

Motley

Jim Benford

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Shooting for the Stars

The big thing that's happened in my life in the last year is that I'm centrally involved in the Star Shot Project. In case you don't know what that is, we're trying to figure out how to build probes to go to the nearby stars. So it's a real SF kind of thing to do and fits right into my previous history. At the end of this *Motley* I'm going to attach an article that appeared few months ago in *Discover* magazine, which describes my earlier work on microwave beam-driven sails. (I see I've cut off the last lines on the final page. It reads: "With four and a half hours of acceleration, a sailship could reach Pluto in one year at a cost of about \$40 million. By contrast, the New Horizons probe took almost nine and a half years..."

Forty years ago I was fortunate to know Bob Forward and become intrigued by his ideas on beam-driven sails. After I left Physics International in 1996 I started trying to do experiments on beam-driven sails and came upon the carbon-carbon microtruss, a new carbon fiber lattice that is incredibly lightweight so that you can actually see right through it. I proposed to NASA to try to lift and fly sails in the laboratory, which had never been done (or even attempted) before. After a lot of work we JPL team & brother Greg) succeeded in 2000 and we went on to look at using microwaves to spin sails and to study the question of whether a beam can write stably on the sail and not fall off. For a good account of our experiments you should read the excellent book on interstellar *Centauri Dreams – Imagining and Planning Interstellar Exploration* by Paul Gilster, Springer Science, 2004. You can find later developments in our *Starship Century* by myself and Greg, Lucky Bat Books, 2013.

Since those experiments ended 13 years ago, I've been figuring out what an optimal beam-driven sail system would be like. Because of that history, when the Breakthrough Foundation, and in particular Pete Worden an old friend of mine, came to be interested in figuring out how to reach the stars, they turned to Greg and me to talk about how to do it. The result was the announcement last April of Star Shot. The effort is divided into 3 parts: the sail, which I'm in charge of, the laser to drive it and the overall system, which must figure out how it all works together as well as how to transmit data back from Alpha Centauri. The project has

notional budget of \$100 million to be spent somewhere in the next 5 to 10 years. We've not gotten fully underway yet, but I have hopes that we will soon be requesting proposals for serious experiments that and theory on the many issues that we face. If you're interested in what those are, go to

<http://breakthroughinitiatives.org/Challenges/3>

and there see quite a list of formidable issues. For the near-term we're going to focus on the question of how to generate a coherent laser beam at ultrahigh power over a mile-scale aperture and how a sail can ride on a beam with very high powers incident on it. That means the sail must have be able to take high accelerations and have an extraordinarily high reflectivity.

So my interest in science and science fiction which started way back from reading Robert Heinlein juveniles is coming to fruition. Now that a rocky planet has been discovered in the habitable zone of Proxima Centauri, the nearest star, sending probes to the stars starts to feel more real. (Note that we talk about 'probes' and we refer to 'sails' or 'sailchips' –the payload is electronics on a chip. But we don't use the term 'starships'. I guess that's because it seems a bit audacious.)

Mailing Comments

The Ogdens: Fantasy Amateur: I greatly appreciate what you're doing for FAPA and I support your campaign. I really must remember to write a short autobiography to go into the Fantasy Amateur sometime soon.

Arthur Hlavaty: Nice Distinctions 29: You appreciate Kim Stanley Robinson's *Aurora*. You probably noted in one of my previous Motleys that it's egregiously wrong scientifically. Robinson makes up 'science' to make his points against interstellar travel. And the conclusion invalidates the thesis! I think it's a terrible novel and lacks all credibility./ Why do you hate Apple so much? Is the largest and most profitable company in the world because it keeps hundreds of millions of people satisfied with its products. I have everything they make, including 3 computers, except NOT the iWatch. / Your remark that a friend posted a link to a screed about how condescending liberals are. In my experience they are pretty much so. They seem to think that they're smarter than conservatives. In my experience with my liberal friends they are generally smart, but know far less of what's going on than I do. Just don't do their homework. They also know less than Bob Silberberg, who's also conservative./ You congratulate yourself that you consider people your equals and want them treated decently, meaning that they should have a living wage and a single-payer health system. Single-payer is just

government run healthcare which I don't think has really been very successful in many places. (Note for example that in places like Canada and Europe there are an awful lot of new drugs that are simply not available cause the governments won't pay for them. And their publics don't know that. Monopolies, as those are, are inefficient. Note also the approaching failure of Obamacare.) / As for 'living wage', unfortunately many people who really need jobs need entry-level positions. But our quickly-rising minimum wages are leaving them behind. Low-skilled people here have huge unemployment figures. So, Arthur, do you think about them when you advocate a 'living wage'? / The Left frequently claims their compassion for the masses but seldom subject that any factual test. The evidence I see locally is quite the opposite. Take for example the rapid escalation of the minimum wage taking place in Oakland. The 1st result was the closure of many small mom-and-pop stores, especially those in Chinatown, which simply couldn't operate under the new wages. They either closed or simply moved out of Oakland. Similarly, when restaurant employers saw the salaries of their waitpersons elevated by government, many adopted a no-tips policy, so as to keep the cost to their customers down. This caused many of the better waiters to leave Oakland; I have spoken to several of them who moved here to the east, where the absence of such "compassionate" policies allows them to make a higher income. In other words, failure to think ahead about the unintended consequences of socially motivated legislation frequently causes dislocations for the very people that the left claims it is compassionate about. / Note the McDonalds' response to this is to gradually automate, so far eliminating about 20% of their jobs: the wages are not proportionate to the skills the few skills they have. That's the way you work your way up the ladder. When I started working back in the 1950s I was making a dollar an hour and very glad to get it. But I thought that the experience of working for a living much more valuable in the long run than the amount of money I made.

Robert: King Biscuit Time 65: Thanks for the summary of the history of FAPA and your own participation in it. You inquire as to what we think about having such a small membership now? And/or do we care? I care and I'd like to have more people more interesting fmz to read. You ask, "Are we just coasting to an uncertain future?" Well, yes, and we always have been.

Keith Walker: The return of deadly earnest?: Your remarks about the rise of Theresa May are interesting because I follow British politics a lot, partly because my wife is English, but also because I've been to the UK about 40 times, beginning in 1957. I certainly agree that the Labour Party is tottering toward extinction under Jeremy Corbin. So it falls to the conservatives to navigate into the post-Brexit future. As for my own view on Brexit, here it is:

The UK is wise to get out now because the EU may not survive the next decade. The original idea of a few strong European states was good, but now there are 28, many extremely needy, and tensions inside the EU are steadily rising.

The EU is a house of cards; best to get out before the roof falls in. It's a 20th century concept that is not faring well in the 21st. Europe is too statist and bureaucratic, it's instincts are to protectionist, it's decision-making bodies too slow and secretive. EU foreign policy is too naïve and feckless about defense and security. The problem with Europe is that it is too European. Best to be the first off a sinking ship.

The EU has shown itself unable to deal with the financial crisis of the last 8 years, the recurring Greek debt crises, the aggression on its eastern perimeter of a revanchist Russia and the migrant crisis coming across the Mediterranean. They have maintained inadequate military and Coast Guard and so have depended upon the kindness of us Americans the last 70 years. They have a slowing economy, high unemployment, especially among the youth who are expected to pay the increasing costs of their welfare states. This is causing them to gradually fall behind economically.

Yet Bernie Sanders says we should be more like Europe! The EU model, a strong central regulatory state, with unelected regulators, is in fact what the Democrats are trying to sell the American people: a strong controlling central government in Washington with states having less and less authority over their own affairs, an enlarged welfare state with higher and higher indebtedness. The irony is that the British, the European country closest to us Americans, have decided to get out of that model and go their own way. Perhaps there's a lesson here for us as well.

Eric Lindsay: For FAPA: I too really appreciated the CD of space music and listened to it several times. I never heard that particular version of the *2001* theme, for example.

John Coker: Stories From The 1st Fandom Archives Volume 5: I really appreciated reading this issue. It gave me quite a feeling for what fandom was like 70 and 80 years ago. And those pictures! Quite fascinating!

Fred Lerner: Lofgeornost: I saw Charles III in San Francisco and enjoyed a great deal. I particularly liked much of it being in iambic pentameter. It seemed quite Shakespearian and appropriate to the infighting of royalty. I recommend you see it.

Riding on a Beam of Light

Sailships may offer our best shot at reaching the edge of the solar system and beyond.

BY STEVE NADIS

→ As teenage brothers and identical twins growing up in 1950s Alabama, Gregory and James Benford both read *Time for the Stars*, Robert Heinlein's 1956 novel about Tom and Pat Bartlett — identical teenage twins who took part in the world's first interstellar space mission. The tale made a lasting impression on the Benfords, who shared the Bartletts' affinity for space and were simultaneously drawn to the world of science fiction.

While still in their teens, the Benfords published 29 issues of the fanzine *Void*. James has since sold a few sci-fi stories, whereas Gregory has published more than 200 short stories and written 31 novels, winning two Nebula Awards along the way.

But the brothers' main pursuit is science. Gregory is an emeritus physics professor at the University of California, Irvine. James, also a physicist, heads his own company, designing high-powered microwave systems for clients like NASA, the Jet Propulsion Laboratory (JPL), Lockheed and Boeing.

Although the Benford twins chose different professional paths, they share a dream: human travel into interstellar space, a quest they liken to the exploration of the American West. In 2013, the brothers hosted the Starship Century Symposium, where scientists and sci-fi writers gathered



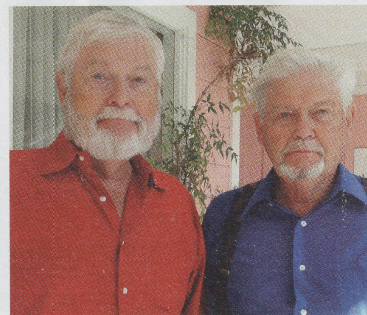
Harnessing the power of light might be the best means of traveling through this enormous universe. In this artist's depiction, a microwave "beamer" in the distance is propelling a sailship forward, theoretically up to 10 percent the speed of light, significantly faster than current speeds.

to advance the prospect of human expeditions to the stars within 100 years.

The Benfords' rationale for such a journey is a modern take on *Manifest Destiny*: "Because we are the descendants of those primates who chose to look over the next hill," they say. "Because we won't survive here indefinitely. Because the stars are there, beckoning with fresh horizons."

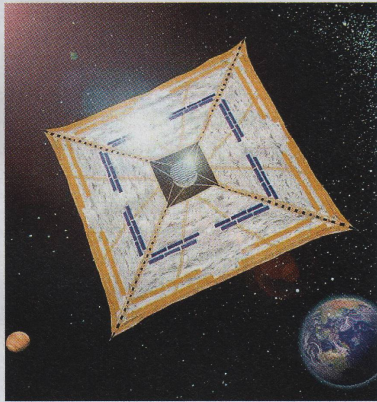
UPLIFTING LIGHT

But how are we to reach those horizons? High-speed nuclear rockets,



James (left) and Gregory Benford have both written science fiction and, as physicists, done their part to help science fact catch up.

TOP: MICHAEL CARROLL. BOTTOM: COURTESY JAMES BENFORD



An artist's rendering of Japan's IKAROS solar sail, the first spacecraft to use the sun's light as its main means of propulsion.

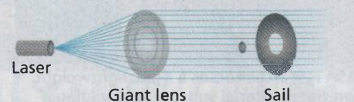
the often-cited next-gen vehicles of choice, are not technologically close at hand. Chemical rockets, the standard since World War II, are too slow; the fastest rocket we've ever launched would take 74,000 years to get to Alpha Centauri, our closest stellar neighbor. Arriving there sooner requires more fuel, but the potential gains are limited: Increasing the fuel load a hundredfold would only yield, at best, a fivefold boost in speed.

Instead, the physics appears most favorable for "sailships." First proposed in 1962 by physicist and science fiction writer Robert L. Forward, and subsequently developed and tested by the Benfords, these spacecraft are defined by their giant sails. The vessels are similar in spirit to the sailboats Gregory and James piloted in their youth along Alabama's Gulf Coast, but instead of exploiting the wind, these spaceships would harness the power of light.

Sailships are the conceptual descendants of solar sails, oversized kites propelled purely by sunlight, like Japan's 46-foot-wide solar sail, IKAROS, which flew past Venus in December 2010. Unfortunately, the push from sunlight alone is rather feeble: It took IKAROS almost seven months to get to our nearest

Sailing Through Space

In the 1960s, Robert L. Forward imagined a beam-propulsion system that relied on a laser and a giant focusing lens to propel a sail through space, as illustrated below.



After the laser's light is focused onto the large, flat sail (with its comparatively tiny payload), the sail could achieve truly impressive velocities without needing to store or process fuel.

Whereas Forward's fictional sailships used lasers, the Benfords prefer cheaper microwaves to power theirs.

planetary neighbor. But a focused and sustained blast of electromagnetic radiation — either in the form of microwaves or lasers — would add orders of magnitude more momentum to the craft.

"The beam stays on the sail for hours as acceleration continues and velocity grows to interstellar speeds," says James. "Ten hours would get you going really fast, about 10 percent of the speed of light."

Whereas Forward's fictional sailships used lasers, the Benfords prefer cheaper microwaves to power theirs. Microwave generators, or "beamers," would initially be based on Earth but eventually could be installed on satellites that convert solar electricity into microwaves.

Gregory sees the beamer as a big-ticket infrastructure investment analogous to laying down railroad

tracks. With beamers in place, sailships could be assembled in space and dispatched from there on diverse missions in almost any direction, like the trains crisscrossing continents today.

NOT JUST SCI-FI

This vision remained hypothetical until 2000, when sufficiently Space Age materials — and financial support from NASA — allowed projects led by James and Gregory to start testing these ideas at JPL and UC Irvine. They were the first to demonstrate that a microwave beam could actually lift a real structure — a tiny sail, about 1.4 inches in diameter, composed of lightweight carbon fibers 10 times thinner than a human hair.

Although that first sailship was a modest one, the Benfords made a surprising discovery: The sail's acceleration was much higher than expected because carbon monoxide trapped in the fibers rapidly boiled off, providing more thrust that turned the diminutive object into a virtual rocket. "The sail came out at 4 Gs and completely slammed into the [ceiling]," Gregory says. This unexpected effect could be exploited by manufacturing sails with special coatings or embedded materials.

As an extra bonus, Gregory says, “After you’ve blown this stuff off, you’ve made the sail even lighter.” And the lighter the sail, the greater the acceleration for a given force. Scaled-up versions of the experimental sails would weigh about 5 tons per square kilometer. But James believes that graphene, an ultrathin form of carbon just a single atom thick, might eventually be used in diaphanous sails weighing just 500 pounds per square kilometer.

In other experiments, the researchers found that a microwave beam can provide a restorative force that stabilizes the sail and keeps it billowed, assuming the sail has the right shape. Previous solar sails had been flat, designed that way to catch more sunlight, but it was difficult to keep them properly aligned with the sunlight. A beam-driven sailship should be concave — resembling an umbrella — to keep it aligned with the beam, so that when light waves hit the sail, they naturally tend to center it on the beam.

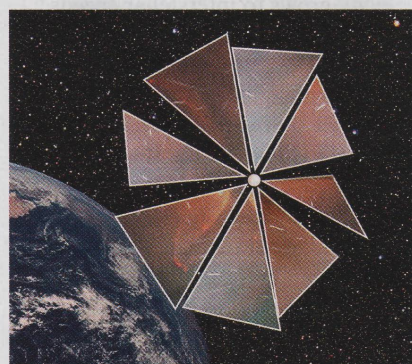
“What needs to happen next will be to carry out real sail experiments in space,” says Gregory. He and James almost got their chance in June 2005, when a Russian Volna rocket was scheduled to launch Cosmos 1 — a 6,415-square-foot solar sail — into space. Unfortunately, the rocket failed 83 seconds after takeoff, and Cosmos 1 never made it into orbit.

The Planetary Society has seen some success with its LightSail designs, but the Benfords’ plans are currently shelved. So, James decided to assess the economic feasibility of beamed propulsion in order to “put some numbers on this idea.” His 2013 study concluded that it would cost about \$30 billion to build a beamer that can send a probe out of the solar system, but once built, the system could be operated cheaply. With four and a half hours of acceleration, a sailship could reach Pluto in one year at a cost of about \$40 million. By contrast,



A NASA researcher holds a rigid, lightweight carbon-fiber material suitable for building a large and efficient solar sail. Without such materials, the sails would be impossible.

With four and a half hours of acceleration, a sailship could reach Pluto in one year at a cost of about \$40 million. By contrast, the New Horizons space probe took almost nine and a half years to reach Pluto and cost about \$700 million.



The ill-fated Cosmos 1, a solar sail experiment from 2005, would've been the first to fly in space, had it actually reached orbit.

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DECODING THE BEAM

Benford’s analysis convinced James Guillochon and Avi Loeb of the Harvard-Smithsonian Center for Astrophysics that sailships might afford the most practical means of space travel, both within and out of the solar system. They also applied the idea to another sci-fi staple: aliens.

“It seems reasonable,” Guillochon and Loeb wrote in 2015, “that intelligent life elsewhere in the galaxy may employ similar technology to facilitate rapid transit between habitable worlds.”

In fact, Guillochon and Loeb’s calculations showed that signal leakage from an Earth-based beamer would be a million times brighter than the radio output from the sun in that same frequency. Looking for signals of this sort around other planetary systems, they said, “could define a new strategy in the search for extraterrestrial intelligence (SETI).”

“I don’t think it’s nuts,” says SETI Institute astronomer Seth Shostak, who considers the idea “clever.” James Benford also found the SETI argument intriguing, and he offered an additional twist: Knowing that leakage from their beamers would be visible elsewhere in the galaxy, advanced aliens might deliberately insert a message into the beam.

If and when we build our own apparatus for powering sailships, perhaps we’ll put a message in our beam as well — assuming, Benford adds, there is “some agreement by mankind of what we wish to say.” Maybe the twin writers can help in that department, too. **D**

Steve Nadis, a contributing editor to *Discover* and *Astronomy*, is co-author of *From the Great Wall to the Great Collider*. He lives in Cambridge, Mass.