On the use of Art in accelerating novel approaches in design and manufacturing techniques dedicated to Space applications

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Abstract
Space exploration is undergoing exciting disruptive change, both through the advent of new business models and through the development of innovative technologies. As a consequence of this accelerated activity, innovative design and manufacturing techniques dedicated entirely to space exploration and exploitation are slowly emerging. These go beyond the simplistic approach of considering space as a harsh environment, and rather offers solutions adequately developed for alien environments such as interplanetary space or planetary bodies. As demonstrated in this paper, the art community is particularly relevant to support these efforts. We present a conceptual artwork designed from the interplay of materials and local astrophysical conditions and which form and substance evolves because of these. Our evolving sculptural installation uses the extreme lunar surface conditions as enablers rather than constraints. Giant Steps, a landmark exhibition of Space Art held in Seattle in 2016, presented a first opportunity to showcase our conceptual artwork to an audience. Future activities for creating a real artwork on the Moon are in line with current collaborative space art projects.

1. Introduction

Recent technological developments have accelerated the pace of the space conquest. Nonetheless, while there are a few timid efforts to innovate, traditional design and manufacturing techniques are still largely in use. We believe, however, that it is possible to partly overcome the shared 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 be increasingly impose itself as an evidence. The sooner we embrace it, the faster we will gain the ability to realise these projects. The art community could play 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 jointly developed by Frederik De Wilde and Guerric de Crombrugghe entitled The Loneliest Man on the Moon. This conceptual project clearly illustrates how shape-memory polymers (SMP) can be used to generate objects which exist on the lunar surface.
2. Adapting to the space environment

Space [1] is considered as a harsh environment. It is important, however, to explicitly state what is implicitly contained 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 these extreme conditions. These range from interplanetary space to the very diverse environments of the different celestial bodies that have been explored. The surface of Venus, for example, is characterised by particularly severe conditions, with a surface pressure a staggering 91.7 times that of the Earth’s with an average temperature of 735 K, a liquid cycle of sulphuric acid and an atmosphere primarily consisting of carbon dioxide. Titan, Saturn’s satellite, is much colder with a temperature of 93.7 K, a liquid cycle of hydrocarbons in an atmosphere of molecular nitrogen. These are alien environments barred to non-augmented 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 Earthling conditions, and are for the most part tested for purpose on the ground prior to being sent into outer space.

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

We suggest that to fully unleash the creative potential offered by designing artefacts 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 be unable to 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 its 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 utilising in-situ materials, see for example [3]. In the latter case, the buildings are usually adapted to reduced gravity conditions with thinner walls and lightweight structure reminiscent to that of bird bones, in order to save on resources consumption. These examples therefore effectively illustrate the new design rules, as they would collapse if built on Earth. Such efforts should be identified for what they are: customised 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, modularisation and miniaturisation of satellite platform have resulted in a widespread democratisation of space missions, now accessible to emerging countries, universities, and even amateurs [4]. On the other hand, the stringent competition on 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 Moon Village [8], and even asteroid mining...
[9], the space manufacturing economy could increasingly become something separated from the 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 is for remorselessly breaking with convention. Traditional, fondly-held ‘rules/constraints’ will need to be set aside if stakeholders must develop truly innovative and inventive thinking [10]. While the function of a tool lies in its very design (i.e. despite aesthetical differences, an hammer in function will always obey the basic rules conveyed by the class of morphologies capable of executing said function, etc.), the class of functions possible of an artwork are multiform. 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. They 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 of the artistic community. We illustrate customised space design by means of an exemplifying case, The Loneliest Man on the Moon.

3. A practical example: the loneliest man on the Moon

3.1 Context
The Loneliest Man on the Moon artwork was conceptualised conjointly by Gueric de Crombrugghe and Frederik De Wilde based on the S.A.D. Astronaut, another piece of art by Frederik De Wilde [11]. It was initially developed as an entry for the Giant Steps competition organised by Vital 5 Productions [12]. The purpose of that competition was to propose an artwork to put on the Moon within certain constraint in terms of mass, volume, and operations. The Loneliest Man on the Moon entry was selected to be exhibited at the King Street Station gallery in Seattle (USA) from the 3rd of March to the 3rd of April 2016. It conceptualises a dialogue between a lonely man on the Moon and inhabitants from planet Earth.

3.2 Redefining the Lunar surface as an habitable place
One of the intentions behind this work was to create a piece of art that could only exist, both in the literal and functional meaning of the word, on the Moon. Two major characteristics of the lunar surface were identified as being the hard vacuum in the order of 10⁻¹³ bar [13] and exposure to intense space radiation originating from cosmic rays and solar flares [14]. Based on these two initial conditions, it was decided to make use of shape-memory polymers (SMP), a smart material that has the ability to retrieve their 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 be operated under the stimulus of pressure. Polymer 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 in a meditative pose, contemplating the Earth made out of such a polymer. Prior to deployment, the statue is thus compressed and packed. Once the package is open, it will deploy at the contact of hard vacuum and harden under the effect of radiation, effectively transforming the man on the Moon into stone. While humans need an ecosystem, atmosphere, pressure, protection from radiation to survive, the man on the Moon can only exist through the absence of these elements.
3.3 Other elements

The statue is equipped with a suite of sensors that could include but are not limited to: thermocouples, magnetometers, and UV sensors. In addition, a telemetry system and a computed unit allow to establish a dialogue between the artwork and the Earth in the form of very short messages. At the ground control centres, users can ask a series of pre-determined questions to the astronaut, some of which are personal, such as “Do you feel lonely?”, some other being more trivial, such as “How’s the weather?” . The question is sent to the man on the Moon, and interrogates its sensors. After some post-processing, the answer arrives back a handful of seconds later: “I might be alone on the Moon, but I currently have a view of over 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 to existence. Without dialogue, it would simply be an oddly-shaped rock. With a dialogue, he becomes humanity’s ambassador on the Moon. A humanoid being, sent on a foreign body to report on his sensorial impressions. While it is not human, it has a human shape and can share what he experiences through his sense: 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 exposition 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 meditation. He remains in full contemplation of the planet that sent him there, and its inhabitants lost in their petty daily business while he stands tall for decades, centuries, possibly eons. He stands forever, statue of stone, allegory of the dialogue that once existed between the ever-changing Earth and the immutable Moon.

3.4 Clues towards further implementation

It should be noted that there was within the Giant Steps competition no plan no 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 will be placed in a realistic rendering of a lunar crater. The later will be put under a vacuum bell jar and illuminated with UV lights, creating simulated lunar conditions. A series of sensors will be placed within the bell jar, providing similar information to what the actual man on the Moon would give.

Nevertheless, through this creative – and conceptual – research, the potential of SMP for lunar exploration is evident. In this specific case, the very interest of using SMP lied in the metaphorical power they conferred to the artwork and in the strength with which they customized in for the Moon. While SMP are actually already intensively research for aerospace applications that include mechanism deployment and even lunar habitats [17], we demonstrated throughout this paper the great advantage they possessed over other technologies: the emergence of design and manufacturing techniques tailored for space. While vacuum is traditionally considered as 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 in some extent be seen as a pioneer of the idea, notably with its Mars spheres [18]. Other artworks based on similar conceptual techniques include for example Richard Clar's Space Flight Dolphin [19] or more recently Anilore Banon's VITEA project [20].
Similar techniques investigated at the inception of the project would lead to similar Moon-specific techniques. Among these, let us cite for example the electrostatic charge of the lunar surface enabling hovering objects [21] or the use of radiation-induced photochemistry, for example to create bioluminescent structures.

4. Conclusion

Throughout this paper, we have demonstrated the importance and relevance of explicitly develop design and manufacturing techniques tailored for space. Indeed, these allow to get rid of the traditional conception of space as being a harsh environment and instead focus on what can be done. Factors such as vacuum, radiation, or extreme temperature are seen as enablers rather than constraints. While this change of perspective will be performed at some stage in the long-term, we believe that the art community can help accelerate it. While we do not claim that this approach is new, especially because SMP have been used in since 1989 to perform art in space, we suggest that it has to be acknowledged and encouraged. These ideas were put in practice with an example: the Loneliest Man on the Moon. It is a conceptual artwork that make uses of the vacuum and intense radiation of the lunar surface to come to life. Because it is made of SMP, the statue can only exist on the Moon. From this object’s point of view, it is thus the Earth 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. inter-stellar space, stars, moons and planets, meteorites, etc.).
7. Saletta, Morgan. “How 3D Printing can be used in Space Exploration.” Startup Smart, May 2016.

Fig. 1a-d. S.A.D. Astronaut, photograph and 3D render, 2016. (© Frederik De Wilde)