Agile Astrophysics Roadmap
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A high-cadence approach for NASA's Astrophysics directorate is proposed. This is the Fast, Smart, Affordable (FSA) philosophy. It is meant to get as many observatories in orbit, as soon as possible. This will be done by pursuing low mass, less-complicated missions. They would still collect valuable science data, but at a low cost. This resembles the new approach that the Planetary Science Directorate adopted 20 years ago.

Outline of FSA Architecture

Star Shade Pathfinder: This will be as small as practicable, no larger than 16-20 meters. This is much smaller than now planned, but reduces technical risks. Reduced development time and a smaller launch vehicle (because of lower mass) reduces cost and provides more assurance of being launched in time to operate with WFIRST.

With its lower mass and closer separation, the smaller starshade will have greater agility. It will be able to perform target-to-target repositioning maneuvers in much less time while using less fuel than larger starshades.

HabEx Lite: Endorsement of this approach by the Decadal Survey team will provide impetus for this FSA mission. HabEx Lite will not include a Coronagraph, thereby reducing risks of large cost growth and schedule delay. Its lower mass, lower complexity and lower mass will allow this project to move expeditiously to launch and operation. It could be ready by the mid-2030s. The Baseline HabEx will not be ready for launch until 2050.

Star Watch Astrometry Probe
Starlight Telescope Array
Starshot Wafer Craft

Less Grand

This roadmap would mean that Astrophysics would launch a larger number of Fast, Simple, Affordable, FSA, spacecraft. Science would be sacrificed, in a certain sense, because these missions would not have extremely-capable payloads. However, in another sense, they would achieve more Science because the FSA missions would actually fly.

First, a small star shade spacecraft should be launched. This Pathfinder Shade will have a diameter of 16 - 20 meters. This will allow its design, construction and testing to be completed by 2025. In turn, this means that it can join WFIRST at L2 early in the mission of that new space telescope. This will further allow the Exoplanet community to gain experience in analyzing the data that can be garnered via a star shade. In the future, a larger, more capable star shade can be launched as part of the HabEx-Lite telescope project. If the Pathfinder Shade is still operational, that will enable HabEx-Lite to use 2 star shades.

It is possible, perhaps likely, that the 75-meter star shade planned for the HabEx Baseline design may cost as much as $4 billion. A star shade that large is an immense undertaking. It will be complex and will require a long series of tests before launch. The tale of JWST's Sun Shield is a lesson to be heeded. It was first assumed to be a straightforward component of the Webb telescope. Real world experience has shown that it has been as complicated to build, and test, as a separate Probe-class spacecraft.

The earlier view of the JWST Sun Shield has translated into hardware that has failed pre-launch tests and has caused years of delay and billions of dollars of extra expense. A similar example was the Sun Shield for the Skylab space station. It was treated as a hardware element rather than as an independent system requiring special attention, funding and testing.

The Star Shade team should view JWST's Sun Shield as a "lesson learned." Star Shades will be much more complex than the Sun Shield. They will need to deploy to a very precise shape, allowing essentially no light leakage. In order to be in a position in which NASA can confidently launch and operate a large star shade for future space telescopes, the space agency should proceed in a stepping stone fashion. The very first Star Shade should be in the 16 – 20 meter size range. This smaller size translates into a larger IWA, but it also translates into a structure that is within the realm of technological and fiscal reality. The next step would be a 32-meter Star Shade for HabEx-Lite.

A Small Star-Shade Pathfinder should be endorsed by Astro 2020. It can realistically be ready to fly with WFIRST. Experience with building, deploying and operating the SS Pathfinder will provide a pathway to the launch of ever larger, more capable star shades. Flight experience is required to verify theories of contrast levels and spectral data acquisition.

HabEx-Lite is a perfect example of an FSA mission. It will use a segmented mirror, with no coronagraph. It would conduct high-contrast imaging solely through the use of a star shade. It is less complex, lighter, and more affordable than the HabEx Baseline concept. The baseline is a wonderful design and would return incredible science data. However, it would likely not fly before 2050. How should the astronomical community react to that scenario? One option would be to plan for an agile program of affordable space observatories. There is no guarantee that Washington will approve and fund these FSA missions, but they stand a better chance with the long fiscal shadows cast by JWST and the ISS and with a shrinking Astrophysics budget.

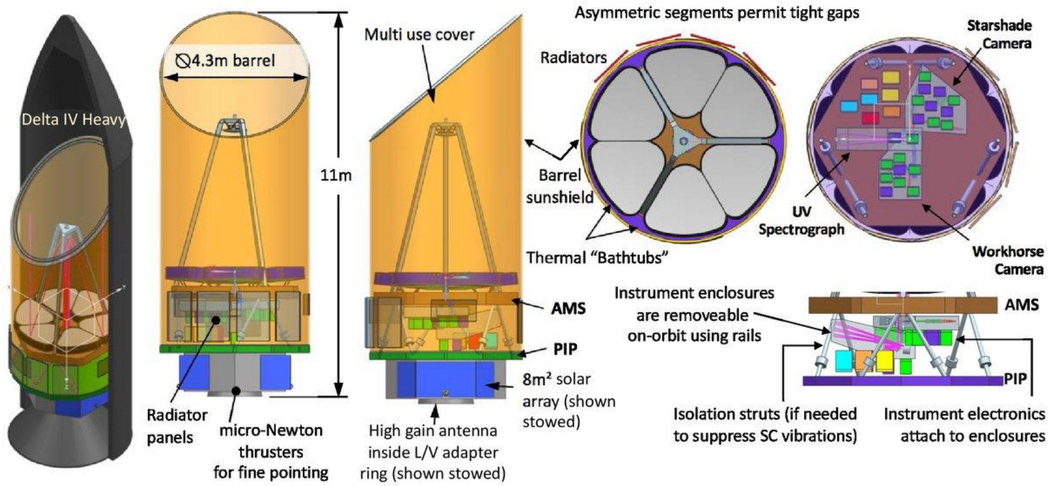

Figure 1: HabEx Lite space telescope

Less Grand

What is the best way forward for Astrophysics? The financial and schedule disruptions of the past decade have taught us how not to proceed. A new approach is recommended. It is the approach taken by the Planetary Science community. One recent example tells the tale. A Flagship mission to Saturn's moon Titan was studied by NASA in the early 21st century. It was a complex spacecraft with several major elements. It also had an estimated cost of $4 billion. That proposal ultimately stalled, with no path forward to future exploration. In June 2019, NASA approved a Faster, Simpler, Affordable mission to Titan, the Dragonfly mobile lander. Its cost is $1 billion and it will fly. This is in contrast to the Titan Flagship mission which was a Grand mission, but whose existence is now limited to the world of papers and posters. The planetary community has reformed their approach to mission size and cadence.

Another example of the FSA approach is the Parker Solar Probe. It languished for years because the Baseline Solar Probe concept would have cost $2 billion. The team scaled back their ambitions, proposing a simpler mission with a price of $750 million. As a result, the Solar Probe Plus (Parker) design was approved and is now flying.

The Europa Clipper team used that same philosophy. A Europa Orbiter had been proposed since the 1990s. It went nowhere for 2 decades because the design was complex and costly. The Clipper mission is simpler and affordable and, as a result, is now approaching Phase C. Even with Clipper's FSA approach, it still faced opposition from the White House and survived because of the efforts of one Congressman.

The high cost and complexity of the JWST means that one decade of science was not conducted. A simpler, affordable version of the Webb telescope could have been launched by 2010. One theme of this plan is flying hardware as soon as possible. This means building a small star shade and HabEx-Lite instead of waiting for more capable, but more complex, expensive and risky spacecraft.

The Ideal vs. the Real

In 2029, there should be 2 space telescopes in operation, i.e., JWST and WFIRST. One could imagine that Congress and the White House will ask why a 3rd one is necessary. This is the fiscal reality that proposals such as HabEx and LUVOIR will face. They would both be amazing science machines. However, the individuals who fund them are not scientists. Politicians will need to be convinced that any new space telescope will be affordable and will not suffer from the endless delays that have plagued JWST. The answer is to keep future observatories as simple as practicable, thereby being affordable. Congressmen may not fully understand the grand science of such missions, but they are very keen about not keeping a lid on space projects.

In addition, WFIRST has been “zeroed-out” of the White House budget proposal for the past 2 years. The reason given was that JWST and WFIRST should be the focus of funding before yet another space telescope project is begun. This is the political landscape that faces the astrophysics community.

The days of relatively easy approval and sustained funding for large space observatories are in the past. We cannot count on the random appearance of another “champion” in the Congress. It is prudent to plan an affordable series of missions. If conditions change, then the Grand space telescopes can be built. Until that happens, the Astro2020 Decadal Survey is asked to endorse the Faster, Simpler, Affordable (FSA) line of astrophysics missions. Such an approach will help to insure that cutting-edge astronomy data will still continue to be produced. Flagship missions are wonderful concepts but they will produce no data if they do not fly, and they will not fly if they are not affordable.

Other Small/Medium Missions

Part of this new approach means putting a uas-level astrometry Probe into space by 2025. That mission (Star Watch) will detect Earth Analogs in nearby star systems, providing targets for the HabEx-Lite space telescope.

The Starlight (Deep Space 3) pathfinder mission should be re-funded. This was part of NASA’s New Millenium program circa 2000. It would utilize the interferometry technology developed in the SIM, Star Watch, and original Starlight project. It would be a forerunner to the dispersed arrays that are the future of space-based astronomy. A recent NASA Science Roadmap contained an illustration of such a visionary mission, the Exo-Earth Interferometer.

Figure 2: Starlight interferometer array

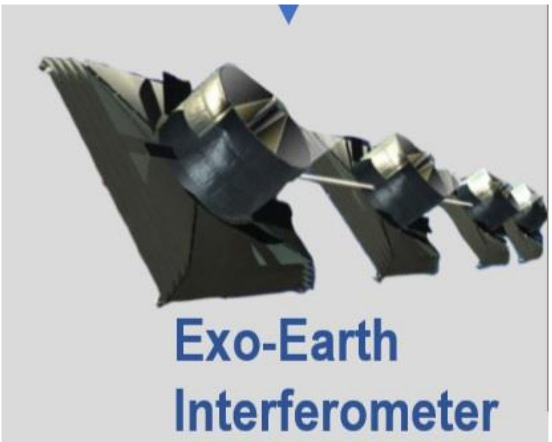

Figure 3: Exo-Earth Interferometer

Another recommendation is for NASA to partner with industry to launch Starshot Wafer Craft to various targets in the Solar System. These wafer-craft will be secondary payloads and will allow real-world experience in building and operating these devices. That experience is necessary to allow for their eventual use as interstellar probes to astrophysical targets that sit light-years away.

The following is an excerpt from a Congressional directive for an Interstellar roadmap:

"The Committee appreciates that NASA has submitted the propulsion technology assessment to enable an interstellar mission to identify the nearest Earth-like planet that shows signs of extant life. The Committee notes that the challenges of interstellar travel are immense and will require monumental advancements in many technology areas. The roadmap proposed by NASA begins with a series of workshops to assess candidate technologies and establish specific technology development milestones.

Within amounts provided, NASA shall initiate these workshops immediately and provide a report on their proceedings no later than 180 days following enactment of this Act. NASA must stay true to its heritage by being bold and pushing the limits of science, engineering, and technology. The Committee looks forward to working with NASA to ensure the roadmap is implemented. As noted elsewhere, NASA shall ensure that it requests sufficient funds in future budgets to develop and implement this mission."

Build a little, test a little, fly a lot

This new approach to an Astrophysics Roadmap has as its main goal a high cadence of missions. Instead of one or two Flagship spacecraft dominating the funding supply for decades at a time, a series of small or medium class missions will be flown. The main advantage of this approach is that data will begin to flow much more quickly.

We can go by the old model of writing about the fantastic things that will be detected by a mammoth space telescope, all the while waiting decades for their manifestation. Or we can start an agile, exciting program of frequent, capable missions.

The Astro 2020 Decadal Survey is asked to endorse this “graduated” approach to Astrophysics mission cadence.