

*Game Theory in Space: The Equilibrium State of The Universe and Its Implications
in Space Law*

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Abstract:

This paper will argue for the adoption of a new foundational principle of space law called Dark Forest Theory: the idea that at its core states that all planets with intelligent life must work to hide from all other planets with intelligent life to avoid a pre-emptive strike. Dark Forest Theory has existed in some form in academia for many years as a game theory-based resolution to the Fermi Paradox, although it did not always go by that name. Dark Forest Theory is neither fact nor law, it is simply to be an assumption on which to base future laws governing Earth's outer space activities. For economic and moral reasons, Dark Forest Theory must operate similarly in space law as the work of John Locke operates in the founding documents of the United States: a philosophical foundation on which we build a legal future.

Section I: What Does Any Of That Mean?

Dark Forest is a theory whose full understanding depends on some cross-disciplinary reading, especially when it comes to practical applications in law today. A full grasp of its importance to us and the urgency with which it should be implemented requires an understanding of the basics of Space Law, The Fermi Paradox and The Drake Equation, and two important facts of physics: 1) It is impossible to move anything faster than the speed of light and 2) the universe is very big. This paper will assume the reader knows none of those first three terms and will explain them in this section.

From the website of the United Nations Office of Outer Space Affairs:

“Space law can be described as the body of law governing space-related activities. Space law, much like general international law, comprises a variety of international agreements, treaties, conventions, and United Nations General Assembly resolutions as well as rules and regulations of international organizations.

The term "space law" is most often associated with the rules, principles and standards of international law appearing in the five international treaties and five sets of principles governing outer space which have been developed under the auspices of the United Nations.

Space law is a nascent legal area and before precedent can be set with case law, it must be set with some axiomatic assumptions about humanity’s values as well as our proper roles in outer space. As a result, the entirety of space law is made up of 5 treaties and 5 principles. They are as follows, each accompanied by my own quippy summary:

1. The "Outer Space Treaty" -- No one can own territory in space
2. The "Rescue Agreement" --You have to help rescue astronauts, even if they are not yours.
3. The "Liability Convention" -- You are liable for damage caused by your space objects.
4. The "Registration Convention" -- Please register your space objects
5. The "Moon Agreement" -- Leave the moon alone.
6. The "Declaration of Legal Principles" --No murder in space
7. The "Broadcasting Principles" -- Careful with your satellites.
8. The "Remote Sensing Principles" -- Don’t do too much spying

9. The "Nuclear Power Sources" Principles -- No space nukes allowed

10. The "Benefits Declaration" -- Space is the province of all mankind. Nations are to cooperate with one another in its exploration and use.

Space as an area of legal study is relatively new and small, but that only makes the precedents we choose to set now that much more consequential. Precedents are often decided through case law, but in this instance, principles will have to do. Right now, none of the principles or treaties of space law address the legal ramifications of a universe in which humanity is not alone because no evidence has yet surfaced to indicate otherwise, but this is a mistake. Humanity should assume that we are not alone until proven otherwise. Of course, proving a negative is an impossible standard, so humanity would effectively assume it is not alone for an indefinite amount of time. According to Dark Forest Theory, such an assumption is an axiom we ignore to our peril.

Before we can explain what Dark Forest Theory really means or the logic behind it, we must understand something called the Fermi Paradox and the closely related Drake Equation. The Drake Equation is a probabilistic formula that approximates the likely number of civilizations in our galaxy with which we could communicate. It takes into account the average rate of formation of stars suitable for the development of intelligent life, the fraction of those stars with planetary systems, the estimated average number of planets per solar system with an environment suitable for life, the estimated fraction of suitable planets on which life actually appears, the estimated fraction of life-bearing planets on which intelligent life can emerge, the estimated fraction of civilizations that develop a technology that produces detectable signs of their existence, and the average length of time such civilizations produce such signs. Using this formula, Drake conservatively estimated that there should be at least 10 communicative civilizations in our galaxy, which does not sound like very many until you consider the long

history of Planet Earth with no convincing evidence of extraterrestrial intelligence of any kind. Ten civilizations are hard to miss when you've been searching for as long and as hard as we have.

The Fermi Paradox essentially asks “where is everybody?” It is the philosophical equivalent to the quantified, probabilistic Drake Equation. Enrico Fermi was a brilliant nuclear scientist who one day in 1950 casually asked his colleagues why no civilization had yet colonized the galaxy. For all intents and purposes, he said, it should not take very long for a civilization to do when observed on a cosmic scale. It may take a civilization 10 million years to colonize a galaxy, but the galaxy is well over a thousand million years old. Where is everybody?

Over the decades, many intellectuals have posited different resolutions to the Fermi Paradox, with explanations coming from a vast range of disciplines from physics to sociology. Some put forth that the reason we have not seen any evidence of extraterrestrial life is that there is none: the probability of life is smaller than the universe is big and we are a massive cosmic coincidence. This is sometimes colloquially referred to as Rare Earth Theory. Another potential reason is that other civilizations are simply too advanced to care what we are up to, The Great Silence Theory. Many theories have been put forth and each of them has an apt and dramatic name. For the purposes of this paper, we will refer to theories like this as Fermi Resolutions. Some Fermi Resolutions are as convincing as Dark Forest Theory, but none of the others are useful as foundational principles of law because it is the only one with legal implications and rules of proper conduct associated with it.

Section II: What Is The Dark Forest?

Game theory as a subject is most popularly explained through the Prisoner's Dilemma, so let's take ourselves through an exercise very much like it in order to understand what Dark Forest Theory actually is.

Imagine you are in an empty room with a button on a podium in the center. The button has a small screen near it which is turned off. There is nothing in the room and you have no way of leaving or communicating with the outside world. Perhaps you don't press the button immediately since you are rightfully anxious and uncertain what it will do, but eventually, your curiosity will get the better of you and you will press it. It is only a matter of time. Once you press the button, the screen activates and reads this message to you:

"There is a stranger in another room exactly like this one. If you press the button a second time, it will kill that stranger. If they press their button two times, you will die."

Perhaps the stranger has not pressed their button the first time and has no idea of the situation. After all, it took you a minute to press your own. But it was only a matter of time for you and it is only a matter of time for them. Perhaps you imagine the stranger has pressed the button once, but you are a benevolent person and do not want to press the button yourself. Unfortunately, you have no way of knowing how benevolent the stranger is. Moreover, you have no way of knowing how benevolent the stranger believes you to be, so even if you trust their benevolence, you can't necessarily trust in their trust of your benevolence. Even if you did, you have no way of knowing if they trust in your trust of their trust of your benevolence and so on. Mutually assured destruction with no ability to communicate meaningfully results in what science fiction novelist Cixin Liu, the one who gave Dark Forest Theory its name, calls The Chain of Suspicion. Eventually, no matter what, the chain collapses and one party kills the other in a preemptive strike.

Now let's modify the exercise a bit: the room is no longer empty. It has everything you need to sustain your life happily and healthily. It's not paradise, but it's enough. You're not sure exactly how you got there and sometimes the question keeps you up at night, but for the most part, you just find ways to happily occupy yourself in your magic room: a magic room that gives you what you need, has no scary buttons and has only the fun kind of screens, like iPads and TVs.

One day you put on some music while you arrange the furniture in your magic room. The magic room has a very nice sound system and you love to play your music loudly while you work. You don't mind the noise, but it occurs to you that you may be bothering the neighbors. Hold on, are you sure you have neighbors? It would make sense for you to have neighbors, but you've never seen them. As you contemplate this, one of the many screens in your magic room reads you a message:

"There are many strangers in many rooms just like this one. Some have a button that can kill you instantly, others do not. No one knows who has a button and who does not. A button can appear in a room at any time. Soon, they will all hear your music."

You aren't sure if your neighbors have the desire or capability to destroy you. You aren't even sure if they exist. But you're still going to turn off your music, right?

That, in essence, is the Dark Forest Theory. The notion that the universe can be understood as a dark forest full of hunters, each searching for any other life form to destroy while hiding from all others. The massive amount of space between civilization-bearing planets makes meaningful communication impossible due to the limits of the speed of light, but destroying a planet or even a solar system is not complicated. Sure, we can't do it right now, but after some achievable advances in nuclear fission technology, we could probably build a nuclear bomb that

could cause a sun to expand and destroy the planets which orbit it. Or simply hurl a small near-light-speed object at the planet itself. The technology is currently out of our grasp, but the idea is extremely simple.

		The Universe	
		>0 Hunters	0 Hunters
One Civilization	Hides	Civilization Survives	Civilization Survives
	Does Not Hide	Civilization Destroyed	Civilization Survives

Of course, communication is technically possible, but when hundreds of years are passing between messages, that communication cannot hold any real weight. The communicating civilizations may be excited to make contact, but they won't be able to conduct diplomacy. And while some planetary civilizations may be incapable of destroying any others (like us), the development of such technology is unpredictable. Our civilization developed from a stone age to a nuclear age in just 6,500 years, a blink of an eye on the scale of the universe. Since destruction is simple and meaningful communication impossible, a chain of suspicion forms. This means that any time a planetary civilization discovers the existence of another, it is in that civilization's interest to destroy the other as soon as possible, so as not to be destroyed themselves. Because of this, every civilization hides from every other civilization. No radio broadcasts, no SETI, just hiding. The Nash Equilibrium state of the universe is a dark and quiet forest.

Dark Forest Theory may be a lot of science fiction nonsense. Maybe Earth is just uniquely teeming with life, or maybe interstellar travel, communication, and warfare are all so difficult that no one has figured it out yet. There are many resolutions to the Fermi Paradox, and whether Dark Forest Theory is the most compelling is subjective and also irrelevant. What

matters is that of all the many reasons we may not have witnessed extra-terrestrial intelligence, Dark Forest is by far the most dangerous.

Section III: Why Is The Dark Forest?

At its core, Dark Forest is a game theory principle first and a legal principle second so here's a good old-fashioned payoff matrix. It is similar to the actual Dark Forest payoff matrix shown above but explains the payoff of assuming the Dark Forest is the case rather than the payoff of abiding by it.

		Actual State of The Universe	
		A Dark Forest	Any Other State
Humanity's Assumption of the State of The Universe	A Dark Forest	Humanity May Survive	Humanity Will Survive
	Any Other State	Humanity Will Not Survive	Humanity Will Survive

No other Fermi Resolution gives this result. By employing some Pascal's Wager logic, it is clear that Dark Forest is a vitally important principle that should be adopted by the international space community as soon as possible, to avoid humanity's complete annihilation.

And that may be enough to convince some people, but the readers of this paper are surely too sharp a group of critical thinkers to accept a Pascal's Wager as a reason to adopt a new foundational legal principle. Fortunately, there are more reasons for the viability of this theory than a simple payoff matrix. To best understand those reasons, it is best to put Dark Forest in the context of other Fermi Resolutions. The scope of this paper is too limited for a full breakdown of each one, but we can divide them into useful categories and throw out the ones which have no

legal consequences. To reiterate, Rare Earth Theory states that Earth is a planet uniquely suitable for intelligent life and no other alien civilizations exist because Earth is a rare planet. There are a large number of Fermi Resolutions that essentially amount to “there are no aliens at all” for various reasons, but none of those theories have real legal or economic ramifications, so we can simply disregard all Fermi Resolutions under the Rare Earth category. This leaves three remaining categories, each with a fun pop-culture-based name: Among Us, Star Wars, and Independence Day. The first category is for all theories which posit that aliens have been found, but for some reason or other, we just don’t realize it. Maybe that’s where octopuses came from, or maybe the government is hiding away the little green men in Area 51. This paper will disregard those theories entirely because although octopuses are very weird, there is no useful conclusion to be drawn from such theories in terms of space law. Among Us theories render SETI to the bounds of Planet Earth and therefore out of the jurisdiction of space law. The second category refers to all Fermi Resolutions in which aliens live “in a galaxy far far away” and will simply never be found by us no matter how hard we look. This deserves the same treatment as the Rare Earth category; we can simply disregard it because although it is more scientific than the first category, it makes no real difference from our current situation legally speaking. The final category is the one in which Dark Forest belongs, essentially saying that aliens are out there and we may one day encounter them. Not only is this category the most fun, but it is also the most scientific and requires the fewest assumptions. If Drake’s calculations are to be considered sound, it is likely that alien life not only exists but exists within our observational capability. Barring widespread conspiracy, this category is the most likely.

A form of Dark Forest Theory was once touted by one of the greatest minds in physics to ever live: Dr. Stephen Hawking. Hawking believed that humanity should not send signals into

space because we are a planet ripe for colonization and exploitation. Although Dr. Hawking's logic regarding colonization does not necessarily hold up to scrutiny, after all, would we expect a civilization capable of interstellar travel to be incapable of harvesting the resources it needs from its own section of the galaxy? But we digress. Although Hawking may not have been exactly correct about an extraterrestrial civilization's motivations for making contact, he still assumed that the universe was silent because everyone was hiding from one another. Even if there were only one advanced civilization that abided by Dark Forest Theory and took every available opportunity to destroy any other civilization it encountered, the equilibrium state of the universe would be as we observe it to be: silent and empty, filled with hidden secrets.

The Fermi Paradox is an unignorable problem. We cannot be certain why we have yet to find extraterrestrial civilizations, but if we choose to ignore the possibility of their existence, we assume an astronomical risk of our own destruction or at the very least, an interstellar war for which we are entirely, hopelessly unprepared.

Section IV: Why Is This A Legal Essay?

We can safely assume at this point that some form of Dark Forest Theory effectively describes the state of the Universe. That being the case, there are some legislative actions to be taken, which fall under two principles: the Hiding Principle and the Deterrence Principle. The Hiding Principle is simple: it includes a heavy regulation of communication and broadcast technology, a complete halting of all CETI and METI operations (communication and messaging of extraterrestrial intelligence), and close monitoring of all activities which could otherwise give up our position in the galaxy. The Deterrence Principle is slightly more far-fetched, but no less important than the Hiding Principle. If Earth were to be threatened by another civilization, our

best hope would be to use the Dark Forest itself as a weapon. While broadcasting technology must be regulated, it should not be halted entirely, as it could be humanity's most useful and cost-effective asset.

First, The Hiding Principle. Humanity needs to avoid playing its music too loudly. At this time, we are mostly safe. Although radio waves do go into space every time we use them and those waves do travel forever, the signals attenuate over vast distances and after a few light-years, the signal is indistinguishable from the noise of the cosmic microwave background. This represents the economic balance of the situation: broadcast technology is valuable and good for society, but we cannot allow it to go beyond a certain limitation or we risk alerting the universe to our location. So where is that magic balancing point?

A civilization becomes potentially dangerous when we cannot meaningfully communicate with them because the distance between our worlds is too vast. If worlds are 500 light-years apart, then each message is received by a civilization entirely different from the one for whom it was intended. Imagine sending a letter to a friend's house knowing that it would not arrive for 500 years. What could you even say? One could argue that it's the same house, but the person you meant it for will be long gone by the time it gets there. Meaningful communication is not possible when so much time is lost with each signal. Even if the messages are only 100 years apart, that is more than enough time for a culture to change or technology to advance to a threatening level, so diplomacy is impossible and a pre-emptive strike is inevitable. At 50 years apart, the threat of pre-emptive strikes is not immediate, but the delay still invites scrutiny between each civilization which could lead to a strike any time one world predicts the other to be within 50 years of becoming a threat, so any diplomatic efforts are precarious at best. At 5 years, a pre-emptive strike becomes far less likely as that is a short enough span that genuine cultural

exchange and sharing of ideas can occur. Civilizations this close together may become capable of destroying one another, but the window of time between communications is small enough that communication can be meaningful and the worlds can keep an eye on one another. Therefore, the level of risk associated with broadcasting our presence to worlds within 5 light-years of us is acceptable

Typically, signal strength is measured in Watts/Hz/square meters, Watts referring to the power output required for the transmission to occur, square meters referring to the surface area of the sphere within which the broadcast must be readable, and Hz (hertz) referring to the frequency of the signal. These factors balance one another to determine what is required for a signal to reach a certain distance. If we impose a legal limit of 5 light-years distance a signal may be allowed to reach, that gives us a radius of surface area of 2.8×10^{34} square meters. To produce a sound above -224 dB (the average noise level of cosmic radiation), a signal would need a power of about 2.5 million watts at a minimized frequency, which is roughly equal to that of the Bolshakovo transmitter near Bolshakovo, Russia, once the most powerful radio transmitter on the planet. To go back to our music metaphor, we are currently capable of playing our music just at the limit where our closest neighbors can hear it. We cannot afford to turn it up any louder.

Beyond regulating our broadcasts into space, there are other hiding activities we must engage in. Specifically, any ongoing attempts to communicate with or send messages into the void of space must of course be immediately halted. There are currently a large number of CETI and METI groups who are working to broadcast into space, each of which is made up of qualified and intelligent individuals who value their research, which is why putting a stop to them will require the force of law.

The writer of this paper is not a scientist, just a nerd. There may be, and in fact almost certainly are, many other expressions of The Hiding Principle besides a strict lockdown on radio transmissions. Who knows what other activities of ours can be seen at interstellar distances? When we eventually come to understand our visibility better, this paper-writer will certainly not be the first to know. That is why it is essential that these principles be adopted now so that the international scientific community is aware of the consequences of their actions and the importance of their discoveries.

We may do everything in our power to hide, but our ability to hide from an attack and our ability to respond to one are very different things. We need both capabilities. What would happen if an advanced civilization on another planet discovered our location and tried to destroy us? The honest answer is, probably not much. If a civilization were advanced enough, they would probably be able to destroy us before we even knew of their existence. However, that does not mean we should be unprepared. There is always a chance that we do have some opportunity to respond. We could use our Dark Forest logic to justify massive investment in interstellar warfare technology, but that would be impractical, expensive, and useless without significant advances in a wide range of scientific fields. Besides, chances are we would be outclassed anyway. In a pond the size of the universe, there is always going to be a bigger fish. Although humanity's extinction is the least efficient economic outcome, avoiding it does not necessarily justify a massive expense toward rapid technological advancement. There is a far more elegant solution: use the universe's morbid non-cooperative game against itself. For a far more manageable economic burden, we can invest in powerful communication and telescope technology which is strictly for the use of Dark Forest Deterrence. This technology would need to never be fully tested, as testing a broadcast would of course play the music too loud and reveal our location, but if used

carefully, it could be more powerful than any other weapon we could create. Should Earth be attacked by an advanced civilization, our most powerful response would be the threat of broadcasting our enemy's location to the rest of the universe. With a sufficiently powerful radio transmitter and the technology necessary to pinpoint the location of other worlds, we could hold the cosmic equivalent of an Intercontinental Ballistic Missile and stave off an attack through mutually assured destruction. To do that, we must adopt the Deterrence Principle: the notion that Earth must be prepared to respond to an attack from another world through an otherwise-illegally powerful broadcast. Of course, the implementation of such a principle would require not only advanced telescope and communication technologies, but also the ability to communicate our capability to the extraterrestrials, but such details are beyond the scope of this paper. What is important now is that the international space community has its priorities properly aligned.

Section V: Conclusion

The actual implications of Dark Forest Theory are as far-reaching as they are frightening. It may prompt a reader to become overwhelmed with existential dread. After all, hiding only works for so long. We may adopt these principles tomorrow, but eventually, something will slip or humanity will lose its way and grow complacent. Maybe humanity stays the course and hides well, but is found anyway through no fault of their own. What then? If there is always a bigger fish in a pond the size of the universe, what hope can we ever have of staying uneaten?

These are questions too big for anyone to answer now. What we do know is that humans tend to act with some strange mixture of decency, self-interest, and an abiding by the law as they understand it. The adoption of Dark Forest Theory as a legal principle in space law is not supposed to save us all: it's supposed to set a precedent. To give us all a road map. When human

beings first understood that what they valued could be owned by individuals, they had to decide what it meant when the values and ownerships of individuals conflicted with one another.

Presumably, after a lot of violence, we collectively decided Thou Shalt Not Steal. In fact, not only shalt thou not steal, but thou shalt not even covet. Maybe humanity will never agree on the nitty-gritty details of who said Thou Shalt Not Steal the best, but pretty much all of us agree with the principle. The principle does not save us from theft, nor covetousness, nor any other form of property right violations. Principle merely explains to us what we know to be fit and provides us with the understanding necessary to respond to what is unfit.

Who knows what the future of space exploration holds? We may find intelligent life in our own solar system, advance at a frenetic pace, and create a utopian alliance without ever sparing a thought for the possibility of interstellar warfare. We may also find that we are even more vulnerable to the hunters than we previously assumed. No one can know how our culture and our capabilities will change in the coming centuries, but we can know what is valuable. We can articulate to ourselves a need to survive as a species. We can economically motivate not only a responsible level of technological advancement but also a frame of mind that considers humanity as a single species united in purpose. The notion that the planet is constantly under threat is one that applies equally to all nations, creeds, and peoples. If we can provide the world with an incentive to preserve itself as a collective simply by adopting an eleventh principle in a short list, what is to stop us from doing just that?

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