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How to design and fly your humanly space object in space?

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ABSTRACT

Today's space exploration, both robotic- and human-exploration driven, is dominated by objects and artifacts which are mostly conceived, designed and built through technology and engineering approaches. They are functional, reliable, safe, and expensive. Building on considerations and concepts established in an earlier paper, we can state that the current approach leaves very little room for art and design based objects, as organizations—typically led by engineers, project and business managers—see the inclusion of these disciplines and artifacts as nice to have instead of a genuine need, let alone requirement. In this paper we will offer initial discussions about where design and engineering practices are different or similar and how to bridge them and highlight the benefits that domains such as design or art can offer to space exploration. Some of the design considerations and approaches will be demonstrated through the double diamond of divergence-convergence cycles of design, leading to an experimental piece called a “cybernetic astronaut chair”, which was designed as a form of abstraction and discussion point to highlight a subset of concepts and ideas that designers may consider when designing objects for space use, with attention to human-centered or humanly interactions. Although there are few suggested functional needs for chairs in space, they can provide reassuring emotional experiences from home, while being far away from home. In zero gravity, back-to-back seats provide affordances—or add variety in a cybernetic sense—to accommodate two astronauts simultaneously, while implying the circularity of cybernetics in a rather symbolic way. The cybernetic astronaut chair allows us to refine the three-actor model proposed in a previous paper, defining the circular interactions between the artist or designer; object or process; and user or observer. We will also dedicate a brief discussion to the process of navigating through the complex regulations of space agencies, from solicitations through development and testing, to space flight. The provided insights to designers and artists, related to agency-driven processes and requirements, may help to deconvolute the steps and may lead to flying their objects or artifacts in space.

1. Introduction

Over the past year our robotic missions continued to explore the solar system with rovers, landers, and spacecraft orbiting and flying by planetary destinations. These missions, as well as today's human exploration missions, are conceived by scientists, engineers, mission architects, technologists, and managers, through integrated thinking and systems engineering approaches. While human space exploration is still limited to the vicinity of Earth, we have plans to send humans to Mars within the next 20–30 years. All of today's space missions are driven by functionality, reliability and safety. They are also expensive, while set in a resource-limited environment, where funding represents a constant uphill battle. This environment focuses on fulfilling basic functional and physiological needs, while considering psychological and self-fulfillment needs as nice to have, something that can be addressed towards the end of a flight project, if resources are available. Artists and human centered designers address such higher level needs, thus currently playing a limited role in our space exploration activities. However, we believe that these higher level needs should play increasingly important roles in our future space exploration plans. First, on near term missions to validate this approach, then implemented fully on subsequent long-duration human missions.

In our previous paper [4] we have introduced considerations for human centered designers and artists, who are creating for the space environment. The scale of these may range from a single artifact to fully immersive integrated systems, such as a habitat. We have discussed fundamental concepts that might be beneficial to designers and artist, including tacit knowledge, cognitive learning, cybernetics, and affordances. We introduced a three-

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actor framework, consisting of the designer or artist, the observer (in this case an astronaut), and the object or artifact. We also provided contemporary examples from the fields of art and design to illustrate these underlying concepts. In [5] we have extended this methodology to the roles of design and cybernetics for planetary probe missions, arguing that human centered design is not limited to human exploration missions, and can be highly beneficial to aspects of robotic missions. This includes improved design dialogs between the project teams and their stakeholders, better communications with the public, and improved design environments.

In this paper we revisit and advance the list of artistic and design considerations for future space missions, including the roles of cybernetics, perception and cognition. We will illustrate aspects of these considerations through a physical artifact, a "cybernetic astronaut chair", which will serve as a discussion point. We will also outline approaches related to a human centered interactive habitat, advancing the current state of practice, which to date mainly focuses on fulfilling basic physiological and related functional needs. Finally, we will provide a brief introduction to agency-driven processes and requirements related to design considerations for space bound objects and artifacts. Better understanding of these processes could be beneficial for space artists and designers and help them to account for these additional requirements throughout their creative cycles.

2. Foundational concepts

Creating and conceiving artifacts involves at least three essential elements. First, a perspective that allows us to look at the world. It consists of a cognitive model of our environment and us in it. Second, an idea about what we wish to create, encompassing our motivations and goals. Third, a suitable process that includes creative thinking and testing through making. This often-iterative process involves guiding choices to move us towards preferred outcomes.

In our earlier paper [4] we have introduced a three-actor model, describing the interactions between an artist/designer, the artifact/object, and the observer/user. These circular cybernetic connections between our environment and cognitive models lead to a constructivist middle ground between an actor (artist/designer or the observer/user) and the environment.

2.1. Cybernetics, perception, and cognition

We built our approach on cybernetics, which is a trans-disciplinary field, initially defined by Norbert Wiener in 1948, as the "Control and Communication in the Animal and the Machine" in his book with the same title [39]. The origin of the word, cybernetics, traces back to the Greek word Kybernetike (κυβερνητική), in relations to governing, steering a ship, and navigating. Cyberneticians study—among others—a broad range of fields, including philosophy, epistemology, hierarchy, emergence, perception, cognition, learning, sociology, social interactions and control, communications, connectivity, mathematics, design, psychology, and management. Many of today's control and network systems associated disciplines, systems engineering, psychology and biology fields find their roots in cybernetics, and often associated with first-order cybernetics. Further advancements looked at the system that is observing the system, called second-order cybernetics. Artistic expressions often fall into this category, reflecting on our environment, experiences, social norms, and defining novel points of views. Second-order cybernetics is also highly relevant to design and design thinking, where the role of the observer is acknowledged and cybernetics is subjected to critique through an observing secondary circular loop [14,9]. Second-order cybernetics is less well know than first-order cybernetics, and is undergoing a renewed interest amongst design researchers. Subsequently, this approach allows us to create new languages and discourses through art and design, leading to new options, conclusions, and outcomes.

We can construct our cybernetic models through the reduction of complex observed systems to simple ones [38], but we need to be aware that "essentially, all models are wrong, but some are useful" [3]. Thus, to draw meaningful conclusions from models, our simplifications have to capture and weigh all the key influencing factors, and ignore those which have secondary effects on the modeled system. This modeling is not trivial and it applies to our processes of creating cognitive views of the world. Furthermore, the fidelity of these models varies between fitting and matching our observations. Simplifications may lead to loss of fidelity, and understanding what can be ignored can significantly impact the usefulness of the models.

Such constructivist approach is based on a philosophical view, which theorizes that all knowledge is constructed by humans, by coming to a common ground between the metaphysical world and our cognitive models of it [20,40,34,33]. It requires participation, opposed to a rationalistic view where the world is observed and discovered neutrally and objectively. As knowledge can be described as justified true belief, Immanuel Kant pointed out that we need both empiricist experiences and rationalistic reasons [20]. We need experiences to create our cognitive models, while creating a model without validation can only lead to theoretical illusions. Radical constructivism was introduced by Ernst von Glasersfeld [13]. According to radical constructivist theory, knowledge is personal, and not transferable between people. Instead, new ideas and models are constructed by each individual, from external inputs, combined with personal knowledge. These emerging constructed models are influenced by a person's subjective interpretation of an experience, instead of an objective reality. This model forms a circular dialog, aligned with the principles of cybernetics. Following a constructivist or radical constructivist approach over other philosophical schools of thoughts is a personal choice, based on a subjective belief in this process. Through selectively choosing arguments it leads to constructing our own ontology, our personal knowing, and our own model of the metaphysical world.

Creating and designing require circular dialogs with the environment, coupled with the concurrent internal dialog of artist or designer. Through these circular loops the available options influence the freedom to create. Within the field of cybernetics, the term "variety" was introduced by W. Ross Ashby [2], referring to the degrees of freedom or more specifically the distinct states of a given system and its environment. For a stable system in dynamic equilibrium, its regulatory mechanism has to have greater or equal number of states than the environment or system it controls, as defined by the Law of Requisite Variety. Ashby states his Law as "variety absorbs variety, defines the minimum number of states necessary for a controller to control a system of a given number of states". This Law also relates to Claude Shannon's information theory, introduced in 1948 [35]. It is dealing with "incessant fluctuations" or noise in the communication system, and can be applied to a broad range of disciplines from art and design to engineering and computer science. The model parses communication to eight piecewise components, which includes: the information source; the message; the transmitter; the signal; the carrier; the noise; the receiver; and the destination. This model can also be applied to human interactions, as shown in Fig. 1, using language and related dialogs as a basis for communicating. For example, when Actor A poses a question, Actor B is trying to understand its meaning. The answer is based on Actor B's