James Webb Space Telescope successfully launches

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The joint NASA, European Space Agency (ESA) and Canadian Space Agency (CSA) astronomical observatory, the James Webb Space Telescope (JWST), successfully launched from the Guiana Space Centre in French Guiana at 12:20 UTC on December 25. The spacecraft was lifted above Earth aboard an Ariane 5 launch vehicle and is now past the Moon as it travels to its final observing point.

The JWST, when fully operational, will peer deeper into the Universe than any previous astronomical instrument. Its primary mirror consists of 18 hexagonal gold-plated segments that are designed to combine into one 6.5 meter diameter mirror, more than seven times the light-gathering power of the Hubble Space Telescope (HST). It was designed by thousands of scientists and engineers from 20 countries and will view further away—and thus further back in time—to when the first galaxies formed over 13.5 billion years ago.

Webb marks an immense scientific and engineering achievement. Its development over the course of 25 years is a further vindication of the materialist outlook of history, that humans can develop a scientific understanding of society and the world and, through that understanding, master nature and themselves. At the same time, the retrograde attitude of the bourgeoisie toward science was on display in the words of NASA Administrator Bill Nelson, a former Democratic senator from Florida, who asserted that astronomy was akin to "the glory of God" because "the firmament shows His handiwork," quoting Psalm 19, and because telescopes "capture the light from the very beginning of the Creation."

The first of hundreds of steps in fully deploying the telescope have so far gone flawlessly. The launch, separation of the telescope from the final stage of the rocket and release of JWST's solar array were carried out exactly as planned. The fourth major milestone, an initial course correction burn 12.5 hours after launch, set the telescope on a precisely calculated trajectory toward its operational station-keeping location. A day after the burn, the spacecraft's high-gain communication antenna deployed, which will allow all subsequent deployments to be commanded manually by mission controllers.

There remain, however, hundreds of steps before the JWST is fully operational, the most critical of which is the unfolding of the telescope's delicate sunshield. The JWST is optimized to observe in infrared light, which means the mirrors and detectors must be kept very cool in order to function. The sunshield consists of five layers of Kapton, an extraordinarily thin and light material, coated with reflective metals that reflect away the heat of the Sun, as well as from Earth and the Moon, designed to separate an 110 degrees Celsius (230 degrees Fahrenheit) hot side from a ?223 degrees Celsius (?370 degrees Fahrenheit) cold side in just six feet.

In order to fit in the Ariane 5, however, the sunshield had to be folded up, and now each of its layers must be uncovered, unfurled and drawn taut in space. Dozens of individual steps must be perfectly performed over the next several days, all of which are remotely commanded as the telescope is well beyond humanity's reach for a manned repair mission. If any of the steps fail, the telescope will be crippled, if not doomed.

The mirror was similarly folded and must undergo an analogous unfolding. After the sunshield is deployed, motors attached to the secondary mirror and the two "wings" of the primary mirror, each consisting of three mirror segments, will steadily move each aspect of the telescope into place. Locks will then hold the disparate parts together, completing the mirror assembly.

If all goes well, the sunshield will be deployed by the beginning of next week, and the mirrors will be locked in place a week after that. During the following two weeks, the individual mirror segments will be aligned with each other to form the largest space-based telescope.

By the time this alignment is complete, 29 days after launch, the JWST will perform a final insertion burn to enter its final halo orbit at the Sun-Earth Lagrange point 2 (L2). The destination is a point of gravitational stability that is perpetually behind Earth relative to the Sun, 1.5 million kilometers (930,000 miles) away. This orbital option is popular for astronomy—telescopes which have used this point include the cosmology satellites Wilkinson Microwave Anisotropy Probe (WMAP) and Planck and the space telescopes Herschel and Gaia—because it offers isolation from the warmth of the Sun and Earth, as well as station-keeping maintained with minimal fuel.

Once JWST settles into its orbit about L2, the telescope's operators at the Space Telescope Science Institute in Baltimore, Maryland, will begin fully commissioning the spacecraft for scientific missions, which are expected to begin in six months.

History and science of space telescopes and the JWST

The modern conceptions of astronomy enabled by lofting a telescope above the Earth's atmosphere date from 1946, when Lyman Spitzer Jr. (1914–1997) wrote a paper outlining "Astronomical Advantages of an Extra-terrestrial Observatory." He noted that a space telescope could observe wavelengths of light which cannot penetrate the Earth's atmosphere and record higher-quality images without its disturbance. Such observatories, he said, were "not to supplement our present ideas of the universe we live in, but rather to uncover new phenomena not yet imagined, and perhaps to modify profoundly our basic concepts of space and time."

Since 1964, US astronomy has undertaken a deliberative study every decade involving its entire scientific community to organize and prioritize its most fundamental and largest scale tasks, among these making Spitzer's vision a reality. These "Decadal Surveys" outline improvements on past accomplishments and the expansion of aspirations as science progresses. The report ahead of the 1970s was explicit: "The ultimate objective … should be the development of a National Space Observatory [which would become the Hubble Space Telescope]. … The exciting role that such a large space telescope (LST) could play in astronomy in the decades to come is discussed. … The LST should lead to a much improved understanding of the most fundamental problems in cosmology, as well as of the broad range of astronomical problems presently being investigated."

The report ahead of the 1980s noted that this continuing program, which culminated with launching the Hubble Space Telescope in 1990, "will represent one of the most momentous advances in astronomical instrumentation since Galileo's first telescope." It also identified the importance of follow-up space telescopes to expand the reach of astronomy into the infrared, much of which cannot penetrate the atmosphere. The 1990s decadal report put the infrared Spitzer Space Telescope atop the list of space priorities following Hubble, but noted, "We must begin now the conceptual planning and technological development for the next generation of [space] astronomy missions to follow," giving as an example a telescope of specifications remarkably close to JWST. The follow-up 2000s decadal report put this "Next Generation Space Telescope," as it was known until 2002, as its highest priority (and most expensive) item: "Its potential for new discoveries will easily rival that of HST when it was launched."

Such conceptual planning necessarily must grapple with not just known science, but future anticipated discoveries enabled by improved technique. The early planning meetings for what would become JWST took place even before its predecessor Hubble was launched. One of chief scientific tasks prioritized early on was to better characterize the formation and properties of planets outside of our own solar system—this before even a single extrasolar planet had yet been identified!

As an example, the original prime scientific justification for the Hubble Space Telescope was to record the properties of a particular category of pulsating stars that serve as yardsticks for measuring distance several times further than was possible with telescopes from the ground. This would place the calibration of distances across the universe on a firmer footing and perhaps raise new issues in the consensus of cosmological understanding. All of this happened—including the new issues!—but as Spitzer foresaw, so much more would unfold over its years of productivity.

And thus Hubble also confirmed the hypothesis of giant black holes at the center of galaxies, took ultra-deep images of the universe at great distances looking back to the early assembly of galaxies, established the existence of matter filaments linking galaxies, probed the chemistry of gas between the stars, resolved images of collapsing disks of gas surrounding newborn stars from which planets are thought to form, verified that powerful gamma-ray bursts are not nearby but at vast cosmological distances and during their several-second lifetimes are the brightest objects in the universe—and more.

Following the success of Hubble, four themes for scientific discovery were outlined for the JWST: 1) to discover "first light," when the darkness of the cooling universe from the Big Bang, filled only with gas, began to fill with newly born stars; 2) to characterize the earliest assembly of galaxies from these stars and the gas from which they formed; 3) to detail the processes involved in the birth of modern stars and planetary systems surrounding them; and 4) to study such planetary systems to uncover the origins of life.

Instruments and capabilities of JWST

Realizing these aspirations dictated the size of the telescope, the colors of light which it would be optimized to collect, and the mix of instruments and their capabilities which would process the light after the telescope gathered it. Four instruments sit at the business end of the telescope, each optimized to study the collected light differently.

Three of the instruments record primarily visible light and the nearby region extending beyond the red end of the visible spectrum. These include the large 40 megapixel survey camera NIRCam provided by the University of Arizona, the Near-Infrared Spectrograph (NIRSPec) built by NASA and its Goddard Space Flight Center and the Fine Guidance Sensor/Near InfraRed Imager and Slitless Spectrograph (FGS/NIRISS) built by the CSA. The two spectrographs further separate and record the distribution of light by color to produce a kind of fingerprint which reveals physical properties of the objects being observed; in the case of NIRSpec hundreds can be recorded simultaneously.

The final instrument, the Mid-Infrared Instrument (MIRI), designed by the ESA with contributions from NASA and the Goddard Space Flight Center, pushes far beyond visible light, extending to wavelengths five times longer than those of the other instruments, or 35 times beyond wavelengths the human eye can perceive. At these wavelengths, it performs both imaging and spectroscopy on its targets.

The emphasis on infrared light arose from a number of factors: the Hubble Space Telescope was optimized to look at visible light and even shorter ultraviolet wavelengths. JWST will complement its capabilities. But the emphasis on the early universe and on collapsing cool gas clouds that form galaxies, stars and planets also dictates this design principle. The early universe is rapidly expanding away from us, and this expansion shifts toward the infrared—dramatically so at its limits—the colors of radiation emitted from objects by the time it reaches us. Additionally, protogalaxies, protostars and protoplanets are cool compared to the objects best studied by Hubble in visible light: they emit the great bulk of their radiation in the infrared. Furthermore, these objects are dusty, and dust blocks visible light from emerging. And, in studying planets outside the solar system, the glare from the enormously brighter parent stars is reduced compared to the brightness of the planets themselves in the infrared.

And finally, infrared technology itself was primitive when Hubble was conceived and built. It has advanced enormously in terms of the size and sensitivity of the solid-state "chips" now used to record it, which has opened up new space for discovery.

The optimizations for these studies dictate station-keeping the telescope 1.5 million kilometers away in its L2 parking orbit, where it can shield itself perpetually from the warmth of not only the Sun but the Earth. It motivated the development of the sophisticated sunshield to allow the telescope to cool even without additional refrigeration to temperatures only 45 Kelvin above absolute zero. For the MIRI instrument, which probes furthest into the infrared and will study the coolest objects, it dictated that additional refrigeration be added to chill its components even further, to only 7 Kelvin above absolute zero. Otherwise, its own warmth would contaminate its measurements.

Capitalist politics and the space program

The many scientific possibilities of Webb, however, have been long disrupted by the project's numerous delays and aborted cancellations. Formal development of a telescope beyond Hubble began in 1989, a year before that mission was launched. Astronomers were aware that Hubble was, from an observational standpoint, not the end but the start of what could be achieved by a space-based observatory.

These plans coalesced into a proposal submitted in 1996 named the Next Generation Space Telescope, which called for an 8 meter diameter telescope that would be launched in 2007 and an estimated budget of $500 million. The original 1996 budget was in reality never going to be met by such an ambitious project, and was set by the 1990s NASA leadership as the agency pushed for “faster, better, cheaper” spacecraft. A far better estimate of the cost was published in 1984 by the Space Science Board, which noted that an infrared observatory built after Hubble would cost about $7 billion in 2006 dollars.

The 1984 estimate proved to be fairly accurate. By 2002, NASA’s cost estimate for the project had grown to $2.5 billion, the same year the project was renamed for NASA’s second administrator (1961-68), James E. Webb. That year the size of the mirror was also scaled back, from 8 meters to the current 6.5 meter design. By 2006, the cost had grown to $4.5 billion.

Some of these delays were caused as the science driving the mission developed and became more concrete. A major progress report from that year described the JWST as a “large, cold, infrared-optimized space telescope designed to enable fundamental breakthroughs in our understanding of the formation and evolution of galaxies, stars, and planetary systems.” Now, however, it is understood that the telescope’s capabilities are in fact inadequate to detect the first stars individually, though it is hoped that the first galaxies can be recorded.

Beyond the actual difficulties and costs of building such a complex spacecraft, however, the project also suffered more than a decade of underfunding from both Democratic- and Republican-controlled Congresses. Rather than provide the necessary funding for JWST up front, NASA was only ever barely allocated enough funding to continue the project year by year, causing a snowball effect of additional delays and costs.

This process culminated in 2011, four years after the original launch date, after $3 billion had been spent and three-quarters of the telescope’s hardware was in development. Rather than continue the project, the House of Representatives appropriations committee on Commerce, Justice, and Science moved to cancel the project altogether. It was only saved after an immense outcry, from both the astronomical community and the general public, against the devastating impact on future scientific endeavors.

The total cost of the project is now expected to be about $10 billion.

While the astronomy community has generally supported the JWST, it has drawn criticism because of its immense cost and complexity. The high cost of the telescope has meant that many other projects have been pushed back or canceled as a result. A 2010 *Nature* article wrote that the JWST was “the telescope that ate astronomy.” The high complexity of the mission means that if anything goes wrong from now until the telescope is deployed, the past 25 years may amount to zero astronomical gain.

That the JWST costs so much, however, is not a true reason to oppose the mission. When Congress proposed to cancel it in 2011, that same body had no issue passing the Obama administration’s $712 billion defense budget. In contrast, the total amount NASA has spent since its inception (adjusted for inflation) is about $650 billion, a quarter of which was spent on the Apollo program that put men on the Moon. The lack of funding in astronomy—and science, health care, education and all other aspects of social life—are dictated above all by the need of American and world capitalism to feed the ever increasing appetite of the stock market and to fuel the drive to war across the globe.

As particle physicist Robert Wilson noted in 1978: “There has never been a French electricity, or a German mechanics, or an American atomic physics. The whole field advances as one big international collaboration, and physics is the same in every country of the world.” Space astronomy is one of the most fundamental demonstrations of this principle.

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