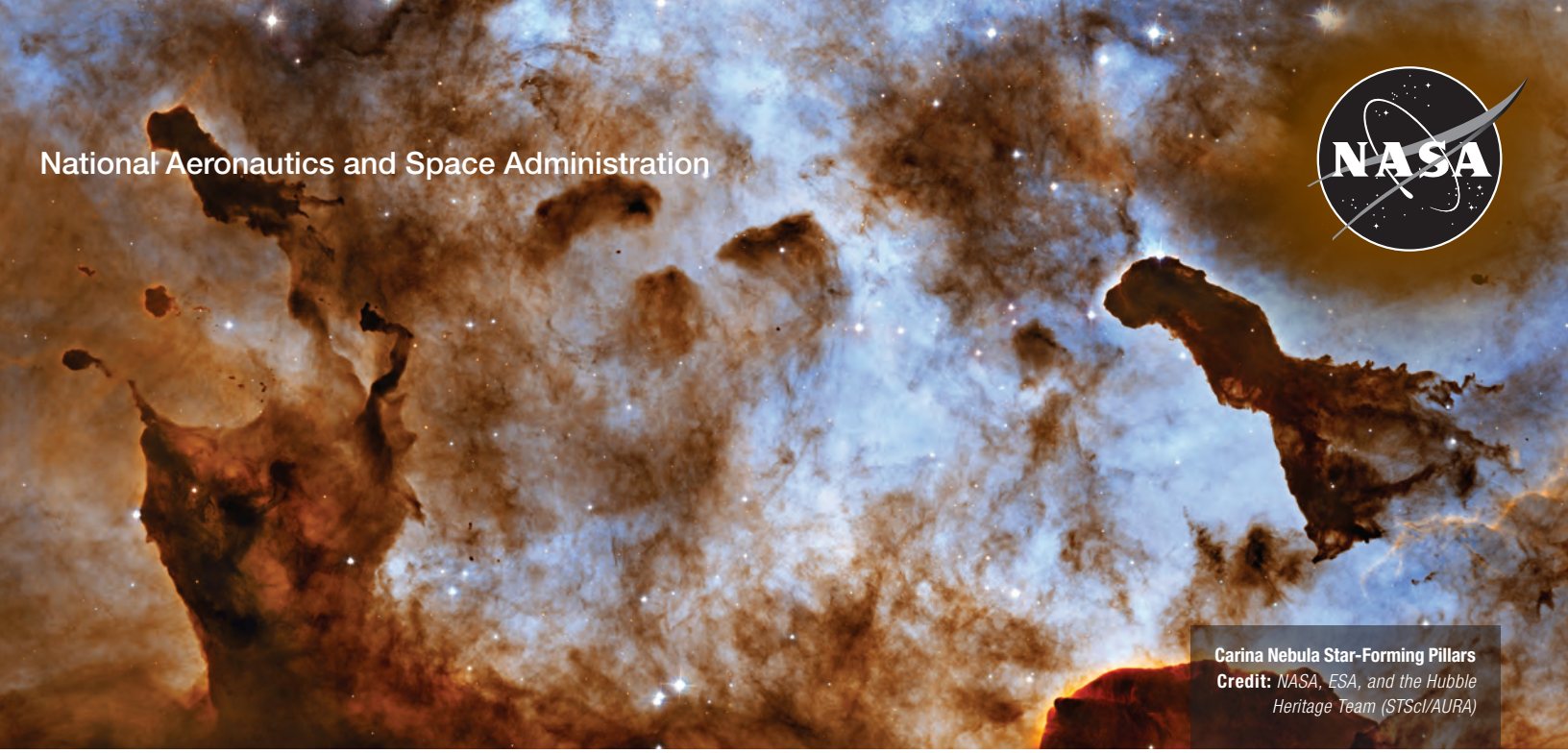

National Aeronautics and Space Administration

Carina Nebula Star-Forming Pillars
Credit: *NASA, ESA, and the Hubble Heritage Team (STScI/AURA)*

WINTER ⌈ 2011 ⌋ VOL ⌈ 28 ⌋ ISSUE ⌈ 01 ⌋

NEWSLETTER

Space Telescope Science Institute

The *James Webb Space Telescope*—It's Complicated, but so Is Leadership

Matt Mountain, *mmountain@stsci.edu*

The recent release of NASA's Independent Comprehensive Review Panel report (the Casani report) on the *James Webb Space Telescope* (*JWST*) has understandably caused consternation within the community, and some of our colleagues' sound-bite quotes decrying the state of space astrophysics were quickly circulated in the press and on the Internet. As the dust has settled, it's important to step back for a moment to reflect on why we want to build such an audacious telescope. The words of the President of the AAS, Debra Elmegreen, in a recent article in *Space News* bear repeating, "We all need to recognize that *JWST* and the initial $5 billion investment cannot be allowed to fail, since so much of future astrophysics research was built upon the foundation it was to provide—as the Casani report concludes, 'JWST *will play a key role in understanding how and when the first galaxies were born, characterizing the planets that are now being discovered around nearby stars, in providing further insights into the nature of the dark energy and dark matter, and into how stars and planetary systems are born. There is no easy path to understanding such complex scientific questions. To do these things at the level needed to advance scientific understanding requires a complex telescope with truly unique capabilities.* JWST *is that telescope."* (*Space News*, "American Leadership in Astrophysics at Risk," 22 November 2010.)

I came to the Space Telescope Science Institute because of *JWST*. Even though I helped to build two large ground-based telescopes, I recognized that there are astronomical observations we struggle to do from the ground. For example, even with 8-m or 10-m telescopes it is next to impossible to take the spectra of high-redshift galaxies to understand the star-formation processes a billion years after the Big Bang. The same is true when trying to measure distant ($z > 1$) supernovae to try and unravel Dark Energy—it's a really tough measurement from the ground. As is mapping dust emission to uncover telltale trails of young planetary systems; this is proving to be difficult even in the closest systems. My colleagues who built the *Hubble* and *Spitzer* space telescopes similarly realized that to take the next steps in exploring the Universe would require a bigger space telescope. There is no mystery why: observational astrophysics is a photon-limited field, and once you have near perfect detectors (as we do), our only free parameters are either to spend millions of seconds on every observation or to increase the aperture of the telescope. A large-aperture space telescope combined with the low backgrounds found at L2 was the basic design rationale for *JWST*, and the broad science this telescope enables was compelling enough to make it the highest-priority large space mission of the 2000 Decadal Survey on Astronomy and Astrophysics.

A decade later, even as our scientific expectations have evolved since the original science case was written—as the Casani report itself notes—*JWST* remains the most scientifically powerful telescope NASA, ESA and CSA will ever have built: *"the next Great Observatory to replace the Hubble Space Telescope."* A decade ago, we were just coming to terms with the possibility of Dark Energy. With *JWST*, we will reach back to the beginning of time to detect very early supernovae and break the possible degeneracy between supernova evolution and Dark Energy. A decade ago, we had not yet begun to measure the constituents of exoplanetary atmospheres with transit spectroscopy using *Hubble* and *Spitzer*. With *JWST*, we will use the same technique; as the recent 2010 Decadal Survey (New Worlds, New Horizons in Astronomy and Astrophysics; NWNH) recognized, *JWST* will be *"a premier tool for studying planets orbiting stars that are smaller and cooler than the Sun."* The goal of detecting liquid water on a planet close to the size of Earth, in the habitable zone around another star, may be within the reach of *JWST*. As NWNH notes, with *JWST "the era of study of … cousins of the Earth … is underway."*

And this does not include the great unknown territory that will be uncovered when we fly a telescope 100 times

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more sensitive than *Hubble*, almost 1000 times more sensitive than *Spitzer*. Imagine the creative energy unleashed by the roughly 8,000 astronomers who currently use *Hubble* and *Spitzer*. According to a White Paper submitted to NWNH (Sembach et al. 2009), over the period 2005–2007, the *Spitzer* and *Hubble* programs alone generated over $130M in General Observer grants, and this community published over 3,000 papers based on *Hubble* and *Spitzer* data. *JWST* is the next *Hubble*, the next *Spitzer*—that's why we are building this ambitious telescope.

It is true *JWST* has confronted us with some seriously tough technological challenges: how to build a telescope 65% the size of the W. M. Keck telescope, but reduce its mass by almost two orders of magnitude compared to a ground-based telescope; how to find a way to package it so it could be launched on an Ariane 5 rocket and deployed a million miles from Earth; and how to operate it at 40K. It's been very hard to manufacture 18 beryllium mirrors that can hold their figures to better than 20 nanometers at cryogenic temperatures, or build a deployable gossamer-like sunshield the size of a tennis court. But we have. The Casani report recognized these technological achievements: *"a substantial amount of cutting-edge hardware has been delivered and is now being tested as part of the first steps toward the overall integration and test of the Observatory."* We are not looking at a trail of technological failures or wasted resources. In fact, what we see is a series of "solved problems" on the complex and difficult journey to build the most powerful space telescope launched by any space-faring nation.

A few weeks ago, *The New York Times* ran an obituary of Joseph Gavin, who designed and built the lunar lander. It drew me back to an earlier era, where doing difficult things in space defined a nation and a generation. The Times quoted Gavin as saying, *"If a project is truly innovative, you cannot possibly know its exact cost and exact schedule at the beginning…and if you do know the exact cost and the exact schedule, chances are that the technology is obsolete."* The Casani report echoed these words: *"from 2002 to 2008,* JWST *struggled with several cutting-edge developments. These developments took longer and consequently cost more than forecast."*

Let us remind ourselves it was very hard to build the *Hubble Space Telescope*. But we did. Today *Hubble* supports thousands of astronomers worldwide, and continues to inspire the public and a new generation of school children with its images of breathtaking beauty.

Now we are again struggling with the consequences of doing something no one has done before. Those of us who have built machines like large telescopes have experienced the myriad ways that unpredictable problems emerge from new technologies, challenging engineering, and the complicated logistics of putting complex things together.

The *JWST* project needs to do better, and the Casani report articulates what needs to be changed. NASA and the Project Team have committed to learning these lessons and regaining the trust of both those who have advocated for *JWST* and the tax-payers who have funded *JWST*. But I don't see an astronomers' hurricane, leaving devastation in its wake. I see committed engineers and scientists struggling to work at the edge of the impossible. I see a community willing to take risks on behalf of science, so we can extend the scientific frontiers and do things no one has done before. I see that building a state-of-the-art machine for science is in the end an inherently complex and tremendously imperfect human endeavor. The cover letter to the Casani report on why *JWST* should go forward finished on a famous quote from the dawn of the Space Age, *"…we do these things and others, not because they easy, but because they are hard."* To finish President John F. Kennedy's quote: *"…because that goal will serve to organize and measure the best of our energies and skills; because that challenge is one that we are willing to accept, one we are unwilling to postpone."*

In the end, someone has to provide "the next *Hubble*" to the next generation. If not us, then who?

"… And this does not include the great unknown territory that will be uncovered when we fly a telescope 100 times more sensitive than *Hubble*, almost 1000 times more sensitive than *Spitzer*. Imagine the creative energy unleashed by the roughly 8,000 astronomers who currently use *Hubble* and *Spitzer*."