Flagships of Science

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Not since the times of Copernicus and Galileo have scientific discoveries so expanded our horizons, challenged basic physics, and invited everyone to reconsider their place in Nature. The flagships of NASA's space science program have carried us to this point, sailing until now before the wind of public generosity. In these slackening times, we realize that success is not durable in itself, but demands thoughtful planning and sustained commitment to continued leadership. Therefore, we should reflect on the terms and conditions of leadership in science, and remind ourselves of its historical substance and value.

When I first came to this country 15 years ago, we had not seen water geysers anywhere in the Solar System besides Earth—yet recently NASA's *Cassini* spacecraft saw them on Enceledus, one of Saturn's moons. We did not know that Pluto has a system of moons, or that we had a tenth planet, Sedna, which is a twin of Pluto in size and probably one of many similar objects lurking in the Kuiper Belt. We had not yet found planets around other stars, and we certainly did not begin to know their properties—as we now have done with the *Hubble* and *Spitzer Space Telescopes*. We did not know that 20% of stars like the Sun have disks of planetary debris, signaling the presence of planets—probably including some planets like Earth. Back then, we believed in black holes, but did not know that *Hubble* would find them at the centers of nearly every large galaxy, or that *Chandra* would find them ubiquitous across the X-ray sky. We estimated that the universe was between 12 and 15 billion years old—and argued passionately about which end of that range was correct. Today, thanks to *Hubble* and the *Wilkinson Microwave Anisotropy Probe*, we know the universe is 13.7 ± 0.2 billion years old. In 1991, we did not know about dark energy, but now *Hubble* has told us that this ineffable entity makes up 70% of the universe.

Before these years of success, in 1962—I was still a child, but five centuries had passed since Copernicus moved the Earth from the center of the universe, and four centuries had elapsed since Galileo used the first astronomical telescope to discover Jupiter's planetary system—Lyman Spitzer wrote:

> "The detection of planets around other stars… is a matter of great philosophical and cultural as well as of scientific interest. Our view of man and his place in the universe naturally depends very much on whether planetary systems like our own are exceptional or whether they occur very frequently throughout the Galaxy. In fact, in many ways, the question of how frequently stars are accompanied by planets capable of supporting life is fully as important as the over-all structure of the universe, i.e., whether space is flat or curved."[1]

From these perspectives of decades, career spans, and centuries, we recognize the durability of great questions and noble goals in science. We see the human value of

NASA's accomplishments. We see the benefits of steady hands, sustained leadership, and flagship programs that take years to develop and operate to full capacity.

When I travel around Europe and Japan, I find that our flagship programs define America's leadership in space science, not our ability to produce post-docs or to mount an average of one medium-class mission a year. The flagship missions tackle the biggest questions and cut the widest path into the unknown. What enthralls the world is this country's ability to take pictures of the moon Mimas silhouetted against the limb of Saturn, and to launch and service *Hubble*, which currently dominates NASA's scientific and public landscape. They see our leadership in our overcoming the immense technological challenges of building the huge, high-precision optics of *Chandra*, which provide an X-ray view of the sky comparable to *Hubble*'s in the optical. They see it is our ability to push cryogenic and detector technologies to the limits with *Spitzer*, to achieve completely new views into dusty regions of star formation and the planetary zones around stars.

This is why people like me come to this country—to be part of an enterprise that has the uncanny audacity, scientific courage, and technological prowess to thrive on the frontiers of science. We come to help launch a *Webb Space Telescope* with a deployable 6-meter telescope into L2 for investigating primordial galaxies. We come to help design a coronagraphic *Terrestrial Planet Finder* with a grasp of light and optical finesse adequate to study the habitability of Earth-like planets around nearby stars. These flagship endeavors truly define America's leadership in space science.

Why is leadership in science so important?

One answer is provided by the recent report—"Revealing the Hidden Nature of Space and Time"—of the National Research Council's Committee on Elementary Particle Physics in the 21st Century. The committee chairman is the former president of Princeton University—economist, not physicist—Harold Shapiro. Arguing that the next large accelerator should be built in the United States, the report states:

> "Leadership in science remains central to the economic and cultural vitality of the United States. To fuel the innovation economy of the 21st century, to maintain national security, and to produce the knowledge needed to ensure our wellbeing in the face of an uncertain and challenging world, the United States needs more than ever before to have a strong base of science and technology. A strong scientific enterprise attracts ambitious and talented students to science. It also makes the United States a desirable place for excellent scientists from abroad to pursue some of the most important challenges on the scientific frontier."[2]

Let us remind ourselves what the particle physics community seeks: not to build a grants program, nor to maintain moderate accelerators, but to build here, on American soil, the next flagship accelerator.

Any NASA decision to give up on a small number of flagship missions would not be merely a quotidian decision of economics and resource distribution. It would be a sea change—a strategic shift by a pioneering nation away from the grandest problems of science, at a time when we know they are within our reach.

[1]Spitzer, L. Jr. 1962, American Scientist, 50, 473.

[2] National Research Council of the National Academies. Committee on Elementary Particle Physics in the 21st Century. *Revealing the Hidden Nature of Space and Time: Charting the Course for Elementary Particle Physics*. Washington, DC: The National Academies Press, 2006.

Figures:

Figure 1. Composite of Hubble, Spitzer, Chandra, and Cassini spacecraft. (Caption: Flagships of NASA’s space science program.

Figure 2. Mimas against the limb of Saturn (caption coming)

Figure 3. HUDF (caption coming)