North Carolina Agricultural and Technical State University

The Alcubierre Warp Drive

A History and Analysis

Marquin Spann, David Vermillion, and Devon Williams

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Dr. Floyd James

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The study of the vast expanses of the universe has been a topic for subject since the first man gazed at the sky. Throughout written history, man has proven mathematical equations that satisfy the observations made from nature and phenomena occurring as a result. With every new discovery, our depth of understanding furthers, our acknowledgement of the unknown deepens and our imagination for what comes next drives us. In 1903, the first successful airplane was flown and in 1961 Russia sent the first person into outer space. With these two historical breakthroughs, our imaginations on what was possible blurred even more. In 1966 film creator Gene Roddenberry aired the first episode of the Star Trek television series about a futuristic life with space travel and alien technologies. Massive ships capable of reaching distant stars almost instantaneously through vibrant funnels of light, teleportation, and time travel help scientists of today think of ways to transform our seemingly realistic imaginations into actual, functioning products.

There are two prevailing methods proposed for making a warp drive move a spaceship. In 1994, Theoretical Physicist Miguel Alcubierre theorized the first probable solution to intergalactic travel. Miguel Alcubierre proposed the predominant method which involves *contracting* the space in front and expanding the space behind the ship (Alcubierre 6). José Natário proposed another method involving *sliding* space rather than squeezing and pushing it (Natário 1). Most of the literature reviewed for this paper assumed Alcubierre's model by default and either ignored or only mentioned Natário's method in passing. Additionally, Natário mentioned the sliding method not so much as a proposed solution to making the process function, but rather simply to point out that squishing space ahead and inflating it behind may not be the only way to make a warp drive work (Natário 1).

Prior to these two ideas, Einstein's theory of relativity 1905 made the idea seem impossible. This theory suggested that: "the speed of light within a vacuum is the same no matter the speed at which an observer travel. As a result, he found that space and time were interwoven into a single continuum known as space time. Events that occur at the same time for one observer could occur at different times for another (Redd)." Time does not pass at the same rate for everyone. A fast-moving observer measures time passing more slowly than a relatively stationary observer would. Therefore, a traveler moving at warp speeds leaving earth for years at a time will return to find out that Earth inhabitants would have aged quite notably compared to the traveler. Depending on the time away from Earth the traveler would be arriving back to a planet that has had more time to advance then the traveler. Warp drive time travel only works in warping to the future not the other way around as to warp to the past.

The concept of a warp drive proposed by Alcubierre, and Natário does not allow for a ship itself to exceed the speed of light. It is the warp bubble that travels past the speed of light from the perspective of outside observers. Inside observers have no acceleration. Incidentally, the mechanics of this setup allows for a round trip from A to B to not cause time-dilation problems typically associated with relativistic travel (Alcubierre 6). What appears to be two years for the occupants will also appear to be two years back home for them. While this is currently only an academic thought experiment with no currently foreseeable method of making it possible, space-time expansion travel did noticeably occur in the past. Specifically, during the universe's formation, two objects sufficiently apart from each other would observe the other to be accelerating away from one another beyond the speed of light (Alcubierre 2). This would occur because the fabric of space-time started very small and then suddenly expanded very rapidly. For example, if a piece of very stretchable cloth were laid out on a table and two coins were put 10 centimeters apart, as the cloth is pulled apart the coins would also noticeably stretch apart with the cloth.

Given these methods of how to make a globally superluminal drive work, there are some additional required pieces to make it operate. Specifically, for superluminal effective speed, due to several energy condition violations, negative energy through exotic matter is required (Alcubierre 9). Alternatively, for the purposes of developing lab models or scale proof-of-concepts, ideally maximized electromagnetic metamaterials could be used. However, they are effectively limited to 25% of the speed of light (Smolyaninov 5–6). While metamaterial-based models will likely be the first to be developed, which will also help improve the mathematical models for negative-energy based superluminal vehicles, not only are even these likely a few decades away from being technologically possible, but because they give subluminal effective speeds, this paper focuses on negative-energy based models.

Observing the geometrical arguments made in Alcubierre's original paper, he recognized that negative energy from exotic matter would be required to counteract the energy conditions violated (Alcubierre 9). While making that astute observation, he appears to have greatly underestimated just how much exotic matter would be needed (Van Den Broeck 3). The exact amount of exotic matter required does vary depending on the chosen geometry and warp bubble thickness chosen (Pfenning & Ford 9–10). With the original parameters laid out by Alcubierre, Chris Van Den Broeck calculated that the amount of exotic matter required was several orders of magnitude larger than the matter in the entire observable universe (Van Den Broeck 3). However, after optimization using work laid out by Michael Pfenning and L. Ford, Van Den Broeck managed to whittle down the required exotic matter to only a few solar masses.

However, in addition to still being untenably large, Van Den Broeck assumed extreme energy densities unlikely to be feasible (Van Den Broeck 8).

Analyses of the works of several authors on the subject matter lead to the conclusion that this thought experiment still has substantial room for improvement before being actively attempted. Alcubierre mentioned at the end of his original article that there are many presently unexplored methods (Alcubierre 9). Some of these may eventually work far better. One last note on the mechanics of this topic is that unlike traditional spatial propulsion methods such as walking, using wheels, propellers, jets, or rockets, the warp drive is a reactionless drive. Specifically, rather than using an active force to achieve a reaction force to provide motion, this drive manipulates the geometry of space itself to achieve relative movement.

To recap, a warp drive works by either squeezing and expanding or sliding space itself. It requires electromagnetic metal materials for proof of concepts at subliminal speeds. It also needs exotic matter to satisfy the necessary geometric equations' demand for negative energy, thus obtaining superluminal speeds. Under both methods, it maintains a stable center that is free from time-dilation, locally-relative acceleration, or locally superluminal speed.

In an article posted By Extreme Tech's writer Ryan Whitwam in 2012, Alcubierre's warp drive theory receives criticism as a possible planet, solar system destroyer. The arguing theory states that when the object forms a warp bubble, high energy particles will accumulate as the ship travels. Once a designation is reached the possibility of explosive release of trapped particles would have the capability of destroying whatever is in front of the ship. Not only is the disengaging of a warp drive potentially dangerous for any leading body, but theory also states that the center of the bubble would also be detonated (Whitwam).

With the introduction of a warp drive as a scientifically proven idea, the main characteristic of application of Alcubierre will be space-time travel. This will in turn extend the reach of humans. Humanity is subjected to multiple types of extinction events like manmade nuclear disasters, warfare, drastic climate changes, ocean acidity, asteroid impacts, and solar coronal mass ejections etc. Specifically, our solar system has very few options for celestial bodies capable of sustaining human life and the inter-solar system travel is beyond the reaches of our known technology. Warp drive could take us outside of our solar system and far beyond our galaxy. However, even with the existence of a warp drive, terraforming and colonizing environments too hostile for human life to exist would require far more advanced technology. A colonizing space industry can expand economic development, create new high tech jobs and innovative technologies that can create new investments and wealth. Resources in space, both in materials and energy, are extensive. Harvesting material like precious metals, gemstones, and rare gases will have a very high return on the initial investment in space infrastructure.

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