100 Year Starship Study™, Response by Winged Cat Solutions

This is a response to DARPA's 100 Year Starship Study™ RFI. In this paper, the authors lay out a plan by which the study's objectives may be completed, overcoming what the authors believe to be the main problems with the proposed scenario.

First, the initial grant is insufficient to purchase even one full rocket launch capable of reaching Earth orbit. Second, there is a trend among organizations to proclaim intent to do something in space, produce many studies, but then fail to bend metal. Third, exact planning over 100 years for an organization is impossible, given the social and technological changes in that time.

We propose to use the initial grant as seed funding to attract private capital, to be paid back with interest within 5 to 10 years, with simple missions to ensure things stay on schedule and under budget. A fixed repayment window - and thus a maximum research time, after which the best guess available must be used - fights the temptation to study indefinitely instead of building and launching the mission. Finally, we recommend setting up conditions so net-present-value estimates will favor development of space, using the inertia that has held humanity on Earth to propel humanity outward instead, changing our proposed organization's structure and governance in response to the resulting social and technological changes.

A vehicle capable of leaving our solar system - a starship - can be built and launched within a few years if there is sufficient reason, as demonstrated by Voyagers 1 and 2, so our proposal spends the balance of the 100 years establishing that reason. We propose a corporation to find asteroids rich in platinum and platinum-group metals, move them into lunar orbit, process the ore there, and deliver it to Earth for sale. A growing need for better processing justifies establishing a colony within 15 years. The colony can be encouraged to form a community in space within 40 years total, so that no subsequent controller might find it convenient to abandon the colony. This community will naturally expand over time, and stands a good chance of having a practical reason to develop a starship in less than 100 years total.

Lunar orbit is preferred over Earth orbit to ease political challenges. In situ processing is not preferred because it will greatly increase operational costs (the Moon is always nearby, but any given asteroid is only close at most once every few years, and many operational necessities can not wait a few years), more than offsetting the savings of not moving the entire asteroid up front. It will also be it far easier to set up a colony if the raw material is already in place; easy access to lunar materials will help later stages of the colony.

A survey of the literature, and consultation with experts, revealed no technological showstoppers. No one seriously questions that these activities could be done given enough money. The challenges, especially at first, are mostly financial and operational.

Survey

The first step is to establish a not-for-profit corporation: tax exempt under Internal Revenue Code Section 501(c)(3) as an organization formed for the purposes of science. Incorporation as a

NPO entices investors by offering a double return: immediate tax breaks from donations, with eventual interest returned on loans. This entity will later reincorporate as a for-profit corporation (near the start of the Mining phase, below), and this formation should be done with that in mind. (Little if any preparation should be done at this time for the stage after that - see Independence - since it would not help, and it would scare off intermediate investors, concerned that they would not be paid back first.) The corporation's next two goals will be selection of a candidate asteroid, and refinement of its business plan to attract sufficient capital.

While there is data about asteroids' orbits, little is definitely known about their composition. Analysis of previous studies, and ground or satellite based spectroscopy of asteroids, will yield useful data for selecting an asteroid with a relatively (at least 100 ppm) high concentration of platinum group metals. A diameter of at least 100 meters is preferred, since the corporation will be repaying its investors primarily from this first asteroid as described in the Mining phase. Smaller asteroids may prove the concept, but would require more investment before profitability; aiming to be profitable with the first asteroid is more likely to succeed. Further, this asteroid should be easy to move into lunar orbit; one that crosses Earth's orbit is best.

Word of this will bring significant political opposition, from those who assume that the asteroid will hit the Earth instead of entering lunar orbit, and that it is up to them to save the planet. They will not be reasoned with, and many will be paid to have this opinion. If left alone, they can and will get governments to shut down the operation. The most effective counter is overwhelming openness. At a minimum, the company's Web site should provide graphics showing where the asteroid will be at any given time (or, at this stage, proposed paths for candidate asteroids), which independent astronomers will verify on their own: asteroids can not be smuggled through space. Ironically, improved protection from potential Earth impacting asteroids will be a (non-profit-generating) side effect of this operation.

Investment

As the selection process proceeds, a business plan with estimates for each phase of the project will be refined. Initial technical evaluations of a drone to move the asteroid into lunar orbit, and to mine and refine it once there, should be done at this time. The total capital required will probably be in the tens or low hundreds of millions of dollars, with costs contained to that level by using existing or simple to develop technology. Most of the initial grant will be expended during this phase, so investors must be courted as soon as practical.

The remaining initial capital will serve to secure appointments and commitments from angel investors; small sums, between one and two million each from multiple investors. Then, revise the business plan with an eye towards acquiring investors in aerospace and mining: these industries stand to gain the most from the emergent opportunities. The NPO will seek commitments from as many firms as possible. This eliminates the problem of being overly reliant on any one firm for input or funds and fashions a "safety net" should one or more firms back out. This can also reduce the aforementioned political opposition, by turning their financial backers into backers of this project instead. Voting stock must not be sold, since control at this

stage must remain with a board of directors devoted to the ultimate plan, but options on the profit for a number of years may entice more investors anyway, and venture debt is also possible.

As investors fall into place, operations will begin with an initial goal to build and launch a drone to maneuver the asteroid into lunar orbit. One important decision will be siting: securing facilities near companies likely to provide assistance. Reliance on any single contractor will be avoided as possible, and bidding contractors will be scrutinized for histories of breaking budget, schedule, and/or feature set. All this drone will do is move the asteroid on the designated orbit and schedule. Additional objectives should be rejected, regardless of promises of (likely insufficient and/or illusory) funding and/or public relations for adding them. Multiple launch partners should be kept in mind while developing the drone, to allow for bidding or negotiation once it is time to purchase an Earth escape trajectory. Engine technology - including the choice between a swarm of drones or one large drone - should be selected for simplicity, low cost, and delivering the asteroid in a reasonable time even though the drone(s) will be much smaller.

Mining

Once the drone is underway, development of solar-powered centrifuges, manipulator drones akin to the Personal Satellite Assistant, and other equipment to mine the asteroid will commence. As these are prototyped, shop them to new investors. Let other companies machine the parts: they benefit from new technologies developed in process, and provide their own fabrication facilities.

Work on the asteroid should commence soon after arrival in orbit. The legal ownership of objects in space is questionable; the longer the rock stays untouched, the more risk that someone else will take it. The main objective at this point is to extract high-value metals from the asteroid for sale on Earth, to quickly pay off the investors.

Lightweight manipulator drones, smelters, and centrifuges, taking advantage of abundant solar energy (possibly up to 90%, by mass, solar mirrors, lenses, and panels), will launch to rendezvous with the asteroid and teleoperated once in place. Mostly-platinum meteoroids will be forged with an ablative iron shell for atmospheric entry and launched at selected areas. The later Apollo missions suggest that reentry can be narrowed to a 10-mile square window. Landing areas will be desert, continental shelf, or other non-ecologically-sensitive wilderness.

The company's agents will perform the actual retrieval to establish legal ownership: ownership of a thing in space may be debated, but whoever picks up an unowned meteorite may claim it. Financial experts will be hired to secure prices and customers for the metal, but the company will mostly sell to the commodities markets.

Colonization

Eventually, the easiest platinum will be extracted, and a fully teleoperated process will no longer be the most efficient way to get the remaining platinum traces (which, even with platinum's reduced price by this point, will still be worth mining). The company will now have enough capital to afford a manned mission to process those traces. Further, the asteroid will now be partially hollowed out, making it easy to carve off a piece, spin it under significant heat (from the

solar mirrors already in place - note that this spinning will also concentrate the traces on the outside), and fill it with air to form a rough O'Neill cylinder, which will initially function like an offshore oil platform. Life support machinery akin to that used on the International Space Station can be sent up with the workers (preferably manufactured from the ISS's proven designs, scaling up by simple redundancy at first - more refined version to serve larger populations can be developed later), although several greenhouses (possibly 75% or more of the internal space of the final structure) should be included to reduce later resupply. In short, further profit will now justify founding a colony in space.

There are many possible designs, detailed in other works. Regardless, the environment should be as Earth-like as possible, minimizing the design of things "for space" as opposed to for a habitat. For example, rather than creating systems and routines for colonists to handle the low gravity, have the colonists spend most of their time in 1 G, with asteroid pieces that need by-hand processing brought inside the habitat to be worked in a shirt-sleeve environment. Optimizing the design to take advantage of microgravity can be done faster, cheaper, and with better results by people living in the colony, but only once they are in fact living in it. The asteroid should contain enough iron for a thick enough hull for Earth-ground-level-equivalent micrometeorite and radiation protection. Only the initially inhabited section need be finished at first, with just enough frame to add the rest later and bulkheads that can be moved out as more structure is completed. As the colony expands, space will be added as needed.

Independence

Once the investors have been paid off, the next goal is setting up conditions for net-present-value estimates to point to R&D of space technology. To do this, lessen or sever ties with Earth-based organizations that might comfortably cease or scale back such operations. The most reliable way to do this is to form the colony's residents into an independent political entity: either a nation allied to the U.S., or one of its states.

Allowing increased freedom would be against the short-term interests of those in charge of the project. Therefore, we suggest making use of the trust any other residents have - not in the governors, but in the government they provide. As it will take time to form a stable government, we recommend a constitution with a schedule built in, keyed to the size (and thus governance needs) of the colony. We further recommend a strategy to establish democratic traditions, to pave the path to either of the desired political forms.

Under 1,000 people, a governor appointed by the board of directors will suffice. At 1,000, the first elections are held for a council of advisers - with no power yet; the point is to establish elections. By 10,000, there shall be a written legal code, with designated judges and law enforcement officials. By 100,000, the council shall gain the power to make laws, with consent from the governor. By 1,000,000, the board and their appointees shall step down, replaced with elected executives with limited spans of service. Further, at 100,000 - comparable to most small U.N.-recognized nations - the colony will apply either for statehood, or for recognition as a nation from, and diplomatic relations with, the U.N. and most countries of the world. The decision should lie with the colonists, but if no other nation will recognize a U.S. territorial claim

in space (similar to why the corporation's agents needed to pick up mined meteorites after landing), becoming a nation may be the only practical option.

This leads to three natural pressures. First, the institution will want to harvest and mine more asteroids to gather more funds and to acquire materials with which to expand. Second, the population will want to encourage immigration, to receive their promised freedoms. These lead to the third: development of space technologies in general - habitation and rapid space transit in particular - will be in the obvious and natural self-interest of the colony.

Expansion

As repayment nears completion, relaxing the focus on simple missions will attract more colonists. The colony should welcome those who wish to conduct experiments in space - taking advantage of the location, ease of isolation (in unattached containers near the station), microgravity, or other advantages. Space tourism will be a sideshow (early colonists must have an economic reason for coming, or they will have little reason to stay), but manufacturing products impossible or impractical to make in a gravity well may become a significant income source. Energy export should be another: the Moon has the raw materials to create arrays of solar panels, with the profits going into making more arrays, and energy sent to Earth as microwaves or manufactured fuels. Perhaps the most critical "nonessential" service will be a K-12 system so that children, and thus entire families, can be brought aboard permanently. The primary goal should be to make sure that the colony survives and thrives. To increase the chances of this goal being adopted, the appointed governors - and, if practical, the board of directors - should live aboard the colony as soon as possible.

Regular travel to and from the colony should significantly decrease the cost of access to space, as pointed out by multiple other studies. Technological progress has always come with a desire to explore, to push the boundaries just a bit further; starting out by harvesting the wealth of the solar system will lead to harvesting the rest of that wealth - first the inner planets, then the outer. Each push will require advancements in space flight, fuel processing, teleoperation, and related technologies. The outer limits of the solar system will be just one more line to cross. Any industrial civilization in this colony's position will inspire and incentivize new generations of researchers to conduct studies in its own self-interest, both with grants and media campaigns of its own design, and just by existing. All that needs to be done is to get one in that position.

Conclusion

We have laid out a plan whereby the initial grant can be magnified, first into a survey institute, then into a mining corporation, and finally into a self-directed and well-funded entity whose interests lie in developing space travel technology. We believe that this will yield a higher likelihood of actually building starships, than a separate entity that aims to develop starships solely for the sake of developing starships, and that this plan is well within current capabilities.

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