Available online at www.sciencedirect.com

SciVerse ScienceDirect

Physics Procedia 20 (2011) 319–330

Physics Procedia

Space, Propulsion & Energy Sciences International Forum - 2011

The Death of Rocket Science in the 21st Century

G. A. Robertson*, D. W. Webb

Institute for Advanced Studies in the Space, Propulsion & Energy Sciences
265 Ita Ann, Madison, Alabama 35757

Abstract

As we enter the 21st century, the lack of a space propulsion science discipline – involving the development of new emerging physical theories and models – within the bounds of Rocket Science forbids any rapid development of ideas and concepts toward new frontiers in spaceflight and implies a stagnate death in the advancement of Rocket Science as a whole. Specifically, the conventional disciplines in Rocket Science lacks foresight into the physics of acceleration to include the nature of gravity and inertia, which is foremost needed for the progression of spaceflight. In this paper is discussed various topics toward the understanding that space propulsion science is not a major player in Rocket Science, but must become so, if Rocket Science is to evolve the necessary new frontiers needed for future space exploration.

PACS: 00; 87.23.Ge, 01.75.+m, 89.65.-s, 89.65.Lm, 89.65.Ef
Keywords: Rocket Science; Aerospace Engineering; Space Propulsion Science

1. Introduction

Within the scope of *Rocket Science* – a term typically used in the US to group *all engineering disciplines* that apply to the research and development of a typical spacecraft or rocket – little if any real *forward research* in the propulsion sciences as a pure science exists. Therefore, it is argued that the term *Rocket Science* is a misused and misleading term.

Throughout the modern literature on *Rocket Science* as it applies to earth-to-orbit spaceflight, there is a strong engineering mindset that lacks a true understanding of the fundamental problem that spacecraft propulsion technologies (to include fuel and associate hardware) drives everything that can be done in space as it constitute the majority of the weight of modern launch vehicles. Therefore the key to

* Corresponding author. Tel.: +1- 256-694-7941.
E-mail address: gar@ias-spes.org

doi:10.1016/j.phpro.2011.08.029

advancing spaceflight lies as a foundation in *Rocket Science* toward the research and development of new propulsion technologies and is the thesis of this paper.

Within conventional *Rocket Science,* this engineering mindset drives the spacecraft community to blindly design spacecraft within a knowledge base that forbids the introduction of new science teachings into the research of new thrust methods and thus new propulsion systems. Whereby, the design of systems to provide propulsive forces using current propulsive or aerospace engineering understandings of spaceflight depends primarily on the application of Newton's third law of reciprocal actions – *for a force there is always an equal and opposite reaction: or the forces of two bodies on each other are always equal and are directed in opposite directions*. That is, current propulsive systems are primarily focused on the brute force application of mass ejection to overcome gravity and inertia without truly understanding either, regardless of the mechanism (thermo, electric, nuclear & etc.). This flaw is a direct result of the mission mentally that drives the research and development for new spacecrafts toward a purely engineering prospective, which resulting in each new spacecraft being more akin to next year's model than a evolutionary next forward.This is not to say that conventional *Rocket Science* has not given incredible advances in spaceflight capability during nearly a century of endeavors.

In this paper, the evolutionary path that has given rise to this engineering mindset is presented, followed by the definitional difference between science and engineering, and a path to correct this flaw. This new path involves the development of a new discipline and profession geared toward a more fundamental science base that has symbiotic bond with the current engineering model. This new discipline is called *Space Propulsion Science* as it involves the development of new emerging physical theories, models and testable concepts that are governed by the scientific communities vs. engineering. As we enter the 21st century, the lack of a *space propulsion science discipline* within the bounds of *Rocket Science* forbids any rapid development of ideas and concepts toward new frontiers in spaceflight and implies a stagnate death in the advancement of *Rocket Science* as a whole. Specifically, the conventional disciplines in *Rocket Science* lacks foresight into the physics of acceleration to include *the nature of gravity and inertia,* which is foremost needed for the progression of spaceflight.

2. Historical Prospective

A visualization of cycles in human events can be shown in a Kondratieff Interval (proposed by Nikolai Kondratieff in 1924), which shows roughly a 55-year cycle in human events. A Kondratieff Interval showing the steps toward spaceflight was done by Scott [1] using the work of Allen [2], who noted that the Kondratieff cycle appears in key space flight milestones and that another breakthrough is due around the year 2012. Figure 1 extends the Scott-Allen Kondratieff Interval to 2067.

This Kondratieff Interval, although informative is a bit misleading. Rockets capable of manned spaceflight are thermo-chemical rockets. The history of thermo-chemical rockets goes back to at least the 13th century.

Further, work in the mid 20th century [*i.e.*, 1940s to 1960s], both in Europe, the USSR and the US, lead to new thermo-chemical rocket technology (predominately liquid rocket systems) for spaceflight that spread across the globe over a shorter period than the 55 year interval proposed by Kondratieff Interval in Figure 1. Such that, by the late 1960s new improved thermo-chemical rockets were being used for manned spaceflight; enabling human spaceflight to the Moon.

However, from a manned spaceflight prospective, it is only now in the earlier 21st century [2000s] that modified thermo-chemical rockets have begun enabling some limited commercial manned spaceflight with limited expansion into other countries [*i.e.*, China]. This pushes the modern man rated thermo-chemical rockets interval towards the 55 year interval from the first manned spaceflights in the 1960s, such that, the next step in manned space flight should occur around 2020.

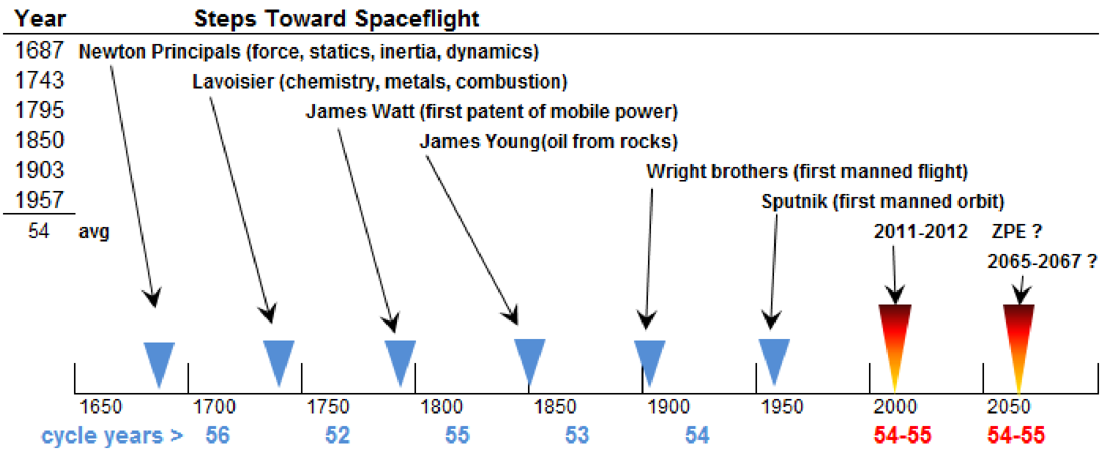

Figure 1. The extended Scott-Allen Kondratieff Interval.

2.1. Modern Rocket Science

With respect to the Kondratieff Interval, *Rocket Science* can be divided into the three intervals as follows.

2.1.1 Interval of Discovery

The first interval of *Rocket Science* was one of discovery and began in the early 1900s and ended in the late 1950s. This interval is highlighted by the following:

1903 – The high school mathematics teacher Konstantin Tsiolkovsky [1857–1935] published (in Russian) *The Exploration of Cosmic Space by Means of Reaction Devices*, the first serious scientific work on space travel. The Tsiolkovsky rocket equation—the principle that governs rocket propulsion—is named in his honor (although it had been discovered previously). He also advocated the use of liquid hydrogen and oxygen as fuel, calculating their maximum exhaust velocity. His work was essentially unknown outside the Soviet Union, but inside the country it inspired further research, experimentation and the formation of the Society for Studies of Interplanetary Travel in 1924.

1912 – The engineer Robert Esnault-Pelterie published a lecture on rocket theory and interplanetary travel. He independently derived Tsiolkovsky's rocket equation, did basic calculations about the energy required to make round trips to the Moon and planets, and he proposed the use of atomic power [*i.e*. Radium] to power a jet drive.

1912 – Dr. Robert Goddard (a U.S. professor and scientist) began a serious analysis of rockets, concluding that conventional solid-fuel rockets needed to be improved in three ways. First, fuel should be burned in a small combustion chamber, instead of building the entire propellant container to withstand the high pressures and temperatures. Second, rockets could be arranged in stages. And third, the exhaust speed [and thus the efficiency] could be greatly increased to beyond the speed of sound by using a De Laval nozzle. He patented these concepts in 1914. He, also, independently developed the mathematics of rocket flight. He proved that a rocket would work in a vacuum, which many scientists did not believe at the time. In 1920, Goddard published these ideas and experimental results in *A Method of Reaching Extreme Altitudes*. The work included remarks about sending a solid-fuel rocket to the Moon, which attracted worldwide attention and was both praised and ridiculed. A New York Times editorial suggested that Professor Goddard: *"does not know of the relation of action to reaction, and the need to have something better than a vacuum against which to react."*

1923 – The physicist Hermann Oberth published *Die Rakete zu den Planetenräumen* ["The Rocket into Planetary Space"], a version of his doctoral thesis, after the University of Munich rejected it.

1924 – Tsiolkovsky wrote about multi-stage rockets, in 'Cosmic Rocket Trains.'

1930s – In the early 1930's, rocket clubs sprang up all over Germany. One of these clubs, the Verein fur Raumschiffarht [Rocket Society], had the young engineer Wernher von Braun as a member. By 1934 von Braun and

Dornberger had a team of 80 engineers building rockets in Kummersdorf, about 60 miles south of Berlin. Von Braun's natural talents as a leader shone, as well as his ability to assimilate great quantities of data while keeping in mind the big picture. With the successful launch of two rockets, Max and Moritz, in 1934, von Braun's proposal to work on a jet-assisted take-off device for heavy bombers and all-rocket fighters was granted. However, Kummersdorf was too small for the task, so a new facility had to be built. Peenemunde, located on the Baltic coast, was chosen as the new site. Peenemunde was large enough to launch and monitor rockets over ranges up to about 200 miles, with optical and electric observing instruments along the trajectory, with no risk of harming people and property.
1943-44 – The *V-2 rocket* was the first ballistic missile and first man-made object to achieve sub-orbital spaceflight, the progenitor of all modern rockets including the Saturn V moon rocket.
1949 – [1st copyright] "Rocket Propulsion Elements" by George P. Sutton (and others dependent on the edition), which sums the work by Tsiolkovsky, Goddard and others. [Earlier versions of this book go beyond Newtonian Physics to cover such topics as nuclear propulsion. However, it is noted that with each revision comes the elimination of these subjects.]
1953 – First launch of the American *Redstone rocket* (Redstone missile), which was a direct descendant of the German V-2.
1957 – *Sputnik 1* (the world's first Earth-orbiting artificial satellite) was launched into a low altitude eliptical orbit by the Soviet Union.
1959 – *Luna 2* [the first craft on the Moon] was the second of the Soviet Union's Luna programme spacecraft launched in the direction of the Moon and is most famous for confirming the earlier detection of the solar wind by Luna 1.
1957-58 – The *Jupiter-C* was a type of sounding rocket used for three sub-orbital spaceflights. The Jupiter-C successfully launched the West's first satellite, Explorer 1, on January 31 1958. This event signaled the birth of America's space program.

2.1.2 Interval of Engineering

The second interval of *Rocket Science* was one of human spaceflight engineering, which began in the late 1950s and started to end in 1981 at the launch of the Space Shuttle; thereafter, a more widespread development of spaceflight across the globe began. This interval is highlighted by the following events:

1958 – *NASA* was established by law and the *50th Redstone rocket* was successfully launched.
1961 – *Yuri Alexeyevich Gagarin* became the first human in space and the first to orbit the Earth.
1959-63 – *Project Mercury* was the first human spaceflight program of the United States. The Mercury-Atlas 6 flight on 20 February 1962 was the first Mercury flight to achieve this goal.
1965-66 – *Project Gemini* was the second human spaceflight program of the United States with 10 manned flights occurring in. Its objective was to develop techniques for advanced space travel.
1961-75 – The *Apollo program* was a human spaceflight program undertaken by NASA with the goal of conducting manned moon landing missions with the first of five manned moon landings on July 20, 1969.
1972-Present – The *Shuttle program* developed a reusable space shuttle sytem, which was first launched on April 12, 1981. The Space Shuttle became the premier US civilian spacecraft for over twenty years and is due to be decommissioned by the end of 2011.
2003 – The Chinese space program launches its first manned space flight, *Shenzhou 5* on October 15.
2006 – *NASA* establishes the manned return to the moon, Constellation program; currently cancelled.
2008 – Chinese space program launches its third manned space flight carrying its first three-person crew and conducts its first spacewalk that makes China the third nation after USA and Russia to do so.

It is noted that the Russian manned space program parallels the US space program and has many significant advantages not noted above that rivals that of the US. These are not included to reduce the size of this article.

2.1.3 Interval of Commercialism

The third interval of *Rocket Science* is one of commercialism. Commercialism of modern rocketry is a death-bell for *Rocket Science* as a pure science. Commercialism even with the best intentions is most about dollars and less about research toward new models and theories that would bring about future rocket systems. Case in point is the automobile industry, which is more about new features [sales] than about developing new propulsive mechanisms [*i.e.*, where are the flying cars]. The prevalent cases for the commercialization of manned space are:

2004 - *SpaceShipOne* makes the first privately-funded human spaceflight, June 21.
2008 – NASA awards Space Exploration Technologies, or SpaceX, a [earth-to-orbit manned] Launch Services contract for the Falcon 1 and Falcon 9 launch vehicles. The contract is an Indefinite Delivery/Indefinite Quantity [IDIQ] contract where NASA may order launch services through June 30, 2010, for launches to occur through December 2012.
2010 – The US plans moving away from NASA derived earth-to-orbit manned launch systems toward commercial systems.

3. Steps toward the Death of Rocket Science

Most of the highlights of the previous section are presented in a Kondratieff like interval in Figure 2, where the first 40-45 years represents the birth of space rocketry, the next 37-41 years represents the interval of *Rocket Science* and the years thereafter presents the death of *Rocket Science*. The intervals in Figure 2 present a story that begins with fantasy, and then lays dormant for years within various rocket societies while engineers figure how to bring fantasy to a reliable field of *Rocket Science*. *Rocket Science* got a boost going toward WWII with the development of the V2, later by the cold-war, which lead to the development of NASA in 1958 with a formally established manned space program in place by the early 1960s. At the end of the Apollo program, *Rocket Science* was reduced to pure engineering as the US moved toward a single space shuttle system that has dominated US civilian manned space launch since.

During the reign of the Space Shuttle, more foreign space launch systems have come into existence, the Chinese launched a manned space program, and the US has become more reliant on Russian earth–to–obit launch systems to make up launches unrealized by the shuttle system. Further as we interred the 2000s, the loosening of space law gave rise to some commercial manned launch systems for tourism [*i.e.*, SpaceShipOne].

3.1 Decline of Rocket Engine Development

US civilian spaceflight through the interval of *Rocket Science* [Engineering] can be better analyzed by comparing the rocket engine energy density (specifically liquid engine) versus time to other engines, such a comparison is presented in Figure 3 [3]. As shown, each line of data represents various engine developments starting with locomotives beginning in the late 1800s through air and space flight into the early 2000s. The 37- 41 years of *Rocket Science* in Figure 2 is well represented by the liquid rocket engine development, which from the 1950s to about 1981 was increasing at a rate of ~2.9% per year (see Figure 3). Then abruptly stop with the Space Shuttle launch in 1981 bringing with it the gradual death of *Rocket Science* toward a more commercial like truck service versus a *Rocket Science* endeavor.

3.2 Paradigm Shifts

An important indicator in the death of Rocket Science is the apparent wavering of paradigms in the development of earth-to-orbit vehicles. Beginning with the US reusable rocket-plane programs, the leading manned space vehicle designs in the US until the establishment of NASA in 1958, which lead to expendable earth-to-orbit rocket programs used in the moon race of the 1960s. Then in the 1970s, the return to a reusable rocket-plane [*i.e.*, Space Shuttle] and in 2005 a return to an expendable earth-to-orbit rocket program. Such wavering is a formable indication that engineers are struggling for new directions in propulsion technology.

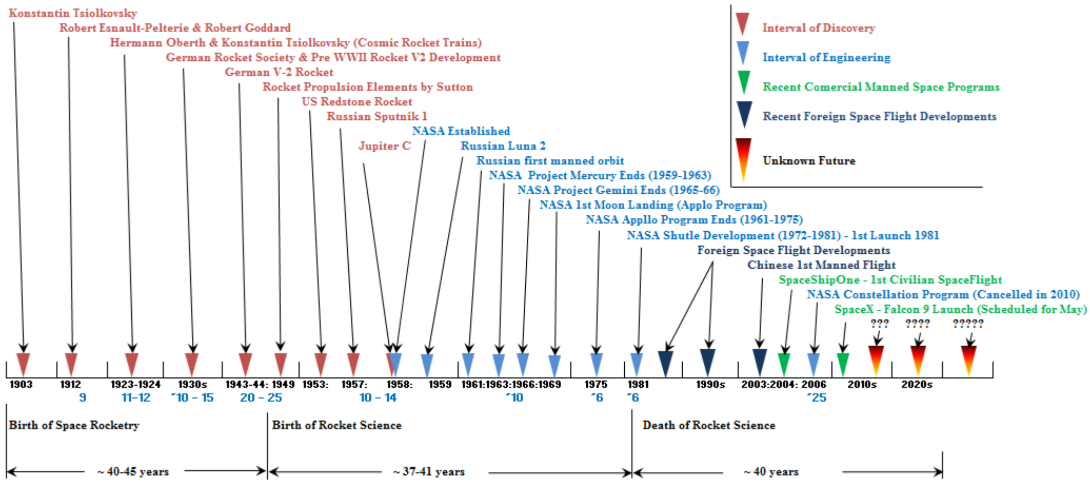

Figure 2. Intervals toward the 21st Century of Space Flight.

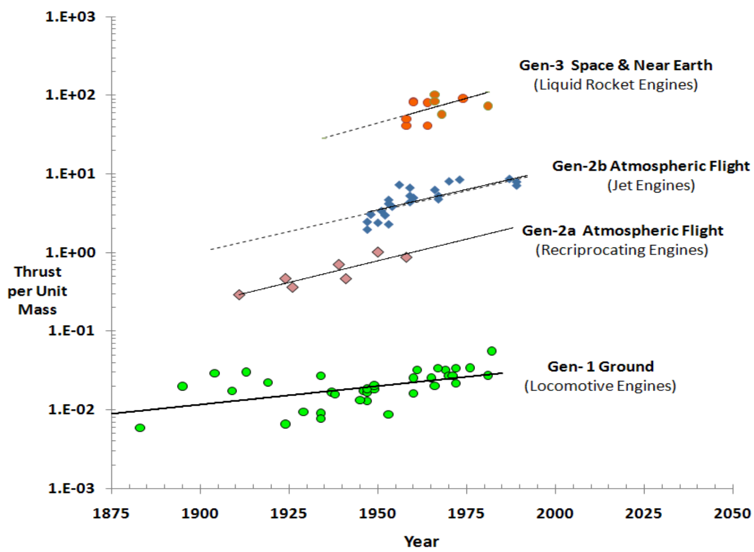

Figure 3. Energy Density versus Time.

4. The Engineering Death Of Rocket Science

Rocket Science's gradual death occurred over the last 50 years of engineering development. A culture, which has over time displaced the interval of discovery with an interval of engineering to the point that scientific discovery, is taboo from the standpoint that the cost of research in the face of ever changing engineering requirements is too risky to pursue.

More to the point, the spacecraft propulsion industry follows the mission guidelines set forth by its governing engineering management organization, where these guidelines are driven more by near term and definable mission goals rather than the far reaching propulsion ideas of the talented scientist and engineers working in the spacecraft propulsion industry or other related scientific fields. This near term motivation instills an engineering mindset with a primary objective to develop not only the propulsion systems, but the entire vehicle – *only within current engineering understandings*. This is done with good intentions, as waiting on new scientific concepts to develop would impede any mission beyond its political mission life, *i.e.*, funding source. Therefore, paying for requirement creeps are of most important to engineering program managers.

Unfortunately, research toward far term spacecraft propulsion technology has been placed almost solely in the hands of the *Rocket Science* or the aerospace engineer community, a community whose training is not in the advancement of scientific ideas, but in the development of hardware. In effect: *Rocket Science as a pure science is dead*.

4.1. Science and Engineering

To clarify the difference between Science and Engineering:

<u>Science</u> – refers to the disciplines and professions that acquire knowledge based on scientific methods to include the development of theories, the derivation of mathematical formulations, or the research of these theories and derivations, which <u>*provides an organized body of scientific knowledge*</u> containing the natural laws and physical resources gained through such research.

<u>Engineering</u> – refers to the discipline and profession that <u>*applies scientific knowledge*</u> in order to design and implement materials, structures, machines, devices, systems, and processes that realize a desired objective and meet specified criteria (missions).

Given these definitions, today's *Rocket Science* is the engineering of rockets. And although much grander, today the field of *Rocket Science* is no different than engineering next year's automobile.

This is noted by Wikipedia, where: *Rocket Science is defined as an informal term for aerospace engineering,* especially as it concerns rockets which launch spacecraft into or operate in outer space….. requiring mastery in subjects including mechanics (fluid mechanics, structural mechanics, orbital mechanics, flight dynamics), [generalized] physics, mathematics, control engineering, materials science, aeroelasticity, avionics, reliability engineering, noise control, flight test…

In fact the term *Rocket Science* has become a joke in the sense that it is used ironically to describe an endeavor that is simple and straight forward by stating "it's not rocket science" (one of the top ten irritating phrases, according to research at Oxford [4]) or "it doesn't take a rocket scientist." It is also used ironically to describe a person who is simple-minded: "He/she's not a rocket scientist." That is, although *Rocket Science* is not meant in a derogatory manner, to instill that one is a "*Rocket Science*" bears a bit of snicker to the person in question, rather than high praise for their achievement.

That is, given the multiple disciplinary subjects in *Rocket Science* as defined by Wikipedia, one may find it hard to define anyone as a *Rocket Scientist* or engineering as research.

5. Future Directions

As one looks back into the interval of discovery [early 1900 to late 1950s] and to some extent the first decade thereafter, the space industry was composed more of physicist, metallurgist and chemist. However, the demand for missile defense in the early years of engineering [specifically after WWII through the late 1960s] required engineers that could design flight hardware, in line to the airplane industry as the aerodynamic nature, control of missiles and general system overview was of primary concern. This became even more apparent with the NASA mission to reach the moon by the late 1960s and the Space Shuttle in the 1970s. This drove Universities and Colleges to create curriculums focused more on aerospace engineering than science. Over time this has produced an industry lacking the knowledge base needed to progress new rocket propulsion concepts. Specifically, the age of the pure rocket scientist ended quietly decades ago amidst the ever increasing engineering management dominated aerospace communities and the increasing segmentation of the science communities, a fact that has become ever so true in the face of limited funding in both sectors.

5.1. Event Changing Performance

Performance toward breakthroughs or event changers is the product of extraordinary, rare and gifted individuals, or the lucky happenstance of coincidental circumstances and fortuitous historical forces. In both cases, it is believed that event changers in spaceflight are considered beyond the reach of current *Rocket Science* as such is not within their knowledge base to make happen within a normal time frame as depicted by a Kondratieff Interval. This is evident in the fact that at this writing, there is no expected event changer in spaceflight, manned or unmanned, foreseen for 2012 or in the next 20 years for that matter that is not of engineering origin, *i.e.*, looks new but is just a different model. In fairness, a 2012 next step in spaceflight could have come about by the development of a reusable single-stage to orbit nuclear rocket, which began around 1956 with the NERVA program, but would probably not have been developed into single-stage to orbit vehicles until the late 1900s – had such development not been squashed by global fears and political agendas in the 1960s. In fact, nuclear thermal rockets are the only candidates that could possibly achieve single-stage to orbit – the next logical step in manned space flight using current technological understandings – *i.e*., thermal physics.

The establishment of performances that leads to breakthroughs or event changers goes beyond "Declaring an Authentic Vision That Calls People beyond Existing Frontiers" or making "Bold Promises to Fulfill the Declaration," but requires "A New Mindset in Leadership and Management" <u>that *Rocket Science* alone does not contain the knowledge base required to lead such breakthrough performances</u>. That is, there is a need to development a new discipline and profession; we call *Space Propulsion Science*, which can produce the extraordinary, rare and gifted individuals who can lead the field of *Rocket Science* in new directions or frontiers unattainable in current *Rocket Science* teachings. For without such professional leadership, performance toward event changers in spaceflight will be slow and come about only through the lucky happenstance of coincidental circumstances or fortuitous forces.

As a note, the NERVA program was a marriage between *Space Propulsion Science* – specially the science of nuclear thermal reaction and *Rocket Science*. [One can only wonder how such a marriage between Science and Engineering would have changed spaceflight in the 1960s and thereafter.] Further, an informal *Space Propulsion Science* program that included thermal single-stage to orbit concepts to include nuclear and conventional propulsion systems did make a brief appearance in the late 1990s with the advent of NASAs Advanced Space Transportation Program, but was eventually ended due to changes in NASA's mission to develop the moon using current technology *i.e., Rocket Science*, before venturing beyond. An idea that was about 25 years overdue and sadly may have pushed the 2065 Kondratieff Interval event out by more than 30 years without a major event changer soon.

5.2. Space Propulsion Science

Space Propulsion Science involves the development of new theories, the derivation of new mathematical formulations, or the research of new concepts derived from these theories and derivations toward providing scientific knowledge that can be used by engineers to design future launch vehicles using propulsion ideas and concepts that are only now coming into focused (for examples see: [5]). The discipline of *Space Propulsion Science* offers a radical, counter-intuitive view that the performance toward event changers can be learned and intentionally carried out by individuals and teams with the proper knowledge base and organizational commitment. Further, *Space Propulsion Science* would put in place "levers and dials" (for example see Figure 5) toward breakthrough performance that would make an individual or organization "extraordinary, rare and gifted." Not as some innate capacity, but instead creating and fulfilling a powerful vision of space exploration extending beyond our solar system. As it is believed that the discipline of *Space Propulsion Science* is somewhere between the disciplines of astrophysics and high energy physics; involving the understanding of matter in the cosmos and its physical properties down to energy scales undetectable by normal engineering methods. A discipline that requires knowledge in Relativistic Field Theory [*i.e*., General Relativity or spacetime], Quantum Field

Theory and the like, but focused on the understanding of inertial and gravitational forces toward applicable propulsive forces for spaceflight.

The fact is that in both Relativistic Field Theory and Quantum Field Theory, there can be found examples were:

Objects can be accelerated by changing the object's external energy density profile.

For example, the Alcubierre [6] WarpDrive and siblings that warps spacetime predicted from spacetime theories with none being verified by experiments, the Casimir force [7] predicted from Quantum theories with verification by experiments (For more examples see; [8, 9]), and the more recent mass density theory by Khoury and Weltman [10] based in both spacetime and quantum theory, which laid the groundwork for a new rocket propulsion theory [11, 12] – all concepts requiring no mass ejection as is required by Newton's third law and used in modern *Rocket Science*.

One must then ask why the aerospace engineers have not carried such notions into other models or concepts that could be utilized today. The answer is simple; these theories lack any overall fundamental *engineering value* that could be applied to any discipline within current *Rocket Science* that is politically justifiable up the management chain. Therefore, there exists a need for a new focus toward a non-engineering discipline as proposed by the discipline of *Space Propulsion Science*, which can stand in face of political uncertainties to drive spaceflight into the future.

6. Mating Rocket Science with Space Propulsion Science

For *Rocket Science* and *Space Propulsion Science* to form a union toward future spacecraft propulsion system development, a means to unite them is needed. Such a union can be made using the similarity between *Design and Research* as engineering is in effect a form of design.

6.1. Design and Research

The Nobel Laureate Herbert Simon affirmed that design is an essential ingredient of the Artificial Sciences and, consequently, a required process in professional activities, especially in Engineering, Architecture, Education and Business [13]. Ranulph Glanville, president of the American Society for cybernetics and expert in design theory, affirms that "Research is a variety of designs. So do research as design [14]." "Design is key to research. Research has to be designed [15]." Further, Frayling [16] asserts that "doing science is much more like doing design."

Both Design and Research are characterized by iterative cycles of generating ideas and confronting them with the world. Both Science and Design use generative and evaluative thinking, but Science stresses the *evaluative* thinking [by logic, deduction, strict and mostly explicit definitions, verbal notations, etc.], while Design focuses on the *generative* thinking, which is usually associative, analogical, and inductive thinking, using loose definitions, and supported by visual representation as doodling, sketching, diagramming, prototyping, etc. (From the International Symposium on Design and Research In Artificial and Natural Sciences).

An increasing number of authors, especially in the last decade, are stressing the relationships between Design and Research. Design is, implicit or explicitly, an essential activity in Natural Science research, and an explicit backbone of the Artificial Sciences [Engineering, Architecture, etc.]. In turn, Design, implicitly or explicitly, includes research activities. In Natural Sciences, design activities [hypothesis construction, experiment design, etc.] are means used in research, with the purpose of generating knowledge to be evaluated [validated and/or verified]. In Artificial Sciences research is one of the means used to generate the knowledge required for design effectiveness. In other words, *Design is a mean for Research, and Research is a mean for Design*. Design and research are related via cybernetic loops in the context of means-ends logic. A visual schematization of the most fundamental relationships between Design and Research is shown in Figure 4.

Research nurtures disciplinary knowledge and Design is usually nurtured by several scientific disciplines, especially in the case of Engineering, Architectural, etc. designs. Consequently, a multidisciplinary field is one of the most adequate contexts for the organization of Design and Research. Furthermore, according to Buchanan [17], one of the four designing areas "is the design of *complex systems or environments for living, working, playing and learning*, and he associates this area to the System Approach and Systems Engineering [*Systemics*]. An increasing number of authors are also associating Design concepts to those of *Cybernetics* (for example; [18]), and, since one of the four areas defined by Buchanan is "Design of Symbolic and Visual Communications," *Informatics* and cyber-technologies are increasingly being used in the design of Visual Communication [Visual Computing, Human-Machine Interface Design, Web Design, Multimedia Design, Graphic Computing Design, etc.]

6.2. Space Propulsion Science Design and Research

Simon's model relating the fundamentals of design and research is given in terms of engineering and research with the relationship between *Rocket Science* and *Space Propulsion Science* in Figure 5. As shown, the current paradigm follows a direct path from the disciplines of *Rocket Science* toward a given mission having a specific application to generate concrete knowledge. As noted by the missing elements, the current paradigm prevents the development of any abstract disciplinary knowledge from being utilized by the *Rocket Science* discipline due primarily to the lack of a *Space Propulsion Science* discipline to provide the linkages for:

1) Synergies – Methods for positive and negative feedback and feed-forward-loops.
2) Input from the multi-disciplinary knowledge base of the *Space Propulsion Science* Community for induction into experimental technologies, and
3) Input from the multi-disciplinary knowledge base of the multi-disciplinary *Rocket Science* Community for the generation of new forward (or abstract) disciplinary knowledge

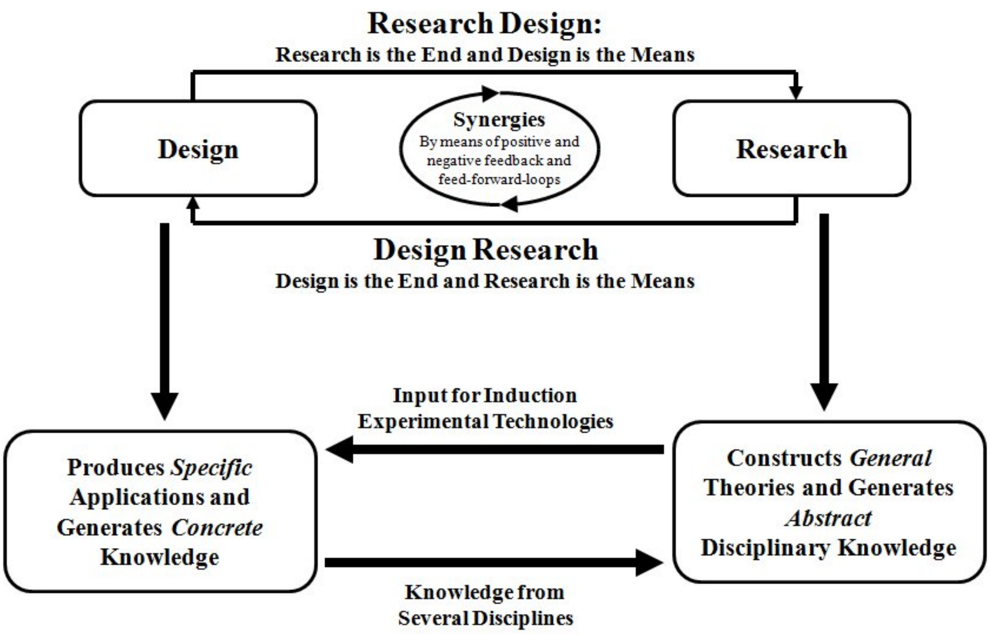

Figure 4. Design and Research Fundamental Relationship.

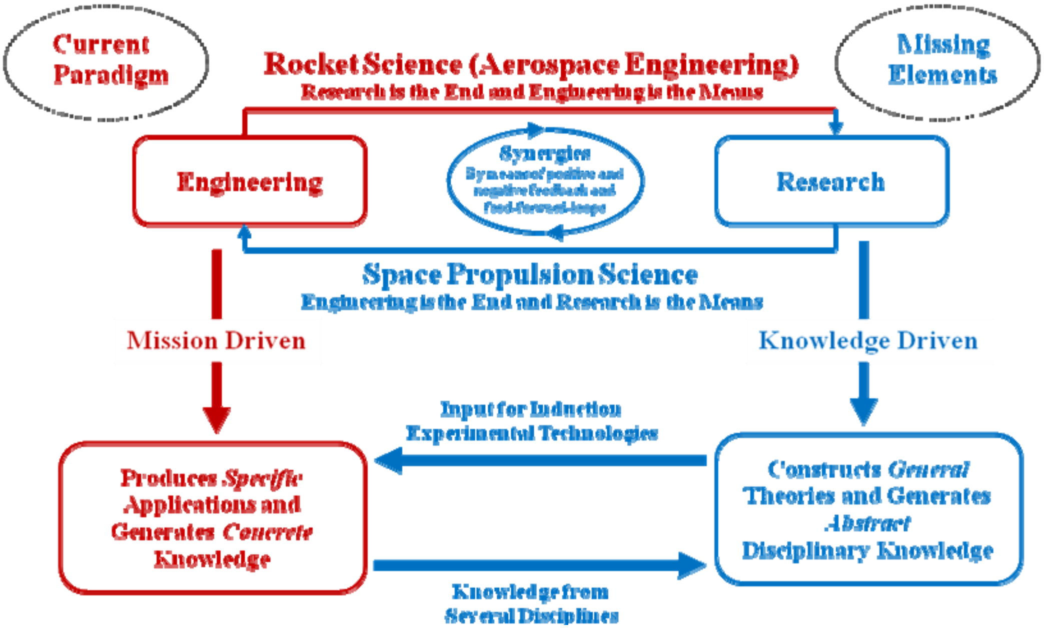

Figure 5. Space Propulsion Design and Research Fundamental Relationship.

From an engineering viewpoint, Figure 5 infers that organizations [or directorates] composed only of rocket science – aerospace engineering – components [*i.e*, division and branches] need to develop smaller but mirroring propulsion science components with

1) Funding sources outside of engineering [*i.e*, missions],
2) Separate line management, beginning at the directorate level,
3) Upper management support sustainable through the hard time as well as the good, and
4) Mutual respect and collaboration across the two components toward a better future for both.

7. Conclusion

As we enter the 21st century, it has been found that modern *Rocket Science* as an engineering discipline is at a standstill toward the next Kondratieff Interval event of 2012, which was predicted to make a paradigm shift in how humans get to space. This standstill can be fixed through the development of a new discipline called *Space Propulsion Science* which involves the development of new theories, the derivation of new mathematical formulations, or the research of new concepts derived from these theories and derivations toward providing scientific knowledge that can be used by engineers to design future spacecrafts using propulsion ideas and concepts that are only now coming into focused.

The fundamental relationship (Figure 5.) between *Rocket Science* and *Space Propulsion Science* is essential for the progression of all future space propulsion systems. As such, our universities need to develop curriculums focused on *Space Propulsion Science* and our aerospace communities (government and commercial) need to develop a formal structure that embraces and sustains *Space Propulsion Science* as an essential part of their organizations and held as an essential growth mechanism.

Acknowledgements

Although, Mr. Robertson is affiliated with the NASA Marshall Spaceflight Center, Huntsville, AL 35812, this paper does not necessarily reflect the views and thinking of NASA or any other US government agency. 256-544-7102; glen.a.robertson@nasa.gov

Although Mr. Webb is affiliated with The Aerospace Corporation, El Segundo, CA 90245, this paper does not necessarily reflect the views and thinking of The Aerospace Corporation or any other US government agency. 714-914-1320; dwebb@socal.rr.com

References

1. Scott, William B., To the Stars, *Aviation Week & Space Technology*, March 1, 2004.
2. Allen, John E., Quest for a Novel Force: A Possible Revolution in Aerospace, *Progress in Aerospace Sciences* 2003 **39**:1-60.
3. Webb, Darryl W., The Historical and Future Economics of Propulsion and Energy Technology: Trends from 1750 and Projections to 2100, Presented at the *Space, Propulsion & Energy Sciences International Forum (SPESIF-10)*, Johns Hopkins University, February 24-26, 2010.
4. Bailey, Charlotte, Oxford compiles list of top ten irritating phrases, *The Daily Telegraph*, November, 2008.
5. Robertson, Glen A., (Ed.), 7th Symposium On New Frontiers In The Space Propulsion Sciences, in the proceedings of *Space, Propulsion & Energy Sciences International Forum (SPESIF-10)*, edited by Glen A. Robertson, AIP **CP1208**, Melville, New York, 2010.
6. Alcubierre M., The warp drive: hyper-fast travel within general relativity, *Class Quantum Grav*. 1994 **11**:L73–7.
7. Milton K. A., *The Casimir Effect: physical manifestations of zeropoint energy*, New Jersey: World Scientific, 2001.
8. Robertson, Glen A., Murad, P. A., and Davis, Eric, New Frontiers in Space Propulsion Sciences, *Energy and Conversion Management* 2008 **49**:436-452.
9. Millis, Marc G. and Davis, Eric W., *Frontiers of Propulsion Science*, AIAA series on Progress in Astronautics and Aeronautics, **227**, AIAA publication, Reston, VA, 2009.
10. Khoury J. and Weltman A., Chameleon cosmology, *Phys. Rev. D* 2004 **69**:044026.
11. Robertson, Glen A., The Chameleon Solid Rocket Propulsion Model, in *Space, Propulsion & Energy Sciences International Forum (SPESIF-2010)*, AIP **CP1208**, Melville, New York, 2010.
12. Robertson, G. A. and Pinheiro, M. J., Vortex Formation in the Wake of Dark Matter Propulsion, in these proceedings of *Space, Propulsion & Energy Sciences International Forum (SPESIF-2011)*, edited by G. A. Robertson, Physics Procedia, Elsevier Science 2011.
13. Simon, Herbert A., *The Sciences of the Artificial* (Third Edition), Cambridge, Massachusetts: The MIT Press, 1996 p. 111.
14. Glaville, Ranulph, Keeping Faith with the Design in Design Research, previously in *Designing Design Research 2* : The Design Research Publication, Cyberbridge-4D Design/drse.html, Editor Alec Robertson, De Montfort University, Leicester, 26 February 1998.
15. Glaville, Ranulph, Researching Design and Designing Research, *Design Issues* 1999 **13**(2).
16. Frayling, C., Research in Art and Design, *Royal college of Art Research Papers* 1993 **1**(1):1-5.
17. Buchanan, Richard, Wickd Problems in Design Thinking, in V. Margolin and R. Buchanan (Eds.), *The Idea of Design*; Cambridge, Massachusetts: The MIT Press, 1995 p. 3-20.
18. Glanville, Ranulph (notes 3 and 4) and Jonas, Wolfang, Design Research and its Meaning to the Methodological Development of the Discipline, in Ralf Michel (Ed.), *Design Research Now: essays and Selected Projects; Basel, Switzerland*: Birkhäuser Verlag AG, Part of Springer Science; 2007 p. 187-206.