# The Implications of Quantum Physics for Aerospace Applications-A review

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**ABSTRACT**

Aerospace engineering has achieved many stunning feats – offering us the modern convenience of the airplane, the adventure of space travel, and the theoretical likelihood of probing the farthest reaches of our cosmos, albeit in inconceivable amounts of time. The rocket revolutionized travel, making it possible to traverse long distances in drastically short periods of time. In some senses, in light of contemporary feats of aerospace engineering, it seems that we have exhausted all the options physically available to us for travel – and that there are no longer any exciting prospects available for aerospace mobility. However, our scientific understanding of the universe is changing dramatically; the classical, Newtonian theory that informs our present conceptualization of aeronautics is now believed to be incomplete. Quantum physics describes a non-linear universe that does not conform to commonplace notions of space and time – a universe that can accommodate new possibilities such as interstellar travel, and can broaden aerospace applications. This exploratory essay considers some of the implications of these interpretations of quantum phenomena for the future of travel, and ponders how these changes might affect present technologies in this most exciting field of engineering.

**KEY WORDS:** quantum physics, travel, aerospace engineering, law of momentum conservation, propulsion, classical physics.

## 1. INTRODUCTION

In the sci-fi motion picture, 'Interstellar', directed by Christopher Nolan, a group of scientists and a seasoned NASA pilot have to travel light-years to a distant galaxy to search for other planets to host the beleaguered human race, as Earth, no longer able to sustain life or grow food, rapidly expires. The film unravels by pitching a plotline that implicates real-life considerations around the possibilities of interstellar travel based on the provisional existence of wormholes and the idea that these topological phenomena solve the problem of traversing incalculable distances within significantly short periods of time. Bearing in mind that the film promulgates the possibilities of inter-galactic voyages, time travel, and interdimensional communication, and treats as plausible the ability of wormholes to safely conduct real objects from one end of space to another, one might be tempted to view the film as nonsensical or 'too strange to be real'. This is especially so when one considers that we do not know nearly enough about wormholes to understand their behaviour or their utility.

Barring the workability of wormholes as a means of interstellar travel, it seems the only way we can 'reach the stars' in humanly conceivable durations of time is to engineer space propulsion technologies that allow faster-than-light travel or new forms of propulsion not dependent on the law of the conservation of momentum – a submission that seems impractical and laughable given the ramifications of Einstein's Theory of Special Relativity. Reference (Kaku, 2015), states that "when discussing the possibility of interstellar travel, there is something called 'the giggle factor.' Some scientists tend to scoff at the idea of interstellar travel because of the enormous distances that separate the stars. According to Special Relativity (1905), no usable information can travel faster than light locally, and hence it would take centuries to millennia for an extra-terrestrial civilization to travel between the stars. Even the familiar stars we see at night are about 50 to 100 light years from us, and our galaxy is 100,000 light years across. The nearest galaxy is 2 million light years from us. The critics say that the universe is simply too big for interstellar travel to be practical."

However, is *Interstellar* laughable, another epitome of the 'giggle factor'? Is the film yet another romanticized fare of high sci-fi fantasy – with nothing in its thick computer-generated imagery remotely plausible or of real value to the field of aerospace engineering? Kip Thorne, an American theoretical physicist known for his contributions in gravitational physics, who served as scientific consultant and executive producer for the film, writes of his experience in situating the scientific aspects of the film beyond the usual trope of the genre (Thorne, 2014). "At our meeting, I suggested to Steven and Lynda two guidelines for the science of Interstellar: 1. Nothing in the film will violate firmly established laws of physics, or our firmly established knowledge of the universe. 2. Speculations (often wild) about ill-understood physical laws and the universe will spring from real science, from ideas that at least some "respectable" scientists regard as possible." In his book 'The Science of Interstellar', published soon after the film was first shown in the United States, Thorne attempts to ground the more fantastical elements of the movie in changing theoretical appraisals of the universe – thus provoking thought about what is possible today. He asks, with a pensive air of intrigue and thrilling possibility attending his words (Thorne, 2014).

"Can you identify in your own life speculations that became educated guesses and then truth? Have you ever seen your established truths upended, with a resulting revolution in your life?"

This paper emerges from such questions – and is focused on briefly highlighting how new paradigms of understanding, occasioned by some relatively recent interpretations of quantum theory, could revolutionize aerospace engineering, and thus bring us closer to a world wherein extended space-travel, safer forms of aerospace transportation, and even time travel are no longer mere subjects of sci-fi films. My objectives are to employ a playful 'what-if' approach, in the context of extensive literature references describing the state and future pathways for propulsion technologies, in order to reinforce a philosophical aesthetic – one which hopefully 'loosens the mind' from the strings of classical, Newtonian physics, and invites new forays into the recesses of a weirder, more counterintuitive cosmos, where radically innovative aerospace applications are possible. I do this by courting and elucidating some wild, provisional, consequences of various interpretations of quantum theory (even if they may not represent any real phenomena) – which may implicate consciousness or awareness as 'resources' for possible propulsion applications. Perhaps, if we worked out from a different paradigm, a different revaluation of what is likely in the universe, we can cross the scientific threshold and traverse the short distances that take us to infinity and beyond.

**The classical limitations of conventional space propulsion applications:** On July 20th 1969, the Lunar Module 'Eagle' landed in a region of the Moon called the Sea of Tranquillity. Neil Armstrong, destined to become the first man to ever set foot on the lunar surface, radioed earth the now famous words: "Houston, Tranquillity Base here, the Eagle has landed". A few hours later, that same evening, a worldwide television audience witnessed Neil Armstrong stepping off his spacecraft's landing pad and onto the lunar body that had inspired folklore and song, and, as if knowing the object of fascination for the first time, said: "That's one small step for a man, one giant leap for mankind." That era represented a high point in the so-called space race, and restored the political dignity and ideological superiority that Americans believed themselves to have lost when the Sputnik 1 (1957) and the Vostok 1 (1961) of the USSR launched an unmanned satellite into space, and put a man into low orbit, respectively.

The Americans had won the race to the Moon, and Armstrong's bold declaration seemed a fitting embodiment of that period and its war-motivated quest for supremacy and reach. However, in spite of the remarkable achievement of landing a man on the moon, the space-race simmered down to a halt in the 1970s, crowded out by the politics of the Cold War and declining support for space adventurism. Apollo 17 in 1972, three years after Armstrong's Apollo 11 had successfully navigated the lunar surface, was the last manned mission to the moon, and brought to an end the era of cosmonauts.

Speculation is rife in the public sphere as to why we have not returned to the moon - from fringe theories about the existence of advanced extra-terrestrial civilizations on the moon, to more conventional explanations bordering on a decline of public interest in space travel. There seems to be no official position on the reason why manned spaceflights haven't flourished in bolder ways since Armstrong's defiant 'small step'. One might however assert that though public imagination grew in leaps and bounds in the days following Apollo 11's lunar landing, the propulsion technologies required for more venturesome missions were never developed. In their 2011 paper, Gravity-Like Fields New Paradigm for Propulsion Science (Hauser, 2011), Hauser and Droscher write: "The 40th anniversary of the Moon landings has come and gone, but the future of humans going back to the Moon looks grim, not even considering a Mars mission, which seems next to impossible. In combination with the high risk aversion of U.S. and European space agencies, these programs will remain paper studies for an indefinite period of time." The reason why the future of interstellar travel looks grim is, according to them, inadequate propulsion or the dearth of breakthroughs in propulsion sciences and applications (Hauser, 2011), "Space propulsion is stuck with the technologies developed in the 50s and 60s of the last century. The fundamental problem can be linked to the underlying propulsion principle that remains unchanged since the days of ancient Chinese rockets. It is the physical principle of classical momentum conservation which stands in the way of producing an efficient and effective propulsion system. It is the basic physics itself that prevents progress. Therefore, only novel physics can overcome this barrier. It can be safely concluded that with present technology and the approved NASA budget, the vision of returning astronauts to the Moon by 2020 clearly is not feasible. Neither will the efforts from private industry change this bleak picture. For spaceflight to mature the only option is to focus on alternative physical concepts and start research in this direction. This insight is not a new one, as can be seen from the history of industrial activities that took place five decades ago."

In no ambiguous terms, Hauser and Droscher identify the principle of momentum conservation of classical physics as a hindrance to novel propulsion applications that are in keeping with our dynamically changing perspectives about reality (though some physicists posit that the equations of classical mechanics do not necessarily support the idea of momentum conservation; that is, in a closed system, momentum can be lost given a finite time (Atkinson, 2007). The law of momentum conservation is the bedrock of fuel-propelled travel (Droscher, 2010). It seems that the idea of conservation of momentum is required for anything to move; that is, for an object to move, it must exert force on something else. Thus, Eleanor Nelson (2014), writes: "A person in roller skates, for example, pushes off against a wall; a rocket accelerates upward by propelling high-velocity combusted fuel downward. In practice, this means that space vessels like satellites and space stations have to carry up to half their weight in propellant just to stay in orbit. That bulks up their cost and reduces their useful lifetime." The classical conceptualization of momentum conservation, which works on the basis of expelled mass and energy, therefore imposes strict limitations on the practicality of propulsion systems (Droscher, 2010).

**Rethinking the universe:** Harold White, during a presentation, *Revolutionary Propulsion and Power for the Next Century of Space Flight*, at the Von Braun Symposium in October 2009, asserted (White, 2009), that "in order to enable bold exploration missions to Mars, the outer solar system, and beyond, we must engage in advanced propulsion research with the goal of developing point solutions that are orders of magnitude more effective than the current arsenal of propulsion technologies. Nothing short of a radical reconceptualization of the physical laws that supposedly govern the universe will suffice – if novel propulsion technologies are to be developed. Classical physics makes no provisions for long range interactions that are not governed by momentum exchange. However, what if we could develop propulsion systems based on quantum theory?

Classical physics makes certain fundamental assumptions about the universe – the most critical of which is that reality is an entirely deterministic, closed system comprised of discrete particles in empty space, objects in a void. There is a strong fundamentalist trust in a tactile, material universe. Though the atom has since lost its place as the envisioned indivisible unit upon which a concrete universe is based, classical mechanics still allows only for a fundamental cosmos with clearly identifiable building blocks.

The advent of quantum physics however brought along with it diminished confidence in some of the Newtonian assumptions about how the universe behaves. Instead of a cosmos with implicit order that could be described according to unchanging mathematical laws, quantum physics revealed a universe that allowed for spontaneity, and one which rested not on predictability but on probability – a realization that prompted Einstein to insist that "God does not play dice." McFarlane affirms (McFarlane, 1988), that "in Newton's mechanistic universe, not only was reality made of matter which followed strict deterministic law, but it was thought to be composed of many separate, independent material particles. So far on our journey into the quantum realm, the materialistic and deterministic assumptions have been undermined." Quantum physics replaces actuality with potentiality, denouncing fixed states and predetermined values. Instead of a 'local' universe, where separate entities have definite fixed points in space, quantum physics – at least according to the Copenhagen interpretation – introduces us to a world that behaves counterintuitively: a nonlocal reality where particles only appear to be separate but are indeed entangled.

Quantum physics posits that space is not an empty void populated by particles, but even more astonishingly, it disturbs the idea of an objective reality 'out there' awaiting observation. Instead, what experiments like the double-slit wave-particle duality experiments have shown is that the observer is not separate from the observation – and the very act of noticing influences the outcome of a process, no matter how closed the system is. In a sense, there are no 'closed' systems. Everything seems bound up in relationship to another, interconnected with everything else. A deeper explicitation of the implications of the Copenhagen interpretation of the quantum theory as a fundamental description of physical reality is that relationships precede objects – or, as summed up admirably by quantum physicist Karen Barad (Barad, 2007), "relata do not precede relations."

Summarily, we are thrust into a world that is not bound by the culturally mediated 'laws' of classical physics, a world that presents exciting opportunities for new applications, a world that is seemingly more agreeable to the desire for interstellar travel.

**Implications of quantum physics for new forms of aerospace travel:** It is already quite evident that if deeper space travel is to happen, we need systems that produce thrust, which are not dependent on burning fuel; that is, we need to look beyond classical physics and its stern limitations around the laws of momentum conservation. We are aided in this quest for more efficient, more effective propulsion applications by no less than a more radical, fundamental vision of reality. The task today is to situate our concepts and ingenuity within an expanded set of parameters – taking advantage of phenomena the 'thin' boundaries of classical physics was incapable of accommodating.

It is thus inspiring to note that some new directions are already opening – based on the resource-expansiveness of quantum theory – albeit that these experiments with novel systems are still in stages of infancy.

In what some analysts deem to be the initial stages of bolder space travel, perhaps on par with the kind of travel enacted in popular sci-fi fixtures like *Interstellar* and *Star Trek*, the American space agency, NASA, last year confirmed news that it had begun working on "impossible" aerospace engines that did not require fuel for thrust. Mike Wall, of *Space.com*, reported (Wall, 2014) that "researchers at NASA's Johnson Space Center in Houston have found that a microwave thruster system that requires no propellant does indeed generate a small amount of thrust", averring that "if the technology pans out, it could make spaceflight far cheaper and speedier, potentially opening up much of the cosmos to exploration, advocates say."

In a related development, scientists were able to produce a limited amount of thrust with an engine that seemed to be interacting with the quantum vacuum of the universe (Maynard, 2014). "Cannae drive technology, a way of propelling spaceships using microwave energy, has been successfully tested by NASA. Such an engine, if thoroughly developed, could shorten the time needed for a trip to Mars from months to weeks. The biggest surprise of the test was that the system worked at all – theory said the engine would not be able to produce any amount of thrust – even the small amounts of power seen in the test. The experiment involved filling a specially-designed container with microwaves. The uneven shape of the canister creates a difference in radiation pressure, causing a thrust forward, toward the larger end of the vessel. Despite what most physicists predicted, the device started to produce a small amount of thrust, slightly over 0.0001 ounces. That amount of force is not large, but just the fact that any at all was measured baffles scientists. The conservation of momentum states that no thrust at all should be produced by such a system." Maynard reports that "if further tests of similar systems are successful in larger Cannae engines, the design could allow the manufacture of ultra-lightweight rockets that could bring human travellers to the nearest star in just 30 years."

Prior to the articulation of the Cannae engines, in a development no less stunning, an Egyptian teenager, Aisha Mustafa, was reported to have produced a propulsion system based on treating quantum dynamics produced by the Casimir Effect as a resource for thrust. Singh (2012), reports that "her propulsion system gets rid of traditional rocket boosters in favour of a more futuristic concept. [one which] utilizes a "moving mirror" cavity, where two reflective flat plates are held close together and then manipulated in order to interact with the quantum particles. By moving the plates (which are made of silicon), energy is created out of nothing and a net force is created which would be used to push, pull or propel a spacecraft."

But the expansive potentials for new quantum propulsion technologies gets even wider (and weirder) when yet another feature of quantum entanglement is considered: teleportation. In 2013, a team of researchers were able to achieve the instantaneous teleportation of the quantum state of a photon to a crystal-encased photon more than 15 miles away (Stratt, 2014). Even though the researchers clarified that the data teleported did not translate to faster-than-light communication – and were actually quantum qubits, not classical bits – the news represents the opening up of "startling possibilities" (Stratt, 2014).

While I am nowhere near a thorough explicitation of the fundamental aspects of quantum theory – or an elucidation of how new interpretations of quantum mechanics might inform the development of new propulsion applications, it is central to the orientation and objective of this paper to ask questions about what might be possible, given our changing notions of reality. This is articulated in form of 'what if' questions. A small number of the phenomena of quantum mechanics is discussed and then loosely considered as a resource for future propulsion applications.

**Quantum Entanglement and nonlocality:** Quantum entanglement disturbs the classical notion of a universe populated by discrete, isolated objects. At subatomic levels, the universe seems to behave differently – as if matter can only be considered in form of vast networks of prior interconnectivity. Einstein presumed that one of the fixed laws governing the universe is the constant speed of light – thus barring the possibility for faster-than-light communication to take place between two points in space. A series of experiments however revealed that some form of unusual communication takes place between two closely affiliated 'particles', so that even if you separate them by large distances, measuring one affects the other instantaneously. Einstein, befuddled by the results of these experiments, called the phenomenon of entanglement 'spooky action at a distance'. Entanglement, often called the grand soap-opera of quantum physics, probably means that we live in a universe that transcends space-time and distance, and is predicated on relationships – so that the older picture of the world emerging from a series of deterministic inter-actions gives way to multiple realities of "intra-actions" (Barad, 2007), a term Barad uses to describe the ontological inseparability of things – in contrast to the notion of interaction, which is predicated on a metaphor of individualism.

What if one of the impediments to space travel is the classical category of distance, and what if quantum entanglement could theoretically provide sources of transportation that enact the strange inseparability observed between entangled 'particles'? This question, excitingly enough, isn't new. In a 2004 article called *Spooky Spaceflight*, Waldron (Waldron, 2004) reported a successful attempt at entanglement-based quantum teleportation that has implications for new forms of space travel: "In brief, the idea is to apply quantum entanglement to ion propulsion. An ion drive system is a form of rocket propulsion which uses a stream of charged particles, or ions, as a rocket exhaust. Ion drives typically yield far lower thrust-to-weight ratios than traditional chemical rockets, but because of their much slower fuel burn rate they can gradually accelerate a spacecraft to speeds that no chemical rocket can reach."

He elaborates further: "While quantum entanglement and quantum teleportation experiments have to date been confined to entangled specimens of materials within the same laboratory, there is no theoretical limitation on how great a distance quantum entanglement can operate across. In other words, once two groups of atoms have been entangled, that entanglement would still be in effect were one of the entangled specimens moved to the other side of the earth or the solar system. Therefore, were two specimens of cesium (to take one example; other materials would also work) to be entangled on earth, then one of the specimens lofted into space, exciting the earthbound cesium sample to produce ions would result in the space-traveling cesium sample becoming energetically excited and producing ions like its earthbound counterpart. A resulting ion stream, produced without the benefit (or hindrance, for that matter) of any form of internal engine system onboard the spacecraft, could propel the craft through space. It would be a kind of engineless drive system, which I am calling the teleportation drive. The actual engine and, even more importantly, its power source-a nuclear reactor, a solar array, or other form of power generation-would remain on earth along with the earthbound, entangled fuel sample."

Perhaps, quantum entanglement invites us to reconsider the language of 'propulsion', and could lead to space travel technologies that sidestep the limitation of distance altogether.

**Consciousness:** Classical mechanics makes no room for the observer. Assuming reality as a closed deterministic framework, classical physics is blind to the influences of observer, and treats reality as perfectly explainable without recourse to consciousness. However, numerous experiments in quantum physics have led physicists to an almost inevitable conclusion – that the observer and the observed are part of the same system, and that the 'mere' act of measurement influences how the universe behaves at subatomic levels. Early theorists of quantum mechanics like Ernest Schrödinger and Niels Bohr posited that 'particles' do not have any values prior to their measurement, and exist in a super-state of wave potentiality – until measured. The very act of measurement 'causes' wave collapse, forcing particles to take on one attribute or another. Prior to the introduction of an apparatus, everything exists in a state of flux, having no value, only the potential-to-value. What wave-collapse means is that awareness might very well be the primal 'stuff' the universe is made of, and that mind and matter are not classically separate or isolated as Cartesian philosophy would instruct. Are there ways, then, that we could treat consciousness as a resource? Is it possible that the physical universe allows for even stranger relationships or 'intra-actions'?

What often escapes popular attention is that hundreds of experiments have been conducted that show more than chance outcomes when telekinesis, clairvoyance and precognitive capabilities are studied. Mayer (2007), writes extensively about histories of ESP research conducted – most of which were strikingly conclusive about the possibility of 'mind over matter' interaction. There is admittedly little or no discussion around the prestigious submissions of institutions such as the Society for Psychical Research, which had numerous publications with excellent

Could this lead to generic propulsion applications for space travel? Does the human mind represent an untapped field of 'fuel' that could power a new generation of propulsion systems? Could telekinetic motion provide sufficient thrust for spacecrafts?

## 2. CONCLUSION

Today's challenge is to brave new frontiers – first in our willingness to ask new questions. Space travel represents a deep-seated human urge to explore the unknown, and more efficient propulsion technologies that are built with new insights today can provide us opportunities to traverse the universe. It is perhaps fitting that the voice of the first man on the moon still reminds us that there is much yet undone and new questions to ask if we are to rise to the occasion of aerospace travel:

"To you we say, we have only completed a beginning. We leave much that is undone. There are great ideas undiscovered, breakthroughs available to those who can remove one of truths protective layers.There are places to go beyond belief."

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