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Sustainable technology management model for space debris control

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Abstract

The development of space technology has caused a spread of pollution beyond the borders of the earth's surface, which in turn, has increasingly become a dormant threat to space exploration. The orbital zone around the Earth swarms with millions of pieces of man-made debris that create potential hazards for telescopes, pressurized equipment and live satellites, among others. There are several causes for this waste. For instance, we can point out the collision of a wide variety of solid objects in space, fuel tank explosions and meteorite impacts or satellite's malfunction while in orbit. Space agencies all over the world have already started to create solutions to mitigate this problem in the Low Earth orbit (LEO). For it is in this orbital zone, that most of the orbital debris is gathered. This represents both a technical and a subsequent economical challenge. Therefore, after considering its major environmental impact, we must suggest a holistic approach for its solution. Technology Management is an industrial activity and an emerging field of education and research that has not been consistently defined yet. To accomplish such task, it's required the identification of innovation processes that are involved in R&D projects in order to introduce the use of technology in products, industrial processes and other structural and functional areas of an organization. This knowledge is also used to establish comprehensive solutions to social and environmental problems. This work aims to present recent progress in the research field, with which we can develop approaches for a management model of technology that integrates sustainable strategies for decision making regarding the control and disposal of satellites at the end of its life-cycle. This model is based on the planning, evaluation, control, execution and implementation of satellite development processes, including those activities in the processes of design, manufacture, satellite services and general administration. This proposal suggests the analysis and assessment of the product's life-cycle as a built in tool in the design process of satellites to identify markers that allow us to establish the sustainable characteristics needed to generate a comprehensive proposal for a management model of technology in Mexico. This will enable a linking between science, engineering processes and administrative disciplines, all of which converge in a model that considers the planning, development and implementation of all technological capabilities in research and Space development with a sustainable perspective.

Keywords: Technology Management, Sustainability, Life-cycle assessment and space debris.

Nomenclature
Cubic centimeter [cm^3]

Acronyms/Abbreviations
Aerospace Industry in Mexico (IAM)
Council of Science and Technology (CONACyT)
Environmental Assessment Life Cycle (E-LCA)
Faculty of Engineering (FI)

International Organization for Standardization (ISO)
Life Cycle Analysis (LCA)
Low Earth Orbit (LEO)
Mexican Space Agency (AEM)
National Autonomous University of Mexico (UNAM)
National Award for Technology and Innovation ® (PNTi)
Research and Development (R&D)
Technology management (TM)

1. Introduction

Earth orbitals, have become hubs of satellite fragments, as well of tools and astronaut's equipment; There are roughly 16,530 objects greater than 10 cm3 [1], deposited in different orbits. For that reason, it has attracted the interest and awareness for an assessment over the environmental impact of space missions, in order to promote solutions.

Regarding the problem of space debris in the Earth's orbitals, measures should be adopted to develop and implement methodologies to define the minimum requirements for, at first, mitigate the amount of orbital debris generated by the exploration of outer space.

Because of the creation of the Mexican Space Agency (AEM), the space technology development in Mexico is nowadays a reality. As a consequence, different institutions have come together to strengthen this initiative with the generation of research and space development for our country.

In the field of development and innovation of Mexican space technologies, we are presented with the opportunity to be a part of the international efforts to define appropriate sustainability measures for space activities and thus, generate environmental impact assessments caused by space missions around the world.

Currently, several countries consider Space debris as a threat to future space missions because its detrimental factor to space technology development.

The Aerospace Industry in Mexico (IAM) has competitive advantages over some other countries due to many different factors such as its geographical position, its proximity to research centers, its aerospace technology development and operative costs and skilled labor, among others. [2]

Mexico has become the world's largest recipient of investment for the aerospace manufacturing sector over the last twenty years, earning around 7,500 million dollars of exports during the last year, the sixth supplier of aerospace products from the United States in the world. [3]

The AEM has a great opportunity to have an active participation in the sector of the space industry, but it is necessary to develop research and technology, integrating different areas of knowledge, which will enable the IAM to grow the appropriate human and economic resources to provide a solid basis for our industry.

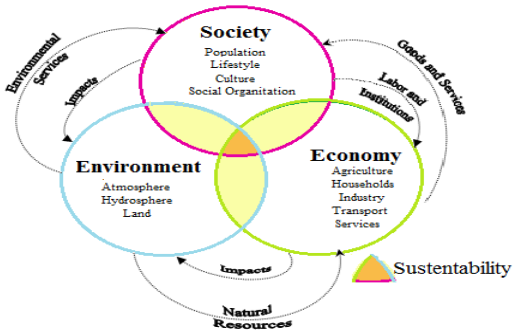

Fig. 1. Sustainability areas and their interactions Adapted from: Calvente M. (2007: 4) “El concepto moderno de la sustentabilidad”.

The Worldwide economic importance of the aerospace industry has brought many changes as a result of an increased use of its applications in the daily life, as well as in scientific and technological development. The number of countries taking part of this industry has increased, either as users of satellite services or as developers of such technologies, increasing the number of space missions in the world. [7]

The development of space technology has become a latent threat. Partly, because appropriate measures for dealing with space debris at the end of the satellite's life-cycle hasn't been considered yet. This makes it urgent to develop international agreements, regulations and the integration of the Sustainability concept for the development of future space missions.

The adoption of the concept of sustainable development in space exploration, will establish appropriate measures to solve the problem of solid waste generated in space strategies and exploration. [8]

2. Methods

2.1 Delphi Methodology

In order to select the proper data collection instrument a review was made over the authors and representative texts in the existing literature on research methodology, assessment tools and methods of data collection depending on the approach and context of investigations. From this review, we chose to use the Delphi method, which consists in a selection of expert groups where participants are asked to give their opinion about the proposed sustainable TM model for space debris. Expert estimations are being obtained in

successive and anonymous rounds with the goal of achieving the greater consensus or with the maximum autonomy of its participants.

As a starting point for the design, we started off from the analysis of the problem related with the lack of sustainable processes in the tool application that are part of the TM, as well as in the satellites design. TM, offers tools to improve transfer, assessment and technology business processes.

Various TM models from several authors were analyzed so we could choose an ideal model that meets the following criteria: Must be systemic and universal and it needs to count on strategic and operational elements as well as tools for satellite technology management which allows to generate an innovative approach for sustainable TM.

3. Theory and calculation

3.1 Technology management (TM)

Technology Management (TM) is an industrial activity and an emerging field of research that has not been consistently defined yet. It encompasses innovation processes through R&D for the use and incorporation of technology in products, manufacturing processes and other corporate functions [9]. This allows a linking between engineering, science and administrative disciplines in order to plan, develop, and implement the technological capabilities required to effectively achieve our aims [10].

The TM provides a number of functions and specific processes (defined by technological development and innovation of organizations) that: integrate, identify, evaluate, select, acquire, assimilate and effectively utilizes the development and innovation in technology as a part of the general strategies for the organization and seeking of a competitive edge through the use of technology [11].

When processes of TM are performed sequentially, systematically and with clear objectives and goals, you can set the basis to define a model of technological management [10, 11], where processes and activities can be joined according to their similarities in functions that facilitate its organization and coordination [11].

In Mexico, we have joined forces to promote technological development of Mexican organizations regardless its specific area or size through the National Model of Technology and Innovation Management © National Award for Technology and Innovation ® (PNTi), which establishes the following basic premises [7,8,10]:

1) Proper technology management strengthens the importance of technological development and innovation within the organization.

2) TM maximizes competitive advantage, based on capacity of development and technological innovation.

3) TM provides consistent and functional methods for the organization to define as technological development will incorporate the use of technology to create, transform and deliver value-added products or services.

The National Model of Technology and Innovation Management © of PNTi, proposes five essential functions: monitoring, planning, enabling, protection and implementation; all of which should clearly reflect the existing relationship with the management processes. In the model all elements and processes involved in each function are systematically and permanently exposed. This allows to establish adequate strategies to be followed by each organization under this model [12], and thus been able to define the functions and processes accordingly to their nature, establishing the expected results for each one of them in such a way that clearly reflects the way they are linked.

As a response to the growing relevance of the innovation business in Mexico, the National Model of Technology and Innovation Management © has been incorporated as a part of the proposed strategies stated in the National Development Plan 2007-2012, which's highlights the importance of scientific activities, technology and innovation, as well as it anticipates strategies to promote the integral development of the country in a sustainable way [13].

3.2 Analysis of the product life-cycle management

Currently, there are methodological tools to assess the environmental impact of different economic activities based on product development. These tools aim primarily to generate the necessary knowledge to establish environmental strategies based on the three pillars of sustainability: Economy, Society and Environment [14]. To achieve this, it is necessary to count with periodic and objective documentation of the process that allow us to determine through an assessment, whether the processes involved in the development of a product are meeting the environmental objectives for the organization. Using these tools also aims to determine to what extent all activities involved in the process of developing a product actually comply with external requirements, internal policies and established environmental standards.

One of these methodologies is the analysis of the product life-cycle management (LCA), which includes all activities and processes involved in the development of a product, and analyzes the process from extraction of raw materials, manufacture, its distribution, use for which it was created; until the end of its useful life; this in order to generate information to make decisions about

product design and use of material, financial and human resources involved to generate sustainable manufacturing process. So the product LCA is a methodology that aims to identify, quantify and characterize the environmental impacts generated by a product throughout its production process [15]; Based on this perspective, the analysis of the product life-cycle management it requires is selecting appropriate for each stage of the cycle processes.

The International Organization for Standardization (ISO) describes the principles for LCA evaluation of the product in the ISO 14040 standard and ISO 14044,

which required elements and recommendations for the assessment of environmental life cycle (E-LCA established) [14]. The LCA is composed mainly by four stages: defining the objective and scope of the study, preparation of the LCA model, determining which variables input and output, assessment of the environmental impact generated by the inputs and outputs and the interpretation of results (Fig. 2); will each of these stages require consider the processes that exist within each part of the process [14,16].

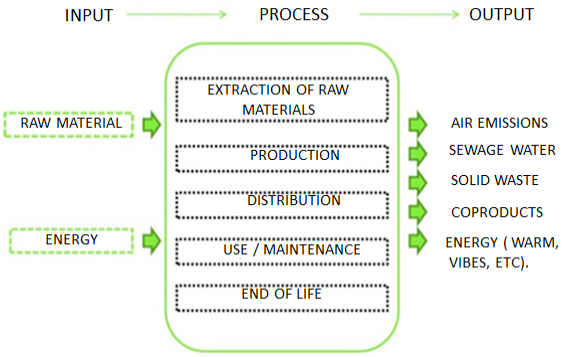

Fig. 2. Stages of the product life-cycle management Translation de http://www.certificadosenergeticos.com/analisis-ciclo-vida-diseno-materiales-sostenibles

4. Conclusions

Several research groups in Mexico are currently working on developing a space program that includes a new infrastructure, industrial participation, training programs and proposals for research and technological development. This program will accelerate the process of incorporation of space technology to the country. The Space technology management model proposed to mitigate space debris (Fig. 3), allows to analyze the environment and the capabilities that are counted in the country; This is intended to define clear objectives to establish guidelines and technological guidelines that should be considered in R&D of small satellites developed in Mexico.

In the specific case of Mexico, it is necessary to adopt international standards for collaboration and development of space missions as part of the guidelines of this model. This proposal will allow Mexico to have a model of TM that includes comprehensive and systematic generation of R&D that comply with international standards in the design, development, prototypes, processes, products and services of space technologies (Fig. 4).

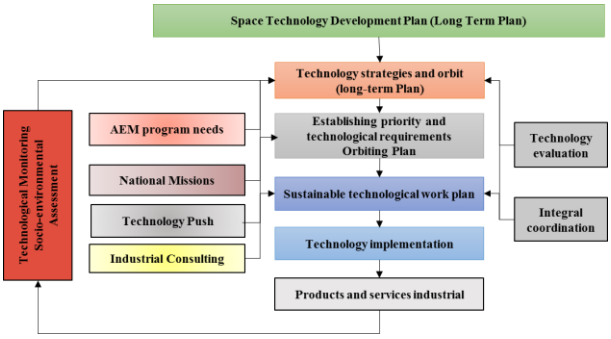

Fig. 3. Proposal Model Technology Management

The incorporation of LCA in design methodologies, allows to establish step by step those procedures fot the functional representation, the search for a conceptual solution and detailed design of the satellite platform. On the other hand, it also makes possible the development of consequent guidelines and improvements in the design, establishing techniques which incorporate the customer's needs in the analysis of requirements and specifications of a product with a sustainable perspective.

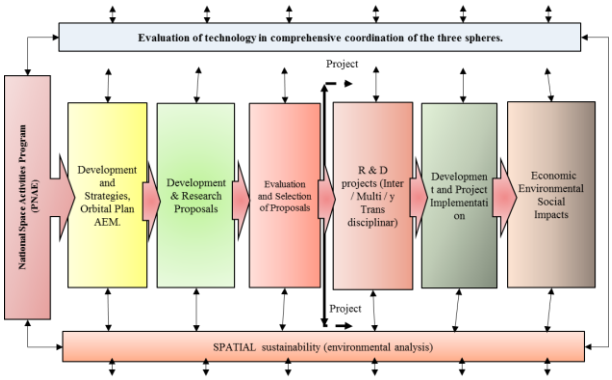

Fig. 4. Proposal Process Model Technology Management

Note that the presented model is a comprehensive proposal for technology management of Space projects in Mexico with a sustainable perspective, in order to mitigate the provision of Space debris in orbits of the earth and thus, the environmental impact they generate with it. To achieve this, it is essential to link scientific research with administrative and engineering disciplines to tackle this matter with a real holistic approach.

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