Effects and Benefits of Space Exploration:
Past, Present and Future
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ABSTRACT
It has been more than half a century since humans first ventured into space. While competing in being the first to land on the Moon, they learned to utilize space for human needs on Earth (e.g., telecommunications, navigation systems). Many space technologies were later applied to basic needs on Earth. Space research and development led to the “transfer of technology” in non-space sectors and became better known as “spin-offs.” They have improved global modern life in many ways. This paper discusses the cost-benefit of space technology spin-offs, as well as the relationships between various space agencies, spin-offs, and commercial enterprises. Other benefits that have come out of space exploration such as psychological, political and environmental effects are also reviewed, as well as the potential future benefits of going to space. Technologies developed for harsh environments on Earth and for those in space benefit all and collaborating both ways is the future.

Keywords: Benefits from Space Exploration, Effects of Space Exploration, Harsh Environment Technology, Space, Space Exploration, Technology

1. INTRODUCTION
Innovation often originates from the least expected places and certainly no one could ever have envisioned how space exploration would change our society the way it has. It is hard to imagine what the world would be like today if the first satellite had never been launched over fifty years ago. Following the start of the space race, American, Soviet and European engineers raced to research for materials that could perform new tasks and withstand extreme temperatures, high-energy particles as well as the stresses of high or zero gravity. Since that time space research has focused on developing technologies and processes to ensure that spacecraft can survive the hazardous nature of the dynamic space environment.

Space technologies fall into many categories that can be classified as materials (composites, alloys, metals), hardware and software, automation and robotics, electronics, sensors and optics, communications, power and energy devices. Much of this space research and development technology can be transferred to new and beneficial applications – derived products on Earth known as “spin-offs.” A spin-off can be the transfer of technology with the transfer of the inventor or ex-employee resulting in the establishment of a new company – “spin-off company”. It can also be the transfer of the
technology itself – “spin-off technology”. The transfer is an innovative event, since the goal is to exploit these transferred inventions. Spin-offs in this sense always possess an innovative character because they are new to the market, an example being an innovative start-up company that emerges from a firm or public research organization (Maselli, 1997). In this paper spin-off will refer to spin-off technology.

Space agencies have their own applied definitions for spin-offs, for example the European Space Agency (ESA, http://www.esa.int/SPECIALS/TP2/) refers to this process as the transfer of space technologies to non-space sectors. Technology that has been commercialized through the National Aeronautics and Space Administration (NASA) funding, research, licensing, facilities, or assistance is known as a NASA spin-off. Most space agencies appreciate the importance of spin-offs and have departments that specialize in collaborating with commercial enterprises in regard to the transferring of know-how.

The general public is often unaware of the fact that many things they take for granted in their daily lives have their origin in space exploration. Instead they may speculate if going to space is worth the price and think it more useful that the money be spent on more pending issues on Earth. Telecommunications (satellite broadcast, Internet access, etc.) still represent the main commercial space market, and several satellite operators have broken records in revenues since 2008 despite the economic crisis (OECD, 2011). Other large revenues include the geo-positioning market (e.g., navigations) and the satellite Earth observation sector. Indeed, these are growing job sectors that rely on satellites. However, there are thousands of not so well-known markets/products, specifically the spin-offs that have come about due to space technology, as well many non-technical/scientific benefits.

In this paper the cost-benefit of space exploration spin-offs is discussed in Section 2. The relationship between some space agencies, spin-offs and commercial enterprises are discussed in the next Section. In Section 4 the paper reviews some of the other benefits that have come out of space exploration that are more difficult to quantify such as psychological, political and environmental effects. Section 5 presents potential future benefits of going to space. The paper ends with a discussion and conclusion.

### 2. COST-BENEFIT ANALYSIS OF SPIN-OFFS FROM SPACE EXPLORATION

With tens of billions of dollars spent on research every year on a world-wide basis, space agencies have access to some of the best technology and facilities in the world. However, it is at times like these – our current global financial crisis – that the general public may pose the question if the benefits of going to space are indeed worth the costs.

Many government agencies around the world are often asked to justify their programs via cost-benefit analysis (CBA). In simple terms this means, that for a given possible decision, if the benefits are larger than the costs, then that decision is said to pass the CBA. On the other hand if the costs are larger than the benefits, then the decision is said to fail the CBA. Realistically, the situation is never a simple one and this is specifically due to the fact that costs and benefits can be defined in many ways: momentary costs and benefits, human costs and benefits, environmental costs and benefits, etc. For example, there is a “physical” cost of a human going to space representing the physiological harm of space travel (Hawkey, 2003). How such ethical issues are addressed can significantly affect space exploration decision making (Baum, 2009). It is often also difficult to estimate the cost of space-based infrastructure (Macauley, 2008). In most cases though, CBA is commonly implemented with costs and benefits being measured in euro, USS, etc. (Sen, 2000).

Collectively, the secondary applications of the original technology – spin-offs – represent a substantial return on national investments in aerospace research and are for this reason