

LONG-TERM PERSPECTIVES ON INTERSTELLAR FLIGHT

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Abstract

Realizing interstellar travel by machines or living beings will require not only scientific and technological progress, but also a shared secular belief among a determined minority that this enterprise is important for the human future. Their efforts may have to extend beyond individual human lifetimes. Historical perspectives, on both the past and the future, are proposed. Interstellar probes could be a more thorough way of searching for alien forms of life and intelligence in nearby systems, particularly if there were intelligent beings who did not employ technologies our astronomical observing devices can detect from here. Perspectives on the ethical, policy, and design issues of such close encounters with alien life and intelligence are described. Ways of accelerating the coming of interstellar probes are suggested.

1: Motivation and Belief

Interstellar travel, by machines or by living beings, is a visionary idea whose realization is beyond our present capabilities. Implementing such a big idea is not just a technical problem to be solved by brilliant scientists and clever engineers. Success also will depend on sustained motivation, a shared belief that starflight is important to Humankind.

Scientists and engineers often shy away from anything that sounds like belief, assuming that belief is an irrational motivation linked to religion. Yet, if we should have learned anything about ourselves during the past century, it is that secular beliefs can be powerful forces even in our supposedly rational age. One need only recall the excesses of nationalism, fascism, and communism.

What motivates individuals to work on studies like Project Daedalus and Project Icarus, or the 100 Year Starship Study? It rarely is monetary reward, career advancement, or public renown. It is above all the desire to make a different future possible. The sense of quest shared by scientists and engineers who work in this field was described by Paul Gilster as the ultimate driver of interstellar flight.ⁱ

2. A Previous Success

Long-term perspectives are not only about the future, but also about the past. The earliest great spaceflight visionary, Konstantin Tsiolkovsky, foresaw that the first manned flight into space would take place in 2017.ⁱⁱ That first flight actually was achieved 56 years earlier. How did that happen?

The conventional explanation is that it was the result of geopolitical competition between the United States and the Soviet Union. That is only part of the story. As sociologist William Bainbridge told us in 1976, commercial opportunities, military necessity, and public enthusiasm were not what took us to the Moon. The Spaceflight Revolution was driven first by the beliefs and manipulations of a highly motivated minority that he described as a social movement. The spaceflight revolutionaries successfully exploited three great nations: Germany, the United States, and the Soviet Union. They overcame the indifference of science, governments, and the general public to realize their dream. Bainbridge concluded that revolutionary technological change is brought about through social processes that operate outside conventional market mechanisms.ⁱⁱⁱ The history of astronautics is not only a history of scientific and technological progress, but also a history of persuasion.

Advocates of interstellar flight might do well to reflect on the history of the successful spaceflight advocacy, which needed decades to sell their ideas. Their progress was not smooth; their quest was marked by raised hopes and disappointments, starts and stops. Yet that advocacy succeeded in transferring its aspirations to many people, and in eroding many others' conceptions of what was not possible. Even in more recent times, many people invested time and money and personal credibility to support expanded human activity in space, though there was no prospect that their efforts would lead to monetary reward or career advancement.^{iv}

The challenge of finding technically sweet solutions to the problem of starflight is exciting, but that alone will not get an interstellar probe built and launched. Realizing this vision will require a secular belief shared among a determined minority willing to sustain their efforts for decades, even generations.

Predictions of revolutionary technological change are rarely accurate. Some goals are achieved earlier than predicted, others later, and some never. Spaceflight visionaries like von Braun foresaw that we might land humans on Mars as early as the 1980s.^v That date has slipped to the 2030s, fifty years later than early advocates had hoped. The current advocacy for landing humans on Mars, that began in the 1980s with the Case for Mars conferences and is continuing through the Mars Society, is trying to revive enthusiasm for this idea. So far, they have not persuaded any government to support their dream. The near term prospects for a voyage to Mars must be seen as highly uncertain when the world's most important space power refuses to set any specific goals for manned spaceflight beyond the space station.

Back in 1975, visionary physicist Robert Forward foresaw a manned mission to a star in 2025.^{vi} Humans won't even be at Mars by then.

Few now remember that the Space Science Board of the U.S. National Academy of Sciences endorsed an interstellar probe in 1988.^{vii} That endorsement proved to be premature; it was left

out of subsequent decadal reports. Yet it established a precedent, a wedge keeping the intellectual door open.

3. Generations

Bainbridge described generations of spaceflight pioneers. In Generation Zero, intellectuals devoted energy to the question of spaceflight before technology had reached the point where the right conclusions could be reached. In Generation One, other intellectuals laid the correct theoretical groundwork for spaceflight, particularly Tsiolkovsky, Goddard, and Oberth. In Generation Two, dynamic persons gained influence over resources and other people to produce actual spacecraft. Here the primary actors were Wernher von Braun and Sergei Korolyov.^{viii}

Von Braun and others shaped the classic agenda for manned spaceflight: a reusable transport to orbit, a space station, a journey to the Earth's moon, and then a landing on Mars. They created a legend of events that had not yet occurred. That legend became an expectation.

In which generation is the interstellar advocacy? Generation Zero, represented primarily by science fiction writers, is behind us. One can argue that people like Robert Forward, Gregory Matloff, Alan Bond, and Anthony Martin have begun laying the correct theoretical groundwork for interstellar flight. Yet that does not guarantee early entry into Generation Two. As yet, there is no von Braun or Korolyov in sight.

The British Interplanetary Society's moonship study of 1939 foresaw many of the correct technical concepts for landing humans on the Earth's natural satellite.^{ix} It took thirty years to make those concepts a reality.

4. The Redoubt

In the absence of public support, visionary ideas may be preserved in what Bainbridge called a redoubt. Those ideas may emerge in a compelling way at a future time when the conventional consciousness has changed.^x Those who persist in the interstellar quest may find themselves in a new redoubt, separated from mainstream opinion.

We have current examples. The Space Studies Institute has continued research in support of Gerard O'Neill's space colonization concept for more than thirty years, though O'Neill passed away long ago.^{xi}

We have seen this in science as well. Individuals active in the Search for Extraterrestrial Intelligence have been listening for signals for more than fifty years, even in the face of ridicule and the absence of confirmed evidence.^{xii} After they lost government funding, SETI researchers in the United States continued their work with private money. The drive to achieve contact is being carried on by a small social movement, operating outside standard institutions to achieve a new goal.^{xiii}

5. Serendipity

History suggests that advocates of starflight should be alert for serendipitous events. The time horizon for the first interstellar probe will advance or recede due to factors that are outside of scientific and technological progress.

The maddening thing about the future, wrote Gilster, is that while we can extrapolate based on present trends, we cannot imagine the changes that will make our every prediction obsolete.^{xiv} The spaceflight revolutionaries did not anticipate the Cold War, yet that geopolitical contest enabled them to accelerate the achievement of their dream.

We already have seen a serendipitous event that helped to revive the interstellar idea: the discovery of numerous planets around other stars. We should recall that, before the 1990s, many astronomers considered such discoveries unlikely.

What event might offer a similar boost in the future? The most popular example now foreseen is the discovery of an Earth-sized planet in a habitable zone around another star.

There may be other events we have not yet imagined. To encourage thinking outside the box, I offer a more ominous possibility: astronomers studying stellar evolution might detect changes in our Sun telling us that we do not have a billion years left on the Earth.

6. Longevity

To carry out interstellar exploration, we must extend our time horizon. A true interstellar mission will require a longer term commitment to a program than anything else we have done in space. For the foreseeable future, interstellar probes will need several decades and perhaps a century to reach any of the most interesting nearby stars.

Stephen Baxter has examined the problem of continuity, noting that the probe may not reach its primary target until its originating scientific and political stakeholders are dead.^{xv} Maintaining staffing and financing for such a program will require multi-generational responsibility. I would add multi-generational motivation. Designing, building, and operating an interstellar probe will be a small step into deep time.

We already have taken our first steps in the direction of long-term continuity in space exploration. NASA has been able to monitor signals from the Voyager spacecraft for more than thirty years, showing that such longevity is feasible if it does not require major expenditures and does not threaten other programs.

Science offers other examples. Since the 1960s, researchers have been trying to develop fusion reactors that can produce commercially competitive electrical power. Though the first generation of researchers has passed on, their successors continue to receive government funding for their work despite the criticism that realizing this dream is always twenty to thirty years away.^{xvi}

One trend may help. Human life expectancy has been growing slowly but steadily for decades. Many demographers expect that life expectancy will continue to rise with no limit yet in sight.^{xvii}

By the time we launch an interstellar probe, a ninety year longevity may not be unusual.^{xviii} The issue may be how long interstellar probe supporters can hold on to their jobs.

7. Secular Beliefs

Some of our fellow humans may complain that commitment to a project that reaches beyond individual lifetimes is irrational. Yet it is a modest effort compared to the time, energy, and money that humans devote to their religions and their ideologies.

It has been argued that religion is primarily about what ought to be.^{xix} So are secular beliefs, and secular hopes.

Here is a currently unfashionable example of how secular beliefs can drive human behavior for generations. For fifty years, Americans and their allies sustained massive societal commitments in response to two powerful secular beliefs known as fascism and communism. After their first waves of victories, the major fascist powers were defeated. Then the U.S. and its allies found themselves facing an expansionist empire espousing a communist ideology that many people thought was the wave of the future. While it now is intellectually fashionable to deride the Cold War, it was a huge victory for the democratic way of life, and it was won without a major hot war.

8. Biological Ethics

There appears to be a widespread assumption that our interstellar probe will search for evidence of alien life, perhaps by targeting the habitable zones around other stars. Such probes may be a more thorough way of discovering extrasolar forms of life than a search for radio signals can be. Radio searches directed toward our solar system by extraterrestrials would have been fruitless throughout nearly all the billions of years of our planet's existence.

How high a priority should starship designers give to the search for life? What evidence should the probe look for? Which instruments should we include? With a limited payload, we will have to make choices. Those choices will rest on the assumptions about the nature of life that prevail at that time.

What if the probe reports ambiguous evidence? What if we are not sure whether the phenomenon we discover is life or non-life, because it is so different from the life we know? Should our machine be programmed to take a closer look?

Humankind already has set a precedent for ethical behavior toward alien life in our interplanetary explorations. Protocols are in place to avoid contaminating other solar system bodies. Implicitly, we have accepted a principle of non-interference. Those rules have been motivated not only by ethics, but also by the self-interest of astrobiologists.

Such rules may be extended to an interstellar probe, suggesting that our machine should not enter the atmosphere or land on the surface of a planet suspected to have life. Remote detection of the by-products of life could motivate us to send a probe, but it also might imply a constraint on that probe's behavior.

9. Encountering Intelligence

What about intelligent life? It is conceivable, though not likely, that our astronomers will remotely detect signs of intelligent life in a nearby system. That would raise a policy and ethical question. Should we send a probe to that destination, or should we avoid it?

If we found no such signs by remote observation, our probe still might find evidence of a non-technical civilization or a technological society that does not emit detectable signals. What are the other signs of intelligence that our probe should look for? What if that civilization is dead, and we find only its remains?

If a living alien civilization discovers our probe, how would they react? What if they had believed that they were the universe's only intelligent beings, as most humans have believed we are for most of our history? What if they never had thought of interstellar exploration? They may not have anticipated contact with other intelligences; our probe could come as a disturbing surprise. Those sentient beings would have to adjust rapidly to this paradigm-shattering experience.

To extraterrestrials, we would be the aliens, whose character and purposes are unknown. Psychologist John Baird speculated that they might consider the probe's senders as gods or mythical beings, whose true reasons for coming would remain a mystery.^{xx}

Imagine a probe that parks in orbit around the planet of a non-technical civilization which detects the object by its reflected light. If that society lacks the means to discern our probe's details and has no way of communicating with it, what might they think?

What if our probe were designed to fly through the target system without decelerating, like the Daedalus starship? That other society would see an alien object pass through their realm without stopping or communicating, a mirror image of the scenario that Arthur Clarke described in his novel *Rendezvous with Rama*.^{xxi} How deflating might that be? How inspiring of awe?

At the other extreme, would the majority of an alien society believe a one-time sighting of our starship? Or would reports of an alien visitor be dismissed as a misunderstanding of a known phenomenon?

To an alien civilization, our probe would be a form of direct contact. In their minds, an alien intelligence will have crossed a threshold by demonstrating its ability to act over interstellar distances. Would this imply that the sending civilization is expansionist? Would it imply that we are a potential threat?

We have no way of predicting the behavior of extraterrestrials except by analogy with our own history.^{xxii} The most reasonable assumption is that those intelligent beings will act in accord with what they believe to be their interests. Yet, we cannot exclude less objective factors such as religion, ideology, or fear of unknown outsiders.

We must recognize how contingent the outcome of contact may be. No single model addresses all the possibilities; no equation can tell us what will happen.

10. Contact Conscience

What are our moral and ethical obligations to a society of intelligent beings less technologically advanced than our own? What role does conscience play?

Should our probe obey Star Trek's often-violated Prime Directive and observe the other civilization invisibly, keeping our presence secret? Should we signal our presence without knowing its effect on them? Should we engage in interstellar nation-building, helping them to achieve what we consider progress?

Isaac Asimov and Stephen Dole, writing before Star Trek, put it this way: "After a prolonged study of the situation, a decision would have to be made whether to make overt contact or to depart without giving the inhabitants any evidence of the visitation."^{xxiii}

What we do will be determined not only by what we find, but also by our conscience. Are there universal grounds for ethics? Is there a universal rationality about contact? We do not know.

Unfortunately, recent dramatic films and television programs about contact have not advanced our thinking. They still foresee that intelligent aliens must be either altruistic philosopher kings who raise us from our fallen condition, or brutal invaders who want our planet for themselves. What a poverty of imagination! Television and film producers need to escape the iconic images about contact they have inherited from the past.

11. A Mirror Image

Here is a test, in the form of a mirror image. If we are thinking about sending out probes, a more technologically advanced civilization may have done that long ago. How would we react to finding an alien probe in our solar system, even the hulk of one that ceased functioning a million years ago? We would know instantly that direct contact is possible.

What would we assume about the alien probe's purpose? Would we interpret the probe's actions correctly?^{xxiv} If that alien craft sent us a message, would we understand it? If that message assured us that the alien machine came in peace, would we believe it? What if that device made no detectable effort to communicate with us?

Our history, our beliefs, and the current states of our cultures would condition our response. Such an alien machine might intimidate us, or it might provoke us to accelerate our own efforts to achieve interstellar flight.

12. Will Our Probe Speak for Us?

Given the long delays in communications between us and our probe, that machine will need to carry a sophisticated artificial intelligence programmed to deal with a variety of contingencies. Should we program that machine to interact with whatever sentient beings it might discover, or should it wait twenty to forty years for instructions from Earth? How independent should our probe be?

Astronomer Ronald Bracewell long ago suggested that a probe might carry a sizeable reference library enabling it to interact with an alien intelligence with the appropriate technology.^{xxv} What should we include in that library? How would our machine convey our intentions?

Our probe will be subjected to the interstellar environment for decades. Will the particles and radiations it encounters affect the on-board intelligence? Might that intelligence mutate to behave in ways we did not intend?

13. Crossing the Threshold

The Drake equation should be modified to include the probability that a technologically advanced civilization will choose to explore beyond its home system with machines. Once we launch our first interstellar probe, we will be one of those civilizations.

Interstellar flight will be the key factor in determining the difference between controllable and uncontrollable consequences of contact. Not whether such flight is possible, as it almost certainly would be for a species more technologically advanced than our own, but whether any civilization is sufficiently motivated to actually explore, colonize, or take other action at interstellar distances.

As long as our functioning machines are confined to our solar system, we are no threat to anybody beyond it. Once we develop the ability to reach other stars with functioning machines, we may become a species of interest.

14. A Paradigm and a Strategy

If we achieve interstellar flight, our concept of the accessible universe could expand exponentially. Yet it takes a long time for people to incorporate a larger concept of their relevant universe into their thinking, to accept an extraterrestrial paradigm.^{xxvi}

Astronomy, SETI, and space exploration can be seen as elements of an unarticulated grand strategy for our species in its larger environment.^{xxvii} Such a strategic vision may not bring early funding, but it can provide a context for future decisions if it is shared by enough motivated people.

While some individuals accept the outward-looking paradigms of exploration and expansion, most do not and must be persuaded to at least tolerate such ventures.^{xxviii} Is the interstellar idea a technophilic overreach, or does it reflect a deeper, unarticulated rationality about the shared interests of our species? The same question arose with the exploration of our solar system, and its not-so-hidden agenda of human expansion to other worlds.

If we discover no alien intelligence, if we are effectively alone, the moral task of assuring the survival of intelligence will be ours. That obligation cannot be limited to the Earth's biosphere, which ultimately will become uninhabitable. It cannot be limited to our solar system, which eventually will become hostile to life. We cannot assume that we have a billion years ahead of us; an astrophysical catastrophe could occur at any time.

Here is the long-term motivation for interstellar exploration: searching for a new habitat for some of our descendants. As Carl Sagan put it, our choice is between spaceflight and extinction.

Interstellar flight may be the way intelligence escapes stellar evolution. It may be the way sentience moves around the galaxy. Those who journey to other stars could be agents not only of panspermia, but also of pan-intelligence. Yet we should be cautious about assuming that expansion will be a universal trend. The possible is not the inevitable.

Those civilizations that do expand beyond their original systems of origin may constitute a small minority of all sentient life forms. They may be a very influential minority.

What happens will depend as much on motivation and morale as on technical advance. As anthropologist Ben Finney pointed out, the contrast between Portugal and China suggests that motivation, not mere size and wealth, is the crucial ingredient for undertaking exploration beyond the known world.^{xxix}

15. Where Do We Go from Here?

So, how do we extend this moment of enthusiasm? Here are a few words of unsolicited advice from an ancient bureaucrat who has seen many programs come and go.

First, keep your focus on unmanned probes rather than inhabited spacecraft. We all know that many people support the robotic exploration of our own solar system not just for scientific reasons, but also because it implies later human exploration and possibly settlement. Yet we must recognize that interstellar flight in inhabited vehicles will be orders of magnitude more difficult -- and expensive -- than robotic exploration. It also will be much farther away in time, and much easier to dismiss as fantasy. Some critics will reject transporting humans to the stars as elitist escapism, as some reacted to Gerard O'Neill's space colony proposals. To make interstellar flight seem more feasible and less controversial, remove humans from the equation.

Second, build your constituency by alliances with other groups. Starflight advocates should be fanatic supporters of the astronomical search for extrasolar planets. No foreseeable event would help their cause more than discovering an Earth-sized planet within a habitable zone, however we may define that at the time.

Make yourselves allies of the astrobiologists. We can hope that they will find extraterrestrial life on Mars or Europa or some other body in our own solar system, but success is not guaranteed. Finding alien life may require interstellar probes.

Actively support the continued exploration of our own solar system, particularly the region beyond Neptune. Developing new technologies is not the only reason. Missions to the outliers of the Sun's empire could be intermediate steps toward interstellar flight by machines.

Third, continue planting a legend of events that have not yet taken place, this time beyond our solar system. Science fiction and science-based speculation instilled the idea of going to the Moon and Mars long before such journeys were possible. Starflight advocates should give

particular attention to teachers, professors, public intellectuals, and expert communicators who can spread the message to younger generations.

Fourth, be prepared to respond when some scientists, particularly astronomers, declare that interstellar flight by machines is impossible. When they do, remind them of what the eminent American astronomer Simon Newcomb wrote in 1893:

The demonstration that no possible combination of known substances, known forms of machinery and known forms of force can be united in a practicable machine by which men shall fly long distances through the air, seems to the writer as complete as it is possible for the demonstration of any physical fact to be.^{xxx}

Fortunately, the Wright brothers were not deterred by such an expert opinion.

Fifth, be prepared to suffer some discouraging blows. Many advocates of interstellar flight secretly hope for eventual government funding. Unfortunately, the budgets of space and research agencies may be tight for the next five years. Without a goal beyond the Space Station, NASA may be in particular danger. Critics will brand studies of interstellar probes as premature and of low priority.

Starflight supporters might learn from the SETI experience. For years, U.S. government support for SETI was buried within larger budget elements. Once SETI became a formal NASA program with high visibility, a legislator killed it.

Sixth, get historians to help by telling you how very long-lived institutions were able to pursue their goals for generations, even centuries. The most obvious example is the Catholic Church, whose organized form has survived repeated challenges for more than 1,500 years.

Seventh, find yourselves a young billionaire who will be around thirty or forty years from now. Has anyone approached Mark Zuckerberg?

Lastly, don't expect quick results, or adherence to a specific timeline. Advocates of interstellar exploration may have to keep the faith without near term results. A conviction that cannot survive five years of hard times is not much of a conviction.

There is nothing inevitable about the coming of interstellar exploration with machines. It depends on what we humans choose to do.

15. Conclusion

Arthur Clarke once suggested three stages of intellectual establishment reactions to a revolutionary idea. In stage one, they say it is completely impossible. In stage two, they say it is possible but is not worth doing. In stage three, they say they knew it was a good idea all along.^{xxxi} Interstellar flight by machines is entering the second stage.

Starflight advocates must keep doing the work to make interstellar exploration seem more feasible to future generations than it seems to us now. Some may become the giants on whose shoulders others will stand.

They should remember the example of the earlier spaceflight revolutionaries. Here is what rocket pioneer G. Edward Pendray said in his book *The Coming Age of Rocket Power*, published in 1945:

Those of us who have spent years in the study and development of rockets have acquired an emotion about them which is almost religious.

We somehow feel privileged, as though we had stood in these years at some obscure crossroads in history, and seen the world change. We do not know exactly what we have loosed into the earth, any more than Gutenberg with his movable type, or De Forest with his radio tube. But we feel in our souls that it is magnificent and wonderful, and that the human race will be richer for it in time to come.^{xxxii}

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term in the kinetic energy formula, millions of times as much energy is required. Accelerating one ton to one-tenth of the speed of light requires at least 450 petajoules or 4.50×10^{17} joules or 125 terawatt-hours[8] (world energy consumption 2008 was 143,851 terawatt-hours),[9] without factoring in efficiency of the propulsion mechanism. The crew of an interstellar ship would face several significant hazards, including the psychological effects of long-term isolation, the effects of exposure to ionizing radiation, and the physiological effects of weightlessness to the muscles, joints, bones, immune system, and eyes. There also exists the risk of impact by micrometeoroids and other space debris.

â– Tsiolkovsky - Interstellar Pioneer. â– NEWS FEATURES â– Work on the interstellar asteroid and i4is Project Lyra â– Pete Worden, Breakthrough Initiatives, at i4is HQ. â– Sir Arthur C Clarke Centenary. â– Models and art at the Mill. what Kelvin Long and Rob Swinney did on their recent USA visit including giving addresses at NASA Goddard and the University of Maryland. We also report interstellar-related work including the. author Deep Space Propulsion, A Roadmap to Interstellar Flight (Springer) » Paul Campbell: Software Engineer » Richard Osborne: Rocket Scientist » Rob Swinney: i4is Education Director, Project Leader, Project Icarus » Terry Regan: creator of the BIS Daedalus model and the i4is 2001 Monolith » Tishtrya Mehta: Astrophysics Researcher. K.F. Long. Deep Space Propulsion. A Roadmap to Interstellar Flight. K.F. Long Bsc, Msc, CPhys Vice President (Europe), Icarus Interstellar Fellow British Interplanetary Society Berkshire, UK. ISBN 978-1-4614-0606-8. e-ISBN 978-1-4614-0607-5. The author is a major contributor to the British Interplanetary Society Project Icarus, which is investigating near-term techniques that might lead to probes capable of reaching our Sun's nearest stellar neighbors. As well as reviewing the current state of interstellar propulsion technologies, Kelvin Long provides an extensive bibliography that will be an invaluable aid to the novice researcher. vii. viii Foreword.

K.F. Long. Deep Space Propulsion. A Roadmap to Interstellar Flight. K.F. Long Bsc, Msc, CPhys Vice President (Europe), Icarus Interstellar Fellow British Interplanetary Society Berkshire, UK. ISBN 978-1-4614-0606-8. e-ISBN 978-1-4614-0607-5. The author is a major contributor to the British Interplanetary Society Project Icarus, which is investigating near-term techniques that might lead to probes capable of reaching our Sun's nearest stellar neighbors. As well as reviewing the current state of interstellar propulsion technologies, Kelvin Long provides an extensive bibliography that will be an invaluable aid to the novice researcher. vii. viii Foreword.