HOW CAN SPACE CONTRIBUTE TO A POSSIBLE SOCIO-TECHNICAL FUTURE ON EARTH?

by G. A. Boy and O. Doule1

SYNTHESIS
SYNTHÈSE

How can space contribute to a possible socio-technical future on Earth?

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Résumé

Comment l’exploration spatiale peut-elle contribuer à un futur socio-technique possible sur la Terre ?

L’ergonomie traditionnelle s’inscrit dans la continuité de la relation entre l’être humain, les artefacts qu’il construit, l’environnement et les sociétés. L’actuel développement technologique sans précédent est en train de briser cette continuité. Nous devons penser l’évolution humaine et sa relation au travail en de nouveaux termes que la conquête spatiale a déjà commencé à façonner. Cet article présente les raisons fondamentales pour lesquelles l’exploration spatiale est essentielle pour la croissance, l’évolution et le développement durable de l’humanité, non seulement au niveau ergonomique individuel mais aussi au niveau sociétal. L’ergonomie prospective doit prendre en compte ces stratégies. Nous faisons l’hypothèse que toute entité placée hors de son environnement naturel — où elle s’est adaptée pour y vivre —, réagit au nouvel environnement — où elle n’est pas adaptée pour y vivre — de façon spécifique pour se défendre, s’adapter et survivre. Non seulement de telles frontières de survie et de nouvelles capacités d’adaptation devront être découvertes, mais nous pouvons aussi mieux comprendre nos exigences vitales nominales actuelles. Pendant le programme Apollo de la NASA, les humains ont déjà étendu leur environnement vital à la Lune. Nous nous adaptions à un nouvel environnement en utilisant un “pont technologique” qui facilite et étend nos capacités d’adaptation beaucoup plus rapidement que ce que l’évolution naturelle ne le permet, lorsque c’est possible. Dans l’espace par exemple, il est impératif d’étendre notre environnement de vie et de travail, mais jusqu’où pouvons-nous aller ? Quelles sont les limites et les possibilités de rendre habitables de nouveaux environnements ? Par exemple, sommes-nous limités à des zones et régions habitables de notre système solaire et notre galaxie ? Sommes-nous capables de nous adapter totalement à la microgravité ? Quelles sont les possibilités technologiques pour nous offrir une ressource d’oxygène et d’eau ? En définitive, que signifie d’être un humain dans l’univers et sur la Terre en particulier ? Nous considérons que ces questions sont cruciales au début du XXIe siècle parce que notre planète Terre est en train de changer rapidement lorsque nous considérons plusieurs paramètres tels que notre démographie globale, notre économie en constante dégradation et notre économie incontrôlable. Nous sommes devant une page blanche exactement de la même manière que lorsque nous analysons

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une vie possible sur Mars. Nous devons mieux comprendre les limites et capacités humaines dans des mondes à la fois naturels et artificiels que nous avons générés, et ce que la nature offre - soit nominalement soit par réaction, à nos coûteuses façons socio-économiques de vivre.

Mots-clés : adaptation, ergonomie prospective, conception anthropocentée, écologie, environnements artificiels de vie, vols spatiaux habités, vie extraterrestre.

I. INTRODUCTION

The ergonomics discipline was born after the Second World War as “the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well-being and overall system” (IEA, 2010). The primary goal was to improve working conditions, mainly physically. Then computers entered the show and physical ergonomics shifted to cognitive ergonomics. Today, our society is changing rapidly not only because of the massive introduction of computers and software, but because of the interconnectivity that we have through computer networks, and the energy crisis in term of moving from oil to renewable energies. More than ever, we need to be prospective and creative and jump into the 21st century to make the third industrial revolution. We are now using smart phones and other modern devices to be connected anytime anywhere. We are no longer isolated as we were in the past. These preliminary observations stress the need for a deeper investigation of our rapidly evolving environment, in the physical sense as well as in the cognitive and emotional senses.

We currently live in a society driven and structured by monetary values, and driven by markets rather than our wisdom and intellectual capacities. These societal priorities are also inherently transferred into the field of research and design. They deform rather than form our environment (Boy, 2013). Since the nineteenth century people experienced several industrial revolutions going from horses to steam machines, to computers and today to the Internet, nanotechnologies and renewable energies. Space can contribute our current socio-technical evolution from several perspectives, including concrete colonization of proximal celestial bodies such as the Moon and Mars, and also, more metaphorically, exploring new ways of re-colonizing our planet Earth. For example, mining on the Moon, that may have significant impact on terrestrial economies and welfare. Mining on the Moon was introduced in early nineteenth century by Russian writer Vladimir Odoevsky (Lytkin, 1998), and this topic is seriously addressed by major world agencies and commercial space industry nowadays. This paper is not about mining and possibilities of harvesting precious resources from space, but about “the heart of space exploration”, the human passion to discover, which attempts to better understand who we are, our living envelope, and technology that can be used on Earth and can contribute to improve and understand life on Earth. More importantly, we will try to
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explore the various relationships between Technology, Organizations and People (the TOP model introduced by Boy, 2013).

We claim that space exploration and research bring new viewpoints on human-centered design (HCD). During the last few decades, we accumulated invaluable knowledge both on how space exploration can be done and why. We believe that designing new artifacts that are intended to improve our lives involves co-adaptation of technology, organizations and people. This paper will focus on such co-adaptation. It will be organized into four mutually inclusive parts: Terraforming and Ecoopoiesis; Space Settlements and Habitats; Human Subsystems; Principles and Technologies Derived. Examples will be presented.

II. TERRAFORMING AND ECOPOIESIS

Terraforming is the process that enables people to convert a sterile planet into a habitable and self-sustaining system. It is mandatory to study the planetary system as a whole. We will talk about a holistic approach. For example, understanding the evolution of our global climate on Earth is crucial. Space exploration and research bring new viewpoints for exploration and research on Earth, searching for analogue systems and providing less biased perspectives.

Space technology brings new means to support investigations and design of livable systems developed during the Apollo program, for example, which brought a lot of new possibilities on the Earth. Another example is radiation and thermal insulation of spacecraft implemented using aluminum, propylene and Mylar, materials that are now commonly used on Earth. Similar situation is regarding clear water technology and fire protection of steel structures. Food service in hospitals and lyophilization of products were first experienced during the Apollo program.

We build great things by necessity. Exploring a new planet requires the creation of things that are necessary for survival. For example, NASA is currently working on a mechanism to make oxygen from regolith, i.e. dust on the surface of the Moon. We need to try and take risks to develop usable, useful and sometimes mandatory artifacts.

Traditional human factors and ergonomics always tried to avoid risk. Ergonomics was for a long time based on work evolution continuity, rejecting work revolution. When we shifted from conventional mechanical-engineering based aircraft to fly-by-wire aircraft, cockpits drastically changed. Pilots became system managers as well as aviators. Safety was also drastically improved even if the nature of accidents also changed. Today, complacency has become a major threat in aviation, because it is much easier to fly than before and pilots tend to rely on automation. We have come to a point where we need to redefine pilot’s job and responsibilities. It is easy to criticize new technology at its beginning, when work changes. However, it is important to understand that there is always a maturity period, where not only the technology has to mature, but also practices. Most human factors work following commercial cockpit automation of the
eighthies did not see this maturity issue, and focused on issues related to things that were still evolving. Today, this technology is more mature and provides more operational safety (Boy, 2013).

Aviation changed our lives. Transportation in general modified the way we live. It enabled connectivity in many ways. It also modified, and still modifies, our environment. The problem today deals with the number of cars and aircrafts more than anything else. These numbers increase because people find transportation means useful and usable, and guess what? They use them massively. The same case is the Internet. Internet changes our lives and connects us planet-wide. Our planet is not the same as in the beginning of the 20th century; it resembles a planetary village that we need to explore. This is a kind of terraforming that is far from being finished. It is just the beginning. But before we enter into more details on terraforming, let’s define Ecopoiesis as a first stage, the induction stage.

Ecopoiesis is a set of emerging life-support phenomena as opposed to forced usual Earth-like phenomena (which is terraforming). Ecopoiesis processes progressively emerge from adaptation and evolution. Of course, we cannot predict how life would evolve on another planetary system, but we can imagine possible futures, model them, simulate them and somehow experience them. We are talking about analogs. The idea of creating self-sustaining life on other planets is also followed by various safety concerns; one of which actually points out a terraformed planet as a refuge for humankind (Strauss, 1990). For example, studying planet Mars supports unveiling planet Earth possible futures by considering past habitability of Martian environment (Stephen & Schneider, 2004). The Martian case can then be extrapolated to planet Earth’s conditions (McKay & Stoker, 1989). More specifically, the Mars Science Laboratory (Curiosity) currently attempts to identify possible states of planet Mars that may involve living forms (NASA/JPL-Caltech, 2012), and that are not excluded to be similar to those on Earth.

![Figure 1: Possible explanations of methane sources and transfer in Martian atmosphere (NASA/JPL-Caltech, 2012).](image-url)
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Thanks to many research efforts and discoveries on other planetary bodies, we have become aware of global planetary changes, human-induced pollution of our planet, and their complex interrelations. As planet Mars was studied for its unknown surface environment and atmosphere, scientists realized the global changes and interrelations of small climate events within the whole planetary system. This “analog” research and particularly its principles were then possible to extrapolate to planet Earth (e.g., research performed by Lovelock) (Millar, 2002).

Consequently, what does it mean to live on Mars? Two primary conditions for life are livable presence of oxygen and water. It is interesting to notice that we are coming back to these premises on the Earth where pollution and rarefaction of drinkable water have become major issues. We often point the negative effect of the first and second industrial revolutions, which did not take into account ecology, but putting to the front economy. Today, the ecological state of the planet Earth is in jeopardy. This is a question of high-level goal. Ecology should not be serving economy, but the opposite. Economy should come back to its initial role of supporting human welfare. We cannot do ergonomics on wrong premises. The real problem today is at the top where economy, and finance in particular, is ruling the world, instead of serving the world.

It is interesting to notice that human beings adapt to extreme environments. This adaptation is almost always constructed cognitively. Aviation was possible only because people thought about what flying was about, i.e. thrust and lift as primary concepts that needed to be understood and designed both cognitively and practically. People cannot fly like birds do, but they were smart enough to build prostheses that enabled them to fly. It is another way of talking about Ecopoiesis and terraforming. The main issue is filling the gap between people capabilities and environmental constraints.

III. SPACE SETTLEMENTS AND HABITATS

Ergonomics in its primary sense, i.e. the science of work, should take into account our evolution: the Homo-sapiens has become the Homo-Technologicus. As already said, it is urgent that we state the right questions regarding technology, organizations and people (the TOP model). Among other things, we need to take into account cultures, society evolution and various migrations (Ardittis & Attali, 1994). New types of settlements have started. Even if the term “colony” has nowadays a very negative connotation, e.g. the colonization of already inhabited countries during several centuries, we can use it in the sense of reference to the original large visionary space settlement concepts that were exploring new ways of living, producing goods and creating new cultures fully independently of resources and culture on Earth.

The idea of moving millions of people into space colonies started to appear during the 20th century when scientists, engineers and architects realized that humankind is going to exhaust Earth’s planetary resources soon and the risk of overpopulation and pollution of Earth was perceived.
as a real risk too (Brand, 1977). The solutions that were proposed were quite poetic and futuristic for their time but certainly not unrealistic for the future. First large space colony was proposed by Russian professor Konstantin E. Tsiolkovski in early 20th century, even if his concept did not address overpopulation or lack of resources. His work pointed out technical feasibility of such a large project. Amongst many other credits, Tsiolkovski holds also credit for a first space settlement considering possibility of creating closed artificial biosphere in outer space (Table 1).

The later twentieth century settlements (see Table 1) by Bernal, O’Neill, Stanford/NASA research team, and architect Paolo Soleri were actually expanding the problem of humans’ resource consummation towards expansion in the universe instead of resolving it (considering limitless resources of the outer space). The complexity of the human biosphere was not understood as well as nowadays and thus the only solution was to replicate a large natural biosphere.

The colonies designed by these masterminds were correctly intended to be self-sustainable so the communities would not need any external input brought from Earth after completion, being a resource-independent habitation system. Nevertheless the overall effort to construct them would be astronomical. These space settlements (colonies) were offering replication of the terrestrial biosphere in mass scale, biosphere that would be closed loop with biological regeneration capability (Brand, 1977). Although the technology to replicate biological life support exists, the International Space Station is still not fully independent of terrestrial resources and chemical, rather than biological, recuperation of the atmosphere prevails.

**Table 1:** List of early space colonies - habitable settlements that support fully autonomous habitation out of the Earth’s surface using biological closed loop environmental life support systems (replicating terrestrial natural biosphere)

<table>
<thead>
<tr>
<th>Author</th>
<th>Concept</th>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Konstantin E. Tsiolkovski</td>
<td>First self-sustainable space settlement concept</td>
<td>1911</td>
<td>Artificial gravity space settlement. Largest diameter is estimated to 30 meter diameter. (capacity unknown)</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Name</th>
<th>Design</th>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>John D. Bernal</td>
<td>Bernal Sphere</td>
<td>1929</td>
<td>Artificial gravity settlement for 20000 people. Habitable sphere has 1.6 kilometer diameter.</td>
</tr>
<tr>
<td>Paolo Soleri</td>
<td>Asteromo</td>
<td>1966</td>
<td>Artificial gravity settlement for 70000 people with habitable central ring 1.4 kilometer diameter.</td>
</tr>
<tr>
<td>Stanford University, NASA-Ames Research Center</td>
<td>Stanford Torus</td>
<td>1975</td>
<td>Artificial gravity settlement for 100000 people with habitable ring 1.6 meter diameter.</td>
</tr>
<tr>
<td>Gerard O’Neill</td>
<td>Island III</td>
<td>1975</td>
<td>Artificial gravity settlement for 1 million people composed of two counter-spun 8 kilometer diameter cylinders.</td>
</tr>
</tbody>
</table>

Introduced in the seventies, space colonies concepts appeared to be the solution to our Earth problems dealing with socio-technical resources, overpopulation and environmental pollution. Their development appears to be longer than expected. However, they induced new thoughts and possibilities on the Earth:

- We now have methods and technologies to address life sustainability in new environments.
- We know that modeling and simulation can help tremendously in figuring out appropriate solutions.
- We improved our understanding of what life-critical systems are.
- We know that we need to address complexity as a whole in order to discover emerging properties of the systems that we are planning to design and develop.
- We also know that we cannot design and develop technology without reference to our past and future, and we should address and design
concurrently technology, organizations and human evolution. More specifically, people roles, capabilities and limitations have to be taken into account.

In addition, the risk humans take when moving to another environment is pictured in humankind history. Humans either over exploit the environment to maximum so it could not support humans’ activities anymore or create technological prostheses (extensions) to enable temporary solution re-initiating the exploitation cycle. When the technological solutions fail, human existence is a subject to inevitable extinction (Dator, 2002).

People discovering new phenomena in a new environment need to learn new skills and understand new knowledge to survive in this environment. It was the case when we started flying (people do not naturally fly, but flying has become a familiar activity during the 20th century). Such learning and understanding involve new cognitive, emotional and societal functions and structures. Discovering outer space functions led to new kinds of technology developments that turned out to be very valuable on the Earth, such as technology spin-offs (e.g., the pacemaker device originally developed for satellite control). Another example is the spin-on biosphere allowing human presence in space that was well tested on Earth. Experiments (Biospheres I and II, 1.2 hectare) proved that it was possible for human beings to live in fully artificial, isolated environment in space. These biospheres were much smaller than proposed colonies in Table 1 with possible exception of Tsiolkovsky’s concept, whose capacity is unknown and dimensions are estimated based on original sketches. We should make clear that it is going both ways; technology transfer processes can be thought as spin-off going from space to Earth, or spin-on going from Earth to space. Again, modeling and simulation are at stake. Analog environments are good solutions to test and discover emerging properties. Such environments have to be as realistic as possible in order to provide good results.

In an artificially controlled and replicated environment, we need to know all aspects of our bodily functions. In our growing polluted and overpopulated environment, we need to test solutions at a reasonably large scale. An example of such a HCD approach for human spaceflights is provided in Figure 2.

Discoveries at any scale in extreme environments may significantly contribute to our knowledge and expansion in our universe. Most importantly, they tend to enhance our quality of life on Earth. National agencies (NASA in particular) already brought many examples of technological spin-offs (Lockney, 2011).

Our socio-technical evolution during the last hundred years and its recent acceleration brought to the front the necessity of re-colonizing our planet Earth. We not only need to understand what we have socio-technically done, but also find out what is the best way to further develop

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technology, organizations and people. We have accumulated a huge amount of technological solutions that we commonly use, such as photovoltaic technology, water purification, thermal insolation, food processing and advanced robotics. Unfortunately, these solutions are not integrated and lead to unforeseen problems. Integration is a key. As in space programs, we need to take a holistic view instead of a cumulative habit. This is more than ever a necessity because we have created a new world where almost everything is now interconnected, therefore increasing the complexity of the whole.

Figure 2: Knowledge transfer between terrestrial and space applications over time.

IV. HUMAN SUBSYSTEMS – LEARNING FROM SPACE FLIGHT

“Understanding physiology at the limits of human tolerance to environmental conditions is a worthy goal in itself but may in addition lead to developments in both knowledge and treatments in clinical settings” (Grocott, 2008).

Safety is the most important aspect of human spaceflight. Spaceflight is extremely risky and a very expensive endeavor (due to rocket propulsion still taking the lead). Therefore, understanding human factors in spaceflight is one of primary requirements.
Ergonomic functions are strongly personalized, and anthropometry is reflected in the design of seats in Soyuz TMA spacecraft for example (Figure 3). Safety is always the primary principle for such precision requirements. A personalized seat much better protects its occupant, and provides more comfort than a standard unit that would be designed based on average sample size (Kuipers, 2012). Space brings customization to the front. Transferring this concept to Earth design and engineering, it is very interesting to observe that despite the usual credo of ergonomics that promotes the adaptation of technology to people, economy and finance impose standardization, which means the adaptation of people to technology. The question is then to define higher-level goals for our societies and people. If we want to explore our planet Earth, as we want to explore the Moon or Mars, we need to adapt technology to people in a deeper sense than what we usually do today.

Further exploring applied personalized anthropometry in space, spacecraft and space stations subsystems need to precisely consider everyone’s physiological processes (Figure 4). Therefore each metabolic process has to be, and is, well monitored prior to the spaceflight. Personalized scales for all human body inputs and outputs are provided, based on measurable inputs and outputs. This data further serves precise planning of human body needs for the length of the mission.
In other words, if we want people to survive in space, we need to take care of them! Would not it be the case on the Earth, which is changing so fast right now ecologically, socio-technically and culturally? When you plan for a trip, you try to organize everything around three main principles that are safety, efficiency and comfort. These are ergonomic principles. It is interesting to observe that France has written the Precautionary principle in its constitution. It was initially limited to the environment, but “there has also been a marked evolution in the French legal system towards the systematic search for a guilty party at the slightest suspicion that an event may have been caused, directly or indirectly, by an element of risk taking” (Boy & Brachet, 2010). It is time to better understand what risk taking really means. In life-critical systems, we have developed regulations and procedures that bound risk. However, these regulations and procedures have increased both in number and content to a point where people barely have time, opportunity and sometimes desire to follow them. Again, integration is at stake. We need to integrate instead of accumulate knowledge and policies.

Lessons learned from the development and use of life-critical systems such as experience with human space flight shows that humans may fail. Human error was the topic of many research efforts during the last three decades. However, this was a very negative view of human’s role, putting people as problems. Therefore, technology and regulations were implemented to be system solutions. But on the contrary, when people are correctly engaged, they can provide solutions. Human engagement requires competence, knowledge, experience, training, motivation, creativity and responsibility.

Appropriate implementation of these space human factors strategies and experience may be extremely useful in human-centered design on the Earth. Pressure on efficiency of the environmental resource utilization will increase with the growing risk of overpopulation and non-reusable natural resources exhaustion.

V. SYSTEMS DERIVED, SPACE SPIN-OFFS, SYSTEMS FOR LIVING

Although national offices transfer a large amount of space technology, materials and procedures, the most important phenomenon derived from the space sector is individual consciousness of life on a very unique planet in the solar system and maybe in the entire universe. This consciousness enables the design of effective closed loop systems supporting humans out of their natural environment.

Therefore another very important aspect is the design approach that carefully integrates all subsystems in order to keep the artificial biosphere
system supporting human with recycled atmosphere. This integration allows human existence in the outer space, and when extrapolated to terrestrial conditions, it enables a fully sustainable individual living envelope. Such envelope, well understood from a technical and systems engineering point of view, may significantly enhance the design of any type of artificially built environment from habitats, large scale architecture of any function and typology or even historical buildings to automotive and aeronautics (Figure 5).

The partially-closed/open loop system operated in the International Space Station (Figure 6) is an excellent example of an integrated technological biosphere supporting human out of his natural environment. It includes not only power and thermal subsystems, station keeping, telecommunication subsystems but most importantly chemical environmental control and life support with water management filtering system.

Number of technologies and subsystems developed for space are already being used in terrestrial conditions (power generation systems, water filtering systems, etc.) but they are often used ad-hoc as an individual technical component or as an addition to an existing system.

Mastering principles of subsystems integration as it has been done on the International Space Station (ISS) and incorporating interdisciplinary integration within the philosophy and strategy of the Ergonomics discipline would enhance not only the terrestrial domain but also the space sector. Although the ISS is the only and most sophisticated habitat humankind has ever built, the internal environmental ergonomics is subject to significant upgrade. The entire station, while designed for research purposes as a laboratory, did not significantly address habitability aspect of the microgravity environment while strictly focusing on survivability.
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Consequently, space exploration contributes to the future of ergonomics by producing human-centered systems and methodologies, and primarily shows technological and cultural evolutions. Once the artificial human envelope integration is mastered (Figure 5), not only solutions to current sustainable and ecological issues can be found, but also the large settlements proposed (e.g., Table 1) will be enabled.

Figure 6: Exemple de système de la Station spatiale internationale partiellement en boucle fermée pour l’eau, l’atmosphère, la nourriture, les détritus et le contrôle thermique (Hanford, 2005).

Figure 6: Example of the International Space Station partially closed loop life support system including water, atmosphere, food, waste and thermal management (Hanford, 2005).

VI. PRINCIPLES DERIVED – CONCLUSIONS

From a prospective point of view, our socio-technical future is very likely directed toward design and development of personalized systems and subsystems, environment, and general focus on the individual living envelope.

Ergonomics not only provides solutions to enhance safety, anthropometrically organized space and cognitive activities as suggested by industry guides for example (EIG, 2012), but also enhances physical conditions, well-being, body regeneration, and at the same time recycles, generates power and provides “personalized and up to date” human-machine interface functions.
A practical example may be comfortable wellness furniture that may be effectively integrated within the working space and station, effectively supporting energy sustainability and autonomy. The Mood Chair (Figure 7) with desktop surface that integrates human power generation for recharging electronic devices is a good example (Tarisa, 2010).

Work is an inherent part of human existence. According to Hannah Arendt, life can be described as and divided into work (of our hands), labor (of our body) and action (placed in the realm of uncertainty) (Frampton, 2002). Ergonomics in its primary sense (i.e., the science of work) should take into account these three components, as well as cultural differences and society evolution.

Ergonomics requires more integration with other disciplines and fields of study in order to “catch a breath” with current human needs. It may need to extend its purely positivist and empirical scientific approaches and broaden its economic interests and outcome also to ethical outcomes (Dekker, Hancock, & Wilkin, 2013). It should become an inherent part of architecture, automotive, aerospace and product design, and become a driver for design and building standards. In the future, it will hopefully become a universal approach based on human-centered design principles that span through a variety of appropriate disciplines and applications. This approach will strongly support integration as a grounding design process. Ergonomics should benefit of space spin-offs that bring innovative design principles and technology. Space applications have been proven not
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only to be cost profitable (Amesse, Cohendet, Poirier, & Chouinard, 2002) but also key for faster research and development (Figure 8) (Goehlich, Blanksby, Goh, Hatano, Pečnik, & Wong, 2005).

Figure 8: Simplified scheme of technology transfer as a financial enabler of research and development in space (Goehlich, Blanksby, Goh, Hatano, Pečnik, & Wong, 2005).

The above described and proposed path of the field of ergonomics could be simply characterized as Personalized Ergonomics that provides system of balancing research and design principles in a Human-Centered way.

But the field of ergonomics has another challenge ahead. The science of work and usage has to start globally emphasize bankrupt aspect of ethics that is disappearing from the work environment and exists thanks to its natural persistence. Technological capability within the product design is intimately related to financial benefits of the product life cycle. Unfortunately, some appliances were created disposable with pre-programmed errors that force their users to change the overall product after some period of time and cause unnecessary expenses. This is an example of financially-driven design, as opposed to human-centered design that promotes sustainable products. We should use technology for the sake of long-term humanitarian evolution, instead of using it for the sake of short-term financial benefits. We need to change this sad contemporary economical approach, and focus on ethical, societal and human issues. Ethics as one of important aspects of Ergonomics will play an important role not only in design but specifically in its organization and management.
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Summary

Traditional ergonomics fits into the continuity of the relationship between people, artifacts, which they build, their environment and societies. The current unprecedented technological development is breaking this continuity. We must think of human evolution and its relationship to work in new ways that space exploration has already begun to shape. This article outlines elementary strategies that explain how and why space exploration is essential for humankind’s growth, evolution and sustainable development, not only at the individual ergonomic level but also at the societal level. Prospective ergonomics needs to take into account these strategies. We claim that if we place any living entity out of its natural environment —where it is adapted to live in—, this entity reacts to the new environment —where it is not adapted to live in— in a specific way to defend, adapt and survive. Not only such survival boundaries and new adaptation capabilities should be discovered, but also life requirements in nominal environments can be better understood. During the NASA Apollo program, humans already extended their living environment to the Moon. We do adapt to a new environment by using a “technological bridge” that facilitates and extends our “adaptation” capabilities much more rapidly than what natural evolution would require whenever possible. In space for example, it is mandatory to extend our living and working environment, but how far can we do this? Can we live everywhere? What are the fundamental limitations and possibilities that needed to be identified? For example, are we limited to habitable zones and regions in our solar system and galaxy? Are we able to fully adapt to microgravity? What are the technological possibilities needed to develop to have sustainable oxygen and water supply? Ultimately, what does it mean to be a human being in the Universe and on Earth in particular? We consider that these questions are crucial in the beginning of the 21st century because our planet Earth is changing rapidly when we consider several parameters such as our global demography, constantly degraded ecology and uncontrollable economy. We are facing a blank slate exactly in the same way as when we analyze a possible life on Mars. We need to better understand human limitations and capabilities.
in both natural and artificial worlds that we have generated, and nature provides either nominally or by reaction to our expanding socio-technical ways of living.

**Key words:** Adaptation, human-centered design, prospective ergonomics, ecology, artificial living environments, human space flights, extraterrestrial life, society evolution, space settlements, technology transfer.