Preface

Until the summer of 2011, I didn't think that I'd write the book now in your possession. I'd thought of writing a book about "advanced and exotic propulsion" in the mid-1990s. But Tom Mahood showed up in then the new Master's program in physics at Cal State Fullerton where I taught and did research,[1] and thoughts of book writing faded away with increased activity in my lab.

The 1990s were the heyday of speculations about advanced and exotic propulsion. But not long after the turn of the millennium, with the "war on terrorism," a looming energy crisis, financial shenanigans, climate change, and assorted political developments, advanced and exotic propulsion faded into the background. Ironically, it was during the 1990s and the first decade of this century that the real motivations for the exploration of advanced and exotic propulsion came to be appreciated: the inevitability of an extinction-level asteroid impact and, if clever critters elsewhere in the cosmos have mastered exotic propulsion, the likely eventual arrival of aliens interested in exploiting the resources of our planet. These threats may sound remote and romantic, the stuff of science fiction, and grade B screen epics with lots of special effects. However, they are quite real and, literally, deadly serious.

In the first decade of this century, chemical rocketeers and their supporters in positions of power in government and industry set about stripping out anything with even a whiff of exotic propulsion from programs with serious funding.[2] This was especially true when NASA was headed by Michael Griffin. "Advanced" propulsion didn't fare quite so badly, for it was widely defined as "electric" propulsion of various sorts, and that had long been understood not to be a threat to the dominance of the chemical propulsion community. After all, electric propulsion only held out any promise for deep space missions if launched from orbital craft with very modest masses. There is no chance that electric propulsion is practicable for Earth to orbit launchers and deep space manned spacecraft. But times have changed. Notwithstanding the resistance of the bureaucracies that deal with spaceflight, the realization that exotic propulsion is the only realistic method for reaching out to the

[1] Though I no longer teach, I still do research.

[2] MS Word's auto speller kept trying to change "rocketeer" into "racketeer" when I wrote this. I was tempted.

stars, and getting significant numbers of people off the planet and out of the Solar System should that prove desirable, has sparked a revival of interest in exotic technologies.

It seems that the revival of interest in advanced propulsion is serious. Why do we say that? Well, because chemical propulsion types are attacking it. They likely wouldn't waste their time doing that if it weren't perceived as a serious issue. An example: When I recently returned from an advanced and exotic propulsion conference (with about 15 attendees), I was greeted by the latest issue of the American Institute of Aeronautics and Astronautics (AIAA) publication *Aerospace America* (the March 2012 issue). On page 24 appears a "viewpoint" piece by Editor-at-Large Jerry Grey entitled, "The ephemeral 'advanced propulsion.'" The sidebar reads, "New technologies with the promise of more affordable, more efficient, and safer propulsion for space launch currently seem to be out of reach. That, however, does not mean that we should stop searching." Wanna bet? Only three paragraphs into the piece Grey allows that, "Unfortunately, advanced propulsion with sufficient thrust for Earth-based launchers requires concepts involving esoteric materials (often described as 'unobtainium') or other new (or as yet unknown) principles of physics such as antigravity, modifying the structure of space-time, employing electromagnetic zero-point energy, faster-than-light drive, or 'wormholes.' None of these is likely to be operational in the foreseeable future." The unspoken inference is that it is a waste of resources to invest in any of these technologies.

Grey's impressive credentials are presented in another sidebar. The piece is quite long, almost entirely devoted to explaining why chemical rocketeering is the only reasonable way to proceed at this time. He wraps up his piece mentioning the recent 100 Year Starship project and the resuscitation of NASA's National Institute for Advanced Concepts (NIAC), closing with, "But don't expect anything approaching *Star Trek's* faster-than-light 'warp drive' for many years to come." Not if you are counting on funding by the government, anyway.

The 100 Year Starship project was a kiss-off of government funding for starship investigations. NASA put up 100 kilobucks and Defense Advanced Research Projects Agency (DARPA) 1 megabuck. They spent 600 kilobucks cranking people up and, then, gave the remaining half megabuck to a consortium of people almost completely unknown to most of the people who had actually been working on "advanced" propulsion. They allowed that there would be no more money from the government to support these activities. As for NIAC, it has never funded anything more challenging than solar sails and space elevators. You may think those pretty challenging. But by comparison with wormhole tech, they aren't. All of this would seem to suggest that Grey's assessment is correct.

Grey's assessment of the state of "advanced propulsion" appears to be justified by what is arguably one of the very best books on time machines and warp drives, by Allen Everett and Thomas Roman and recently published (2011) by the University of Chicago Press. Everett and Roman's book is, in a word, outstanding. If you are looking for a book that covers the theory of wormhole physics developed in the last several decades, Everett and Roman's book is the one you'd want to read. Their take on wormhole physics is strongly influenced by arguments developed by Roman and his colleague Larry Ford and others, loosely called "quantum inequalities" and "energy conditions." Quantum inequalities – which lead to the appearance of the negative energy needed to make wormholes – lead

Everett and Roman to the conclusion that the discovery of the laws of quantum gravity will be required for wormhole physics to advance farther than its present state. You might think this unimportant, but as Everett and Roman note in their epilogue:

> An efficient method of space travel could be an important issue for the survival of the human race. For example, we know that asteroid impacts have occurred numerous times in the history of our planet. One such impact sixty-five million years ago quite probably ended the reign of the dinosaurs. We know that if we remain on this planet long enough, eventually another such catastrophic impact will happen and possibly herald the end of our species.... So it would seem that it should be a fundamental goal for us to develop the capability to get off the planet (and out of the solar system).

They go on, several pages later, to remark:

> A theory of quantum gravity could, and many believe would, be as scientifically revolutionary as quantum mechanics, but will it affect humanity to the same extent? The energy scale of quantum gravity [the "Planck scale"] is so enormous [really, really enormous] that we may not be able to manipulate its effects in the near future, if ever.

Some speculative comments follow based on the supposition that mastery of the Planck scale might eventually prove possible.

This book is not a competitor to Everett and Roman's excellent contribution to wormhole physics. It is predicated on very different circumstances from those that they imagine. Where they, and Grey, assume that overall our present understanding of physics is pretty thorough and well worked out, and that "new" physics in the form of quantum gravity or something equivalent will be required to make wormhole tech a reality, this book is predicated on the supposition that our understanding of present theory is not so thorough and complete that we can assume that it precludes the development of wormhole tech. As you will find in the following pages, this view was not expected. Many of the key insights were not actively sought. In a very real sense, much of what is described in what follows was little more than a sequence of accidents, such as blundering onto a paper that happened to have just the right argument presented in an easily accessible way and stumbling onto a flaw in an apparatus that made the system perform in some unexpected but desirable way. Having tolerant friends and colleagues willing to listen to sometimes inchoate remarks and ask good questions helped. The metaphor that comes to mind is the well-known joke about the drunk looking for his or her keys under a streetlamp.

Kip Thorne, prodded by Carl Sagan, transformed advanced and exotic propulsion in 1988 with the publication (with his then grad student Michael Morris) of the foundational paper on traversable wormholes (in the *American Journal of Physics*). That work made plain that if you wanted to get around the galaxy quickly, you were going to have to find a way to assemble a Jupiter mass of negative rest-mass matter in a structure at most a few tens of meters in size. And to be practical, the method would have to depend only on the sort of energy resources now available that could be put onto a small craft. That prospect was so daunting that those of us working on advanced and exotic propulsion just ignored wormholes – and kept on working under our personal streetlamps as we had before. The path traversed by most of us to our streetlamps was a search of the professional literature for anomalous observations on gravity and electromagnetism and for speculative theories that coupled gravity and electromagnetism in ways not encompassed by general relativity and standard electrodynamics (classical or quantum).

When Thorne published his wormhole work, nothing anyone working on advanced propulsion was doing looked even remotely like it might produce the needed technology. The options were either to give up or to keep on looking for less ambitious propulsion schemes, illuminated by the streetlamps we had found, that would nonetheless improve our ability to explore space. After all, even a drunk knows that it's pretty stupid to look for your keys in the dark, no matter where they may actually be.

In the fall of 1989, after finding a flaw in a calculation done a decade earlier, I abandoned the streetlamp I had been working under for many years for another. That was not a pleasant experience. Abandoning a research program done for more than a decade is like divorce. Even in the best of circumstances, it's no fun at all. Though I didn't appreciate it at the time, several keys were in the gravel at the base of the new streetlamp I had chosen. No penetrating insight was required to see them. Just fabulous good luck. It is said that the Great Spirit looks out for drunks and fools.

If you are plugged into the popular space science scene at all, from time to time you hear commentators remark that given the mind-boggling number of Sun-like stars in the galaxy, and the number of galaxies in the observable universe, the likelihood that we are the only intelligent life-forms in the galaxy, much less the universe, is essentially zero. If there really are other intelligent life-forms present, and the physics of reality enables the construction of starships and stargates, the obvious question is: Why haven't we been visited by more advanced life-forms or life-forms of roughly our level of intelligence or greater that mastered high tech long before us? This is known in the trade as the Fermi paradox, for Enrico Fermi posed the question on a lunch break at Los Alamos in the early 1950s. His words were, "Where are they?"

A non-negligible number of people today would answer Fermi's question with, "They're already here, and they are abducting people and doing other sorts of strange things." Most serious scientists, of course, don't take such assertions seriously. Neither do they take seriously claims of crashed alien technology secreted by various governments and reverse engineered by shadowy scientists working on deep black projects.

Good reasons exist for scientists not taking popular fads and conspiracy theories seriously. Even if there are a few people who have really been abducted by aliens, it is obvious that the vast majority of such claims are false, regardless of how convinced those making the claims may be that their experience is genuine. In the matter of alleged conspiracies, it is always a good idea to keep in mind that we, as human beings, are wired to look for such plots in our experiences. Finding patterns in events that might pose a threat to us is something that has doubtless been selected for eons. When such a threat actually exists, this trait has survival value. When no threat is present, thinking one to be so is unlikely to have a negative survival impact. Others will just think you a bit odd or paranoid. Maybe. But you are still alive.

A more fundamental reason exists, though, that discredits the conspiracy schemes. It is predicated on the assumption that even if crashed alien tech exists, and our smartest scientists have had access to it, they would be able to figure out how it works. Is this reasonable? You can only figure out how something works if you understand the physical principles on which it is based. The fact of the matter is that until Thorne did his work on wormholes and Alcubierre found the warp drive metric, no one really understood the physical principles involved in starships and stargates. And even then, no one had a clue as to how you might go about inducing Jupiter masses of exotic matter to do the requisite spacetime warping. Though you might be the brightest physicist in the world, you could pore over the wreckage of an alien craft and still not have a clue about how it worked. Imagine giving the brightest physicists of the early nineteenth century a modern solid-state electronic device and asking them to reverse engineer it. How long do you think that would take?

Actually, there is an important point to be made in all of this talk of understanding and being able to master a technology. Although most of us might be willing to admit that dealing with the unknown might be challenging, indeed, perhaps very challenging, we would likely not be willing to admit that dealing with the unknown might prove completely insuperable. After all, we deal with unknowns all the time in our everyday lives. Our experiences and prior education, however, equip us to deal with the sorts of unknown situations we routinely encounter. As Thomas Kuhn pointed out in his *Structure of Scientific Revolutions* more than half a century ago, the sciences function in much the same way by creating "paradigms," collections of theories, principles, and methods of practice that guide practitioners in the field in handling the problems they address. Actually, paradigms even guide practitioners in the selection of problems sanctioned by their peers as worthy of investigation.

This may sound like the practitioners of a discipline collude to circumscribe things so that they only have to work on tractable problems that assure them of the approbation of their colleagues when they successfully solve one. But, of course, that's not the case. The practice of what Kuhn calls "normal" science can be exceedingly challenging, and there is no guarantee that you will be able to solve whatever problem you choose to tackle.

That said, there is another order entirely of unknowns and problems. In the quirky turn of phrase of a past Secretary of Defense, there are "unknown unknowns" in contrast to the "known unknowns" of paradigms and everyday experience. They are essentially never tackled by those practicing normal science. And when they are tackled by those with sufficient courage or foolhardiness, they usually try to employ the techniques of the normal science of the day. An example would be "alternative" theories of gravity in the age of Einstein.

As the importance of Special Relativity Theory (SRT) became evident in the period of roughly 1905–1915, a number of people realized that Newtonian gravity would have to be changed to comport with the conceptualization of space and time as relative. Perhaps the earliest to recognize this was Henri Poincaré. In a lengthy paper on relativity and gravity written in 1905, but published more than a year later, he did precisely this. His theory was not the precursor of General Relativity Theory (GRT). It was constructed using standard techniques in the flat pseudo-Euclidean spacetime of SRT. Not long after, others, notably Gustav Mie and Gunnar Nordstrom, also tackled gravity in the context of what would be called today unified field theory. They, too, used standard techniques and flat spacetime.

When Einstein told Planck of his intent to mount a major attack on gravity early in the decade of the teens, Planck warned him off the project. Planck told Einstein that the problem was too difficult, perhaps insoluble, and even if he succeeded, no one would much care because gravity was so inconsequential in the world of everyday phenomena. Einstein, of course, ignored Planck's advice. Guided by his version of the Equivalence principle and what he later called Mach's principle, he also ignored the standard techniques of field theory of his day. Rather than construct his field theory of gravity as a force field in a flat background spacetime, he opted for the distortion of spacetime itself and the non-Euclidean geometry that entails as his representation of the field.

It is easy now to look back and recognize his signal achievement: GRT. But even now, most do not appreciate the fundamentally radical nature of Einstein's approach. If you look at the history of gravitation in the ensuing century, much of it is a story of people trying to recast GRT into the formalism of standard field theory where the field is something that exists in a flat spacetime background and is communicated by gravitons. That's what it is, for example, in string theory. String theory is just the most well known of these efforts. GRT, however, is "background independent"; it cannot meaningfully be cast in a flat background spacetime. This property of GRT is pivotal in the matter of wormhole tech. It is the property that makes wormholes real physical structures worth trying to build.

The point of this is that if Einstein had not lived and been the iconoclast he was, the odds are that we today would *not* be talking about black holes and wormholes as real geometric structures of spacetime. Instead, we would be talking about the usual sorts of schemes advanced in discussions of deep space transport: electric propulsion, nuclear propulsion, and so on. Radical speculation would likely center on hypothetical methods to reduce the inertia of massive objects, the goal being to render them with no inertia, so they could be accelerated to the speed of light with little or no energy. That is, the discussion would be like that before Kip Thorne did his classic work on wormholes.

You sometimes hear people say that it may take thousands, if not millions, of years of development for us to figure out how to do wormhole tech. Perhaps, but probably not. The key enabling ideas are those of Einstein and Thorne. Clever aliens, if they did not have an Einstein and a Thorne, may well have taken far longer to figure out wormhole tech than, hopefully, we will. We have been fabulously lucky to have had Einstein, who recognized gravity as fundamentally different from the other forces of nature, and Thorne, who had the courage to address the issue of traversable wormholes, putting his career at serious risk.

If you've not been a professional academic, it is easy to seriously underestimate the courage required to do what Thorne did. As a leading figure in the world of gravitational physics, to stick your neck out to talk about traversable wormholes and time machines is just asking for it. Professionally speaking, there just isn't any upside to doing this sort of a thing. It can easily turn out to be a career ender. Those of lesser stature than Thorne were routinely shunned by the mainstream community for much less and often still are. It is likely, though, that in the future Thorne will chiefly be known for his work on wormholes. And both his work and his courage will be highly regarded.

The plan of this book is simple. The material is divided into three sections. The first section deals with the physics that underlie the effects that make the reality of stargates possible. The principles of relativity and equivalence are discussed first, as the customary treatments of these principles do not bring out their features that are important to the issue of the origin of inertia. Next, Mach's principle and the gravitational origin of both inertial reaction forces and mass itself are dealt with. Derivation of "Mach effects" – transient mass fluctuations that can be induced in some objects in special circumstances – complete the first section.

In the second section, after an overview of past experimental work, recent experimental results are presented and examined in some detail. Those results suggest that whether or not stargates can be made, at least a means of propellant-free propulsion can be created using Mach effects.

The first two sections are not speculative. The physics involved is straightforward, though the emphasis differs from the customary treatments of this material. Experimental results can be questioned in a number of ways. But in the last analysis, they are the touchstones and final arbiters of reality.

The third section is different. The central theme of this section is the creation of an effective Jupiter mass of exotic matter in a structure with typical dimensions of meters. This discussion is impossible unless you have a theory of matter that includes gravity. The Standard Model of relativistic quantum field theory – that is, the widely accepted, phenomenally successful theory of matter that has dominated physics for the past half century – does not include gravity. Indeed, this is widely regarded as its chief defect. For the purpose of making stargates, that defect is fatal. Fortuitously, a theory of the simplest constituents of matter, electrons, that includes general relativity has been lying around for roughly 50 years. It was created by Richard Arnowitt, Stanley Deser, and Charles Misner (commonly referred to as ADM) in 1960. It has some problems (which is why it didn't catch on either when proposed or since). But the problems can be fixed.

When fixed, the ADM electron model allows you to calculate how much exotic matter is available in everyday matter, normally screened by the gravitational interaction with chiefly distant matter in the universe, if a way to expose it can be found. Such exposure can be achieved by canceling the gravitational effect of the chiefly distant matter with nearby exotic, negative rest-mass matter. The amount of exotic matter needed to trigger this process is minuscule by comparison with the Jupiter mass of exotic matter that results from exposure. Mach effects provide a means to produce the exotic matter required to produce exposure. All of this is spelled out in some detail in the third section. And we finish up with some comments on how you would actually configure things to make a real starship or stargate.

There may be times, as you wend your way through the following chapters, when you ask yourself, "Why in God's name did this stuff get included in a book on stargates?" Some of the material included is a bit confusing, and some of it is a bit arcane. But all of the material in the main body of the text is there because it bears directly on the physics of starships and stargates. So please bear with us in the more difficult parts.

So who exactly is this book written for? Strictly speaking, it is for professional engineers. You might ask: Why not physicists? Well, physicists don't build starships and stargates. They build apparatus to do experiments to see if what they think about the world is right. You'll find some of this sort of activity reported in the second section. But moving beyond scientific experiments requires the skills of engineers; so they are the target audience. That target audience justifies the inclusion of some formal mathematics needed to make the discussion exact. But grasping the arguments made usually does not depend critically on mathematical details. So if you find the mathematics inaccessible, just read on.

You will find, as you read along, in the main part of the book, that it is not written like any engineering (or physics) text that you may have read. Indeed, much of the main part of this book is written for an educated audience who has an interest in science and technology. This is not an accident. Having read some truly stultifying texts, we hope here not to perpetrate such stuffiness on anyone. And the fact of the matter is that some, perhaps much, of the scientific material belongs to arcane subspecialties of physics, and even professional engineers and physicists in different subspecialties are not much better prepared to come to grips with this material than members of the general public.

If you are an engineer or a physicist, though, you should not get the idea that this book is written for nonprofessionals. Mathematics where it is needed is included for clear communication and to get something exactly right. Nonetheless, we hope that general readers will be able to enjoy much, if not most, of the content of this book. For if the material in this book is essentially correct, though some of us won't see starships and stargates in our lifetime, perhaps you will in yours.

http://www.springer.com/978-1-4614-5622-3

Making Starships and Stargates
The Science of Interstellar Transport and Absurdly
Benign Wormholes
Woodward, J.F.
2013, XXVI, 279 p. 92 illus., 85 illus. in color., Softcover
ISBN: 978-1-4614-5622-3