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# Space Science and Nation's Development: Evaluating the Benefits of Space Science

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**Abstract**

Space science has a major role and giving impacts on our society for the last 50 years and will continue providing returns on the investment. The Return on Investment (ROI) could be in the form of new knowledge that provides an understanding to the world problem such that relating to the Earth-Sun relationship. These can be directly beneficial or indirectly one. Other than that space science will provide an economic opportunity as well as protecting us from massive destruction against asteroid impact of vast solar flare. This paper maps the space science benefits in the new of knowledge and strategic and in the same time projected future benefits.

*Keywords:* Space science; Return of Investment; Intangible benefits



## ■ 1.0 INTRODUCTION

Today's world is very competitive especially with the limitation of resources. Government is accountable to justify to one's society the outcome from every expenditure made. People would like to see the result and benefits or outcome for every government's programs. After 60 years since the beginning of the space age, space science R&D activities are loosing to applied and commercial research which outcomes seems tangible and directly benefiting end users.

Recently, there has been a considerable concern about the future of basic research because of purported changes in the nature of knowledge production and increasing pressures on scientists to demonstrate the social and economic benefits of their work (Calvert, 2006). But apart from profit driven research (mainly applied research) to design new or better products, there is another important but often neglected dimension in R&D, namely, basic research (Prettner & Werner, 2016). Nevertheless, we believed that space science is still relevant, if not play a major role in the next 50 years. Hence this paper attempt to look back at the definition and areas under space science, argue its important from the explicit benefits from each one of them. The main intent then is to demonstrate that space science can economically and strategically benefits the nation's development (Metzger, 2016).

Whilst the many review focuses on quantified estimates, this is not its sole mean. In recognition of the many varied values or impacts that are intangible, the review also considers returns (where available) on wider context or benefits such as environmental and social benefits, which are often qualitative in nature. However, although such benefits are an important part of the story, assessing the *quantified* economic impact as much as possible can be helpful to make the case for space funding, and to help inform the choices around prioritization of limited resources (Saddler et.al, 2015).

It is the intent of this paper, which aims to fill this gap by collecting, analyzing, synthesizing and mapping the existing evidences on the returns of space science R&D. The main source of information were from published literature, reports by various institutions and case studies. The mapping is expected to show the direct and indirect benefits of space science R&D in term of economic and strategic return, at the same time projects future benefits. This mapping will be a basis (first step) in developing a model to quantify economic and strategic benefits derived from space science R&D, or for that basis, any basic science R&D.

## ■2.0 DEFINITION AND SCOPE

### 2.1 Basic Science Research

Basic science research mainly embarks on "curiosity oriented" research but strategic, with uncertain process or final product (Martin & Salter, 1996). The primary objective is to acquire new knowledge for the sake of science (Salter & Martin, 2001). Conducting basic science research is one source to produce new knowledge. Capacity to produce and use new knowledge is the key driver in contributing to the success of national economy competitiveness (BĂTĂGAN, 2008). According to BĂTĂGAN (2008) also, knowledge is a key concept and a main source of innovation. Other than that, the nation becoming a good in technological progress, access to more knowledge and information is paramount. Due to that, BĂTĂGAN (2008) concluded that the investment in research is important factors to produce knowledge dynamic and economic growth.

### 2.2 Space Science

For this study, the definition of space science is adopted from the United Nation Committee of Peaceful Uses of Outer Space (UNCOPOUS). According to (COPOUS, 2014), space science spans a wide variety of scientific fields, ranging from astrophysics, human and robotic space exploration, and satellite-based communications and position services all the way to life sciences. Space science continues to be of fundamental importance to the ability of nations to utilize space technology and its applications for the benefit of their societies in that it advances our knowledge about the universe and humankind's role and destiny in it, stimulates the development of new technology, applications and solutions that enable us to address the challenges facing humanity, and inspires people from all walks of life, young and old. Due to space programmes take place on the edge of knowledge (Hof et.al, 2012), space science is an ideal tool for global capacity-building in science and technology. Basically, space science can be divided into six (6) main areas as the Figure1 below.

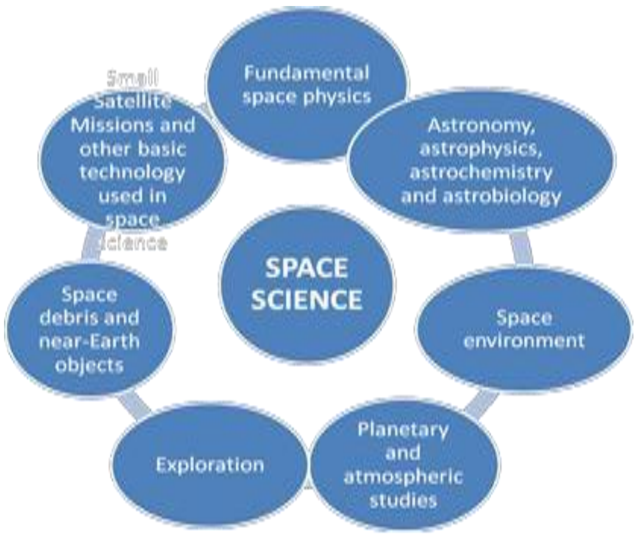


*Figure 1: Sub-division area of space science according to UNCOPUS*

### 2.3 Economic

There are various outputs as a result of knowledge activities, however, this study focuses on economic benefits as an output from space science R&D rather than environmental, social and cultural benefits. The economic term is very broad and has a blurred boundary between the economic and non-economic benefits. For example, according to (Salter & Martin, 2001), the definition of economic benefits can be direct and less direct such as competencies, techniques, instruments, networks and the ability to solve complex problems.

### 2.4 Strategic sectors

According to Reverso dictionary, strategic means relating to the most important, general aspects of something such as a military operation or political policy, especially when these are decided in advance. While according to Cambridge dictionary, strategic industry defines as an industry that a government considers to be very important for the country's economy or safety. There are various perspectives on strategic sectors. For the baseline, referring to *bcg.perspective* website, "A strategic sector is one in which you can obtain a competitive advantage and exploit it". Strategic sectors are defined entirely in terms of competitive differences. From the literature studies, there are clear evidences to demonstrate that space and space science fall under the strategic sectors as shown below (HM Government, 2017):

i) Space programme use for capacity building, strategic key technologies and competitiveness
ii) Space programme use for security purposes
iii) Space programme able to create new and emerging technologies that can lead to economic and social benefits (Ross, 2014; OECD, 1991
iv) Space program is a unique tool to enhance space diplomacy, international collaboration
v) Space programme always serve as a niche area and very authoritative to Increase nation competitiveness

As conclusion, space is, without doubt, a very strategic sector which supports jobs and economic growth in Europe. It is a driver of innovation and research, has significant political ramifications and affects the daily lives of all our citizens (*Keynote Speech of Hon Chris Agius at the 9th Space Policy Conference – 24th January 2017).*

## ■ 3.0 CONCEPTUAL FRAMEWORK TO HARNESS BENEFITS FROM SPACE SCIENCE R&D

In every nation, fostering economic growth is one of the paramount objective of policymakers and economist and currently extended to Researcher, Scientist and Engineers (RSE). They are challenges to demosntrate the economic benefits of space science as listed below:

i) The empirical literature on the returns to investments in space is limited (57 relevant studies have been identified and reviewed), and in general, suffers from a range of methodological weaknesses and limitations, including: a lack of consistency in terminology, definitions, typologies, methodologies, and only partial coverage of impacts – with significant unquantifiable benefits being a recurring theme (Sadlier et.al, 2015).
ii) Recently, there has been considerable concern about the future of basic research because of purported changes in the nature of knowledge production and increasing pressures on scientists to demonstrate the social and economic benefits of their work (Calvert, 2006). But apart from profit driven research (mainly applied research) to design new or better products, there is another important but often neglected dimension R&D, namely, basic research (Prettner & Werner, 2016). Overall, the policy makers in specific and the general public still questioning the economic benefits in conducting basic science R&D.
iii) Various economic approaches has been developed to measure the economic performance and benefits of basic science R&D. However they are drawback for every method that need further works. There is a potential richness of alternative measure which has not been explored (Popper, 1995).
iv) Many space-related impact studies have been carried out in the past, but there is no conclusive, comprehensive evaluation of the economic and social effects of public investments in space(Ocampo, Friedman & Logsdon, 1998)
v) Such evaluations are not easy to perform, for several reasons: the space sector is not a recognized category in official statistics; social benefits, which are likely to be very important, are hard to assess; and impacts from R&D are complex and occur in the long term (Clark et al., 2014)

Although the challenges are big, they lay a bigger opportunities as quoted by (Jasentuliyana, 1995) "*Basic science - including space science - is vital for national development, but developing countries often meet obstacles to participation in the international scientific community.* According (BĂTĂGAN, 2008), (Frontier Economics, 2014) and (Metzger, 2016) the relationship or framework of conducting space science R&D and the return which contributes significantly to the nation's development is demonstrated in Figure 2 below.

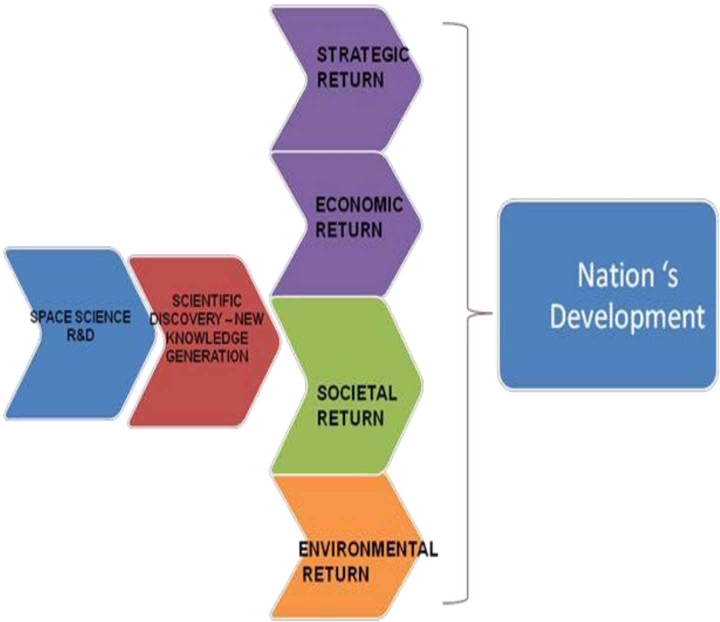


*Figure 2: Conceptual framework*

Generally, the output of conducting space science R&D is new knowledge that can be mapped to four (4) main sectors as shows. From these four (4) sectors, the focus of this study is in strategic and economic return.

## ■ 4.0 RESULT AND DISCUSSION

After conducting an analysis of the 18 journal (Range from 1995-2017) and 13 reputation reports (range 1999 – 2017), the initial finding as shown in graph format as Figure 3 below.

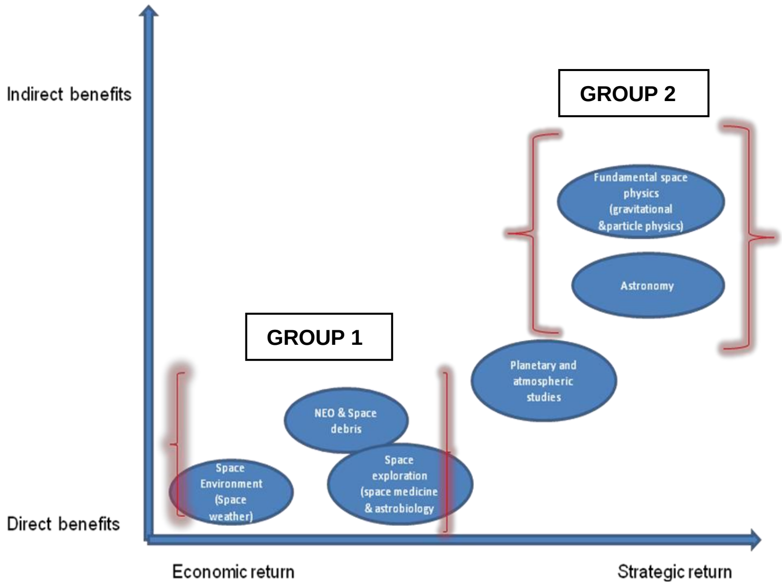


*Figure 3: Result (Initial Finding): Evaluating the ROI of Space Science R&D*

Using space science definition adopted from UNCOPOUS as explained in Figure 1, the six (6) area of space science is mapped accordingly. From the graph, there are clear separations to regroup the area of space science into two (2) big groups named group 1 and group 2. Three (3) are under Group 1 is space environment (space weather), Near Earth Object (NEO) and space debris and space exploration. Group 1 is the area which includes direct benefits in term of economic return. Direct benefits means the return is immediate and is materializing now. The most prominent is a space environment area which space weather is a subset. Space weather is a rapidly growing field of science which studies processes occurring in the area of space between the Sun and the Earth (Innocenti et al., 2017). The development of space weather forecasting capabilities is a task of great societal relevance because space weather effects may damage a number of technological assets, among which are power and communication lines, transformers, pipelines and the telecommunication infrastructure (Innocenti et al., 2017). Space weather events also such as solar flares, the ejection of energetic particles from the Sun, and geomagnetic disturbances, can have measurable detrimental impacts on satellite operations, the ubiquitous Global Positioning System (GPS), high-frequency (HF) airplane communications, navigation, aviation, and the electrical power grid. These disruptions can have ripple effects, so that even economic sectors that are not ostensibly dependent on space assets (e.g. financial services) can suffer losses (Coker, 2017).

According to (Hapgood & Thomson, 2010), combating space weather will create a business opportunity to saving our modern technology in order to minimize risk. Therefore the industry party should consider consequences of space weather event (Benfield, 2013). Estimates on the costs of such events are rare, but Benfield (2013) does point to a 2004 report from the U.S. National Academy of Sciences that estimated the economic costs of a repeat of a May 1921 event that involved magnetic field changes at USD$2 trillion in the U.S. for the first four years, but with recovery taking up to 10 years. The rapid emergence of technology and business dependencies means that mainstream re/insurance professionals are unlikely to be able to accurately price this risk, offer coverage or issue exclusions. Further, supply chain disruption mitigation measures, contingent business interruption policies and enterprise risk management strategies rarely cater adequately for the scenarios that can arise out of extreme space weather (Benfield, 2013). Besides that, It has been suggested a repeat of the 1859 space weather event would produce a potential economic loss of USD44 billion for lost satellite transponder revenue plus about USD24 billion for the replacement of geosynchronous satellites. An 1859-calibre storm would produce satellite anomalies at about 100 times the rate produced by the most severe storm in the period 1996-2005 (Odenwald, Green, & Taylor, 2006). Other than that, the 1996-2005 sunspot cycle damaged around 15 satellites at a cost of about USD2 billion (Odenwald et al., 2006). Due to that, re/insurance industry awareness of geomagnetic storms has grown in recent times, but accurate assessment of risk still remains in its infancy for all but a few niche sectors. As our understanding of space weather impacts on business expands, so do the opportunities to provide risk management solutions, including insurance against the risks posed by those impacts (Hapgood & Thomson, 2010).

Beside than economic benefits, space weather also offering a strategic return such as predicting space weather is a top priority to defend key societal infrastructures and to expand the human presence in space (Innocenti et al., 2017). Space weather have a very close relationship with the security sectors. For example, in May of 1967, a solar storm brought the world to the brink of nuclear war due to disruption of high-frequency communication across the polar cap (Knipp et al., 2016). This was at the height of the Cold War, and the United States interpreted the radio disruption as jamming by the Soviet Union. Other than that, at the peak of solar cycle 23 in March 2002, during Operation Anaconda in Afghanistan, ionospheric variability hampered UHF communications. The miss-communications resulted in an intense firefight that left seven Americans dead (Kelly, Comberiate, Miller, & Paxton, 2014). Space weather phenomena impacts human civilization on a global scale and hence calls for a global approach to research, monitoring, and operational forecasting (Head, 2015). Therefore, space weather is a natural area for international cooperation and collaboration (White House, 2010; Commission Europe, 2011).

Group 2 is the area which includes indirect benefits and is fallen under strategic return. Indirect benefits means the outcome takes some time for the society to experience the benefits. This is the area which the output from R&D, mainly knowledge, need more research to translate from fundamental to applied research, technology before entering commercialization research. It will take 15-20 years before the new knowledge can be converted to something practical benefits. Astronomy area is unique and have a strategic criterion as well as providing practical information on Earth-besetting problems, space science and exploration are vital tools for capturing the public imagination and encouraging young people’s interest in space (Ocampo et al., 1998). Astronomy is long lasting legacy (Ubertini et al., 2012) and very important for society and culture and help attract young people to the physical sciences. (Ubertini et al., 2012)(Bode, 2010). Astronomy is based on observation, with links to mathematics, physics, chemistry, computer science, geophysics, material science and biology (Monnet, Molster, & Melnick, 2007), therefore astronomy can become a catalyst to develop future and high-end technologies which is dual-use. Due to very powerful and precision of telescope system it is now possible to study objects which are so far away that they are seem at a time when the universe was only 5% of its present age, and perhaps even more astoundingly - to detect and characterize planet orbiting other stars and to search evidence of life (Bode, 2010). Other strategic return is to gain understanding the entire electromagnetic spectrum from radio to high energy x-rays which can be used for various (Ubertini et al., 2012). This is the best example how scientific discovery which is new knowledge contribute significantly to strategic and economic benefits. They are many others un-quantified benefits, but have strategic benefits such as below (Ocampo et.al, 1998):

i) The space science and exploration achievements of the last several years have captured the world’s attention, interest and imagination. The people of Earth have shared the excitement of discovering and exploring other worlds of our solar system and of looking beyond it into the cosmos; this is an era that may prove as epochal as was the period of exploring the new worlds on Earth a half-millennium ago
ii) Primary benefits of this new age of discovery are in their impact on humanity’s appreciation of its own global habitat in the context of the solar system and the universe beyond
iii) Basic science is a key to the prosperity of a nation, and it is almost impossible to expect significant economic and social development without a sound educational and research base in the field of basic space science (Jasentuliyana, 1995)
iv) For all of human history, in all of human cultures, people have wondered about their place in the cosmos, the nature of planets and stars and their relation to Earth, whether they are alone, and the evolution of the universe, stars, planets and themselves
v) The search for life in the universe (and indeed all aspects of planetary exploration and space science) require broad and multidisciplinary approaches; there is room for all. Through widespread communication, instant availability of data and information, and the interest especially of children in discovery, space science and planetary exploration are becoming world-wide participatory activities, not just ones of a few countries

vi) Space science motivating education and scientific literacy

vii) Discoveries in basic science have very often had tremendous consequences of new technologies and thus have changed society (Schopper, 2016). The recent discovery at European Organization for Nuclear Research (CERN) that this electromagnetic force and the weak nuclear force are only two components of a more fundamental force, might have similar consequences for technology remains to be seen by future generations (Schopper, 2016). The Large Hadron Collider (LHC) Grid, the much more powerful successor of the World Wide Web (WEB), has been developed for the LHC experiments. Whether its relevance for society will be as important as the WEB cannot be predicted (Schopper, 2016).

## ■ 5.0 CONCLUSION

The world is facing great challenges and space science R&D offers some solution, for example in combating global climate change, protecting Earth from asteroid impacting and in the same time increasing economic opportunities, advancing technical and science knowledge and improving our technically competent workforce (Fisk, 2008). The conclusion that is drawn from this research mapping clearly shows there are relationship between space science R&D which contributed significantly to economic (new and future economic) and strategic benefits(current and future) of the nation. This in in-line with (Schopper, 2016) claims that scientific progress and technical innovations are increasingly considered as necessary elements for economic growth.

This mapping is the first step and as a reference to develop a framework or model for evaluate the relationship between space science R&D with an economic and strategic return. The model will provide an outline for the country's space science R&D sector development until 2030, with the objective of preparing the country's potential in the space sector to contribute to the development of the new economy, as well as of strengthening the national strategic agenda. Space science R&D is a fundamental need if Malaysia would like to advance and use space technology and space application for a socioeconomic development of the nation. Last but not least, space science R&D is the foundation to assure the sustainability of the national space programme.

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