Have Starship, Will Travel
The Newsletter of the Interstellar Research Group
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IRG's 8th Interstellar Symposium - A Report

BY COLIN WARN

Colin Warn is an Associate Propulsion Component Engineer at Maxar, with a Bachelor of Science in mechanical engineering from Washington State University. His research interests range from electric spacecraft propulsion to small satellite development, machine learning and machine vision applications for microrobotics. He has published two papers on the topics of nuclear gas core rockets and interstellar braking mechanisms in the Journal of the British Interplanetary Society. When not working on interstellar research, he can be found teaching music production classes or practicing martial arts.

A few weeks ago I had the honor and privilege to attend and present at the 8th Annual Interstellar Symposium, which was held at the incredibly beautiful campus of McGill University in Montreal, Canada. This was my second time attending this conference, the first being in Tucson, Arizona in 2021. As when I last attended, this conference gathered a group of academics, artists, and engineers to answer the great existential question: How (and should) humanity travel to the stars?

To capture the discussions for future me and others to reminisce on, much like my writeup at the last conference, this conference report will be written from the perspective that I feel the most natural writing in: My own. In the two years since my first Interstellar Symposium, I've had the fortune to take a job at Maxar as a propulsion engineer, working primarily on plasma thrusters for NASA's Lunar Gateway as well as a mix of other government defense programs. This job has been an invaluable experience, as it not only has helped me fill in the gaps of much of my self-taught propulsion knowledge, but also has really crystalized what knowledge isn't taught in textbooks that is crucial to making theoretical advanced propulsion systems a practical reality. This knowledge, acquired in the last couple of years, helped me be "less impressed, more involved" at this conference. I'm forever thankful to the Maxar propulsion team I work with for giving, and continuing to nurture, that skillset.

Day 1 — Monday

The conference started off a bit rocky: My flight from New York was delayed one day, so I ended up not flying in until Monday night. While disappointed that I missed most of the first days' talks, it was a pleasure to talk to some of the day's presenters in the late afternoon happy hour. I particularly enjoyed my conversation with Setthivoine You of Helicity Space. Discussing the technical development roadmap and promise of his magnetic-reconnection fusion drive was incredibly insightful and taught me a lot: Everything from the thermal problems they're experiencing, to the lifetime problems due to channel erosion are all analogous to problems we see on the plasma thrusters at Maxar. Also thankful to him for reminding me of one of the big benefits of a fusion drive: That once fusion ignition is achieved, there is a net positive energy gain from the actual fusion reaction. This means that their thruster wouldn't require an external power source to continue the reaction, unlike current electric propulsion which requires separate power sources such as solar arrays/nuclear fission plants.

A fine turnout for "Interstellar Travel: Are We Ready?" Cameo from Mathias Larrouturou from my first conference on the right, now enhanced with facial hair.

I was also excited to make it into Montreal in time for the major public talk of the symposium: "Interstellar Travel: Are We Ready?" It ended up being a rich discussion between the principal investigator of the mission that went to explore Pluto (Alan Stern), an impressively knowledgeable space lawyer AJ Link, and a cast of other panelists from NASA and the University of Santa Barbara who we'll revisit later. Trevor Kjorlien, the moderator, was a natural at fielding a list of questions on topics ranging from space accessibility to the practical limitations of interstellar travel (an analogy from Trevor: If the distance from Earth to Alpha Centauri was a football field, our furthest spacecraft has traveled the distance of one index card).

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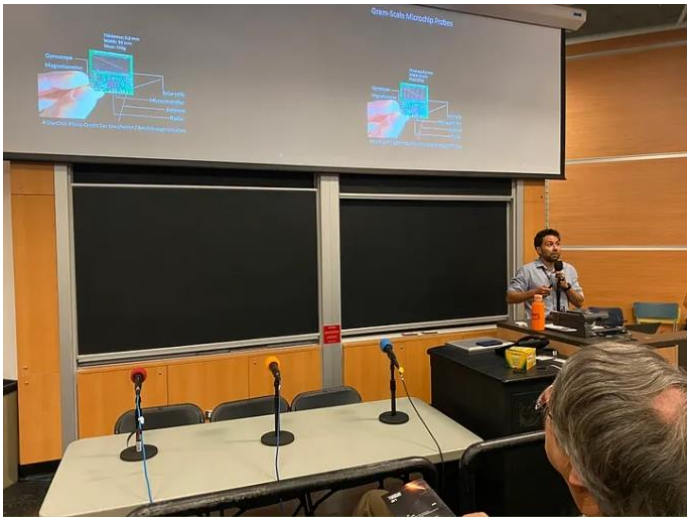
Day 2 — Tuesday

The following day began my first full day at the conference. And as was the case at the last conference, the entire day was filled with some very smart people talking about some very cool ideas on well-crafted PowerPoint decks. Richard Norte, an energetic and engaging presenter, blew our minds with a counter-intuitive idea on making a solar sail reflective: Place a bunch of tiny holes roughly smaller than the wavelengths of light being reflected in the sail! Poking your own holes is definitely one way to get around the micrometeoroid problem in space.

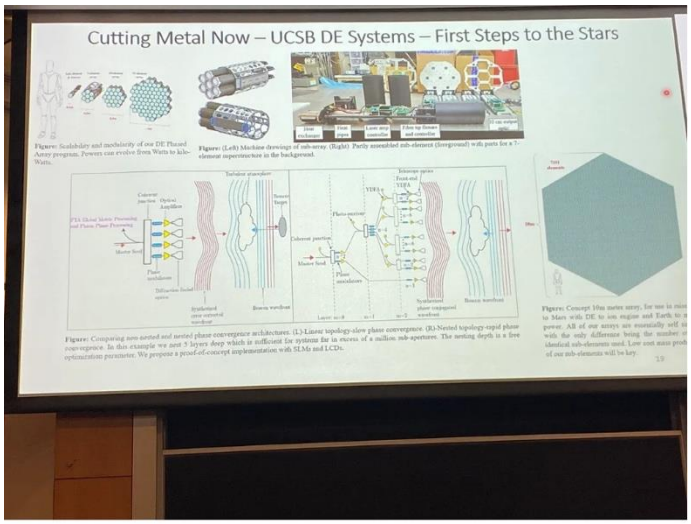


Richard Norte, starring as himself.

His PhD-candidate student Lucas Norder, who is working with him on the technology, quickly became a post-conference friend to tour Montreal with as we found out that he and myself were sharing the same hostel. Kid knows a lot about machine learning optimization, and also has that great Dutch perspective on life. Very charismatic and hilarious. Can't wait to hang out with him again.

The indelible Phil Lubin, a mastermind of the beamed energy technology upon which much of the conference is built, then gave a detailed update on the status of the first beamed energy module prototypes his lab has been working on. Though I keep in touch with him via yearly phone-calls/road-trips down Highway One to Santa Barbra, it was delightful to interact with him at the conference with other like minds. The Technology Readiness Level of his beamed energy system, the path forward to development, and its adaptation to industry for spacecraft mission-enabling profiles continue to be talking points that I revisit with him every year (and upon which I based my talk at this conference).

Phil Lubin et. al at the public seminar: *Interstellar Travel, Are We Ready?*



Initial prototypes of laser modules that are designed to eventually be used for kilometer-scale arrays.

Day 3 — Wednesday

Sonny White of NASA's EagleWorks, moderating the morning series of lectures

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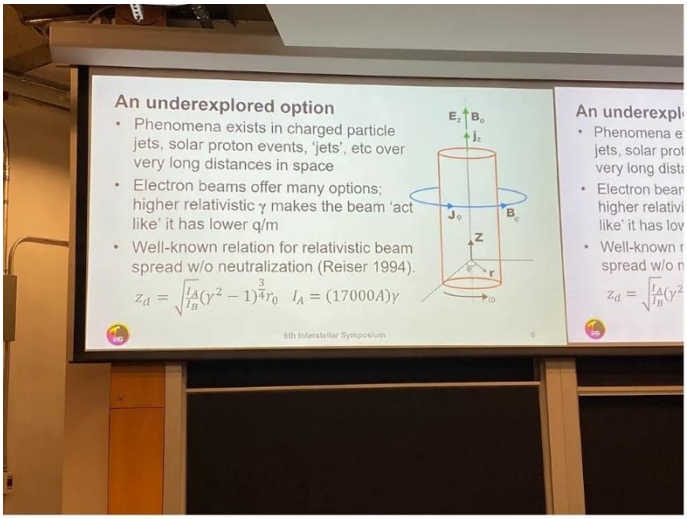
More than halfway through the symposium, the talks continued to be as strong as the previous days. Dr. Rene Heller of the Max Planck institute analyzed an interstellar sail mission profile that could explore all three stars of the Alpha Centauri system. His calculations concluded that a sphere/hemisphere may be an ideal shape for such a sail so that any incident photon flux is uniformly distributed. It sounded like, talking with him afterwards, his group needed more work to determine the effects of such a sail interacting with the local magnetic fields in their mission profile (i.e. eddy current-induced forces on the spacecraft).

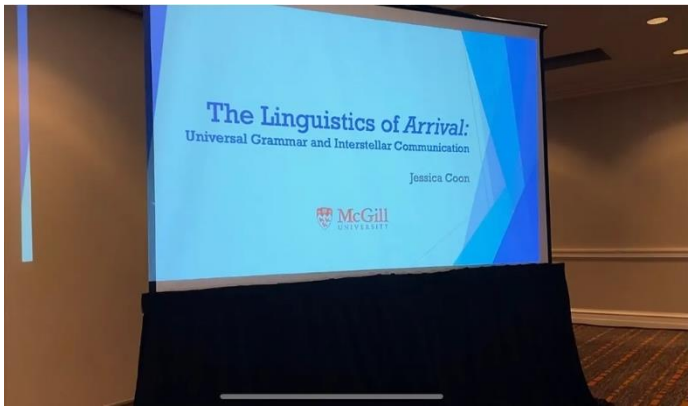
On the same day, Gerrit Bruhaug's presentation on interstellar communication via X-ray and Gamma-rays proved to be one that stimulated a lot of conversation and references in future talks. Could it be that other galactic systems are using these communication technologies, and we just don't have the equipment set up to listen to them? He also had a great poster on using electrostatic fields to solve the fissioning plasma core containment problem in nuclear gas core rockets. He also had many pointed questions for the presenters throughout the entire conference, and was by far one of the most impressive attendees to engage with. Tom Bone presented an interesting talk on using thermionic emission to harness the power of Bremsstrahlung-generated radiation (his first presentation as a master's student!). Additionally, Jeffrey Greason revisited the concept of using electron beams for beamed energy applications.



Snapshot of Jeffrey Greason's presentation

Towards the end of the day, it was exciting to hear about a mission concept Joseph Cassady and his team at Aerojet Rocketdyne put together to travel to interstellar objects using technologies readily available today. How exciting to see commercial industry proposing ideas like this at the conference. The forthcoming whitepaper from them is one to read when it comes out.

However, the highlight of the entire day was the banquet talk given by Jessica Coon, linguistic advisor for the hit box-office movie *Arrival.* In one hour, she gave a high-level overview on everything linguistic: How all languages share a "Universal Grammar," that language's effect on thought is at best extremely subtle, and most importantly, that the idea that being a linguist is synonymous with being a polyglot is a myth. Topping that off with formally meeting NASA's Dr. Les Johnson in person at dinner made Wednesday as eventful as the previous day.



Jessica Coon, linguistic advisor to the hit movie Arrival, at her banquet talk


View of downtown Montreal from the top of the conference hotel.

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Presentation from yours truly.

Day 4 — Thursday

The final day of talks, and the day in which I gave my own! The morning kicked off with a solid overview from Breakthrough Initiatives on the current state of work involving the widely acclaimed Breakthrough Starshot. We learned about the current state of sail stability analysis, laser array engineering schematics, and future work to continue to develop the technology that is currently humanity's best engineering solution to the problem that is interstellar travel.

After Breakthrough, I presented my talk on the coupling of beamed energy to potential future commercial interests: More specifically, the coupling of beamed energy to electric propulsion, with its ability to scale better than other nuclear/solar power sources for certain mission profiles. Subjectively, I think the first half of my talk ended up being less-polished than I would've liked as I worked through the verbal tics born from cumulative nights of drinking and sub-optimal sleep to enable the engaging late discussions with fellow attendees at the top of the hotel. That said, from the conversations and comments at the end of the conference I think the talk went fine: My impression was that the key points were communicated to those who took an interest, and sedative to those who needed to catch up on sleep.

Canada Arm: Much bigger in person than on TV.

Rounded out the day with an insightful talk by IRG's Stephen Fleming on the promise of quantum computing-enabled optics to circumvent the Rayleigh limit: Potentially enabling up to a couple of orders of magnitude increase in imaging resolution.

A quick visit to the Canadian Space Agency and a Montreal-sponsored "water tornado" on our bus ride back rounded out the conference. To tie up the loose ends that I missed from the Monday portion of the conference, I ended up talking to Emmanuel Duplay about his initial prototype for a laser-thermal propulsion system. He and his team are using lasers to ignite and sustain a plasma that heats the propellant gas (something that hasn't been explored for rocket propulsion in decades). They had problems igniting plasma with a spark plug, so they ended up transitioning to a tungsten rod to get a more consistent/efficient ignition. Excited to see the forthcoming whitepaper from him towards the end of the year, formally presenting what we informally discussed.

Conclusion

Re-reading my writeup of the 2021 Interstellar Symposium, I find it surreal that many of the novel conversations I found unreal back then are now just a part of my daily life. During my day job, one week I'm discussing the thruster-life implications of a plasma thruster whose confining magnetic field isn't optimized for its propellant, the next week I'm talking with one of the top researchers of the Max Planck Institute about whether the effects of stellar magnetic fields compromise his as-presented interstellar mission profile. To think these sorts of conversations are habitual for me now is a bit stunning, especially given that I didn't know even the basic trigonometry six years ago when I decided to make the transition from music production to rocket science. A huge thank you to fellow attendees, but most importantly Andrew Higgins and his army of McGill volunteers, who flawlessly organized and executed a conference to remember. It will be hard for Texas to top this when the 9th Annual Interstellar Symposium comes to town in 2025, when we get to do all this again in two years.

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Report From Montreal
BY Michel Lamontagne

An active member of the interstellar community, Michel Lamontagne pursues interests in heat transfer for starships and enjoys illustrating interstellar concepts in his artwork. Michel is a French Canadian from Quebec who lives in the Montreal area.

After the opening ceremony, the presentations started with one of the patrons of the event, the Canadian Space Agency. John E. Moores presented some of the projects the CSA are working on, that might eventually have Interstellar applications. In particular, Canadarm 3, Starchip, the Infrared Imager of the James Web Space telescope and Canada's participation in the Osiris Rex Asteroid sample return mission.

The following presentation was from another patron, the International Astronautical Association IAA. The IAA president described IAA membership and structure: Basic sciences, Engineering Sciences, Life sciences and Social Sciences. He then gave the podium to a star speaker, the astronaut (and former Governor General of Canada) Julie Payette. Payette got her bachelor's in electrical engineering from McGill, and was happy to return to her Alumni for the event. She showed a genuine interest in the Interstellar question, and was seen listening attentively for a number of later talks.

In an inspirational talk, Payette described the importance of the human presence in space. Many students went up to meet her in the breaks between the talks, and she shared career advice with them, and told them that passion tended to pay with results, sometimes in the most unexpected ways. It was interesting to learn that choral singing was instrumental in her astronaut career! After her talk, she was presented an achievement award by the IAA, of the kind previously given to John Glenn and Valentina Tereshkova, so she is in prestigious company! At the same time, Les Johnson, one of the pillars of the IRG organization, was awarded an Honorary IAA membership for his exemplary involvement in research and science outreach.

A short break was followed by a keynote speech from Frank Tipler, American mathematical physicist and cosmologist, discussing “The Ultimate Rocket and the Ultimate Energy Source, and Their Use in the Ultimate Future”. Tipler presented the results of an experiment purporting to show proof for some of the cosmological equations of his Omega point theory. The theory points to the use of vacuum energy as a propulsion mode and energy source, and although quite abstract, the presentation was certainly entertaining.

I missed the following presentation, Joseph Gottlieb “Should we colonize (interstellar) space?”, having been called away on mundane matters from my day job. I did get to hear most of Claudio Maccone's presentation of some of his work on gravitational lensing: “Human Interstellar Expansion driven by Gravitational Lensing”. In particular, how gravitational lensing could be used as an amplifier for SETI communications.

Maccone proposed that the gravitational focus might be explored for signs of Interstellar communications, as the lens allows for communications at much reduced power levels. The author also presented his ideas on using lenses as bilateral communication systems, and how these could exist already between a multitude of stars, but be unseen by us until we ourselves reached the gravitational lens focal point.

Lunch was followed by a one hour panel, that was more fundamentally a presentation by Alan Stern, Stephane Linter and Setthivoine You, on the current status of the work at Helicity, a company dedicated to the development of a fusion drive in the near future. Stern, building on his long experience as a NASA project leader (notably New Horizons) presented what new missions might be achievable with a fusion drive.

Stephane Linter presented the business plan for the company, and how they might achieve a progressive roadmap towards fusion, in particular an interesting 'augmented ion drive' mode, based on SEP and some fusion gain. The roadmap aims for a test prototype in space by 2032. Setthivoine You presented some of the hardware built at this time, and the simulations done for the fusion reactions.

Image 1: Alan Stern, Stephane Lintner, Setthivoine You presenting “Helicity Fusion

Propulsion Drive: The Company, the Technology and the Applications". The fusion mechanism, pulsed magneto inertial fusion, a form of magnetized target fusion, is an interesting intermediate between ICF and tokamak-type magnetic fusion that lends itself to a rapid development path where injectors could be combined into larger and larger engines, eventually reaching high thrusts and significant neutron and Bremsstrahlung absorption in a simple package. The focus of the company is now on preparing a first prototype, that they hope will validate the mathematical modeling. They are also targeting Deuterium-deuterium fusion at first, as that fusion fuel is much more accessible than others.

After the afternoon coffee break, Alex Gmerek presented an "Astrobiology payload for Interstellar missions". Although clearly developed for exploration of the Solar system the instrument suite presented by Gmereck provides an interesting number of functions in tiny packages, suitable for cubesat missions, or very low mass Interstellar explorers.

Image 2: Alex Gmerek presenting "Searching for Extrasolar Life – An Astrobiology Payload for Interstellar Missions".

This presentation was followed by Victor Toth's "Look before you leap: Using the solar gravitational lens to explore exoplanets". The extreme difficulties of actually implementing gravitational lensing, the technical problems involved in reaching the focal line, navigating to the correct position and extracting the information from the annular image that the gravitational lens creates were all covered in detail. The precision needs to be extremely high, on the order of hundreds of meters, and Toth presented some ideas on how to achieve that precision.

The evening outreach event "Interstellar Travel: Are We Ready?" was held before a large audience at the McGill Leacock building. Les Johnson, AJ Link, Alan Stern, Philip Lubin, Erika Nesvold, Trevor Kjorlien were all part of the presentation . Kjorlien asked the panel a number of open questions, with particular emphasis on how interstellar travel might be achievable in the future, and why thinking about it today could bring immediate benefits . AJ Link was particularly interesting as he challenged the audience on the accessibility of space to disabled people, and the need for outreach towards all the communities that might usually be omitted from space research.

Image 3: Public Outreach Event "Interstellar Travel: Are We Ready?" with Les Johnson, AJ Link, Alan Stern, Philip Lubin, Erika Nesvold andTrevor Kjorlien.

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Reflections on Breakthough Starshot
AN EDITORIAL BY PAUL GILSTER

If we're going to get to the stars, the path along the way has to go through an effort like Breakthrough Starshot. This is not to say that Breakthrough will achieve an interstellar mission, though its aspirational goal of reaching a nearby star like Proxima Centauri with a flight time of 20 years is one that takes the breath away. But aspirations are just that, and the point is, we need them no matter how far-fetched they seem to drive our ambition, sharpen our perspective and widen our analysis. Whether we achieve them in their initial formulation cannot be known until we try.

So let's talk for a minute about what Starshot is and isn't. It is not an attempt to use existing technologies to begin building a starship today. Yes, metal is being bent, but in laboratory experiments and simulated environments. No, rather than a construction project, Starshot is about clarifying where we are now, and projecting where we can expect to be within a reasonable time frame. In its early stages, it is about identifying the science issues that would enable us to use laser beaming to light up a sail and push it toward another star with prospects of a solid data return. Starshot's Harry Atwater (Caltech) told the Interstellar Research Group in Montreal that it is about development and definition. Develop the physics, define and grow the design concepts, and nurture a scientific community. These are the necessary and current preliminaries.

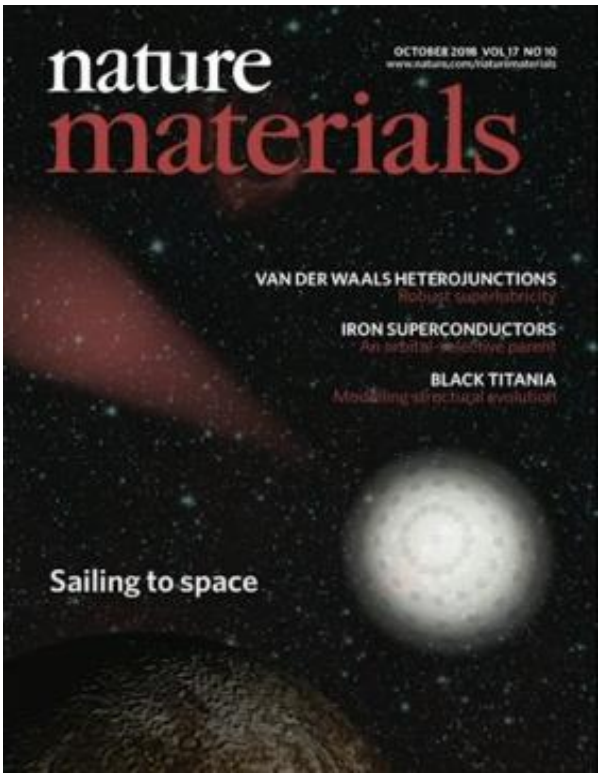

Image: The cover image of a Starshot paper illustrating Harry Atwater's "Materials Challenges for the Starshot Lightsail," *Nature Materials* 17 (2018), 861-867.

We're talking about what could be a decades-long effort here, one that has already achieved a singular advance in interstellar studies. I don't have the current count on how many papers have been spawned by this effort, but we can contrast the ongoing work of Starshot's technical teams with where interstellar studies was just 25 years ago, when few scientific conferences dealt with interstellar ideas and exoplanets were still a field in their infancy. In terms of bringing focus to the issue, Starshot is sui generis.

It is also an organic effort. Starshot will assess its development as it goes, and the more feasible its answers, the more it will grow. I think that learning more about sail possibilities will spawn renewed effort in other areas, and I see the recent growth of fusion rocketry concepts as a demonstration that our field is attaining critical mass not only in the research labs and academy but in commercial space ventures as well.

So let's add to Atwater's statement that Starshot is also a cultural phenomenon. Although its technical meetings are anything but media fodder, their quiet work keeps the idea of an interstellar crossing in the public mind as a kind of background musical riff. Yes, we're thinking about this. We've got ideas and lab experiments that point to new directions. We're learning things about lightsails and beaming we didn't know before. And yes, it's a big universe, with approximately one planet per star on average, and we've got one outstanding example of a habitable zone planet right next door.

So might Starshot's proponents say to themselves, although I have no idea how many of those participating in the effort back out sometimes to see that broader picture (I suspect quite a few, based on those I know, but I can't speak for everyone). But because Starshot has not sought the kind of publicity that our media-crazed age demands, I want to send you to Atwater's video presentation at Montreal (https://www.youtube.com/watch?v=jV2sNOYzaFA) to get caught up on where things stand. I doubt we're ever going to fly the mission Starshot originally conceived because of cost and sheer scale, but I'm only an outsider looking in. I do think that when the first interstellar mission flies, it will draw heavily on Starshot's work. And this will be true no matter what final choices emerge as to propulsion.

This is a highly technical talk compressed into an all too short 40 minutes, but let's just go deep on one aspect of it, the discussion of the lightsail that would be accelerated to 20 percent of lightspeed for the interstellar crossing. Atwater's charts are worth seeing, especially the background on what the sail team's meetings have produced in terms of their work on sail materials and, especially, sail shape and stability. The sail is a structure approximately 4 meters in diameter, with a communications aperture 1 meter in size, as seen in the center of the image (2 on the figure). Surrounding it on the circular surface are image sensors (6) and thin-film radioisotope power cells (5).

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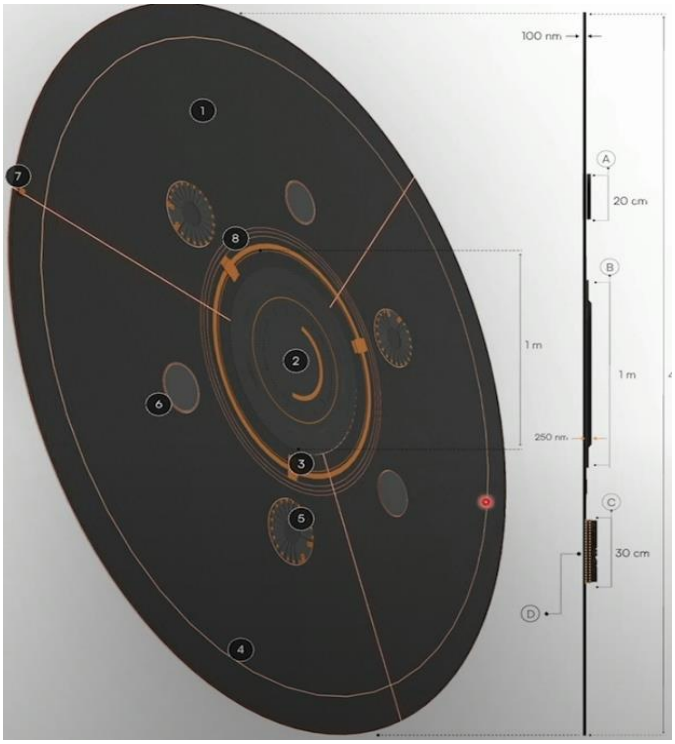
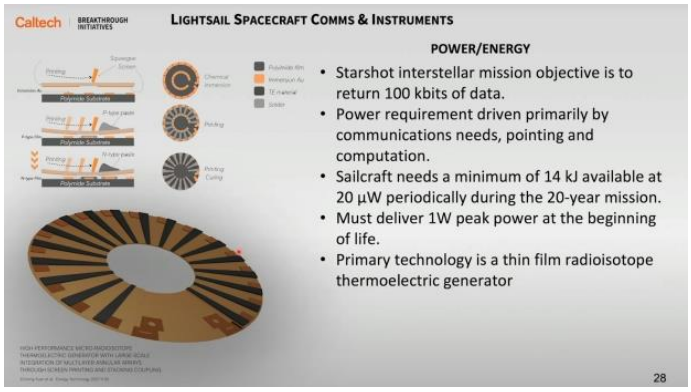


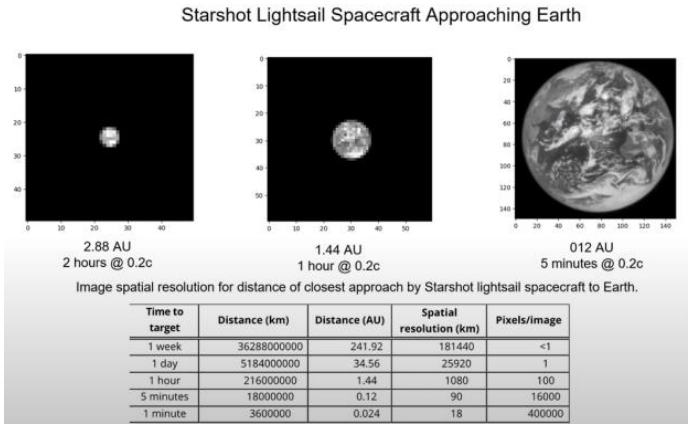
Maneuvering LEDs (4) provide attitude control, and thin-film magnetometers (7) are in the central disk, with power and data buses (8) also illustrated. A key component: A laser reflector layer positioned between the instruments that are located on the lightsail and the lightsail itself, which is formed as a silicon nitride metagrating. As Atwater covers early in his presentation, the metagrating is crucial for attitude control and beam-riding, keeping the sail from slipping off the beam even though it is flat. The layering is crucial in protecting the sailcraft instrumentation during the acceleration stage, when it is fully illuminated by the laser from the ground.

How to design lensless transmitters and imaging apertures? Atwater said that lensless color camera and steerable phased array communication apertures are being prototyped in the laboratory now using phased arrays with electrooptic materials. Working one-dimensional devices have emerged in this early work for beam steering and electronic focusing of beams. The laser reflector layer offers the requisite high reflectivity at the laser wavelength being considered, using a hybrid design with silicon nitride and molybdenum disulfide to minimize absorption that would heat the sail.

I won't walk us through all of the Starshot design concepts at this kind of detail, but rather send you to Atwater's presentation, which shows the beam-riding lightsail structure and its current laboratory iterations. The discussion of power sources is particularly interesting given the thin-film lightweight structures involved, and as shown in the image below, it involves radioisotope thermoelectric generators actually integrated into the sail surface. Thin film batteries and fuel cells were considered by Breakthrough's power working group but rejected in favor of this RTG design.



So much is going on here in terms of the selection of sail materials and the analysis of its shape, but I'll also send you to Atwater's presentation with a recommendation to linger over his discussion of the photon engine, that vast installation needed to produce the beam that would make the interstellar mission happen. The concept in its entirety is breathtaking. The photon engine is currently envisioned as an array of 1,767,146 panels consisting of 706,858,400 individual tiles (Atwater dryly described this as "a large number of tiles"), producing the 200 gW output and covering 3 kilometers on the ground. The communications problem for data return is managed by scalable large-area ground receiver arrays, another area where Breakthrough is examining cost trends that within the decades contemplated for the project will drive component expenses sharply down. The project depends upon these economic outcomes.



Time to target	Distance (km)	Distance (AU)	Spatial resolution (km)	Pixels/image
1 week	36288000000	241.92	181440	<1
1 day	5184000000	34.56	25920	1
1 hour	216000000	1.44	1080	100
5 minutes	18000000	0.12	90	16000
1 minute	3600000	0.024	18	400000

Image: What we would see if we had a Starshot-class sailcraft approaching the Earth, from the image at two hours away to within five minutes of its approach. Credit for this and the two earlier images: Harry Atwater/Breakthrough Starshot.

Using a laser-beamed sail technology to reach the nearest stars may be the fastest way to get images like those above. The prospect of studying a planet like Proxima b at this level of detail is enticing, but how far can we count on economic projections to bring costs down to the even remotely foreseeable range? We also have to factor in the possibility of getting still better images from a mission to the solar gravitational lens (much closer) of the kind currently being developed at the Jet Propulsion Laboratory.

Economic feasibility is inescapably part of the Starshot project, and is clearly one of the fundamental issues it was designed to address. I return to my initial point. Identifying the principles involved and defining the best concepts to drive design both now and in the future is the work of a growing scientific community, which the Starshot effort continues to energize. That in itself is no small achievement.

It is, in fact, a key building block in the scientific edifice that will define the best options for achieving the interstellar dream. And while this is not the place to go into the complexities of scientific funding, suffice it to say that putting out the cash to enable these continuing studies is a catalytic gift to a field that has always struggled for traction both financial and philosophical. The Starshot initiative has a foundational role in defining the best technologies for interstellar flight that will lead one day to its realization.