The Newsletter of the Interstellar Research Group

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Have Starship, Will Travel

How Far Can Civilization Go?
BY ROBERT H. GRAY

Robert H. Gray, author of The Elusive Wow: Searching for Extraterrestrial Intelligence, has searched for radio signals from other worlds using the Very Large Array and other radio telescopes. In today's essay, Gray takes a look at a classic benchmark for assessing the energy use of civilizations, introducing his own take on Earth's position in the hierarchy and how these calculations affect the ongoing SETI effort. His scientific paper on the extended Kardashev scale appeared in The Astronomical Journal (https://iopscience.iop.org/article/10.3847/1538-3881/ab792b). Photograph by Sharon Hoogstraten.

Human civilization has come an amazingly long way in a short time. Not long ago, our major source of energy was muscle power, often doing hard work, while today much more energy is available from fuels, fission, hydro, solar, and other sources without breaking a sweat. How far can civilization go?

It's probably impossible to say how far civilizations can go in areas like art or government, because such things can't be measured or forecast, but energy use is measurable and has trended upward for centuries.

The astrophysicist Nikolai Kardashev outlined a scheme for classifying civilizations according to the amount of energy they command, in order to assess the type of civilization needed to transmit information between stars. He defined Type I as commanding the energy available to humanity in 1964 when he was writing, Type II could harness the energy of a star like our Sun, and Type III would possess the energy of all of the stars in a galaxy like our Milky Way.

Harnessing the energy of stars might sound like science fiction, but solar panels are already turning sunlight into electricity at a modest scale, on the ground and in space. Gerald O'Neill and others have envisioned orbiting space settlements soaking up sunshine, and Freeman Dyson envisioned something like a sphere or swarm of objects capturing all or much of a star's light.

Carl Sagan suggested using Arabic numerals instead of Kardashev's Roman numerals, to allow decimal subdivisions, and he suggested more uniform power levels. He re-defined Type 1 as 10^{16} watts—very roughly the Sun's power falling on the Earth—and he rounded off Type 2 and 3 levels to 10^{26} and 10^{36} watts respectively, so planetary, stellar, and galactic categories increase in steps of 10^{10} or ten billion. A simple formula converts power values into decimal Types (the common logarithm of the power in megawatts, divided by ten). In the recent year 2015, human power consumption was 1.7×10^{13} watts, or Type 0.72—we're short of being a Type 1.0 planetary civilization by a factor of roughly 600. In 1800 we were Type 0.58, and in 1900 we were Type 0.61.

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2021 Scholarhip Winners

Following a competitive process with many high-quality applicants, the Interstellar Research group has chosen three students as the recipients of our 2021 scholarships. With the support of Baen Books (who sponsor the Tim Bolgeo Memorial Scholarship), Rob and Ruann Hampson, and Jay and Beth Roye, we are awarding these deserving students one graduate scholarship ($2500) and two undergraduate scholarships ($2500 each). These scholarships were created to encourage the next generation to study science, technology, engineering, and math (STEM) fields that support the research needed to get humanity to the stars.

Our winners are David Webb (graduate), Morgan Barkhurst (undergraduate), and Colin Warn (undergraduate).

Read the two undergraduate essays on pages 3 to 5 of this issue.

HOW FAR CAN CIVILIZATION GO? (CONT'D)
BY ROBERT H. GRAY

The 2015 total power consumption works out to an average of 2,300 watts per person, which is 23 times the 100 watts human metabolism at rest, but it's not many times more than the 500-1,000 watts a human can produce working hard. Maybe we haven't gone all that far, yet.

I recently extended the scale. Type 0 is 10^6 watts or one megawatt, which is in the realm of biology rather than astronomy—the muscle power of a few frisky blue whales or several thousand humans. That seems like a sensible zero point, because a civilization commanding so little power would not have enough to transmit signals to other stars. Type 4 is 10^{46} watts, roughly the power of all of the stars in the observable Universe.

One use for the scale is to help envision the future of our civilization, at least from the perspective of energy. If power consumption increases at a modest one percent annual rate, we will reach planetary Type 1 in roughly 600 years and stellar Type 2 in 3,000 years—roughly as far in the future as the Renaissance and ancient Greece are in the past. That simplistic growth rate would put us at galactic scale Type 3 in 5,000 years which is almost certainly wrong, because some parts of our galaxy are tens of thousands of light years away and we would need to travel faster than light to get there.

There are, of course, many limits to growth—population, land, food, materials, energy, and so on. But humans have a history of working around such limits, for example producing more food with mechanization of agriculture, more living space with high rise buildings, and more energy from various sources. It's hard to know if our civilization will ever go much beyond our current scale, but finding evidence of other civilizations might give us some insight.

Another use for the scale is to help envision extraterrestrial civilizations that might be transmitting interstellar signals, or whose large-scale energy use we might detect in other ways.

If we envision ET broadcasting in all directions all of the time, they would need something like 10^{15} watts or 100,000 big power plants to generate a signal that our searches could detect from one thousand light years away using the 100-meter Green Bank Telescope. That means we need to assume at least a Type 0.9 nearly planetary-scale civilization—and considerably higher if they do anything more than broadcast—a civilization hundreds or thousands of times more advanced than ours. That seems awfully optimistic, although worth looking for. If we envision civilizations soaking up much of a star's light with structures like Dyson spheres or swarms, then unintentional technosignatures like waste heat re-radiated in the infrared spectrum conceivably could be detected. Some infrared observations have been analyzed along those lines, for example by Jason Wright and associates at Penn State.

If, on the other hand, we envision ET transmitting toward one star at a time using a big antenna like the 500 meter FAST in China, then we need to assume only something like 10^8 watts or one-tenth of one big power plant, although the signal would be detectable only when the antenna's needle beam is pointed at a target star. To catch intermittent signals like that, we will probably need receiver systems that monitor large areas of sky for long periods of time—ideally, all-sky and full-time—and we can't do that yet at the microwave frequencies where many people think ET might transmit. A modest prototype microwave receiver system called Argus has been monitoring much of the sky over Ohio State University in Columbus for a decade with very low sensitivity, and an optical system called PANOSETI (Panoramic SETI) is planned by Shelly Wright of UCSD and Paul Horowitz of Harvard to potentially detect lasers illuminating us.

Detecting some signature of technology near another star would be a historic event, because it would prove that intelligence exists elsewhere. But the U.S. government has not funded any searches for signals since Sen. Richard Bryan (D-NV) killed NASA's program in 1993, even though thousands of planets have been discovered around other stars.

Both Kardashev and Sagan thought civilizations could be characterized by the amount of information they possess, as well as by energy. An information scale much like the energy scale can be made using 10^6 bits or one megabit as a zero point—roughly the information content of one book. Sagan thought that 10^{14} or 10^{15} bits might characterize human civilization in 1973 when he was writing on the topic, which would be Type 0.8 or 0.9 using the power formula (he used the letters A, B, C… for 10^6, 10^7, 10^8… bits, but letters don't allow decimal subdivisions). More recent estimates of humanity's information store range from 10^{18} to 10^{25} bits or Types 1.2 to 1.5, depending on whether only text is counted, or video and computer storage are included.

Nobody knows what information interstellar signals might contain. Signals could encode entire libraries of text, images, videos, and more, with imagery bypassing some translation problems. What might motivate sending information between stars is an open question; trade is one possible answer. Each world would have its own unique history, physical environment, and biology to trade—and conceivably art and other cultural stuff as well. Kardashev thought that the information to characterize a civilization could be transmitted across the Galaxy in one day given sufficient power.

Whether any interstellar signals exist is unknown, and the question of how far civilization can go is critical in deciding what sort of signals to look for. If we think that civilizations can't go hundreds or thousands of times further than our energy resources, then searches for broadcasts in all directions all of the time like many in progress might not succeed. But civilizations of roughly our level have plenty of power to signal by pointing a big antenna or telescope our way, although they might not revisit us very often, so we might need to find ways to listen to more of the sky more of the time.

Additional Resources

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2021 WINNING UNDERGRADUATE SCHOLARSHIP ESSAYS

Following a competitive process with many high-quality applicants, the Interstellar Research group has chosen three students as the recipients of our 2021 scholarships. With the support of Baen Books (who sponsor the Tim Bolgeo Memorial Scholarship), Rob and Ruann Hampson, and Jay and Beth Roye, we are awarding these deserving students one graduate scholarship ($2500) and two undergraduate scholarships ($2500 each). These scholarships were created to encourage the next generation to study science, technology, engineering, and math (STEM) fields that support the research needed to get humanity to the stars. In this issue of our newsletter, we present the two winning undergraduate essays, with the graduate scholarship essay scheduled for publication in the next issue.

The Interstellar Research Group "was created to foster and assist the study, research and experimentation necessary to make human interstellar travel a reality, with untold benefits to life on Earth," said IRG President Emeritus John Preston. "We can imagine no better way to demonstrate that goal than the creation of these scholarships, helping new generations of thinkers, builders and explorers to set their sights on the stars."

WHAT I CAN DO TO HELP FURTHER HUMANITY'S EXPANSION INTO SPACE

BY MORGAN BARKHURST

Our first undergraduate winner, Morgan Barkhurst, is a freshman college student who studies solar sails in her spare time. She is pursuing a degree in Materials Engineering at the University of Central Florida. She is a space enthusiast who is fascinated by the science, math, and mystery of the universe. She is a two-time intern with NASA Marshall and has published with AIAA on her personal research project. She worked to repair Florida Gulf Coast University's Egan Observatory. Her recent work includes a trade study for a Lunar Safe Haven structure with NASA Langley and Marshall. She enjoys dancing like no one is watching as a creative release and is driven by her passion to learn new things and work collaboratively on challenging problems.

Interplanetary travel and even interstellar travel are not going to happen on their own. It will take years of collaboration, finances, and time to develop the necessary technology. I hope to be a small part of that effort so three generations from now, humanity can travel among the stars.

Ever since I have stumbled into the niche area of propulsion that is solar sails, I have been infatuated with the idea that light could be used as a "propellant." In August 2020, I was able to publish my research on the application of graphene to solar sail gossamer films, discovering by my rudimentary setups that graphene can significantly improve the reflectivity of these thin films. This is an exciting discovery, but the technology is not possible at this time. The largest monolayer piece of graphene created was about the size of a credit card, which is certainly not large enough to cover a future solar sail. Solar sails will only get bigger, but graphene technology is much more meticulous. This may sound discouraging; however, if we are not learning what needs to be improved, we will not have the time to improve it. We need people to explore the seemingly impossible, so we can eventually make it possible.

Last summer, I had the privilege of interning at NASA Marshall Space Flight Center, in which I was lucky enough to work on developing another type of in-space propulsion: electric sails, or e-sails. While this propulsion device is still in conceptual stages, it shows what I believe to be great potential. More specifically, an e-sail would theoretically be able to accelerate longer than a solar sail. Last summer, I worked with a team attempting to measure e-sail thrust within a lab setting – the first time anyone has tested this that I am aware of. I was able to help the team with testing design and help get them to a phase where preliminary testing was Feasible.

I have already created and been involved in multiple efforts to further the capabilities of humankind to travel through the galaxy. Since the beginning of my professional career, this is a desire that I hold close to my heart. Although I know I will not live to see my efforts fully pay off, I believe the world needs people like me to help get humanity closer to interstellar travel. Although my e-sail internship concluded last summer, my desire to advance the technologies of in-space propulsion devices did not. Under the advice of a colleague, I hope to repeat my research on graphene and its application to solar sails with higher precision. I also have a few questions about the combined material's tensile and electromagnetic properties that have been left unanswered. The pandemic has placed this goal on hold, but once lab spaces are more accessible, I plan to continue this study.

This summer, I will be working with NASA Marshall and NASA Langley on Lunar Space Haven, a sustainable astronaut habitat on the moon. This work is obviously still at a very conceptual and theoretical stage, but hopefully, it will be put to good use when needed. More specifically, I will analyze potential structures made of varying materials based on their efficiency to shield astronauts from radiation and micrometeoroids for longer periods of time. This project is directly correlated to the efforts of expanding humanity into space.

Following my internship, I will begin my undergraduate degree at the University of Central Florida. When I visited the campus, I reached out to a nanomaterials lab to get the chance to see some of the interesting research happening at UCF. Following my tour of the lab space, I was offered a lab assistant position for Fall 2021. The lab works with graphene, aerogels, thin-film coatings, lunar dust mitigation, and many other niche areas. I plan to begin working there as soon as I start classes to gain more research experience. I believe the research occurring there is utterly unique, and it would give me the chance to put my nanomaterial knowledge to the test. While the lab is more of a development lab, the applications of these materials will likely have ripple effects in the future of human spaceflight.

These are just a few examples of my near-term goals to help the effort of space exploration. I am an advocate for the increased NASA funding proposed by the Planetary Society to the Biden Administration. I believe the ways in which we search the cosmos will have benefits on our planet as well. There is interesting work being done at MIT called Space Enabled. This team works to put space technologies to use on our own planet to mitigate carbon emissions and slow the climate crisis. I hope to someday be in a position where I can advocate more publicly for space exploration and its importance for humankind.

In the long term, there are so many things I hope to be a part of that will help our expansion to space. I am interested in other in-space propulsion devices besides solar sails and e-sails, as well as unique research that will make a difference in the future of spaceflight. Being a materials engineering major, I am naturally drawn to the material challenges that prevent us from testing and launching other propulsion devices, but I am also interested in the engineering and logistic challenges that keep us from launching devices such as e-sail and many others. I am incredibly impressed by the prior generations that managed to journey to the heliopause with the Voyager missions, but I believe we can and will do better than that. I believe humans will live to see photos, videos and potentially travel to distant worlds. But that will not be possible without people taking interests in space exploration at its elementary phases.

When we work together, we accomplish great things. I hope my future career will be riddled with collaboration and ingenuity that will lead to groundbreaking discoveries. They may not be applicable during my lifetime, but I hope that my research efforts will help generations to come to venture to places we could only dream of today.

20 YEAR PLAN FOR INTERSTELLAR SPACE PROPULSION BY COLIN WARN

When Colin Warn, our second undergraduate winner, made the switch from a career in music to re-enroll in college, it was for one reason: To advance the bleeding edge of interstellar propulsion, and to do so with an enthusiastic team of people. Whether it was developing his college's first satellite to space in a university that doesn't have an aerospace department, or creating a Hall Effect Thruster in a university that doesn't even have a plasma physics department, he and his Washington State University classmates have never let a lack of resources stop them from making their space-fairing dreams a reality. When he's not writing whitepapers on topics such as interstellar braking methods, or pursuing summer research topics such as machine vision-powered tracking of microrobots, you can find Colin teaching music production, or training mixed martial arts at a nearby gym.

Interstellar space propulsion with the Interstellar Research Group is very much at the same point in its timeline that rocket propulsion was with the Verein für Raumschiffahrt in the 1930s. Many lessons between both groups can be drawn, though hopefully the former of these groups will keep an eye on who is in power if the military begins to take interest.

Step 1: Develop the technology

Step one is to create a roadmap that uses feasible technology at an affordable price-point. Humanity would love to go to another star system, but not if it bankrupts them in the process. In addition, a 20-year analysis on promising interstellar propulsion technologies should be based on current physics. As much as warp drives and worm holes would be great, they are currently not possible in our current understanding.

A quick flip through K. F. Long's "Deep Space Propulsion" [1] shows us the most promising realms:

- Electric propulsion
- Nuclear fusion and fission propulsion
- Beamed energy propulsion
- External nuclear pulse propulsion
- Antimatter propulsion

Out of these five technologies, external nuclear pulse propulsion and the combination of beamed energy, potentially in combination with electric propulsion, are the two most promising areas. If humanity had to travel to another solar system by 2025, external nuclear pulse propulsion would likely be the only way forward due to systems such as Project Orion and Project Daedalus being the interstellar propulsion technologies with the highest Technology Readiness Level (TRL).

If given a longer time horizon however, analysis by Lubin [2] concludes that beamed energy will outperform every other technology: Even a perfectly efficient antimatter propulsion system. Given the rocket equation significantly penalizes carrying the power source on board, the lowest cost interstellar solution will only happen if one keeps the power source at home and beams the energy. The problem of beam diffraction and spreading for beamed energy systems can be mitigated through photon-particle self-guiding effects. [3] Recent research has shown that combining beamed energy with direct drive electric propulsion, in addition to enabling high speed interplanetary travel. [4] This may be a crucial steppingstone in soliciting the funding for a more ambitious Project Starshot that beams this energy onto gram sized wafers that reach Alpha Centauri in 20 years. The same beamed energy system could be used for both applications.

Therefore, given our current understanding of physics, the most cost effective, viable option for interstellar travel in twenty years will be a beamed energy system. The power for this system will likely be generated by nuclear plants or solar energy. To avoid the geopolitical concerns of putting into the hands of a single country a high-powered laser which has the potential to deorbit or destroy any spacecraft it wants, the beamed energy system should either be distributed among many countries or should be placed on the far side of the moon. The later of these options is more likely, as the photon-particle self-guiding effects have only been shown to work in environments at sub-Kelvin levels so far.

Step 2: Develop the will

To fund a major undertaking such as sending a probe or humanity to another star system, one must look at the motivations for similar historical undertakings. Neil deGrasse Tyson, when talking about his blurb in The Columbia Encyclopedia of the 20th Century, argues that there are three reasons a major project historically gets funding: War, praise of a deity or royalty, or the promise of economic return. [5] If a strong advocacy case is to be built for the need of interstellar exploration, an argument which uses any or all of these three reasons will have the strongest Effect.

The development of beamed energy, the technology that will likely be the backbone of interstellar travel, will primarily advance thanks to the large budgets of defense contractors harnessing the technology for applications such as missile and drone

defense. Much like NASA's Hubble was a military satellite design repurposed for stellar observation, the beamed energy propulsion systems of tomorrow will likely be the repurposed beamed energy systems of the military today.

Further colonization of our own solar system will likely need to be the next step before serious conversation about funding for interstellar missions is solicited. The case for exploring other solar systems is much more difficult to make if our own solar system has been barely explored. As elucidated in step one, the same beamed energy propulsion systems that will be used to send probes to other solar systems can be combined with modern electric propulsion systems to enable high speed exploration of our own solar system: Killing two birds with one stone. Therefore, a near-term plan for building advocacy towards interstellar space propulsion should bring awareness and research funding to the areas which will enable quicker transit times of our own solar system.

Additionally, efforts to sustain the rising enthusiasm around space exploration should be continued. The world has seen the dawn of a new space age, a Space 2.0, thanks to companies such as SpaceX and Blue Origin. Voracious public appetites for movies such as Interstellar and The Martian show that a new wave of enthusiasm is growing and stronger than ever. The first US astronauts flown back to the space station on the first American made rocket in a decade garnered millions of views from around the world. Billions of dollars are being poured into contracts to set up lunar colonies. Millions are being poured into the electric propulsion technologies that, when connected to direct drive beamed energy sources, will enable rapid exploration of the solar system.

In conclusion, for a reader who is interested in practical next steps in advocating for interstellar missions, continue to advocate for the current trend of interplanetary travel. When possible, bring more awareness, research, and funding to beamed energy technologies. Finally, aim to create so much economic abundance in society that every citizen does not have to worry about where the next meal is coming from, but rather whether the latest class of citizens will survive their trip to Mars.

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UPCOMING INTERSTELLAR AND SPACE EVENTS

25-17 September 2021. IRG 7th Symposium. Website: https://irg.space/irg-2021/

16 October 2021. NASA launches its Lucy mission to study the Trojan asteroids

25-29 October 2021. International Astronautical Congress in Dubai, United Arab Emirates. Website: https://www.iafastro.org/events/iac/iac-2021/

16 December 2021. NASA's Artemis I uncrewed lunar orbital test flight.

18 December 2021. NASA launches its James Webb Space Telescope.