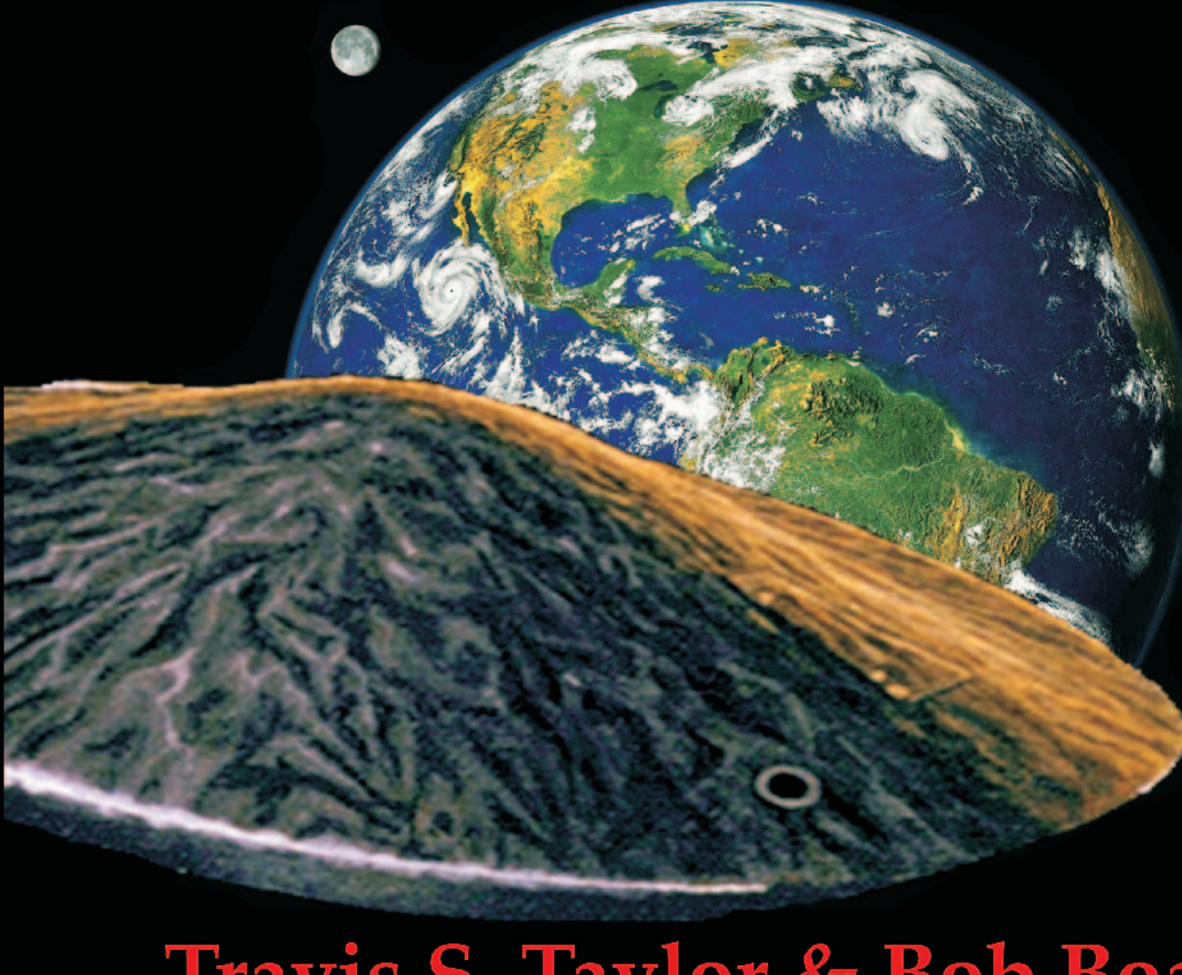
An Introduction to Planetary Defense

A Study of Modern Warfare Applied to

Extra-Terrestrial Invasion



Travis S. Taylor & Bob Boan

with

R.C. Anding & T. Conley Powell

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Other Books by Travis S. Taylor

Warp Speed

The Quantum Connection

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Dedication

We dedicate this text to those unfortunate citizens and heroes who lost their lives in the September 11, 2001 terrorist attacks on America. America was unprepared for those attacks. It is our hope and desire that with this book we will stimulate enough impetus to take advantage of lessons learned from our lack of planning and preparation. Being similarly unprepared for an invasion from extra-terrestrials would prove far more catastrophic and would likely end humanity. A response to the call to plan and prepare will add great purpose to the September 11, 2001 victims' unfortunate fates.

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About the Authors

Principle Authors:

Dr. Travis S. Taylor

Travis Shane Taylor is a born and bred southerner and resides just outside Huntsville, Alabama. He has a Doctorate in Optical Science and Engineering, a Master's degree in Physics, a Master's degree in Aerospace Engineering, all from the University of Alabama in Huntsville; a Master's degree in Astronomy from the Univ. of Western Sydney, and a Bachelor's degree in Electrical Engineering from Auburn University. He is a licensed Professional Engineer in the state of Alabama.

Dr. Taylor has worked on various programs for the Department of Defense and NASA for the past sixteen years. He is currently working on several advanced propulsion concepts, very large space telescopes, space based beamed energy systems, future combat technologies and systems, and next generation space launch concepts. He is also involved with multiple MASINT, SIGINT, IMINT, and HUMINT concept studies.

He has published over 25 papers and the appendix on solar sailing in the 2nd edition of *Deep Space Probes* by Greg Matloff.

His first science fiction novel is, *Warp Speed*, and his second is *The Quantum Connection* published by Baen Publishing. He is also working on two different series with best-selling author John Ringo also by Baen Publishing. He has several other works of both fiction and nonfiction ongoing.

Travis is also a Black Belt martial artist, a private pilot, a SCUBA diver, races mountain and road bikes, competed in triathlons, and has been the lead singer and rhythm guitarist of several hard rock bands. He currently lives with his wife Karen, his daughter Kalista Jade, two dogs Stevie and Wesker, and his cat Kuro.

Dr. Bob Boan

Dr. Boan has been an active member of the space community for over a quarter of a century. He has worked on a variety of manned and unmanned space programs at different levels of responsibility over that time. Prior to his space experience he was a member of academia. He taught primarily chemistry. He taught courses from high school through graduate school in several states.

Dr. Boan is also recognized as a community expert on SIGINT, IMINT, and Communication systems and concepts. He also has significant MASINT experience. He has multiple relevant patents and technical publications.

Dr. Boan has attended a variety of colleges and universities. He received his BS from Campbell University, then Campbell College. His Master's was awarded by the University of Mississippi. He earned his doctorate at the Florida Institute of Technology.

Dr. Boan has significant experience as an author. He has authored a number of technical publications. He has compiled a book of witticisms and a fiction novel and is currently working on two new novels; one of which is science fiction he is coauthoring with "Doc" Travis Taylor.

Dr. Boan has been featured in Marquis' *Who's Who in the South and Southwest* and in Marquis' *Who's Who in America*.

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Mr. Anding received his bachelor's degree in Electrical Engineering from Mississippi State University. He has additional studies in systems engineering, digital signal processing and electromagnetic environmental effects. Mr. Anding has applied his creativity and expertise to solve a diversity of engineering problems for over 25 years. He has designed electronics and systems for space, military, industrial and medical products. He was the prime contractor's chief engineer for the design and development of a furnace system to grow semiconductor crystals in microgravity on both the Space Shuttle and the International Space Station. He supported its use on multiple Spacelab missions, including training of the astronauts and sitting console for payload operations during missions.

Mr. Anding was the chief engineer, along with Dr. Taylor as chief scientist, for the development of a novel new mission and spacecraft for exploring Pluto. He has designed and supported equipment on Navy fighter aircraft, Army main battle tanks, and attack helicopters. Non-invasive cardiac monitors for medical market, industrial robotics for the nuclear segment and user authorized handguns are just a few more examples of his broad experience base. He is currently designing controls for demilitarization of binary chemical weapons and beginning research and development for future fuel cell based power systems for rugged environments as well as applying unmanned aerial vehicles for defense purposes.

Dr. Thomas Conley Powell

CONLEY POWELL holds a B.A. in physics from Berea College, an M.S. in engineering science from the University of Tennessee Space Institute, and a Ph.D. in mechanical engineering from the University of Kentucky. He is a senior scientist with BAE Systems in Huntsville, Alabama. Before joining BAE, he was a faculty member at the Space Institute; a member of the technical staff at Arnold Engineering Development Center, near Tullahoma, Tennessee; and a member of the technical staff of Teledyne Brown Engineering, in Huntsville. He has taught graduate courses in subjects ranging from astrophysics to nuclear engineering, and has worked in areas as diverse as aircraft control and nuclear fusion. However, his specialties are space trajectories, attitude dynamics, and numerical analysis. Recently he has developed an innovative fire-control system for artillery and surface-to-surface and surface-to-space rockets. He is writing a textbook on orbital mechanics.

He lives in Athens, Alabama with his wife Judy, who is an interior designer, and their two cat, Mr. P. and two dogs, Bonnie and Scruffy MacGruff. His hobbies (in no particular order) are science fiction, crackpot literature, and weight lifting.

Introduction

This book was written to be considered seriously as a starting point for developing defensive and offensive concepts in the event that an attack from advanced extra-terrestrials occurs. The goal of this textbook is not to refute, discuss, defend, or even enter into an argument about government conspiracies, UFO cover-ups, alien autopsies, or any other examples of the “UFOlogy” genre. While we call upon science fiction for terms and examples, this text is actual science and experience. We base all our analyses on the facts to the extent possible. We supplement these facts with logical extension where possible.

It is our opinion that the possibility, however small or large, of such an attack exists from the simple fact that there are numerous other star systems in addition to ours. The possibility of extra-terrestrial life is, without a doubt, finite. In fact, the probability is overwhelming. We would be extremely arrogant, and perhaps ignorant, to believe Earth to be the only celestial body with a lifeform somewhat similar to our own. Whether or not the nonzero probability is large or small is of course unknown through scientifically verifiable and widely accepted evidence. However, the probability is finite! This being the case, it is also likely that if these ETs exist, some of them might wish us harm in some fashion or other for reasons known only to them.

We have several goals for this book. Those goals include:

- to discuss briefly the probability of a visit by ET
- to discuss the possible types of these ETs
- to categorize ETs by their ranges of power
- to take a first look at weapons for offense and defense
- to take a first look at the possible intentions for visits by the different categories of ETs
- to issue a call for preparation for a visit from ET
- and depending on their respective degree of power, could we defend ourselves against them or not? This is a question we hope to at least begin to answer - if not answer, begin thinking about how to answer.

A text of this type might have been very useful to the Native Americans when the Europeans – though not from a distant celestial body, ETs of a sort themselves - entered the Americas. This or any other similar text would have been of value only if the Native Americans had heeded the call for preparation as we ask our civilization to do. The analogy holds well in that the Europeans were from a much more technologically advanced civilization than the Native Americans – just as a visiting ET would be more advanced than we are. The Europeans entered the Native society and began to conquer and assimilate it. In some cases this occurred peacefully and in others, not so peacefully. There was little that the natives could do to stop the advance of the White Man. The best they could do was delay the inevitable even though they slowly adopted the military technology of the Europeans – it was too little, too late. However, as we will discuss later in the book, the Native Americans employed many tactics that are today known as "guerilla" tactics or more properly asymmetric warfare.

Asymmetric warfare is an overpowering in numbers and/or technologically advanced force attacking a smaller – much smaller in most cases – force. An example of this type of warfare is the second Gulf War or Operation Iraqi Freedom whereas the superior forces of the United States Coalition Force were plagued by the Iraqi insurgent forces. A small number of insurgents employed improvised explosive devices and other asymmetric warfare tactics to prolong their presence on that culture. In an alien invasion humanity might just find itself in the situation of the smaller "insurgent" force.

We would be the Natives if attacked by aliens. The human race is to be considered as one civilization with multiple factions within it. Again the Native American analogy holds true since there were also many various Indian Nations. The Europeans, ETs this time, are coming we must assume. Will they be nice or nasty? Do we wish to become extinct as some Natives did? Do we wish to travel our own "Trail of Tears?" Do we wish to be assimilated into a European society as happened to some of the Native Americans? Or will we fight back? Perhaps we should prepare for the worst and hope for the best. Now is the time for preparation before it is too late!

With the data and discussion gathered within this book, we hope to spark some interest in developing a defense strategy for the human civilization. In the event that one day some smooth talking aliens show up with some shiny trinkets and strands of beads, hopefully, we will be more prepared than the Native Americans were. If ET comes will we trade Manhattan, the US or the Globe? If the shiny beads are a cure for cancer or world hunger or perpetual energy, what would we trade? It would be too late at that point to have much of a bartering position if the aliens could simply take what they wanted.

It is said that those who do not learn from history are doomed to repeat it. We should learn from the fate of the American Indian. We should develop a strategy for dealing with the arrival of ET. It is likely that this strategy is best developed as a people of the planet as opposed to that of a country. Had the American Indian had the communications and transportation capabilities that we enjoy today, they could have joined all of the Indian nation forces to produce a force to produce an entity that may have immediately defeated the European ETs despite having inferior military technology. Sheer numbers and knowledge of the battle fields would have overwhelmed the Europeans and sent them home unlikely to return, at least without significant preparation.

Had the Indians themselves been making preparations for their return and had they joined forces, history would have a very different story to tell. They probably would have defeated the intruders even with their inferior weapons. On the other hand, as we will discuss in the various sections of this book, cooperative preparation may not be very easy to achieve. Therefore, the USA should at least do its part whether the remainder of the countries of the Globe participate or not.

If a hostile ET showed up and left, we would prepare for his return. He, too, would prepare for his return with more forces and/or technologies. We should prepare now and improve our odds that he would not return. Let's PREPARE NOW AND SURVIVE LATER. This is our thrust in this book. Being prepared will continue to percolate as the best strategy throughout the discussion in this study.

We are merely suggesting the development of a strategy. A strategy is needed even if it is never put into action. We have a responsibility to ourselves and our progeny to prepare for the possible. We leave the implementation of the strategy to our elected officials. We will however attempt to define levels of power at which selected aspects of a strategy are rendered futile.

A major issue in convincing governments and the public that we need to prepare is that we do not know whether or not we are alone in the universe. If we are the only intelligent lifeform, an interesting question relative to our existence arises. Are we an accident? Are we the result of an experiment? If we were an accident, then we weren't intended to exist at all. Certainly if we were not intended to exist it is logical to assume that no intelligent lifeform was intended to exist. Were we an unintended and unexpected byproduct of evolution? If we are the result of experiment, then the experiment must have had a bad result. If the result were not bad, why would there not be other intelligent lifeforms in the universe? If either of the scenarios is true, then it is reasonable to assume that we are the only intelligent lifeform in the universe. There are of course religious arguments for a single species universe, but the science is weak and will not be discussed here.

If we are the only intelligent lifeform in the universe, why is there such a vast universe? It is certainly not obvious what benefits we get from the rest of the universe if any. It is also not obvious that the rest of the universe takes anything beneficial from us. Could so many stars and celestial bodies be required to stabilize our solar system so that we select lifeforms are allowed to exist? One can only reach the conclusion that if we are the only intelligent lifeform, we are incredibly special. But, why us? If one scrutinizes the history of mankind, one would be hard pressed to find the type of universal positive behavior that one would anticipate and expect from a very special, favored species. How would we explain Hitler, Genghis Kahn, Idi Amin, Saddam Hussein, the Khmer Rouge and other sadistic rulers in this light? Each of these people probably meant well by their standards but not by the standards of the mainstream populace.

Both accident and bad experiment as explanations for our being alone in the universe are in contradiction with popular beliefs. A fundamental belief in many religions is that there is an omnipotent, benevolent Supreme Being who is the creator. If the Supreme Being is truly omnipotent, there could not be an accident. There could not be a result that is unexpected, only ones that are predetermined. An experiment could not go awry. An experiment could not have a bad ending except by design. A bad ending would be inconsistent with the benevolence of this so-called creator. The outcome would be well known at the beginning.

So, we suggest that we continue along the lines of reasoning and the more scientifically supported concept that we are not alone in the universe. How much company we have is unknown, although we will discuss this later. The point is that we most likely are not alone. At least logic would suggest such a conclusion. Therefore we feel that we should be prepared for future interactions with other civilizations. If we do not prepare now, it is likely that we will pay for our present inactivity in the future with our extinction.

Finally, the question arises: "How do we prepare?" We will discuss in this book various concepts of warfare, force-on-force theory, and possible future technological and military capabilities. Also, in the light of many of the modern natural disasters, it is quite clear that the civilian aspect of humanity has little, if any, emergency response capabilities that could be implemented effectively in a planetary wide disaster such as a planetary wide invasion (or even large scale meteor impacts). We attempt to address the initial aspects of modern military and civil defense requirements for surviving an invasion from advanced alien civilizations. We are making no claim that this is an all encompassing text on the subject. In fact, this book is merely scratching the surface of the topic and we hope that we can continue to dig deeper into the new aspects and paradigms necessary for planetary defense. Hopefully future editions and even *Advanced Planetary Defense Concepts* with more detailed applications and scenario simulations will be developed in the future. In the meantime, we will begin with ***An Introduction to Planetary Defense***.

1

The Statistics – Probability of an Alien Invasion

Is an alien attack possible? Of course it is. Statistically speaking, almost anything is possible. There is a better question to ask, which is, "What is the probability of an alien attack"? The likelihood of an alien attack can be discussed statistically but only after making some logical assumptions. For now, we will take an elementary mathematics approach to calculating this probability. This is an incomplete approach but is a good place to start for demonstration purposes.

There are about four hundred billion stars in the Milky Way galaxy alone. We know that at least one star system (our own) within the Milky Way Galaxy has developed intelligent life, at least as defined by our scale. So that suggests statistics of at least one civilization per galaxy. How many galaxies are there? There are billions, maybe more. So, there should be billions of star systems with intelligent civilizations even if there is only one intelligent civilization per galaxy!

Just one inhabited star system per galaxy seems preposterously low though. Again, there are four hundred billion stars in the Milky Way. That leads us to a probability of 0.25×10^{-11} of intelligent life existing. Such a probability would lead us to the conclusion that we are an accident or a special, unique freak of nature. Perhaps a more likely approximation can be gathered by making some further assumptions.

1.1 The Drake Equation

How many planets are there in the galaxy which host technical civilizations? This question has been pondered by mankind since before the beginning of our own technical civilization, which is only a few hundred to a few thousand years old depending upon the definition used. There is no doubt that primitive man must have wondered what amazing or horrible things could be lurking out in the stars. In 1961 the Cornell astronomer Frank Drake developed an approach for estimating the number of civilizations in the Milky Way. Drake proposed what has since become known as the "Drake Equation". The approach has become generally accepted in the Search for Extra-Terrestrial Intelligence

(SETI) community as the tool for analyzing factors that are crucial to civilization development. The equation is

$$N = R_{*} f_p n_e f_l f_i f_c L \quad (1.1)$$

where N is the number of civilizations in the Milky Way that developed systems which produce created electromagnetic emissions detectable from Earth, R_{*} is the rate of formation of stars suitable for the development of intelligent life, f_p is the probability of those stars having planetary systems, n_e is the number of planets per solar system that can support life, f_l is the probability that life actually occurs on those planets, f_i is the probability that intelligent life occurs, f_c is the probability that the intelligent life develops technology that produces electromagnetic signals detectable from Earth, and L is the length of time that the civilization is sending out these detectable signals. A discussion of each of these factors is in order.

R_{*} is fairly well understood. Observations from ground and space based telescopes over the last few decades have enabled a good estimate of this value to be about 1.5; that is on average 1.5 new stars per year. As we know, half stars are not created. We would think that about 3 new stars that are suitable for life to develop around are being formed every two years. So,

$$R_{*} = 1.5 \quad (1.2)$$

Exciting new observations of many planets around many stars leads us to understand that planets are a byproduct of star formation. So, as a star forms, planets are frequently born as a byproduct. There are some situations where this appears not to be the case. But these instances are exceptions, not the rule. Modern astronomical observations suggest that about ninety percent of stars formed produce planets. This leads to a value of 0.9 for f_p.

$$f_p = 0.9 \quad (1.3)$$

The number of planets per solar system that are suitable for life (i.e., number of "Earthlike" planets) is more considerably difficult to estimate. Some astronomers believe that these types of planets must exist within the zone around their star where liquid water can exist. We refer to water as the liquid state of the compound H_2O as opposed to steam or ice as the gaseous and solid states, respectively. Until recently, it was not realized that the Jovian moon Europa has a very deep liquid water ocean beneath its icy surface. Also, at one time Mars must have had liquid water on its surface. This leads to an interesting discussion about the potential for life on Europa and Mars. We should be prepared for the fact that if there is life on Europa, it might be anatomically dissimilar to lifeforms with which we are familiar. The lifeforms, including intelligent ones, might be so dissimilar that we might not immediately identify them as intelligent. An important question is "Why must the life be water based?" Titan, for example, might very well have liquid methane oceans, lakes, or rivers. It is possible that methane based lifeforms could and do exit. However, to keep the discussion simpler, we will only consider water-based life at this point as we have a better chance of understanding such lifeforms.

Using the elementary approach, we could say that at least three out of the 15 or more planet sized objects in our solar system have or have had liquid water on or in them at some point in their lifespans. Therefore, the probability (again from the freshman approach) that a planet in our solar system has water is three divided by 15 or one fifth (0.2). And the number of planets is three. If other than water based life is considered we would anticipate that the number becomes larger; the probability will vary with the other mediums assumed in addition to water. Again, for this argument we will only consider water-based lifeforms. Also, it is unknown if our solar system is typical although we are beginning to observe many star systems with multiple planets. Since Mars and Europa are not completely Earthlike we will be conservative in our estimates and will divide the value by two. So the number of Earthlike planets or planetoids per solar system is

$$n_e = 1.5 . \tag{1.4}$$

For convenience we will use "planet" to refer to planets, planetoids, moons or other bodies which could be a home to ET. Just because a given planet is suitable for life does not necessarily mean that it will develop life. Or does it? Scientists have found strange forms of life in the most hostile environments on Earth. Chemosynthesis based creatures have been found in underwater caves and at the bottom of the sea. Laboratory experiments show that amino acids can form out of a chemical soup as a result of the introduction of electric arcs. These amino acids are the building blocks of life as we know it and much more highly energetic conditions can occur from planetary electric storms than those experienced in chemical soup tests. These more energetic conditions increase the probability of biogenesis. It has become widely accepted that if a planet can support life in any weird and imaginable way, then it will, eventually, almost certainly, form life. The SETI community typically uses a value of one for the fraction of planets that actually develop life. Therefore

$$f_l = 1 . \tag{1.5}$$

Of the number of planets that develop life, how many will form intelligent life? Originally, Drake and his colleagues decided that all planets that form life would eventually develop intelligent life. Mars may, or may not, very well be in contradiction of this conclusion. Planetary scientists using probes have recently seen evidence of freely flowing water on the Martian surface having existed sometime in the past million years or so. It is very likely that eventually we will find microbial and other simple life on Mars. There is also the theory introduced by NASA that microbial life did exist on Mars based on evidence from meteor rocks found on Earth. If this is the case and Mars did form life, where is the intelligent life? Perhaps it is extinct? Perhaps it is there and we fail to recognize it? Perhaps it has yet to develop? Perhaps its evolution was ended by some cataclysmic phenomena.

At this point in the Martian evolutionary cycle, all evidence points to Mars maturing and aging. The Martian environment is very harsh and it would appear that Mars is not evolving life as we recognize it any longer. Therefore, it is possible that the original conclusion by Drake and his colleagues was a bit optimistic. Of course, there are those who might claim that a civilization could have formed on Mars and we just never knew it.

That is possible. However, it would be difficult for such a civilization to leave without a trace unless it was very, very long ago and has been decayed and engulfed by the surface dust over time. Thus far we have found no evidence of such. For now we will conclude that Mars has never evolved intelligent life.

What about Europa? With its deep ocean and most likely very volcanic sea bottom due to the huge gravitational tides from Jupiter and its other moons, it is highly probable that there are strange little fish swimming around in its oceans right now. We can make no further conclusions about Europa simply because we have a severe lack of hard data. What we can assume is that Europa is at the beginning of its evolution and that intelligent sea-based creatures may still develop there eons from now.

So, from the three planets in our solar system that have most likely created life, presently only one of them has appeared to have developed intelligent life. It is still possible that Europa will. It is highly unlikely that Mars will. Of course, it is possible that a string of comets could strike Mars, heat it up, and give it a thicker atmosphere and an environment more suitable for evolution of life. We will not consider these possibilities whose probabilities are too difficult to calculate accurately at this time due to our lack of a priori knowledge of each event should they happen at all.

It is possible that as the Solar System matures, Venus and/or later Mercury may develop an aqueous environment. If that were to happen, they too might be capable of supporting life – even intelligent life as we recognize it. This possibility is also left out of our statistical treatment of the possibility of intelligent life other than that which we recognize on Earth.

Therefore, the elementary approach suggests that two thirds of the planets in our solar system that can develop life will develop intelligent life. This means that

$$f_i = \frac{2}{3} \approx 0.67 \ . \tag{1.6}$$

Is it possible that any of these planets, which develop intelligent life, will develop civilizations with the capability to communicate with other planets? Assume now that communication merely means that we can detect some form of electromagnetic signal from their civilization. Drake’s group estimated this number to be between ten and twenty percent of the intelligent civilizations. This range of percentages seems far too low and far too conservative. If a civilization develops, eventually they can be detected as our communications technology catches up to, or surpasses, theirs. It is reasonable to assume that there are lifeforms that communicate in spectral bands that we have yet to discover or know how to use. It is also reasonable to assume that there are lifeforms that use communication technologies beyond our understanding of physics and therefore undetectable by our technologies. The problem here with these conservative estimates is that Drake used a far too loose a definition for “civilization” or for “intelligent life”. One of these “loose” assumptions was that dolphins are intelligent but never decided to build communication equipment. Nonsense! Dolphins are not intelligent life. Agreed they are smarter than the average bear, but they do not build tools and have not, to our knowledge, made attempts to communicate with the human race on a mass or any other basis. Using this assumption, dogs, chimps, parrots, cats, and a lot of other creatures would be considered intelligent. Are we just too dumb or just not advanced enough to understand these species? Most of us would argue definitely not, especially when referring to dogs and cats!

We will define here that an intelligent civilization is a civilization that develops a society, tools, and the desire to improve conditions through use of the race's abilities. Perhaps many of the creatures on Earth will eventually evolve to become "intelligent" but for now only humans have exhibited the traits as per our definition.

It is possible however that some of these civilizations are smarter and more xenophobic than we are. The more xenophobic-minded civilizations might be more protective of their society and will hide their communications signals with hopes of not being detected by hungry aliens. This could be an excellent defensive strategy. Drake did suggest there would be such civilizations.

As the world witnessed during the Cold War, secrets are hard to keep. If some industrious group really desires to learn a secret, they will eventually figure out a method to do so. A really good example of why a civilization cannot hide easily from advanced civilizations is the development of extremely large aperture telescopes. We are not talking about slightly larger than Hubble Space Telescopes here. We are talking about telescopes with primary apertures hundreds of kilometers in diameter. NASA is already conducting studies and experiments to develop such telescopes that could even image features on the extra-solar planet's surfaces, not just images of distant planets themselves. Recently in his book *The Sun as a Gravitational Lens: Proposed Space Missions*, Claudio Maccone, a space scientist at Alenia Aerospazio in Turin, Italy, suggests implementing the sun's gravitational lensing effect (as predicted by Einstein's General Theory of Relativity) in a telescope. In other words, the sun could be used as a lens producing an aperture the diameter of the sun. Its focus is at about six hundred astronomical units away. If the proper equipment were placed at the Solar focus, extremely detailed images of extra-solar planetary surfaces could be captured. Civilizations only moderately more advanced than we are could quite possibly implement such a telescope. Therefore, even quiet civilizations could be seen through such a telescope. Eventually, detection of such civilizations may not depend on their directly communicating with us by sending signals. The light from their star bouncing off of their alien rooftops and then onward to our giant telescope may be enough.

It is most likely that any advanced civilization could eventually detect any lesser-advanced civilization. Therefore, Drake's estimates of ten to twenty percent seem quite low indeed! Barring a major planet-killing event all "intelligent civilizations" per definition will eventually be detectable by a more advanced civilization. Hence, the value of the communication (which should be changed to detection) fraction is one hundred percent of all lesser-advanced civilizations. Making the arrogant assumption that half of all civilizations are less advanced than we are suggests that fifty percent of all civilization are detectable. For conservatism we will assume that only a quarter of those civilizations are less advanced than us, resulting in

$$f_c = 0.25 \tag{1.7}$$

This ironically is not far from Drake's original conclusion but for different reasons.

The last factor pertaining to how long will a communicating or detectable civilization remain detectable is really a guess at best. Drake suggested between one thousand and a hundred million years. Again, he used different criteria for communication. If we assume detection as part of communication, then any lesser-advanced civilization would remain detectable as long as they existed or until they leapfrogged us in technological advancement or lost the resource base to sustain their communication technology. For example, if a civilization had ever developed on Mars, we would see its ruins with our telescopes even if the civilization no longer existed for some reason. This is true unless it were a totally subterranean culture. The length of time that the Martian civilization would be detectable would be the length of time that the Martian civilization overlaps the length our civilization lifetime. This could only be a few million years! OUR SPECIES ANCESTORS ARE ONLY ABOUT 3 TO 5 MILLION YEARS OLD – the telegraph is less than 175 years old.

We have produced electromagnetic spectra potentially detectable by ET for less than 100 years by technical means such as those we know today. Our earliest signals have yet to reach many planets with the potential to host intelligent life. We may not have been detected by ET yet because we are too immature. However, if we consider the possibility of our speech or consciousness being detectable by more advanced technology than we possess, we could have been detectable for 3-5 million years (although the human species is about 200,000 years old its ancestral lineage is much older).

Although the likelihood that the detectable time of alien civilization might be very large, some conservatism should be used in order to have a plausible and realistic answer. Assume that this factor relates to the detection of live civilizations and to the overlap of that civilization being alive now while we are looking. This assumption reins in the range of values. Since we are missing a validated method to determine this value, we will use Drake's most conservative predicted value, where

$$L = 1000 \,. \tag{1.8}$$

Inserting the values for the above factors into equation 1.1 yields a value of about

$$N \approx 340 \tag{1.9}$$

detectable civilizations during the life of our civilization. The application of more conservative or liberal values for any or all of the factors changes the results significantly. With unknown factors chosen mostly by assumption, it is probably better to discuss a range of values of N in orders of magnitude. Assuming the lower end of the range to be an order of magnitude less and the upper range to be an order of magnitude higher then N is somewhere between thirty-four and three thousand four hundred detectable civilizations!

Now consider equation 1.1 without the factor L. This gives a rate of detectable civilizations developed per year as

$$dN = R_* f_p n_e f_l f_i f_c = \frac{340}{1000\,\text{years}} = 0.340 \,. \tag{1.10}$$

This set of mathematics leads us to the conclusion that a new detectable civilization develops roughly every three years. Remembering the order of magnitude error bars suggests a range on the rate at which detectable civilizations develop from once every four months to once every 30 years. Therefore, there is a reasonable probability of at least two new intelligent civilizations developing during the average life time of a human being. If we assume the development of new intelligent civilizations to have been constant at one every thirty years, at least 100,000 detectable civilizations would have developed during man's three to five million years on Earth. For further discussion, we will consider only the median value of one civilization every three years. However, be sure to remember the impact of the possible range of values.

During the time taken for man to mature from the point of standing upright to building the first telescope (roughly 3-5 million years), more than one million detectable civilizations could have possibly developed. Even if we use the lower end of estimates of the age of the Earth, three billion years, more than one billion detectable civilizations have possibly developed since Earth was formed! Figure 1.1 shows a log-log scale graph of the number of civilization that develops as a function of time in years. The range is from one year to five billion years. Note that in the 10 thousand years of so-called human civilization more than fifty thousand detectable civilizations may have formed. In the hundred or so years that humans have mastered flight more than 50 alien civilizations may have developed.

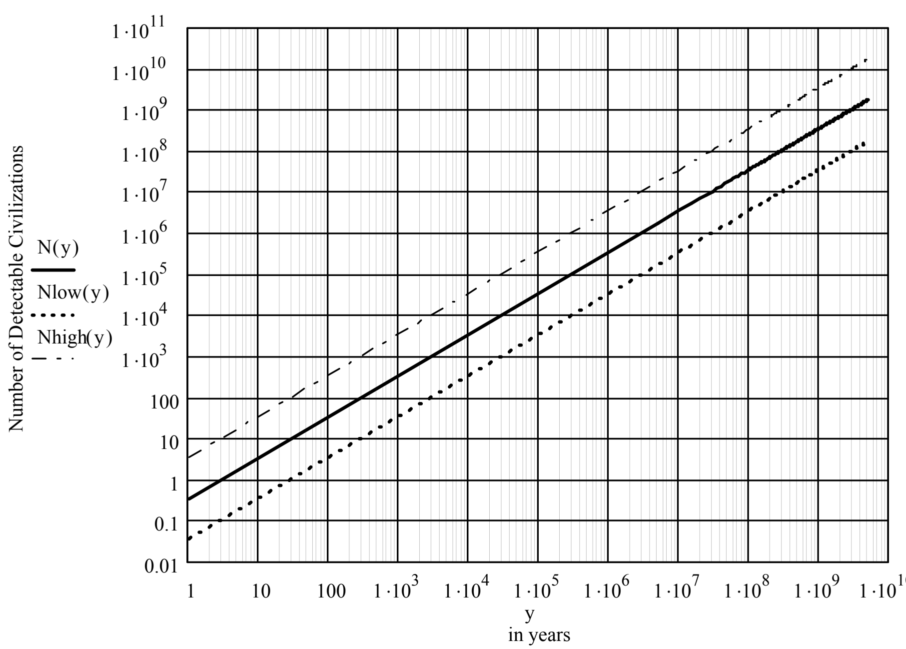

Figure 1.1 The number of detectable civilizations that develop over time in years

Now consider equation 1.10 as the rate of development of new detectable civilizations. The argument made previously for the value of f_c was that 25 – 50% of the civilizations were lesser-advanced. In other words, 50 -75% of the intelligent civilizations were more advanced than ours. This also suggests that equation 1.10 is also the rate of development of more-advanced civilizations that are undetectable to us for whatever reason.

Assuming that some fraction of these advanced cultures decide to travel to other systems then the number of "travelers" can be expressed as

$$dN = R_* f_p n_e f_l f_i f_c f_t \qquad (1.11)$$

where f_t is the percentage of traveling civilizations. What would be a good estimate for this factor? One could argue that eventually all such civilizations would eventually want to venture out and explore space. *However, that may be a purely human motive!* But, it is probable that such a civilization would have a need over time for more resources than are available within one star system. It follows that celestial travel is possibly a long-term requirement for the survival of a species. No matter how much we would like to stay at home, we must eventually either venture out into our world for food and resources as we deplete our domestic supplies or someone must bring them to us if our civilization is to endure. It is reasonable to assume that this same scenario exists for many, if not all, other civilizations. Therefore, an infrastructure must be developed for such survival. It is possible that some civilizations would reach such a point of advancement that any needs for survival could be manufactured right out of the very fabric of spacetime, but such advanced cultures would probably have had to travel in their past to have survived to reach such a point. Hence, all advanced civilizations must reach a point where traveling is required; therefore,

$$f_t = 1. \qquad (1.12)$$

Let us assume that civilizations older than one billion years have evolved into godlike or "Q" like (from *Star Trek: The Next Generation*™) and will not be considered in this calculation. From the calculations conducted thus far, about half a billion (see Figure 1.1) traveling civilizations of interest are possibly present in our galaxy now.

Now we need a velocity factor that describes how fast these advanced aliens can travel. Assume the time period of the human civilization to be about ten thousand years (some would debate that three to five is more correct but there are cities dating back even further than ten thousand years). The Milky Way galaxy is about one hundred thousand light years in diameter. If the aliens can travel just one percent of that distance in ten thousand years then the velocity factor for their civilization becomes

$$v = \frac{(0.01)(100{,}000\,\text{lightyears})}{10{,}000\,\text{years}} = 0.1\,\text{light years / year}. \qquad (1.13)$$

This velocity is nonrelativistic and is reachable using physics, as we currently know it. In fact, it is possible that spacecraft propulsion technologies currently being studied, such as Solar and Laser Sails, could offer such velocities. The human race will have developed such technology within the next few years to the next few decades. This nonrelativistic speed is much too conservative an estimate. A billion-year-old civilization has a high probability of being much further advanced in the development of propulsion technologies. Even civilizations at least a few hundred years older than our civilization should have much faster propulsion technologies. We will assume this very conservative velocity for now.

Now consider that the galaxy is a two dimensional circular surface area whereas the stars of the galaxy are uniformly distributed about that circle. This is not actually the case but it is a fair approximation of the galactic structure. Therefore, if there are a half billion travelers of interest in the galaxy then the density of travelers, σ_t, in the Milky Way is

$$\sigma_t = \frac{500x10^6 \text{ travelers}}{\pi R_{galaxy}^2} = 0.064 \frac{\text{travelers}}{\text{lyr}^2} \quad . \tag{1.14}$$

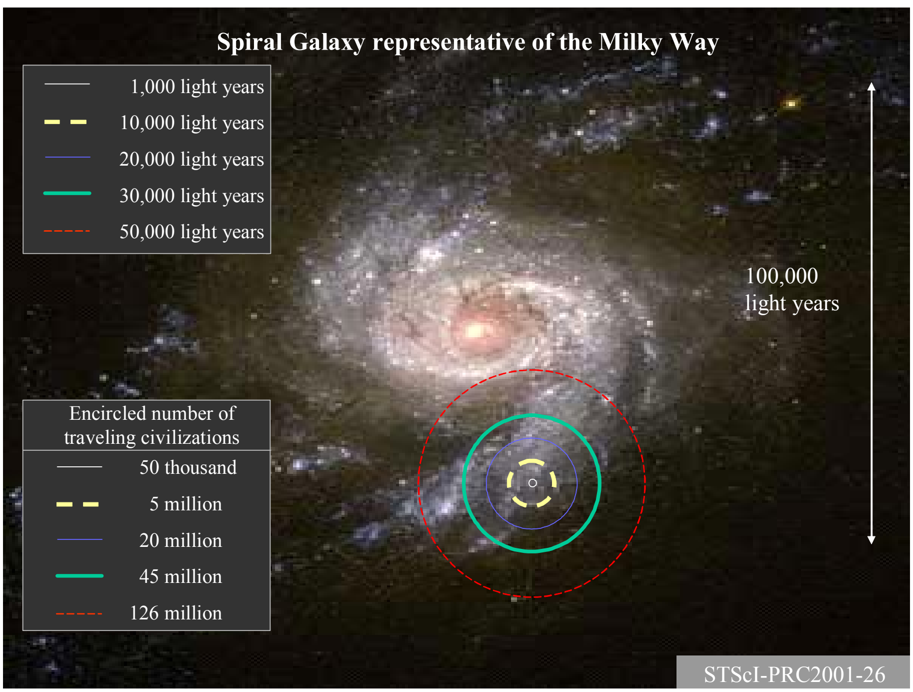

Figure 1.2. Theoretical number of traveling civilizations imposed on the galaxy (the spiral galaxy image comes from the Space Telescope Science Institute Public images WWW site)

An Introduction to Planetary Defense

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