The 100 Year Starship Endeavor

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1. Introduction

The 100 Year Starship Study (100YSS) is an unprecedented, multi-disciplinary initiative that challenges humanity to identify commercially sustainable ways to design, develop, and build a manned vehicle for interstellar space travel within 100 years, by the year 2111.

Aside from the obvious technical challenge, there are numerous organizational challenges to mounting a multi-generational endeavor to launch a human Starship mission. First and foremost is the need to develop

a clear vision and mission statement for such an ambitious undertaking; the scope of such a mission is truly a global undertaking.

Nevertheless, current and past multinational space projects demonstrate that there are additional obstacles inherent in such large scale international projects. Particularly challenging is the difficulty of building international consensus on the very need to embark upon a multi-generational mission, and one whose core technology does not yet exist. In the current globally hard-pressed financial environment, it will be difficult to obtain political support for a single massive project towards this goal.

This suggests that it will be critical to move forward step by step, perhaps with shorter-term robotic analog Starship missions and commercial demonstrations. Spreading knowledge of the threat of near-Earth objects, as exemplified in December 2011 with the near-collision with Asteroid 2005 YU55, shows that planetary defense should be an increasingly important driver of space investment, technology development, and exploration over the coming century.

In their recent book The New Universe and the Human Future: How a Shared Cosmology Could Transform the World, authors Nancy Ellen Abrams and Joel R. Primack argue that, "...we are living in a cosmically pivotal moment today, and we have a higher level of responsibility than any generation that came before us... We and our children may be the most significant generations of humans that have yet lived."

If it happens, such a venture into interstellar space may well prove to be an event of exactly such significance.

2. Vision

Some Native Americans believe that in making important decisions, one has the responsibility to think seven generations ahead. While this is an admirable and visionary core principle, it may not be sufficient to motivate the interstellar stage of humanity's movement into space.

Yet just such a multi-generational challenge was issued in 2011 by NASA and DARPA, the United States Department of Defense Advanced Projects Research Agency, in the form of the "100 Year Starship Study" (100YSS). DARPA is the source of funds and NASA will administer the award. This request for proposal was organized as a business plan competition for an organization that can, without government funding, lead a technology research program for a century towards the goal of launching of a manned Starship by the year 2111.

The solicitation introduces the challenge as follows:

> "The 100 Year Starship™ (100YSS™) is a project seeded by the Defense Advanced Research Projects Agency (DARPA), with NASA Ames Research Center as executing agent, to develop a viable and sustainable non-governmental organization for persistent, long-term, private-sector investment into the myriad of disciplines needed to make long-distance space travel viable. The goal is to develop an investment vehicle—with the patronage and guidance of entrepreneurs, business leaders, and technology visionaries—which provides the stability for sustained investment over a century-long time horizon, concomitant with the agility to respond to the accelerating pace of technological, social, and other change."

The unique nature of the 100YSS Study has led to speculation regarding DARPA's actual intentions, and a summary of DARPA's history may offer some visibility into this unusual context.

DARPA's mission is to develop technology for the military, but this definition omits important historical context. The real key to developing an understanding of DARPA's activities is to consider the concept of "Technological Surprise," which refers to activities of foreign nations that demonstrate a surprising technological capability, and one that domestic scholars or authorities could not have predicted.

DARPA's mission is described on its website as, "To maintain the technological superiority of the US military and prevent technological surprise from harming our national security by sponsoring revolutionary, high-payoff research bridging the gap between fundamental discoveries and their military use."

In fact, the agency that became the modern DARPA was created in response to the technological surprise of the launch of Sputnik in 1958. The initial stated goal of DARPA at the time was to maintain technological superiority for the United States, and to avoid any such technological surprises in the future. This function evolved over time to include creating such technological surprises for the United States.

To fulfill its goals, DARPA is charged to look beyond contemporary needs and capabilities as defined by the military itself. In this regard, military historian John Chambers has noted that, "none of the most important weapons transforming warfare in the 20th century – the airplane, tank, radar, jet engine, helicopter, electronic computer, not even the atomic bomb – owed its initial development to a doctrinal requirement or request of the military." And to this list, DARPA would add unmanned systems,

Global Positioning Systems (GPS), and Internet technologies.[1]

DARPA is perhaps most famous for its support of the early Internet. Indeed, DARPA (then called ARPA) was instrumental in supporting the early computer networking research of the 1960s, which initially networked together two computers at two California universities. Other projects have ranged from autonomous cars with no human driver (DARPA Grand Challenge) to the 15,000 mph unmanned bomber aircraft (Hypersonic Research Program) with additional projects including natural language interpretation algorithms (eventually made available to the public in Apple's Siri virtual personal assistant software), and robots that refuel themselves by foraging natural resources (EATR).

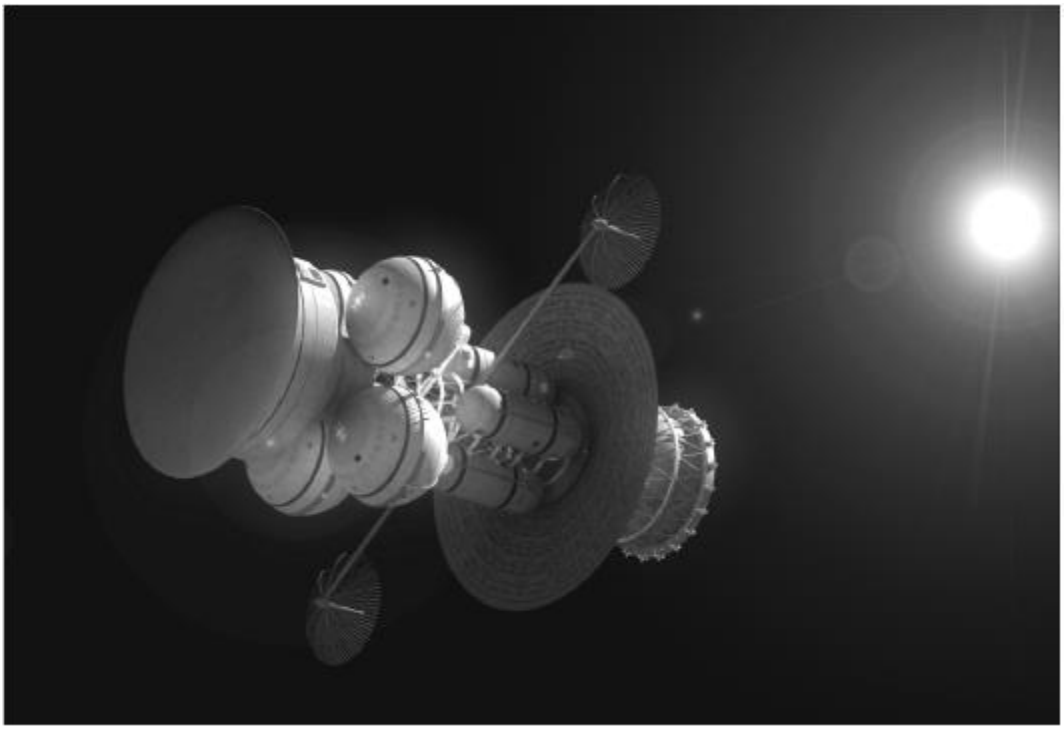

Figure 1: Icarus Pathfinder
This illustration by Adrian Mann shows a concept for an interstellar spacecraft. Reprinted by permission.

In keeping with its history, the purpose of the DARPA 100 Year Starship Study is to challenge academia, industry, and the public to identify methods to improve humanity's technological, economic, and sociological capability to a level such that we are capable of building and launching a manned, interstellar Starship in a commercially sustainable way.

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[1] Chambers, John, ed., The Oxford Companion to American Military History. Oxford University Press, 1999. p 791.

After the 100 Year Starship proposal due date, DARPA subsequently announced two additional challenges: software to enable reassembly of documents that had been shredded to be put back into legible form, and methods to reuse otherwise defunct satellites or their components in orbit.

What is unique about the 100YSS is that DARPA primarily undertakes technical challenges. If the challenge itself does not identify technical goals, then such goals are generally expected to be included as part of the response. Further, DARPA typically focuses on relatively short term technology development efforts, and its flat organizational structure is intended to enable the rapid deployment of technical approaches to problems. DARPA embraces high-risk, high-reward positions.

The 100 Year Starship stands out in that it deviates from the normal DARPA model by asking for an organizational plan instead of a technical plan. Instead of the "standard" DARPA approach of a technology development challenge with a 2 to 4 year goal, this is a business plan competition for an organization that will endure for a minimum one-hundred-year lifetime, an organization that is intended to enable an unprecedented technical achievement on a colossal scale. It further aims to do so with a relatively small award that was eclipsed by the cost of the study itself. Hence, DARPA spent more than the actual award amount on running the program that would identify the recipient. For example, DARPA had a 3 day conference with over 1000 attendees at a major hotel, and also had to run their program internally for several years. This undoubtedly cost more than the US$ 500k they eventually plan to award.

3. Challenges

In a recent article about the 100YSS project, Lou Friedman, former Executive Director of the Planetary Society wrote, "Interstellar flight is a vision for some and science fiction for others. I recall a discussion I had with Freeman Dyson a few years ago about whether we were further from interstellar flight than was Leonardo Da Vinci from the airplane."[2]

This illustrates the colossal scale of the technical challenges involved in interstellar flight. Da Vinci's time was three centuries prior to the initial attempts at powered flight: Are we that far from mastering nature to the point at which she will permit interstellar flight?

Among technical experts as well as well-informed generalists there is

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[2] Friedman, Lou. "Mind expansion," The Space Review, Monday, November 21, 2011.

a tremendous uncertainty as to the possibility, or even the practicability of placing almost any time scale on such a massive speculative event. In a world where technology is changing exponentially, the better argument might be about when the technology will be available, not so much about if the technology will ever exist.

Recent discoveries of Earth-like planets orbiting other stars may provide a powerful near-term motivation to begin the technical work necessary for interstellar flight. The discovery of "other Earths" with even the possibility of human-compatible atmospheres suggests that such a planetary diaspora may become a realistic option at some point in the not-so-distant future.

Scientific motives or the need for self-preservation may also contribute to public and commercial support for this goal. Indeed, many scientists, notably Stephen Hawking, have observed the need for humanity to eventually become a multi-planet species in order to avoid extinction.

4. Structures & Longevity

The authors of this chapter are part of the "Global Starship Alliance," one of the teams that submitted a proposal to DARPA for the 100YSS project.

> [Editor's note: A definitive announcement has not been made as of the publication date of this volume, but the authors' team appears to be the competition runner-up.]

In preparing our ideas we examined some very long-lived organizations, seeking to identify factors that may contribute to establishing a long-term visionary organization that can endure a 100 years plus or preparation for a mission that may then last hundreds more.[3]

Hudson's Bay Company was incorporated in 1670 by charter, and remains the oldest commercial corporation in North America, now at 342 years of operations. A fur trading business for much of its existence, today it owns and operates retail stores throughout Canada.

The Dutch East India Company was chartered in 1602 when the States-General of the Netherlands granted it a 21-year monopoly to carry out colonial activities in Asia. It was also the second multinational corporation established in the world, and the first company to issue shares

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[3] Most of the facts related to Hudson Bay Company, the Dutch East Indies Company, and the National Geographic society were established via Wikipedia search.

of stock. It remained an important trading concern and paid an 18% annual dividend for almost 200 years. Weighed down by corruption in the late 18th century, the Company went bankrupt and was formally dissolved at age 198 in 1800.

Founded in 1888 (and now 123 years old) the National Geographic Society, headquartered in Washington, D.C., is one of the largest non-profit scientific and educational institutions in the world. In 2010, the Foundation's endowments totaled more than $130 million, and the income from these endowments is used to support the creation and dissemination of educational resources, professional development for teachers, public awareness, policy reform and other programs that enhance geographic education.[4]

These organizations share the fact that they are concerned with the exploration and development of new frontiers, which by definition also necessitates a risk-tolerant posture, and they also share the fact that they demonstrate a close exploration and development relationship between private entities and governments. These factors will also be characteristics of the 100YSS.

And so will international cooperation. During most of the short 50-year history of human space flight, international space cooperation was primarily dictated by Cold War and US-Soviet superpower politics. But as the Cold War ended, the International Space Station became the largest international science and technology project ever undertaken, a global effort involving many nations and decades of effort and investment.

It is clear that that similar motivations will be central if and when an interstellar mission is undertaken. However, 100YSS will also have to be "sold" to the public based on shared global imperatives and justifications, such as establishing the enabling technologies for planetary defense, or as the central vision and imperative for humanity becoming a multi-planetary species.

The actual technical implementation of a 100YSS is undoubtedly an international undertaking. Indeed, most "mere" space science missions in our time have international participation. An interesting question raised by the 100YSS process is the extent to which government structures and limitations can hinder attempts at truly humanity-wide projects. For

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[4] Interesting to note that science fiction writers Jerry Pournelle, Larry Niven and John Barnes also used the National Geographic Society as the legal and financial vehicle for their fictional Herot starship mission, writing in great detail about how to handle and pay off the finances of such a mission while in flight and also to measure the benefits of such a ventures.

example the United States has a body of law called the International Traffic in Arms Regulations that governs the sharing of technical information with foreign nationals. The United States State Department maintains a list of technologies that fall under this protection. This includes most spacecraft related technologies regardless of their intended application. This means that it is very difficult for the international technical community to even talk about the technical issues with American experts. There are several current proposals working their way through the American political system to ease these restrictions on benign technology items. However it remains to be seen whether the political will can be wielded to make such a change. Any international project along these lines will need to navigate these waters.

The international cooperation paradox suggests that there is a logical construct for all international parties to work together to achieve a resource and talent intensive endeavor that is for the greater good of all of humanity. However, this seems to often be at odds with the logical construct, that seems, inherent in the human condition. And that is a condition where politics, bureaucracy and petty self-interest sometimes prevails over the great good of the community and humanity.

The April 24th, 2011 audacious announcement of a new company, called “Planetary Resources,” focused on the mining of asteroids, by a consortium of international billionaires, may symbolically have defined a new era, where international commercial space, may one day rival the past cooperation of governments and nation states.

5. Conclusion

There are a number of critical and fundamental challenges to mounting a multi-generational endeavor to launch a human Starship mission. Foremost is the need to develop a clear vision and mission. There are both national and international challenges related to developing a consensus about the need, utility, and the desirability of embarking on such a starship mission.

It may be particularly difficult to build an international consensus on the need to embark upon a multi-generational mission when its core technologies do not yet exist. In the current financial environment, allocation of significant resources for a huge commercial, technological, and scientific project is not likely to resonate nor find sustainable support without also providing significant and on-going near-term benefit. Consequently, when DARPA and NASA announced the 100YSS initiative,

it was expected by many in the space community that there would be only a modest response.

In reality, however, this bold announcement inspired hundreds of visionaries in the space community, and they formed dozens of different teams that are responding to the DARPA request for proposal. As noted, the authors of this chapter are part of one of those teams.

After long consideration, we proposed and continue to advocate the following recommendations:

The creation of an organization that we provisionally refer to as the "Open Source Starship Alliance," which has brought together all of those scientists, technologists, and visionaries from the many teams that bid on the DARPA project to participate on an ongoing basis, in a community dedicated to the efforts and the vision of 100 Year Star Ship. Essentially, the DARPA 100YSS process has created a focal point and a catalyst for bringing many like-minded people together who share an interest in this ambitious project. It may turn out that this emerging community may be one of the greatest value drivers of the 100YSS initiative.

A robotic analog 100YSS mission to serve as a "precursor mission" for the ultimate goal of a human starship mission, a robotic craft on an interstellar journey as a first test of technologies and to identify unknown challenges.

The creation of numerous, smaller, commercial-focused missions that would create the seeds of a long-term commercially sustainable space ecosystem that will eventually be necessary for sustainable robotic and human starship missions.

Critical imperatives driving the 100YSS include the need for planetary defense, and the imperative for humanity to become a multi-planetary species.

In the recent New York Times bestselling book Abundance, world renowned aerospace engineer Burt Rutan is quoted as saying, "Revolutionary ideas come from nonsense. If any idea is truly a breakthrough, then the day before it was discovered, it must have been considered crazy or nonsense or both – otherwise it wouldn't be a breakthrough."[5] This paradox of innovation and perception of nonsense before breakthrough has, throughout history, bedeviled policy makers and legislators who are in the business of allocating public resources for science and technology projects.

We have discussed the challenges related to the longevity of

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[5] Diamandis, Peter and Steven Kotler. Abundance: Why the Future will be Much Better Than You Think, Free Press, 2012, p. 229.

commercial organizations. But do civilizations themselves have the endurance that would be required to send a starship into the heavens? Civilizations themselves cannot become great without great ideas, and certainly starship technologies, among the only ideas that can save our species from eventual extinction, are some of the greatest ideas of all human history.

A presenter at the 100YSS Symposium held in Orlando, Florida, September 29 – October 2, 2011, described this underlying paradox in economic terms:

> "The future value in starship technology is nearly infinite due to its capacity to save the human species from extinction and perpetuate the species beyond the limited capacity of Planet Earth. However, the present value of such technology is very low due to its extreme cost and limited near term application."

At a recent gathering of space visionaries, glasses were raised and a toast was proposed to the 100YSS initiative: "To the stars, or under the table!" an expression of ultimate commitment to this goal.

As of publication date of this book, the current status is that the Jemison Foundation seems to have won, as news was leaked on Dec. 31, 2011 that a decision had been made, and leaks over the next week confirmed the Jemison Foundation had been selected. However, as of April 19, 2012, there has been no official confirmation from DARPA, nor any transfer of funds.

The 100YSS challenge offers humanity the opportunity to choose a clear and compelling vision and a path to the stars, and just as importantly, to leave behind the current political muddling and chaos that holds back our planet's shared potential.

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Jeffrey Nosanov currently works at NASA's Jet Propulsion Laboratory (JPL) for the Radioisotope Power Systems (RPS) program. In 2011 he represented the RPS program at the United Nations Committee on Peaceful Uses of Outer Space meeting in Vienna, Austria. He works on proposals and business strategy for JPL. He was the first person in the United States to earn an LL.M. degree in Space and Telecommunications law, following his J.D. at New York Law School at which he was a public interest fellow. For the LL.M., he wrote a thesis on the International Traffic in Arms Regulations (ITAR) and their impact on the competitiveness of the United States Space Industry, which was published in the journal Astropolitics.

Michael Potter

Michael Potter serves as Director of Paradigm Ventures a family investment firm focused on high technology ventures. Previously Potter was Vice Chairman, founder and President of Esprit Telecom plc., a pan-European competitive telecommunications services provider. During his eight years at Esprit, the team grew the company to 1,000 employees in more than nine European countries and a market capitalization of a billion US dollars. He was formerly an international telecommunications analyst at the Center for Strategic & International Studies (CSIS) in Washington, D.C. Potter was also Vice Chairman of the founding Board of the European Competitive Telecommunications Association (ECTA).

As a first-time documentary filmmaker he created the award winning film, Orphans of Apollo. Potter previously worked on the 13-part WGBH Series, War & Peace in the Nuclear Age. He is a member of the Board of the Trustees of ISU, and was one of the founders of the ISU Scholarship fund which has raised scholarships fund for more than 15 scholars. He is on the Board of Directors of the Manna Energy Foundation, a non-profit foundation that is installing clean water solutions in high schools in Rwanda, on the board of advisors of Odyssey Moon, the first entrant into the Google Lunar Xprize competition.

Michael is a Senior Fellow at the International Institute of Space Commerce and a director Global Connect. His articles on high technology business and policy have been widely published.

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