National Aeronautics and Space Administration

30 Doradus Nebula
Credit: *NASA, ESA, and E. Sabbi (STScI)*

[2015] VOL [32] ISSUE [01]

NEWSLETTER
Space Telescope Science Institute

Towards a 2020 Vision for the *Hubble* Space Telescope

K. Sembach, *sembach@stsci.edu*

As we approach the 25th anniversary of the launch of the *Hubble Space Telescope* on April 24, 1990, it seems appropriate not only to look back at *Hubble*'s achievements, but also to look forward to what is yet to come. There will be plenty of opportunities to reminisce in the coming months, so let's turn to *Hubble*'s future. Indeed, *Hubble* has always been about bringing the future a bit more into focus—forward leaning, pushing the envelope, blazing frontiers, and opening new horizons to curious minds everywhere.

Long before the start of the mission, someone coined a phrase that captures the essence of *Hubble*'s ability to surprise—"conscious expectation of the unexpected." That philosophical approach underlies the concept of NASA's Great Observatories, *Hubble*, *Chandra*, *Fermi*, and *Spitzer*: broad-based missions that go beyond focused experiments. It still serves well as a reminder that being open to new lines of research—ones we cannot yet envision—is just as important as planning the next steps along known lines. With this in mind, the Institute and the *Hubble* project at Goddard Space Flight Center use a five-year window to set priorities for technical work and observing initiatives. Maximizing the science from the observatory and its archives is always the top goal, of course. And this is where you come in—we want your help in shaping *Hubble*'s legacy. How can you help? We'll get to that in just a bit.

Hubble 2020 Vision Statement

Operate the *Hubble Space Telescope* until 2020 or beyond so that there is at least one year of overlapping science observations with the *James Webb Space Telescope*, performed in a manner that maximizes the science return of both observatories, takes full advantage of *Hubble*'s unique capabilities, addresses the astronomical community's scientific curiosity, and engages the public and students in scientific discovery.

In the past, a five-year timescale roughly coincided with the interval between *Hubble* servicing missions, and it was not surprising that each upgrade of the observatory spurred an evolution of technical and scientific goals. Because Servicing Mission 4 is now over five years behind us—and because the launch of the *James Webb Space Telescope* is now less than five years away—it makes sense to take an inventory of what we have learned, and, with *Webb* firmly in mind, to refresh our thinking about *Hubble*'s future.

Hubble's power to revolutionize has never been greater than now. The instruments are calibrated better than ever, and we are using them in ways we had not anticipated at the time of the last servicing mission. For example, with the new spatial scanning mode for Wide Field Camera 3, it is possible to achieve very high differential photometric precision (~30–50 ppm) on exoplanet transit depths, and to achieve relative astrometric measurements of a few tens of *micro* arcseconds. These capabilities exist today because of our dialog with astronomers wishing to push *Hubble* even further than had been thought possible. Consider also the performance of "ordinary" imaging or spectroscopic observations. Astronomers worldwide can propose for sharp, deep, and stable images, or for different flavors of spectra, from the ultraviolet to the near infrared, from 110 nm to 1.7 microns. Such observing power is unique, and will remain so for the foreseeable future.

Shortly, *Webb* will complement *Hubble*, adding the infrared wavelength region. *Webb* will produce comparable pictures and multi-object spectra of the universe between 600 nm and 28 microns—overlapping *Hubble* at very near-infrared and long-optical wavelengths. When both observatories are operating, we expect strong demand for *Hubble* observations of *Webb* objects and vice-versa. Both observatories will make discoveries that only the other can investigate further. This will be synergism writ large.

We expect many more years of robust operation for *Hubble*. Past hardware problems have typically involved either electrical issues in the science instruments or mechanical failures of the gyros. Most of *Hubble*'s subsystems have considerable redundancy, including the science instruments. For example, the Wide-Field Camera 3 and Cosmic Origins Spectrograph both have dual-string electronics. Also, due to prudent investments in engineering and the ground-system over the past decade, we can now operate *Hubble* with only *one* gyro, if needed.

In 2013, NASA formally analyzed subsystem lifetimes and found that the observatory should remain highly capable for the remainder of this decade—assuming that we continue to mitigate the degradation and failure modes of the hardware. If these investments are adequately funded, there is every reason to believe that *Hubble* will sail through the anniversary in 2020 with flying colors.

Preparing for the coming epoch of scientific reciprocation between *Webb* and *Hubble* is a top priority for the Institute and the *Hubble* project. The scientific potential and operational synergies of these two "great observatories" are so deeply intertwined that we have given this effort its own vision statement!

We expect *Hubble* and *Webb*—separately and together—to address the top scientific questions of 2020, which will surely include:

- What are the properties of planetary systems around other stars? It is now clear that there is a tremendous variety of planetary systems, many, perhaps most, quite different than our own. Understanding these systems may very well provide clues to our own origins.
- When did the first stars and galaxies form? *Hubble* is pushing closer than ever to the beginning of galaxy formation through its Frontier Fields initiative, but *Webb* will push back in time even further and increase the sample. Together, the two observatories will trace stellar and galactic evolution over the entire age of the universe.
- What is dark energy? This is one of the most interesting questions in all of physics, and we're just beginning to formulate the paths toward an answer.
- How does dark matter affect the evolution of galaxies? Observing dark matter, or more properly the effects of dark matter on ordinary matter or light, requires a multi-pronged approach that requires multi-wavelength data and a combination of spectroscopic and imaging information. *Hubble* and *Webb* have unique capabilities that together can be used to study dark matter on scales ranging from the sizes of stars to clusters of galaxies.
- How and where do black holes form? Peering into the hearts of galaxies and stellar clusters, both *Hubble* and *Webb* provide unique information about the motions of gas and stars used to constrain the black hole masses. Both observatories are well suited to studying the host environments and investigating the sources of matter fueling black holes.
- How are the chemicals of life distributed in the universe? *Hubble* has taught us much about the cycles of matter and energy in environments of all types, and *Webb* will expand that knowledge. These are complex processes requiring a multitude of observational inputs to understand the chemistry, physics, and dynamics affecting the fate of chemical compounds.

So what's new? The *overlap* between *Hubble* and *Webb* in the 2020 timeframe is *really new*. It will magnify and multiply their separate forces for research. The union of *Webb* and *Hubble* will further signify a time in astronomy without precedent. Indeed, the sheer magnitude of opportunities in the *Hubble–Webb* era cannot be easily summarized. Here are just a few examples of synergistic programs:

- The atmospheric composition of planets around other stars is a field of intense study with *Hubble,* and will be a primary research area with *Webb*. As new exoplanets are discovered by *Kepler*, the *Transiting Exoplanet Survey Satellite*, and other observatories, studies by *Hubble* and *Webb* combined will yield fresh insight into how planets—perhaps even earth-like planets—form and evolve.
- *Hubble* is currently exploring the cosmic frontier at redshifts of $z \sim 9$–10, corresponding to times when the universe was only a few hundred million years old. *Webb* will explore beyond this time horizon, approaching the Big Bang—and the beginning of time—ever more closely. *Hubble* will identify candidate fields for *Webb*, and will follow-up *Webb* discoveries with new, tailored observations of particular fields.
- *Webb* will study star-forming regions in great detail. To complete the census of these stellar nurseries, and to investigate newly discovered protoplanetary systems, *Webb* findings will call for complementary *Hubble* observations at optical and ultraviolet wavelengths.
- Throughout its lifetime, *Hubble* has monitored weather and climate on planets in the solar system. In the *Webb* era, new observations will extend the time coverage and increase the diagnostic power by probing more deeply into the atmospheres of the giant planets. Combined, the two observatories will essentially provide a "3D" view of these atmospheres.
- *Hubble* provides unique insight into the properties of individual stars and the aggregate stellar populations of stellar clusters and galaxies of all types. Reconstructing the star-formation histories of nearby galaxies with complementary *Hubble* and *Webb* observations will place studies of distant galaxies and metal enrichment on a solid foundation. Follow-up studies of rare types of stars will likely also be useful for understanding the ages of some stellar populations.

There will be no lack of exciting science for *Hubble* to pursue—before *and* after *Webb* is launched. Indeed, the amount of *Hubble* observing time proposed is typically six times more than is available. There is clearly no shortage of good ideas—but that has always been true. The two new factors are *Hubble*'s finite lifetime—no more servicing missions are planned—and the synergism with *Webb*.

The 2020 Vision is a rallying point for *Hubble* stakeholders to strategically plan for the opportunities, issues, and trade-offs of the *Hubble–Webb* era. We intend it to be a framework for ensuring that *Hubble* remains at the forefront of astrophysics well beyond its 25th anniversary.

The 2020 Vision embraces the principles that have made the mission so successful: operations guided by science, partnership with other NASA missions, a fair time-allocation process that gives top priority to demands for *Hubble*'s unique capabilities, and public outreach, which shares the excitement of scientific discoveries with the public and students. Implicit in the vision is a commitment to maintain a healthy grant program so that the astronomical community continues to be active and engaged in *Hubble*'s success.

The Institute is soliciting white papers from the community about how best to structure *Hubble*'s science program in its remaining years. Suggestions might include new observing initiatives akin to the *Hubble* Frontier Fields or Treasury programs. Perhaps we need a new proposal category for *Hubble* to prepare for *Webb*, or a reciprocal observing agreement with *Webb*, like that already in place for *Chandra*, *Spitzer*, *XMM-Newton*, and the National Radio Astronomy Observatory. Perhaps we need new ways to structure the *Hubble* time-allocation process in the years that overlap with *Webb*.

These possibilities will be under discussion—and more, including ones that you might suggest. Put on your thinking caps. What do *you* want *Hubble*'s future to look like? We hope that you will send us your thoughts in response to the white paper call and help us shape *Hubble*'s 2020 Vision.