



A systematic review of the Space technology transfer literature: Research synthesis and emerging gaps



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ABSTRACT

In order to justify high expenditure during this period of financial crisis, Space Agencies have attempted to increase the returns on their investments in Space missions by encouraging the commercial use of advanced technologies. The development of a technology transfer process from Space to Earth not only benefits the Aerospace industry but also the network of national companies. Technology transfer has been shown to stimulate innovation in business and commerce, support economic growth and provide a return on public investment in research and development (R&D). The aim of this paper is to systematically review the Space technology transfer literature and to suggest directions for future research. The range of research and studies in the literature on this topic requires a systematic review to summarize the results in an unbiased and balanced manner and to interpret these in a way that highlights the research gaps. This article presents an overview of the dominant thinking (explicit in selected articles from 1995 to present), indicating the problems of analysis, research gaps and a future research program.

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1. Introduction

In 2011, NASA reported that approximately 100 companies had used spin-off technologies. Some of the benefits of this use were more than 12,000 lives saved, more than 9200 jobs created, and savings of more than \$6.2 billion [51]. In 2011, infrared satellite images were used to locate over 3000 ancient settlements in Egypt and may also be used to help protect archeological sites from looters. A biotechnology company launched 30 mice on NASA's final shuttle mission in July 2011 to test an antibody that might help prevent bone deterioration, which occurs at an accelerated pace in living creatures in Space. Lessons learned from this research could lead to more effective bone treatments for the world's population.

The U.S. Space economy grew by 12% in 2011, reaching an estimated total of \$289.77 billion. As in past years, the majority of this growth was a result of commercial success rather than increases in government spending [51].

The potential inherent in Space technologies to be transferred and to generate new innovative processes has been evident since the founding of NASA and it is forecast also in future [15]. In 1960, NASA created an Office of Technical Information and Educational

Programs to implement a technology dissemination strategy, and since then it has continued to promote transfer programs, supporting firms in their demands for technology and disseminating information through the annual publication "NASA Spinoffs" [49].

Similarly, other countries and their Space agencies also began to take an interest in the processes of Space product transfer. Over the last 50 years, scholars and scientists have reported, and in some cases analyzed this phenomenon in major international journals. However, no one has ever collected and interpreted this body of publications. The primary objectives of this article are to systematically review the Space technology transfer literature and to provide direction for fruitful future research.

A systematic review of the literature follows an explicit, rigorous and transparent methodology [17]. Applying this definition, we constructed a database of 40 articles. The search phase was performed according to the following criteria: firstly, we selected only studies that focused on the transfer of Space technologies from the Space industry to Earth's industrial system. We excluded transfer processes that take place within the Space sector or at international level. Space agencies or firms responsible for the construction of Space systems can transfer knowledge to suppliers of components or services, or to other companies they collaborate with for R&D purposes. In addition, Space agencies collaborate at an international level, mutually exchanging knowledge and know-how. Secondly, we limited our review to academic literature, excluding

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articles that had not been peer reviewed. The intention was to exclude all popular articles that did not contribute to the growth of scientific theory. Finally, we selected literature from the period 1995–2012. This last decision was twofold: electronic databases containing the full text of articles have only been available since 1995, and it is particularly in recent years that researchers have begun to discuss the issue of the transfer of Space technologies.

The criteria selected for interpreting the database coincide with the areas of major interest in the development of technological transfer processes, namely: actors, geographical context and industrial sectors, motivations, Space technologies, paths, models and mechanisms, impact/effectiveness and determinants.

The results contain a summary of findings from each area of interest, plus an additional section on the definitions of technology transfer (TT). The conclusions include those that are referred to in the literature as “future researches”; in other words, the gaps that are still open and which researchers are invited to investigate. The paper is organized as follows: firstly, we describe the methodology used for identifying and selecting the papers. Secondly, we review the papers along descriptive characteristics, the definitions of technology transfer concept and along six items of classification. Thirdly, we indicate some remaining issues for further investigation.

2. Methodology

The analysis process involved the completion of the following activities [21]:

- Step 1: Select the database to consult and set time limits;
- Step 2: Selection of articles;
- Step 3: Classification and analysis of the resulting database.

2.1. Search for papers

To identify the collection of papers for review, we conducted an electronic journal database search. This decision was motivated by the fact that the database is an electronic archive of journals and bibliographic references that can be searched in a comprehensive and dynamic manner. The scientific value of the information is guaranteed since the content selection is conducted by qualified scientific committees. We used the online databases ProQuest-ABI/Inform and ScienceDirect because they store the abstracts and full texts of the majority of ISI management journals.

An electronic database search requires the digitization of keywords in the search Spaces provided. Generally speaking, the most difficult part of conducting a good search consists in figuring out which terms to use and how to combine them to find literature that is “on topic”. This requires separating the search statement or question into concepts and keywords as well as using synonyms for these keywords. Keywords were put in quotation marks to avoid an oversupply of publications.

Our objective was to conduct a survey of all published research on technology transfer from Space companies to the industrial system, written in English between 1995 and early 2012.

Bozeman (2000) [10] defines technology transfer (TT) as the process that allows the passage of a technology from one organization (donor) to another entrepreneurial organization (receiver), but there are many definitions and synonyms for the concept of transfer. The most common are the following (Fig. 1):

- Technology adoption (or acquisition). For ESA (2012) [16] “technology transfer is the process of adapting and adopting technology originally developed for one sector (Space) into another sector (non-Space)”;
- Technology valorization (or adaptation). Ref. [5] suggests a broader definition by proposing that technology transfer involves an intentional, goal-oriented interaction between two or more social entities, during which the pool of technological knowledge remains stable or increases through the transfer of one or more components of technology;
- Technology commercialization. Often the marketing concept is implicit in that of transfer. For some researchers, ideas and concepts are moved from the laboratory to the marketplace [44,56];
- Diffusion of technology. Sociologists [46,47] have defined technology transfer in the context of the diffusion of innovations. This has led to a confusion whereby many researchers, and even practitioners, refer to the terms *technology transfer* and *technology diffusion* interchangeably. Whereas in the notion of transfer, the idea of a project is implicit, diffusion of technology usually takes place without any prearranged plan and as a result of market forces. While conceptually distinct, the two processes are often connected in industrial practice because transfer programs often precede diffusion processes and constitute the essential premise on which diffusion depends [43];

Spin-offs. Frequently in Aerospace studies, the term technology transfer is replaced by the term *spin-off*, although the latter was created, and is commonly used in the managerial literature, to indicate a new business entity formed to commercialize one or more related inventions generated from the research work of a parent institution [45]. A spin-off can be described as a technology that is transferred from one mother domain to other industries for which it was not initially intended [48].

In relation to the reference context, the keywords used were as follows (Fig. 2):

- Space industry and Space sector. The terms *industry* and *sector* are often used interchangeably to describe a group of companies that operate in the same segment of the economy or share a similar type of business. In the case of Aerospace, the sector

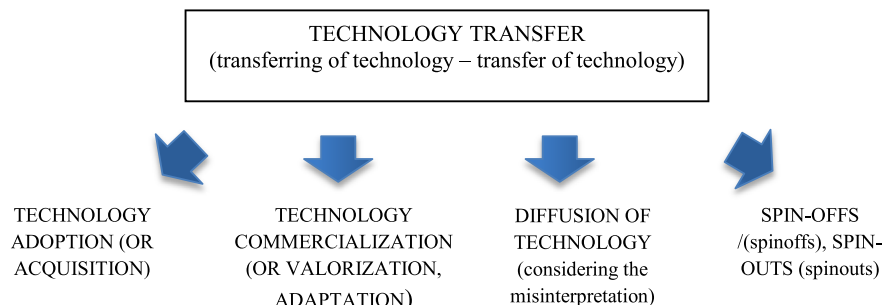


Fig. 1. Technology transfer and its synonyms.

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