate devices able to sustain themselves in these extreme conditions. Such conditions range from interplanetary space to the diverse environments of the celestial bodies that have been explored. The surface of Venus, for example, is characterized by particularly severe conditions, with a surface pressure a staggering 91.7 times that of Earth’s, an average temperature of 735 K, a liquid cycle of sulfuric acid and an atmosphere primarily consisting of carbon dioxide. Titan, Saturn’s satellite, is much colder, with a temperature of 93.7 K and a liquid cycle of hydrocarbons in an atmosphere of molecular nitrogen. These alien environments are barred to nonaugmented human inquisitiveness.

Despite these constraints, humanity has managed to explore the surface of both these bodies by means of spacecraft engineered to take measurements, photographs and detailed images. What these have in common, for our purposes, is their terrestrial origin: They are also able to function under earthly conditions and are for the most part tested terrestrially prior to being sent into outer space.

We postulate that, from a design perspective, space has to some degree been treated as a constrained extension of Earth and its physical features. Engineers have obeyed traditional design rules and used the available manufacturing processes, restricting engineers to the constraints imposed by the supposedly harsh environment.

We suggest that, to fully unleash the creative potential offered by designing artifacts for space, it is essential to consider the environmental conditions not as constraints but rather as enablers. Following that logic, a space probe...
designed for Mars should actually be designed specifically for Mars and not be fully operable under Earth-like conditions. This strategy is not new, as demonstrated for example by the numerous suggestions for buoyant probes to explore Venus. In taking advantage of Venus-equivalent conditions, these probes make use of Venus's very high pressure levels to displace themselves and thus function at very low cost [2]. Similarly, numerous architectural studies have been performed to design habitats on the Moon and Mars, with additive manufacturing utilizing in-situ materials [3]. In that case, the buildings are usually adapted to reduced gravity conditions through use of thinner walls and lightweight structure reminiscent to that of bird bones, in order to save on resource consumption. These examples therefore effectively illustrate new design rules, as such structures would collapse if built on Earth. Such efforts should be identified for what they are: customized, space-specific, endogenous design and manufacturing techniques.

This new logic is particularly relevant in the current context of rejuvenated space exploration. On the one hand, modularization and miniaturization of satellite platforms have resulted in a widespread democratization of space missions, now accessible to emerging countries, universities and even amateurs [4]. On the other hand, the stringent competition in the rocket launcher market means that access to space is increasingly affordable. These two factors allow space mission operators to take on greater risk, and as a result new technologies or design approaches will be experimented with and tested [5].

Moreover, with the advent of large-scale satellite constellations [6], in-space additive manufacturing [7], European views on building a lunar village [8] and even asteroid mining [9], the space manufacturing economy could increasingly become something separated from Earth's. It is therefore very likely that dedicated design solutions will emerge and impose themselves as the most cost-efficient solutions.

The involvement of the artistic community offers the opportunity for remorselessly breaking with convention. Traditional, fondly held “rules/constraints” will need to be set aside if stakeholders are to develop truly innovative and inventive thinking [10]. While the function of a tool lies in its very design (i.e. despite aesthetic differences, a hammer in its function will always obey the basic rules conveyed by the class of morphologies capable of executing said function, etc.), the class of possible functions of an artwork are multi-form. In other words, a particular artistic intention can be expressed in different forms. Artists, unconstrained, therefore enjoy greater freedom than the engineer when it comes to seeking new solutions. Artists are uniquely positioned at the forefront of the development of new design and new manufacturing techniques. Once explored by the art community, these processes, techniques and materials could perhaps then be appropriated by spacecraft designers for other purposes.

Let us explore this role we propose for the artistic community. We illustrate customized space design by means of an exemplifying case, The Loneliest Man on the Moon.

A PRACTICAL EXAMPLE: THE LONELIEST MAN ON THE MOON

Context

We jointly conceptualized The Loneliest Man on the Moon artwork based on the S.A.D. Astronaut, another artwork by De Wilde [11]. It was initially developed as an entry for the Giant Steps competition and exhibition organized by Vital 5 Productions [12]. The challenge of that competition was to propose an artwork to put on the Moon within certain constraints of mass, volume and operation. This work conceptualizes a dialogue between a lonely man on the Moon and inhabitants of planet Earth.

Redefining the Lunar Surface as a Habitable Place

One of the intentions behind this work was to create a piece of art that could only exist, in both the literal and functional
meanings of the word, on the Moon. Two major characteristics of the lunar surface were identified: being a hard vacuum on the order of 10–15 bar [13] and exposure to intense space radiation originating from cosmic rays and solar flares [14].

Based on these two initial conditions, we decided to make use of shape-memory polymers (SMP), a smart material that has the ability to retrieve its original shape from a deformed one under the effect of an external stimulus [15]. For certain SMP, that transition from one state to another will deploy under the stimulus of pressure. Polymers provide the additional advantage that they can be coupled with photopolymerization properties, i.e. exposure to UV radiation will cause the polymer to harden [16].

The man on the Moon is a schematic human figure made out of such a polymer; the figure is in a meditative pose, contemplating Earth. Prior to deployment, the statue is compressed and packed. Once the package is open, it will deploy upon contact with the hard vacuum and will harden under the effect of radiation, effectively transforming the man on the Moon into stone. While humans need an ecosystem, atmosphere, pressure and protection from radiation to survive, the man on the Moon can only exist through the absence of these elements.

Other Elements

The statue would be equipped with a suite of sensors that may include but are not limited to: thermocouples, magnetometers, UV sensors. In addition, a telemetry system and a computerised unit would allow a dialogue to be established between the artwork and Earth in the form of very short messages. At the ground control centers, users would ask a series of predetermined questions to the astronaut, some of which are personal, such as “Do you feel lonely?” while some others are more trivial, such as “How’s the weather?” Each question sent to the man on the Moon interrogates its sensors. After some postprocessing, the answer would arrive a few seconds later: “I might be alone on the Moon, but I currently have a view of all of Asia: over 2 billion people!” or “It’s a warm 200°C at the moment. Luckily I’m not a human, otherwise I would be long dead.”

It is only through the establishment of this dialogue between the man on the Moon and the users that the former comes into existence. Without dialogue, it would simply be an oddly shaped rock. With dialogue, the man on the Moon becomes humanity’s ambassador on the Moon—a humanoid being, sent to a foreign body to report sensorial impressions. While it is not human, it has a human shape and can share what it experiences through its senses: thermocouples instead of nerves, photoreceptors instead of eyes, etc. It is neither man nor machine.

Nevertheless, as time goes by, loneliness begins to act on the man on the Moon. As his electronic components degrade through exposure to intense radiation and his solar panels get dusty, his answers become scarce and make less sense. Because he has no heart, it is his entire body that hardens in this world of solitude.

Eventually, he becomes silent, lost in the deepest medita-

**Clues toward Further Implementation**

It should be noted that there was within the Giant Steps competition no plan to actually send an artwork on the Moon. Therefore, we suggested to manifest this concept in the gallery exhibition through a mock-up. A smaller-scale statue would be S.A.D. Astronaut, placed in a realistic rendering of a lunar crater. The latter will be put under a vacuum bell jar and illuminated with UV lights, creating simulated lunar conditions. A series of sensors would be placed within the bell jar, providing similar information to what the actual man on the Moon would give.

Through this creative—and conceptual—research, the potential of shape memory polymers for lunar exploration is evident. In this specific case, the very interest in using SMP lies in the metaphorical power these polymers confer to the artwork and in the strength with which they customized it for the Moon. While SMP are actually already intensively researched for aerospace applications that include mechanism deployment and even lunar habitats [17], we demonstrated throughout this paper the great advantage they possess over other technologies: the emergence of design and manufacturing techniques tailored for space. While vacuum is traditionally considered a constraint, it can—and should—be seen as an enabler.

It should be noted that the use of SMP to create artworks in space is not new. The French artist Jean-Marc Philippe could to some extent be seen as a pioneer of the idea, notably with his Mars spheres [18]. Other artworks based on similar conceptual techniques include for example Richard Clar’s *Space Flight Dolphin* [19] and more recently Anilore Banon’s *VITAE* project [20].

Similar techniques investigated at the inception of a project would lead to similar Moon-specific techniques. Among possible Moon-specific conditions that could become enablers, let us cite for example the electrostatic charge of the lunar surface enabling hovering objects [21] or radiation-induced photochemistry enabling the creation of bioluminescent structures.

**CONCLUSION**

Throughout this paper, we have demonstrated the importance and relevance of explicitly developed design and manufacturing techniques tailored for space. Indeed, these allow us to get rid of the traditional conception of space as a harsh environment and instead focus on what can be done. Factors such as vacuum, radiation or extreme temperature can be seen as enablers rather than constraints. While this change of perspective will take place at some stage in the long term, we believe that the art community can help accelerate the process. While we do not claim that this approach is new,
especially because SMP have been used since 1989 to perform art in space, we suggest that it has to be acknowledged and encouraged. These ideas were put into practice with an example: *The Loneliest Man on the Moon*, a conceptual artwork that makes uses of the vacuum and intense radiation of the lunar surface to come to life. Because it is made of SMP, the statue can exist only on the Moon. From this object’s point of view, it is thus Earth’s environment that is harsh.

---

**References and Notes**

1. The word “space” is here understood in its broadest sense: anything that is non-Earth (i.e. interstellar space, stars, moons and planets, meteorites, etc.).
11. D.P. Nair et al., “Photopolymerized Thiol-Ene Systems as Shape Memory Polymers,” *Polymer (Guildf)* 51, No. 19, 4383–4389 (September 2010).
16. D.P. Nair et al., “Photopolymerized Thiol-Ene Systems as Shape Memory Polymers,” *Polymer (Guildf)* 51, No. 19, 4383–4389 (September 2010).

GUERRIC DE CROMBRUGGHE (b. 1988) is an aerospace engineer. After pursuing his postgraduate education at the von Karman Institute and the University of Queensland, he started working as a strategy consultant and project manager. He is now business development manager for SABCA but still pursues his scientific and artistic interests through various collaborations.

FREDERIK DE WILDE (b. 1975) works at the interstice of art, science and technology: he has studied fine arts, media arts and philosophy. The conceptual crux of his artistic praxis are the notions of the inaudible, intangible and invisible. An excellent example is the conceptualization and creation of the Blackest-Black artwork series made in collaboration with American universities and NASA.