News Feature: Breakthrough Starshot Communications Workshop - May 2020

Summary and i4is contributions

Reported by Robert G Kennedy III and the i4is team

The Starshot Communications Workshop in May 2020 included Robert Kennedy, Robert Swinney, Dr Andreas Hein, Eric Hughes and Marshall Eubanks (Space Initiatives Inc). In this article Robert summarises the workshop and i4is contributions - with inputs from other team members.

See elsewhere in the issue for *The Interstellar Downlink - Principles and Current Work*. John Davies introduces the downlink problem and reviews the current status of the subject.

Introduction

Last year, on 11-12 April 2019, i4is sent an international team (Andreas Hein, Kelvin Long, Nikolas Perakis, Robert Kennedy; Marshall Eubanks could not attend) to Berkeley, California to participate in Breakthrough Discuss, which is part of Breakthrough Starshot. Because the Breakthrough Initiatives are funded by a Russian, the big springtime events always coincide with Yuri's Night on 12 April every year. The story about that wonderful event can be found in Principium 25, beginning p.13.

As an outgrowth of that participation, plus our own exploratory work on the challenge of interstellar communications, i4is was formally invited to participate in Starshot Communications Workshop this year. The organizers state-

> "The Starshot program envisions and intends to demonstrate proof of concept and technological capability for ultra-fast light-driven nanocrafts [sic], and lay the foundations for a first launch to the nearest star systems, within the next generation. One of the main challenges for this program is to send data back from distances of several light years, given the extreme constraints on size, volume, mass, and power. The aim of the workshop is to set out and discuss the parameters of the communications challenge, and propose system concepts, and the associated technology research and developments required."

Just a few of the major challenges are:

- A propagation distance back to Earth that is four orders of magnitude greater than the outer planets in our system.
- Severe mass limitation on the probe in order that it be accelerated to relativistic speeds by the beamer.
- Attitude control of the probe for purposes of scientific observations and pointing of an antenna or aperture to Earth.

This time the i4is contingent included Andreas Hein, Rob Swinney, Marshall Eubanks, Eric Hughes, and Your Humble Narrator (Robert Kennedy). Originally planned as a two-day in-person meeting, like every other thing on Earth, it got converted to a virtual event due to the COVID-19 pandemic and postponed to a new date, also historic: 8-9 May, the 75th anniversary of VE Day and Den Pobeda (Victory Day) in Russia. Its formal title was: "Breakthrough Starshot's first (virtual) workshop on Communications/Downlink for Low Mass Interstellar Probes".

Approximately 75 people from all over the world tuned in via Zoom to the first day's program, a five-hour series of introductions and presentations by Breakthrough's volunteer scientists on the overall communications problem. This included a briefing on what would be the approach to the following day's program, the actual workshop, which was subdivided into eight breakout groups, also five hours long.

Group 1 – Physical basis of communication

Group 2 – Transmitter optics (including opportunities for light sail/comms integration)

Group 3 – Probe transmitter signal generation (including, eg laser technology)

Group 4 – Receiver optics (including opportunities for beamer/comms integration)

Group 5 – Receiver optical detection

Group 6 – Receiver noise sources and mitigation

Group 7 – Transport layer options

Group 8 – Accommodating and exploiting multiple probes

Approximately half of the attendees on the first day showed up for the second day, including all of the i4is team. During online pre-registration, people had generally been allowed to pick which breakout group they would join, but in a few cases the organizers overruled that and made their own assignments to ensure an even spread of minds. For i4is, the assignments turned out to be strangely fortunate and productive. Eric Hughes participated in Group 1 led by JPL's Slava Turyshev; Marshall Eubanks in Group 4 led by Jeff Kuhn of the Institute for Astronomy at University of Hawaii; Andreas, Rob, and Robert all ended up in Group 8, led by Danny Jacobs of Arizona State University. Other than Danny Jacobs the lead, Group 8 was composed entirely of i4is members! The other registrants didn't show up. But in this case, "less was more". After a morning of brainstorming that can only be described as exhilarating, the entire crowd reconvened for the final hour, during which each lead got 5-10 minutes to summarize their group's results.

In the course of this cooperative effort, we all came to appreciate much more the challenges of Breakthrough Starshot. But the learning went both ways. Five of the eight groups independently came to the same conclusion: that the only hope of successful communication at such range with such small spacecraft was to launch a multiplicity of probes working in parallel. This was, as I understand it, outside the ground rules—nevertheless that was the collective judgement. Fascinating.

The Group topics

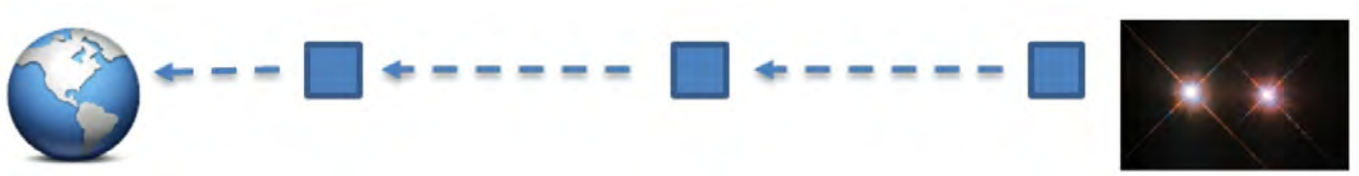
The Starshot Communications Workshop Summary, sent to all participants, summarised the group topics for the workshop see the table on the next page.

Eric Hughes observations on Group 1 - Physical basis of communication

The most notable takeaways/realizations of Group 1 (Physical Basis of Communication) Breakout Session on Saturday May 9 were that:

(1) If you can beam a probe in one direction, you can beam an SGL (solar gravitational lens) receiver in the other.

(2) That relay communications subdivided into N segments can be N times as efficient, just on the basis of transmitted and received power. For a twenty-year campaign and weekly launches, N ~1000. (For hourly launches, see VIII below, N would be ~100,000).

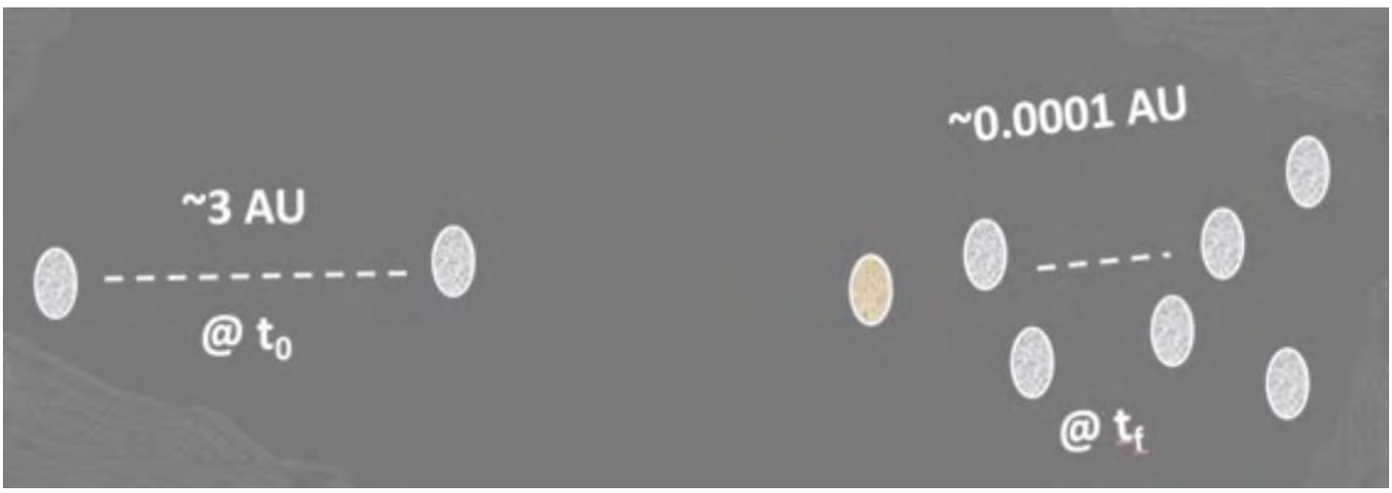


Equally spaced probes relaying data back. If no velocity differences are imposed, the average distance would be 2 to 3 AU. Using a combination of initial velocity tuning, timing, and navigation control, closer approaches could be arranged.

Credit: from Jacobs et al, Starshot Interconnect Report (Starshot Communications Workshop Report from Interconnect Focus Group, Daniel Jacobs, Andreas M Hein, Robert Swinney and Robert Kennedy) not yet published

Robert Kennedy's observations on Group 8 - Accommodating and exploiting multiple probes

The most significant takeaway from Group 8's collaboration was that a chain (or "bucket brigade" in the words of the lead, Danny Jacobs) of relatively closely-spaced probes was the only feasible way (with known science and foreseeable engineering) to provide communication link between here and another star. "Closely spaced" in this context means an inter-probe separation of order 2-3 astronomical units. This in turns means a continuous firing tempo by the launch laser, say every other hour, boosting circa 100,000 probes to their 0.2c cruise velocity over 20 years. (Even so, the unit price per probe is still dominated by the launch energy.) Furthermore, by "modulating" (Andreas's word) the initial launch velocity of each probe, Robert and Andreas argued that it would be possible to arrange massive albeit temporary clusters of probes to form precisely at the time of encounter with the target star. In artillery this is called "time on target, ToT".



Network geometry formation example by adjusting launch velocity and launch time.
Credit: Jacobs et al, Starshot Interconnect Report cited above

The clusters in turn permit the basis for parallel networks with large virtual apertures as developed by Marshall Eubanks in our proposal to NIAC two years ago. Finally, modulated the launch velocity allowing some probes to overtake other probes enroute provides redundancy and resilience along the entire chain from the homeworld to the target star so that the continuity is maintained (to whatever factor of safety is defined by the architects) despite the inevitable loss of individual probes.

Eric Hughes also comments on Group 8 "It's a very different vision than what was first proposed by Breakthrough four years ago. However five different groups independently arrived at similar conclusions, which speaks powerfully to the validity of the idea"*.

What happened next - Robert Kennedy reports

The work didn't end there. In the following two weeks, all the groups put their thoughts down on paper and fleshed them out in Summary Reports. For Group 8, this meant writing a proper paper consistent with the format of Astrophysical Journal (known as "ApJ"). For Your Humble Narrator this involved dusting off some very old rusty skills in text processing-typesetting, a distant cousin to LaTeX. The Summary Reports were all finished and uploaded to Breakthrough by May 26.

The draft report was issued to the participants for review and comment earlier this month. The final report is expected to be posted as soon as next month. The work in this report, mostly by volunteers, will inform the first series of Requests for Proposal for Communications to be let hopefully later this year.

i4is participation in Breakthrough has been highly favorable, in terms of improving our working knowledge, building new relationships and partnerships, and raising the field's awareness of us. It has also beneficially influenced the White Papers that we are writing for the Decadal Survey.

* The paper "Relaying Swarms of Low-Mass Interstellar Probes", Messerschmitt et al (see reference 8 in *The Interstellar Downlink Principles and Current Work* elsehere in this issue, will be the subject of a review paper in a later issue of Principium.