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EXPANDING THE FRONTIERS OF SPACE ASTRONOMY
We help humanity explore the universe with advanced space telescopes and ever-growing data archives.

Our Strategic Goals:
- Excel in the science operations of NASA’s current and future astrophysics flagship missions.
- Advance state-of-the-art astronomical data, archives, and tools for scientific discovery.
- Make the world’s astronomical information accessible to all.

Letter from the director
At the Space Telescope Science Institute, we take great pride in serving the astronomical community and expanding the frontiers of space astronomy for all. We strive to serve with integrity and create a legacy of excellence as we help humanity explore the universe. We believe open access to astronomical data makes the world a better place, one in which everyone is invited to participate in the wonders of the universe revealed by the missions and archives we operate.

I was delighted to recently award nearly 500 hours of director’s discretionary time to 13 early release science programs for NASA’s James Webb Space Telescope, which will generate some of Webb’s first science results and demonstrate the investigative capabilities of this extraordinary observatory. As we prepare for and eagerly anticipate launch, we are also working hard to keep NASA’s Hubble Space Telescope at peak scientific productivity and operate it as we look forward.

In just a short time, the 2020 Decadal Survey will be upon us. For over 50 years, this proven process for organizing the collective scientific priorities of the astronomy community has recommended a complementary slate of innovative large and small projects that have engaged thousands of talented people in a common quest to explore the universe. I encourage everyone who is passionate about astronomy to support the decadal survey process, think outside the box, and help shape a bold future for the field.

I hope you find this year’s report as interesting and exciting as I do. It is a brief but powerful snapshot of our work and some of the people behind the scenes who every day bring the universe down to earth and make the institute a great place to work.

Open access to extensive data from new observatories like NASA’s Wide Field Infrared Survey Telescope (WFIRST), which will produce Hubble-quality images over large swaths of the sky, is essential to extracting science. We are focusing on new services and products that allow everyone to visualize and use data in ways that could only be imagined a short time ago. It’s hard to believe we celebrated the 25th anniversary of the Barbara A. Mikulski Archive for Space Telescopes (MAST) in October 2017, but even harder to anticipate all the changes the next 25 years will bring. Yet reimagining our archives for scientific discovery in the era of big data is exactly what we must do as we look forward.

Preparing for the Next Great Space Telescope
Teams at the institute will manage everything from the missions operations center to the science operations after the launch of NASA’s James Webb Space Telescope.

For several years, the James Webb Space Telescope, or Webb, emerged from Chamber A of NASA’s Johnson Space Center in Houston on Dec. 1, 2017. The telescope’s combined science instruments and optical element exited the massive thermal vacuum testing chamber after about 100 days of cryogenic testing inside it.

The institute, which will serve as mission operations center and will lead the science operations for the telescope, is in a near-constant state of activity leading up to launch. In the last year, staff have not only installed new equipment and software, they have also conducted frequent rehearsals, acting as if it’s launch day—and each date that follows during the observatory’s six-month commissioning process—again and again.

These rehearsals are essential. About 100 positions in the control center must be staffed 24 hours a day for six months after launch, which means every seat not only needs several people to round out a regular staffing schedule, but also a few professionals who are cross-trained to ensure the team doesn’t miss a beat.

Once the first science operations begin about six months after launch and deployment, staff will download, process, store, and distribute 25 gigabytes of data from the telescope every day. These data will be publicly available through our Barbara A. Mikulski Archive for Space Telescopes (MAST). Throughout the next year, staff will continue testing to ensure all subsystems and processes work correctly, and that every detail has been checked and crosschecked.

Our work is only possible with the support of our partners: NASA Headquarters, NASA Goddard Space Flight Center, the European Space Agency, and the Canadian Space Agency. Collectively, we’re working to ensure that Webb will be the next great space observatory.
When the James Webb Space Telescope arrived at NASA’s Johnson Space Center in Houston, Texas, Hurricane Harvey was not even a blip on the radar. On July 10, Webb entered the historic Chamber A. Scientists, engineers, and an array of support staff from NASA facilities and its partners, including colleagues from the institute, began about 100 days of intense cryogenic testing. As the storm approached in late August, staff was reduced to move as many people as possible out of the path of the storm. Those who remained kept essential operations running for five days. Areas of Texas flooded, some receiving as much as 50 inches of rainfall.

What might sound like a Herculean effort was purposeful. Webb was in space-like conditions—about 236 Celsius. It took three weeks to achieve, and bringing it back up to room temperature requires an additional three weeks. The observatory—and the staff who supported it—had made the choice to weather the storm.

When the testing ended in late October, teams had extensively run through Webb’s flight and science operations, communicating to every staff member who persevered. When the testing ended in late October, teams had extensively run through Webb’s flight and science operations, communicating to every staff member who persevered. When the testing ended in late October, teams had extensively run through Webb’s flight and science operations, communicating to every staff member who persevered.

The early release program is scheduled to take place during the first five months of Webb’s science operations, which follows a six-month commissioning period. The 13 science programs represent almost 250 investigators from 18 countries, 22 U.S. states, and 106 unique institutions. In addition to producing science that will inform future observations with Webb, these teams will develop extensive documentation, scientific software, and data products designed to help the astronomical community maximize the scientific output of the mission.

Through almost 500 hours of observations, several of Webb’s most anticipated studies will make great scientific strides while demonstrating innovative ways to use Webb’s instruments. One will use all four instruments in time-series mode. Another will show how two instruments complement one another. Others will lead researchers to write algorithms to extract complete data sets, create software and tutorials, generate representative data sets, and publish science-ready maps of relevant features.

The astronomers supporting early release science will further the field by creating new, publicly available tools—and empower the rest of the astronomical community to produce high-quality science more quickly.

Advancing Webb’s Scientific Capabilities

To allow the research community to be as scientifically productive as early as possible, in November a committee made up of subject-matter experts recommended science programs for Webb’s Director’s Discretionary Early Release Science Program, and Director Ken Sembach selected 13. These observations span a wide range of science areas and instrument modes, including surveys of galaxies and their nuclei, stellar clusters and star formation near and far, the chemistry of interstellar and circumstellar matter, and the characterization of planets around the Sun and other stars.

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to keep the community well informed throughout the mission.

In addition to essential online support, our staff members have planned and hosted more than two dozen workshops across the U.S. and Europe for the science community since 2015, with 11 in 2017 alone. Two notable workshops were multi-day events at the institute in May and Caltech in December, which focused on proposal planning, specifically how the process works, and the requirements.

These sessions also included hands-on demonstrations of the tools our teams have released to support astronomers. The December workshop focused on the director’s early release science programs, providing time for extensive discussion. More workshops are planned in 2018, all with the goal to help astronomers write proposals that will maximize the use of Webb’s instruments and increase its scientific output.

Our staff will continue to simulate datasets to help astronomers prepare to apply for time to use Webb, call for new proposals, plan for its science archives, and share details about the science it will produce. We are contributing to the foundation of its mission and science operations, knowing Webb will fundamentally change our understanding of the universe.

CAPTURING THE WORLD’S ATTENTION

A look at the Director’s Discretionary Early Release Science Program by the numbers:

- **106** Proposals
- **13** Science Programs
- **106** Institutions
- **248** Investigators
- **456** Science Collaborators
- **18** Countries
- **22** U.S. States

BY LOCATIONS

Is an alien megastructure—a Dyson sphere—in our midst? Fortunately, no. Thanks in part to the archives at the institute, researchers were able to definitively demonstrate that an alien megastructure is not transiting a star more than 1,500 light-years away. It is much more likely that the previously unexplained, erratic dips in light are caused by a massive cloud of dust that moves unevenly around the star.

Researchers had studied the star, KIC 8462852, for years, but it wasn’t until 2017 when they compared the data in ultraviolet light to data previously examined from NASA’s Kepler Mission that they proved the dips were not as drastic as previously thought. Ultimately, they found that although the dimming and brightening was significant, it wasn’t unusual.

Research like this isn’t unusual either. In astronomy, it’s the norm. Researchers at astronomical observatories, colleges and universities, and NASA centers and facilities build teams of experts to address problems that pull from new, and often existing, data for research. Frequently, they turn to our own Barbara A. Mikulski Archive for Space Telescopes (MAST) for good reason. At the end of 2017, MAST contained almost three petabytes of astronomical data from more than 20 missions.

Add, Multiply, Empower—Repeat

Our archives team manages data from more than 20 missions and helps astronomers build community.
The Era of Big Data

It’s fair to say that science invented the term “big data”: a 1997 NASA report was the first to cite the term. NASA’s Hubble Space Telescope has sent tens of gigabytes of data every week for more than 28 years, resulting in more than 150 terabytes of science data in total. The largest sky survey ever conducted, the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS), is more than two petabytes. After launching, NASA’s James Webb Space Telescope will send about five petabytes by the end of its mission, and NASA’s Wide Field Infrared Survey Telescope (WFIRST) will send upwards of 10 petabytes. All of these data are (or will be) stored in digital archives that can be accessed any time of day and from anywhere one has access to the internet.

Mining archival data is essential for astronomers. By pulling data about the same target, they can accurately determine if an event is an anomaly or part of a pattern. In 2017, more than 330 papers were published in peer-reviewed journals based on new observations, while more than 375 used only archived data, and almost 170 publications relied on both new and archived data. More than 7,600 authors contributed to this original research. Publication rates for the data MAST manages for other observatories isn’t far behind.

The quantity of information we manage is only part of the story: It must be accessible and easily manipulated by researchers who regularly retrieve large and complex data sets from MAST online. To meet these challenges, the institute created the Data Science Mission Office in 2016 to deliver more data, more efficiently and more effectively to our users. We not only provide access to well-calibrated high-quality data, we actively respond to scientists’ queries, and, most importantly, encourage collaboration among the astronomical community. The contributions from astronomers outside the institute ensure we continuously evolve.

Empowering researchers to mine our archives is essential to our success, which is why we hosted the workshop “Detecting the Unexpected: Discovery in the Era of Astronomically Big Data” at the institute in February. Over four days, we discussed a number of approaches to analyze large datasets, including using artificial neural networks or deep learning, new data visualization techniques, and how to go beyond machine learning by integrating citizen scientists. We also asked attendees to suggest ideas, tackle those concepts, and present their findings after a daylong build. This workshop allowed us to seek new ways to enhance the process of discovery.

Rethinking Community

Researchers are frequently innovators. To answer a question, it’s not always as straightforward as pulling information to analyze and publishing the findings. Often, it means working with other experts on that topic, rethinking how to approach it, and, sometimes, writing new software to analyze it.

Consider Kepler. Initially, it used four reaction wheels to point its instruments to measure the dip in brightness of a star due to a planet periodically transiting it—leading to highly precise measurements of thousands of exoplanet candidates. After the mission was rebooted and renamed in 2016, K2 continues to operate, but cannot use two of its reaction wheels, which reduces its ability to point precisely for extended periods.

Researchers using K2’s data archives designed a new solution to address this issue, known as a self-flat fielding correction. This technique accounts for the non-uniform responses of K2’s detectors and improves the photometry by factors of two to five, significantly increasing the precision of its data. The researchers’ contribution now means fellow astronomers can rely on the corrected data, which is available in MAST.

Examples like these caused the archives team to reimagine our role in the astronomical community. Now more than ever, community is central to our work. We’ve made a concerted effort to build strong partnerships with our users, connecting them not only to resources in person or online, but also to one another. As a result, we more than doubled our holdings of community contributed products in 2017, which now total almost 30 terabytes. Astronomers contributed a series of data products, including images, spectra, light curves, catalogs, data models, software, and tools that apply to a range of missions within MAST.

Accessing the Night Sky

For almost four years, the Pan-STARRS1 telescope near the Haleakala Observatories in Maui, Hawaii, scanned the night sky. By the end of the project in 2014, each spot visible from Hawaii had been observed between 10 and 20 times in five filters; another survey went deeper, observing 10 fields through long exposures, leading to the discovery of thousands of supernovae that will be used to study the evolution of the universe. The world’s largest digital sky survey, produced by the University of Hawaii Institute for Astronomy, is now available through our archives.
It’s a very big universe out there and astronomers’ work is never done when it comes to counting and cataloging stars. This new version of our Guide Star Catalog, which was first released in 1989, provides important information on nearly one-half billion stars, over 20 times as many as the original contained.

To ensure its successful release, institute staff helped perform data quality checks, wrote archive-user documentation, tested and installed the local data storage and database query system, and designed, built, and deployed the web-based user interfaces to the archive system. The first release, in late December 2016, included data that show the average of each individual epoch surveyed. More than 20 million images, totaling 61 terabytes, were downloaded in the first year, averaging more than 1 million queries each month. In 2018, the second set of data will be released, providing a catalog that gives the information and images for each individual epoch.

Pan-STARRS1 has provided an excellent challenge to our archives team updated the positioning of the guide stars used to “lock” onto targets before making observations with ground- or space-based telescopes by matching data from our Guide Star Catalog to the Gaia catalog—a three-dimensional map of the Milky Way that has unprecedented positional and radial velocity measurements led by the European Space Agency. Our updated Guide Star Catalog was released in 2017, enabling the scientists and engineers who use and operate Hubble and, soon, Webb to know with much greater accuracy just where these space telescopes are pointing on the sky.

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Through all of our work, we aim to bring together the objectives of all the missions of the institute in a single, coherent vision for data processing, archive services, and community software to maximize the scientific impact of our missions and archive. Our focus is not only on technologies, but also engaging and training the astronomy community. We are actively working with researchers across the world to write, upload, and share software that will support the whole community as they analyze this vast range of scientific data.

This sky survey—and missions operated around the world—also benefited from another innovation. The
SOFTWARE TO SUPPORT THE SCIENCE

How do you point a space telescope, gather and calibrate the data it returns—and deliver it to the science community and the public? Software developed by teams of engineers at the institute support almost every piece of the process of NASA’s Hubble Space Telescope. These systems will also support the complete process for the NASA’s James Webb Space Telescope.

Many systems informed one another (Hubble’s software was frequently revised for Webb and, in some cases, returned to Hubble to improve its observations). In 2017, engineers delivered the second release of the software system for Webb’s Science and Operations Center, creating a coherent system built on many subsystems, and was successfully tested with external facilities, such as the Deep Space Network and the high-fidelity Webb spacecraft simulator at our partner Northrop Grumman Aerospace Systems.

Here, we provide a simplified view of the process for Webb—from a request to use the telescope all the way through to its delivery—showing how software supports each step.
WEBB’S SUBSYSTEM OVERVIEW

THE PROPOSAL PLANNING SUBSYSTEM provides the proposal generation, processing and planning functions to manage the science programs, and generates the observation plan.

THE FLIGHT OPERATIONS SUBSYSTEM sends the command programs from the ground, receives, and processes data from the spacecraft.

THE OPERATIONS SCRIPTS SUBSYSTEM provides the programs to the spacecraft, which autonomously selects the sequencing and executes the observations, optimizing its efficiency.

THE WAVEFRONT SOFTWARE SUBSYSTEM optimizes the observatory’s optical performance, detecting misalignments that allow staff to make adjustments.

THE DATA MANAGEMENT SUBSYSTEM provides data processing, archiving, calibration, distribution, and analysis functions to support the science programs and observatory’s maintenance.

THE PROJECT REFERENCE DATABASE SUBSYSTEM provides definitive sources of configured data for the mission.

THE PROPOSAL PLANNING SUBSYSTEM

The Future of Large Space Telescopes

While the transit method provides a powerful technique for studying some exoplanets and their atmospheres, only a fraction of planets transit their parent stars. Can we instead directly image faint, rocky planets as they orbit other stars?

First, consider our current capabilities. NASA’s Hubble Space Telescope and today’s largest ground-based telescopes take images that reveal large, Jupiter-like planets that orbit fairly far from their stars. These observatories are unable to resolve images of small, rocky planets like Earth since they orbit too close to their stars. One way to meet this challenge is to use a large space telescope with a coronagraph, an instrument that blocks the bright glare from a star to produce a dark area that allows us to see far fainter light from exoplanets.

Next, consider the contrast: If seen from outside the Solar System, the Earth would appear 10 billion times fainter than the Sun. To be able to study small, rocky planets like the Earth or Venus, future observatories will also need much larger mirrors. Fitting observatories with large mirrors into launch vehicles that have a preset size may require the mirrors to fold like origami (much like NASA’s James Webb Space Telescope will do), and unfold in space.

These linked challenges—developing advanced coronagraphs and large, segmented mirrors for observatories—are what drive the scientists and engineers working at the institute. They are developing optical technologies for use in future large space telescopes, which contribute to the mission concepts being developed for review in the 2020 Decadal Survey, including the Large Ultraviolet/Optical/Infrared Surveyor (LUVOIR) and the Habitable Exoplanet Imaging Mission (HabEx).

Established in 2012, the Russell B. Makidon Optics Laboratory is based on bedrock: It’s the same stable site where staff at the institute scanned a collection of photographic plates of the sky that became the Guide Star Catalog in the 1980s. (This catalog allows NASA’s Hubble Space Telescope—and telescopes around the world and in space—to automatically lock onto targets before beginning observations.) In 2017, with several new team members on board, the optics lab team made rapid progress in developing new concepts and technologies to enable future space telescopes to achieve the highest contrasts.
Searching for Life on Exoplanets

While segmented mirror technology enables large telescopes to fold for launch, it also can pose challenges when designing the coronagraph, which requires complex masks to block starlight. Imaging Earth-like exoplanets will require combining more advanced masks that are optimized for segmented telescopes, along with sophisticated wavefront control algorithms and adaptive deformable mirrors that carefully control the removal of bright starlight.

Optics lab team members have taken the lead in designing the complex coronagraph masks needed for segmented apertures, as part of a nationwide study in partnership with scientists at NASA’s Jet Propulsion Laboratory, NASA’s Goddard Space Flight Center, Advanced Nanophotonics, Inc., and several universities. They use supercomputers to carefully model how light interacts with the coronagraph components to produce optimized designs that thoroughly block a star’s light while minimizing any incidental blocking of planet light.

The shaped pupil masks designed by the optics lab team have been recognized as the highest performing designs from any of the study teams, and the only ones that meet the performance needs of LUVOIR, which will be designed to directly image a significant number of rocky (potentially Earth-like) exoplanets orbiting Sun-like stars.

In addition to this progress, the optics lab staff also needs to run hardware tests to show the designs will work in practice. This is why they developed a testbed to advance high-contrast imaging technology of exoplanets using a segmented telescope in space. Named HiCAT, the testbed combines wavefront sensing, wavefront control, and coronagraph starlight suppression. In 2017, the optics lab achieved a first demonstration of a coronagraph with a simulated segmented telescope.

The next step is fabricating the coronagraph masks, which must be as black as possible. Two technologies have been tested on HiCAT. The first consists of black silicon masks produced by collaborators at NASA’s Jet Propulsion Laboratory. The second, newer technology uses a dense forest of carbon nanotubes to produce an ultra-black coating, darker than pure black velvet and at least 10 times better than specialized NASA black paints. The world’s first carbon nanotube coronagraph masks were delivered to the institute in 2017, and are actively being used in ongoing tests.

Another milestone for the testbed was installing two more deformable mirrors for precise control of starlight, bringing the total up to three. One deformable mirror is segmented, with 36 computer-controlled hexagonal mirrors that can be precisely controlled to billions of a meter; this stands in for a large, segmented telescope, but is a thousand times smaller to allow lab-scale tests.

The other two deformable mirrors precisely control and focus light so the coronagraph can produce the deepest dark hole. Another system senses and corrects for jitter from air turbulence or small vibrations within the lab. Sophisticated, highly automated software controls all these pieces, allowing hands-off experiments to run 24 hours a day.

The first dark-zone experiment with all three deformable mirrors and the carbon nanotube masks was successfully achieved early in January 2018, which is notable since this is the first time a coronagraph design optimized for a segmented space telescope like LUVOIR was demonstrated to achieve high contrast on an actual segmented mirror.

By investing heavily in both the theory and design of coronagraphs, and the practical hardware demonstrations of these systems, the optics lab staff will continue advancing starlight suppression with a segmented telescope. And, as always, the team looks to the future. Their work will contribute to the technologies needed for future large space observatories—and how we will search for life in other solar systems.
Merging Software and Science

Consistent change is the theme of Christopher Moriarty’s career. His work as a software engineer has led him to contribute to gaming and artificial intelligence research projects; he’s also well-versed in modern software engineering standards. That’s why it makes perfect sense that he took the initiative to become the first software engineer to work full time in the institute’s Russell B. Makidon Optics Laboratory.

In this role, he’s entered uncharted territory: Helping to develop a next generation coronagraph for a large, space-based telescope concept that will resolve Earth-like planets around stars outside our solar system. The instruments on the testbed are extremely sensitive; some require humidity control and backup power monitoring, which is why Moriarty has worked to lay a foundation for the experiments.

Throughout 2017, he has redesigned the entire software infrastructure. Now, the system can autonomously operate the testbed while also monitoring humidity and power conditions. All of this is done with a bigger picture in mind: ushering in advances in software engineering to push the institute to the forefront of astronomical research.

The software Moriarty wrote allows the lab to operate 24/7, which increases efficiency by enabling long experiments to run nights and weekends, while ensuring safety. “If we have an outage and begin using back-up generators, the script will ask the servers, ‘Are you having a power failure?’ If I get, ‘Yes,’ twice, the software shuts the system down quickly and safely,” he explains.

In 2017, Moriarty also developed a library to control the deformable mirrors, and implemented an algorithm to create a dark zone (known as speckle nulling). “When you move a coronagraph into a light path, the remaining light seeps through in unpredictable ways, like a splatter of ink,” he shares. “The software finds those speckles and uses deformable mirrors to null them out, which in theory would only leave behind the light from a faint object like an exoplanet.”

At this point, it’s safe to say he’s hooked. “I think I’ve found my niche,” Moriarty says. “I’ve always liked working with hardware and writing software to support it. Now, I’m involved in research that allows me to do both while introducing fascinating challenges.”

A GALACTIC COLLISION

Color and light dance through NGC 5256. Smoke-like plumes are flung in all directions and the bright core illuminates the chaotic regions of gas and dust swirling through the galaxy’s center. Also known as Markarian 266, NGC 5256 is about 350 million light-years away from Earth. It is composed of two disk galaxies with nuclei that are currently only 13,000 light-years apart and are in the process of colliding. Their constituent gas, dust, and stars swirl together, igniting newborn stars in bright star formation regions across the galaxy.

Each merging galaxy of NGC 5256 contains an active galactic nucleus, where gas and other debris are fed into a supermassive black hole. NGC 5256 was previously imaged by Hubble as part of a 2008 collection of 59 images of merging galaxies. The 2017 image adds H-alpha data taken from the Wide Field Camera 3 to the previously available data, making the gas visible.
Enhancing a Prolific Observatory

NASA’s Hubble Space Telescope is the most scientifically productive observatory in history. Anyone in the world can propose to use Hubble. The latest cycle of requests for its time led to an oversubscription of five to one; researchers’ demand is, quite simply, relentless. In response, staff at the institute works to ensure that Hubble’s observing program remains robust, as evidenced by an extremely efficient schedule, and the telescope’s extended capabilities. In 2017, its data were used in more than 900 peer-reviewed papers in scientific journals—surpassing 15,300 throughout its 28-year history. Here, we share a few 2017 improvements made to push its stellar output to new limits.

Reveling in the Details

Patricia Royle is used to doing work that’s never been done before. Challenging projects have driven every moment of her 20-year career at the institute. As a senior program coordinator for the Hubble Space Telescope, she works closely with astronomers to determine precisely when observations can happen and often her assignments focus on very large programs. A prime example of this is the Hubble Ultra Deep Field, a program that ran from 2003 to 2004 and produced a million-second-long exposure to reveal some of the earliest galaxies in the universe.

Royle went on to manage the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey (CANDELS) program, which required three years of constant observations. She supported the program by working through every detail (often repeatedly) of the planning and scheduling to maintain its observations. “I loved it,” she says. She also coordinated the observations for Frontier Fields, which led to super-deep views of the universe.

She hasn’t stopped asking for new challenges. “It doesn’t matter how much we see—there’s so much more out there,” Royle says. Over the years, her team has made significant process improvements. “The Hubble Deep Field South [released in 1998] had five program coordinators and 150 orbits. Now I’m able to work alone on projects with 600 orbits.” She and her colleagues currently build weeklong calendars 11 days in advance and evolve for each project and each orbit.

Royle’s current focus is the Panchromatic Comparative Exoplanetary Treasury Program. Through almost 500 orbits, it will produce the first large-scale comparative study of exoplanets. “This program is testing all we can do with Hubble’s planning, scheduling, and processing operations,” Royle shares.

It also presents exciting challenges. “Exoplanets have precise windows for observation. They pop up, disappear, move, and shift. One may only be observable for 15 minutes once every three-and-a-half days. Another has a 40-minute window every eight days. This project will push our limits.” Best of all? Her excitement is palpable. “The wow factor of Hubble has never worn off,” she says. “I’m still amazed I get to work on such an awesome telescope.”
Making Every Second Count

Each Hubble observation can lead to groundbreaking science, which is why our teams continually introduce new efficiencies. First, consider the challenges: Hubble orbits a mere 340 miles above Earth, which limits what it can see and when. Observation program coordinators have to consider the location of the Sun, the Moon, and Earth itself while creating the schedules, in addition to needing the precise location of Hubble in its orbit.

Next, add the observation requirements to the mix. Some programs can be completed in a few hours, others only after hundreds of (albeit non-contiguous) hours. Another focus is the target type. For example, observing exoplanets is extremely difficult—the windows of opportunity often open only for a few minutes every few days. Suffice it to say that planning Hubble’s observations is like building a 1,000-piece puzzle—for each observation.

In addition to their wealth of scheduling experience and ongoing upgrades to the scheduling process, our extremely resourceful staff members have also introduced new ways to execute the observations, which ensure scientists don’t lose valuable time. Scientists may also design flexible observing programs (on top of requests for regular observations) that contribute to Hubble’s efficiency by obtaining “Snapshots” or SNAP programs.

Our teams took this one step further by creating an ultra-flexible observing program. Although it understandably has the lowest priority of all observing programs, the Super-SNAP program is executed when short gaps in the schedule appear. Its goal is to use time absolutely no other program is able to use. In 2017, this Super-SNAP program captured previously unobserved bright galaxies and led to a 1 to 2 percent increase in Hubble’s efficiency. What’s more, all images taken through these programs are immediately made public, leading to an increase in their use in scientific research.

For example, this program led to observations of the galaxy that hosted the 2017 gravitational-wave event, just months prior to the cataclysmic event. These archival data helped establish the properties of the binary neutron stars that merged to create the gravitational waves. (Learn more about this story on page 35.)

This is a montage of galaxies observed with Hubble’s Advanced Camera for Surveys as part of a schedule-gap filler program. Each image is of a previously unobserved galaxy and was obtained with only one filter, making use of time that would otherwise not be used for science.

Reconfiguring Instrument Calibrations

Although Hubble’s last servicing mission was in 2009, its state-of-the-art science instruments still offer unparalleled capabilities. Part of this is because they are consistently updated through enhancements to the operations of the instruments and how the data are processed. In 2017, we completed two noteworthy updates.

The first relates to the charge-coupled device detectors Hubble’s instruments use to create images. Throughout years of radiation damage from energetic particles in space, these detectors suffer from traps that cause the light in pixels to be displaced. Our teams have mitigated this problem by writing a script that puts the displaced light back in the correct pixels. Using data obtained in 2017, our teams updated the algorithms and reference files needed to make these corrections, allowing Hubble to continue to produce razor-sharp, consistent images.

Other notable enhancements are the updates to the precise locations of spectral positions used in Hubble’s Cosmic Origins Spectrograph. This detector becomes less efficient at photon-to-electron conversion when it is exposed to photons, which means it is necessary to relocate the spectral positions every few years. Each time we conduct one of these lifetime position shifts, our teams have to determine the precise location of the next position and the associated best-focus values, verify the performance at the new location, and update the calibration reference files and flight software.

This maintenance is essential since this instrument provides sensitive ultraviolet spectroscopy that is unmatched by any other observatory and impossible to collect from the ground. Through initiatives like these, our teams are ensuring Hubble will remain scientifically productive for years to come.

It’s very likely Hubble will continue to operate through the mid-2020s, as shown by ongoing engineering studies. In 2017, Hubble team members developed innovative operational approaches that will increase the lifetime of one of the ultraviolet detectors, preserving and extending the legacy of ultraviolet astronomy into the next decade.

This means that the observatory will send back extremely valuable, unparalleled ultraviolet observations that will be combined with infrared data from NASA’s James Webb Space Telescope—in the very same way it has supported fellow observatories for decades. In the coming years, Hubble will continue to play a uniquely powerful role that will resolve new mysteries about the universe.
Empowering Staff

Susan Reed starts each workday the same way: She huddles with members of the information technology (IT) department who directly support staff at the institute to review everything that happened in the last 24 hours. Were there outages? If so, what is our response to mitigate the effects? Which calls may indicate a larger problem is afoot? And, almost as soon as the meeting has begun, it ends—each person with a short, focused list of actions.

This is only one example of how Reed, the IT branch manager since 2015, connects with employees. “It’s my job to remove obstacles,” she explains. She makes herself available to staff throughout the day to hear new ideas and help make decisions. She knows, like all of the leaders at the institute, that she can’t be a single point of failure. Instead, Reed empowers her staff to identify issues and problem-solve, all in support of their colleagues, both in IT and throughout the institute.

This is why she introduced cross-training among her employees. For example, every service-desk staff member knows how to triage the requests received from across the institute—and, as a result, are more aware of their IT colleagues’ areas of expertise. This has made it easy for staff to collaborate in support of a project, leading to innovative ideas and new efficiencies.

Reed has also helped her staff automate a slew of standard processes. Instead of a complicated paper-based system, the IT department has adopted detailed, but straightforward, online forms. Now, connecting a colleague to a loaner laptop or iPad is almost immediate—and tracked. This approach also prompted her staff to create a form for requests between IT teams, which ensures a reduction in interruptions and that all the required information is in one spot.

Reed and her team plan to continue to roll out the benefits of automation to other teams at the institute, increasing efficiencies and allowing more time for both the “big sky” thinking and detailed attention that our projects require. Her passion for the position is ceaseless. “The coolest part is helping people grow while meeting our goals,” she says.
Expanding the Frontiers of Space Astronomy

The Wide Field Infrared Survey Telescope’s field of view will be 100 times wider than NASA’s Hubble Space Telescope, which means it will be able to create large-scale maps of the night sky much more quickly, but at the same high-quality resolution. Its observations will survey billions of galaxies and observe the light from stellar explosions in an effort to understand the mystery of dark energy and the expansion of the universe. The observatory will also discover thousands of exoplanets, perform detailed characterization of a sample of exoplanets, observe stars in neighboring galaxies, and study the birthplaces of stars and planets.

It’s been an exciting year for WFIRST. Astronomers, scientists, and engineers at the institute have partnered with teams at NASA’s Goddard Space Flight Center, NASA’s Jet Propulsion Laboratory (JPL), IPAC at Caltech, and WFIRST’s Formulation Science Working Group to formulate the mission, which is slated to launch in the mid-2020s. In 2017, we made strides in defining the requirements for the observatory’s ground system, establishing baselines for its science requirements, developing operations concepts, and estimating the mission’s lifetime cost.

The institute will be the WFIRST science operations center, partnering with Goddard, IPAC, and others. We will manage the mission’s observation scheduling system and data archive, support dark energy and supernova surveys, and run the Wide Field Instrument image processing system. To do this, the institute’s staff is building on extensive expertise with similar missions. We will adapt existing software and systems where possible, while developing and exploiting new technologies to meet WFIRST’s unique science goals. This approach will streamline costs, while focusing resources in the areas that will have the most impact on the science.

Mapping the Universe

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SPOTLIGHT ON A GLOBULAR STAR CLUSTER

Released in December 2017, this NASA Hubble Space Telescope image shows globular star cluster Messier 79, also known as M79 and NGC 1904. Located 41,000 light-years from Earth, M79 contains about 150,000 stars packed into an area measuring only 118 light-years across.

Most globular clusters are grouped around the central hub of our pinwheel-shaped galaxy. However, M79’s home is nearly on the opposite side of the sky from the direction of the galactic center. One idea for the cluster’s unusual location is that its neighborhood may contain a higher-than-average density of stars, which fueled its formation. Another possibility is that M79 may have formed in an unusual dwarf galaxy that is merging with the Milky Way. The image is a combination of observations taken in 1995 and 1997 by Hubble’s Wide Field Planetary Camera 2.
Simulating WFIRST Data

In addition to a 2.4-meter primary mirror (the same size as Hubble’s), WFIRST will have two instruments to execute its science program: The Wide Field Instrument, a camera with imaging and spectroscopic capabilities in the visible and near-infrared wavelengths, and a visible-light coronagraph. How will it work? Scientists at the institute have built upon software simulation tools first developed for NASA’s James Webb Space telescope to help astronomers assess what the universe will look like through the eyes of WFIRST.

The first concerns the point spread function—how the two-dimensional distribution of light in the telescope focal plane will appear for astronomical sources or targets. WebbPSF for WFIRST helps astronomers predict the observatory’s performance at particular combinations of wavelengths of light, field positions, and pixel scales.

A second tool is an exposure time calculator, which simulates small galactic or extragalactic scenes for a variety of observing modes. Pandora measures three-dimensional data cubes based on user-specified spatial and spectral properties of one or more sources. These projections allow astronomers to appropriately handle realistic point spread functions, detector readouts, correlated detector noise, and multiple photometric and spectroscopic extraction strategies. Finally, the team released the Space Telescope Image Product Simulator (STIPS) software. It produces simulated imaging data for complex wide-area astronomical scenes for a range of stellar and/or galactic populations.

Teams that support WFIRST are also looking ahead to the promise and challenges of its data. For example, the observatory will be able to obtain spectra of every object in the Wide Field Instrument’s field of view. While Hubble and Webb have similar capabilities, WFIRST will have a field of view that is 100 times larger than Hubble’s, which means that new and robust, fully automatic methods of identifying and extracting spectra from an image (and combining spectra of the same object from multiple images) are required. Several astronomers at the institute developed a method to do this in 2017, which is described in the March 2018 issue of the Publications of the Astronomical Society of the Pacific.

Institute astronomers have also been thinking about other innovative ways of using WFIRST, such as using the large field of view to measure the precise location of stars, allowing astronomers to measure very small motions of stars across the sky over a period of time. This technique can be used for a range of investigations, including determining how stars move within our galaxy, measuring its detailed structure, discovering exoplanets around nearby stars, and searching for stellar-mass black holes.

Through software and algorithm development, scientists and engineers at the institute have provided the astronomy community with tools they can use to inform the design of mission systems and requirements, enabling WFIRST to meet its science goals.

Answering Engineering Challenges

WFIRST has many unique science operations challenges not faced by Hubble or Webb. It mixes dedicated, large, homogenous surveys with smaller, heterogeneous programs. Its science and calibration requirements for the surveys are much more stringent and it will produce a much larger data volume.

To meet these challenges, engineers and scientists at the institute have worked to develop concepts for science operations systems that can meet the mission’s requirements for scheduling observations, processing and delivering the data to an archive, and providing a flexible framework to allow scientists to access and work with the data. Scientists at the institute have also co-led the effort to identify how to calibrate WFIRST’s data to meet the strict levels needed for its primary surveys.

This work has resulted in the publication of technical reports on a range of topics, including the impact on scientific observations of different concepts for mission scheduling and guiding the telescope. Scientists and engineers at the institute are also collaborating with other Association of Universities for Research in Astronomy (AURA) centers. For example, we are incorporating lessons learned from the development of the Large Synoptic Survey Telescope (LSST) in Chile.

Astronomy in the 2020s

In June, the institute hosted a workshop to explore the scientific reach of WFIRST and detail how its data will enhance and enrich current and future space- and ground-based observatories. “Astronomy in the 2020s: Synergies with WFIRST,” which featured more than 30 speakers, drew more than 100 astronomers and scientists from around the world.

Attendees spent three days discussing how today’s cutting-edge topics are likely to evolve over the next 10 years and the best ways for WFIRST to collaborate with current and future astronomical facilities to answer scientific questions. It quickly became clear that WFIRST’s power lies not only in its novel design and survey strategies, but also in how its wealth of data can be combined with data from other observatories, spurring new observations that expand upon discoveries made with WFIRST data.

One natural area of synergy is with Webb. WFIRST is expected to find many objects that can be further detailed by Webb in multi-band, high-resolution imaging and sensitive infrared spectroscopy, which will reveal detailed characteristics about these targets. This partnership means we will not only be able to see wider, but also deeper, while expanding our understanding of a range of targets, including fainter galaxies best imaged in infrared wavelengths.

There are several very good reasons why WFIRST was the premiere mission that came out of the National Science Foundation’s 2010 Decadal Survey from the National Academies of Sciences, Engineering, and Medicine. It will build on Hubble’s legacy by providing major advances in all areas of astrophysics through competitive guest observer and funded archival investigator programs. Finally, its data will be combined with data from the other major astronomy missions of its era, which will further the field in ways we can’t yet foresee.
An Eye on the Universe

Myles McKay began preparing for this summer’s total eclipse in March. As a trainer for the volunteer project Citizen CATE (Continental-America Telescopic Eclipse) Experiment, he traveled to Missouri and South Carolina to meet and train citizen scientists. The project’s goal was to capture a full cadence of images of the inner corona during its 90-minute trek across the U.S.

He explained how to set up the equipment and use software to collect images, all while fielding observers’ questions. Volunteers went on to capture thousands of images, which will help the National Solar Observatory (which is also operated by the Association of Universities for Research in Astronomy) learn about solar wind and storms, and the physics of the Sun’s corona.

McKay’s preoccupation with physics and analysis never ceases. He brings this energy to his current role as a research and instrumentation analyst at the institute, where he’s supported Hubble since 2016. What he likes most about the role is its breadth of interesting projects. “I have the opportunity to learn about various calibration programs and Wide Field Camera 3 [WFC3] instrumentation,” he says.

His work has led him to learn Python, which allowed him to improve the accuracy of WFC3’s ultraviolet and visible bias reference files by using a more complete set of data and update its calibration. He appreciates that the team is always open to new ideas. “If you suggest an improvement to the process and can prove it will work, the answer is, “Do it,” McKay shares. “My team is always open to new approaches.”

He also inspects Hubble WFC3 images—looking for scattered light, filtered ghosts, and other anomalies to flag for review. What’s next? Earning a PhD and becoming an astronomer are in his future, but first, he says, he plans to learn more about Hubble’s instrumentation. “It surprised me how much I enjoy data management,” he shares. “It’s very interesting.”

Hubble in the News

Read the most exciting news stories publicized in 2017.

NASA’s Hubble Space Telescope has captured the world’s attention for more than 28 years for good reasons: It constantly delivers stunning imagery and scientific data to help astronomers make new discoveries and confirm long-held theories. This year was no different. Read a few of the exciting stories our news team publicized.
Earth-Size, Habitable-Zone Planets

NASA’s Spitzer Space Telescope revealed the first known system of seven Earth-size planets around a single star. The exoplanet system, called TRAPPIST-1, is only 40 light-years away. Three of these planets are located in an area called the habitable zone, where liquid water is most likely to thrive on a rocky planet. The system sets a new record for the greatest number of habitable zone planets found outside our solar system.

Following up on the Spitzer discovery, NASA’s Hubble Space Telescope initiated the screening of four of the planets, including the three inside the habitable zone. The new results were published in the journal Nature, and announced at a news briefing at NASA Headquarters in Washington. Using Spitzer data, the team precisely measured the sizes of the seven planets and developed first estimates of the masses of six of them, allowing their density to be estimated. Based on their densities, all of the TRAPPIST-1 planets are likely to be rocky.

Astronomers plan follow-up studies using NASA’s upcoming James Webb Space Telescope. With much greater sensitivity, Webb will be able to detect the chemical fingerprints of water, methane, oxygen, ozone, and other components of a planet’s atmosphere. Webb also will analyze planets’ temperatures and surface pressures—key factors in assessing their habitability.

First Light from a Gravitational-Wave Event

Hubble was one of an armada of space- and ground-based observatories to capture the afterglow of a kilonova, conclusively identifying it for the first time as a source of gravitational waves.

The kilonova was caused by the merging of two neutron stars in the galaxy NGC 4993, located 130 million light-years from Earth. This sent ripples across the fabric of space known as gravitational waves. The gravitational waves were measured by the Laser Interferometer Gravitational-Wave Observatory (LIGO). The subsequent afterglow, seen across the electromagnetic spectrum, was caused by heating from the decay of radioactive elements formed in the neutron-rich debris.

Hubble helped quickly locate the newly appearing visible source that was tied to the LIGO detection. Hubble, along with NASA’s Swift and Spitzer space missions, followed the evolution of the kilonova. Hubble’s near-infrared spectrum revealed the motion and chemical composition of the expanding debris. The spectrum matched what theoretical physicists had predicted for the outcome of the merger of two neutron stars. This conclusively tied the kilonova to the gravitational wave source.

Neutron star mergers create a maelstrom of hot debris when they collide. The kilonova forges many of the universe’s heaviest elements, including platinum, gold, and plutonium.
Possible Venting Activity on Europa

When Galileo discovered Jupiter’s moon Europa in 1610, along with three other satellites whirling around the giant planet, he could have barely imagined it was such a world of wonder. This revelation didn’t happen until 1979, when NASA’s Voyager 1 and 2 flew by Jupiter and found evidence that Europa’s interior, encapsulated under a crust of ice, has been kept warm over billions of years. The warmer temperature is due to gravitational tidal forces that flex the moon’s interior—like squeezing a rubber ball—keeping it warm. At the time, one mission scientist even speculated that the Voyagers might catch a snapshot of geysers on Europa.

Such activity turned out to be so elusive that astronomers had to wait over three decades for Hubble to monitor the moon. A newly discovered plume, seen towering 62 miles above the surface in 2016, is at precisely the same location as a similar plume seen by Hubble on the moon two years earlier. These observations bolster evidence that the plumes are a real phenomenon, flaring up intermittently in the same region.

The location of the plumes corresponds to the position of an unusually warm spot on the moon’s icy crust, as measured in the late 1990s by NASA’s Galileo spacecraft. Researchers speculate that this might be circumstantial evidence for material venting from the moon’s subsurface. The material could be associated with the global ocean that is believed to be present beneath the frozen crust. The plumes offer an opportunity to sample what might be in the ocean, in the search for life on that distant moon.

Gravitational Wave Kicks Black Hole out of Galactic Core

Normally, hefty black holes anchor the centers of galaxies. Researchers were surprised to discover a supermassive black hole speeding through the galactic suburbs. Black holes cannot be observed directly, but they are the energy source at the heart of quasars—intense, compact gushers of radiation that can outshine an entire galaxy. Hubble made the discovery by finding a bright quasar located far from the center of the host galaxy.

Researchers estimate that it took the equivalent energy of 100 million supernovas exploding simultaneously to jettison the black hole. The most plausible explanation for this propulsive energy is that the object was given a kick by gravitational waves unleashed by the merger of two black holes as a result of a collision between two galaxies. First predicted by Albert Einstein, gravitational waves are ripples in the fabric of space that are created when two massive objects collide.
Blistering Pitch-Black Planet

Twice the size of any planet found in our solar system, WASP-12b is as black as fresh asphalt. Unlike other planets in its class, the planet has the unique capability to trap at least 94 percent of the visible starlight falling into its atmosphere. The temperature of the atmosphere is a searing 4,600 degrees Fahrenheit, which prevents the formation of reflective clouds on the day side. The planet orbits so close to its host that it is tidally locked, which means that the same side always faces the star. Its host star is also gobbling up material swirling off the exoplanet’s super-heated atmosphere. This oddball exoplanet is one of a class of so-called “hot Jupiters” that orbit very close to their host star and are heated to extreme temperatures. WASP-12b circles a Sun-like star 1,400 light-years from Earth.

New Use for a Century-Old Relativity Experiment

Albert Einstein reshaped our understanding of the fabric of space. In his general theory of relativity in 1915, he proposed the revolutionary idea that massive objects warp space, due to the effects of gravity. Astronomers had to wait a century, however, to build telescopes powerful enough to detect this gravitational warping phenomenon caused by a star outside our solar system. Hubble observed the nearby white dwarf star Stein 2051 B as it passed in front of a background star. During the close alignment, the white dwarf’s gravity bent the light from the distant star, making it appear offset by about 2 milliarcseconds from its actual position. This deviation is so small that it is equivalent to observing an ant crawl across the surface of a quarter from 1,500 miles away.

Comet or Asteroid?

Astronomers categorize the minor bodies in the Solar System according to their location and physical composition. Comets are a loose collection of ice and dust that fall in toward the Sun from beyond the orbits of the major planets, and grow long tails of dust and gas along the way. Asteroids are rocky or metallic and are relegated to a zone between Mars and Jupiter. But nature isn’t that tidy. Hubble photographed a pair of asteroids orbiting each other that have a tail of dust, which is definitely a comet-like feature. The odd object, called 2006 VW139/288P, is the first known binary asteroid that is also classified as a main-belt comet. Roughly 5,000 years ago, 2006 VW139/288P probably broke into two pieces due to a fast rotation.

Martian Moon Orbits the Red Planet

While photographing Mars, NASA’s Hubble Space Telescope captured a cameo appearance of the tiny moon Phobos on its trek around the Red Planet. Discovered in 1877, the diminutive, potato-shaped moon is so small that it appears star-like in the Hubble pictures. Phobos orbits Mars in just 7 hours and 39 minutes, which is faster than Mars rotates. The moon’s orbit is very slowly shrinking, meaning it will eventually shatter under Mars’ gravitational pull, or crash into the planet. Hubble took 13 separate exposures over 22 minutes to create a time-lapse video showing the moon’s orbital path.
Beyond the orbit of Neptune lies a frigid, dark, vast frontier of countless icy bodies left over from the Solar System’s construction 4.6 billion years ago. This region, called the Kuiper Belt, was hypothesized by astronomer Gerard Kuiper in 1951, but it took another four decades for astronomers to confirm its existence. The largest bodies are called dwarf planets, with Pluto being the biggest member.

Astronomers uncovered a moon around another dwarf planet by using the combined power of three space observatories, including archival images from Hubble. Called 2007 OR10, it is the third-largest dwarf planet in the Kuiper Belt. With this moon’s discovery, most of the known dwarf planets in the Kuiper Belt larger than 600 miles across have companions. These bodies provide insight into how moons formed in the young Solar System.

Download images, watch videos, and read the full news releases:
HubbleSite.org/news/year/2017

Capturing the Public’s Attention

With every project we create, a team at the institute aims to make astronomy exciting, engaging, understandable, and relevant to an increasingly diverse audience. To do so, we combine the expertise of astronomers, education specialists, science writers, visualization and imaging specialists, designers, and web developers.

We produce and coordinate a range of experiences using current scientific data, including exhibits and displays, immersive visualizations, hands-on activities and event support, video creation, article production, and new applications for hand-held devices to help the public visualize and understand complex, yet awe-inspiring, science. We are deeply connected to the science of NASA astrophysics, the science community, and the partnerships that expand our reach.
A Profoundly Meaningful Partnership

In 2015, NASA's Science Mission Directorate selected the NASA's Universe of Learning partnership as one of 27 competitively awarded science, technology, engineering, and mathematics (STEM) learning programs in the country. Led by a team at the institute, this partnership provides a direct connection to the science and scientists involved in NASA's astrophysics missions by creating learning experiences for audiences of all ages and backgrounds across the country.

We focus on four interconnected categories: data tools and participatory experiences, multimedia (including the museum exhibit ViewSpace detailed below) and immersive products, exhibits and community programs for informal education settings, and professional learning experiences. This programming, which is externally evaluated, reaches informal educators at museums, libraries, and planetariums; visitors of informal learning venues; undergraduate instructors; and lifelong learners of all ages.

One example of this work in informal learning is Girls STEAM Ahead with NASA, a partnership with public libraries that kicks off during National Women's History Month and continues through the spring and summer. The program is built on the foundation laid by NASA Science4Girls and Their Families, a pilot project offering hands-on activities and materials, which ran from 2012 to 2015, with evaluation results showing library staff gaining confidence with STEM programming.

In 2017, we've built on that success. Our team and partners pooled their experiences from a broad range of NASA astrophysics missions to directly participate in or support activities in 25 libraries, and sent materials to 110 additional libraries in 39 states. By empowering library staff to incorporate science and subject-matter experts into their learning environments, we aim to expand the number of young women who are able to make a personal connection to science. In 2018, we'll continue to add new locations, particularly those that are underserved, and encourage and support activities throughout the year.

Overall, the NASA's Universe of Learning activities have reached more than 500 venues in all 50 states. In 2018, we will work with new and existing partners to extend our reach and impact.

A Visual Connection to the Universe

One of the signature products of NASA's Universe of Learning is ViewSpace, which is produced at the institute in collaboration with our partners. Nearly 200 science centers, planetariums, universities, and informal learning centers across the United States stream ViewSpace daily. The self-updating video exhibit contains more than 10 hours of content, and captures the attention of young and old alike with space and Earth science programs.

Several goals direct the content we create. One goal is to illustrate how science is done. In October, ViewSpace shared the news of an unprecedented, worldwide collaboration of scientists, heralding in the age of multi-messenger astronomy. On August 17, light from a gravitational
View the Universe

Interested in showing ViewSpace at your informal learning center?
Sign up for an account at ViewSpace.org

Tonight’s Sky

A wave source was detected. In the following weeks, many of NASA’s space-based observatories followed up with observations across the electromagnetic spectrum.

ViewSpace demonstrates scientific findings like these in ways that capture people’s attention. We do this not only by sharing amazing images, but, more importantly, by pairing them with data and explanations that help change viewers’ perspectives of the universe itself. Ultimately, scientists used the data from multiple observatories to confirm that the merger of two neutron stars caused the gravitational waves. This science would not have been possible without this worldwide collaboration.

Our programming aims to trigger viewers’ imaginations about the future possibilities in science by connecting them directly to new findings. With every segment we add, our team works to help audiences make an emotional connection to the science, which inspires them not only to learn more, but also to share their sense of inspiration and wonder.

Experiencing the Science of Webb

Imagine you’re flying through space—and no space suit or oxygen is required. That’s exactly what you’ll feel when donning a virtual reality (VR) headset and diving into the VR experience that centers on the James Webb Space Telescope at Lagrange point 2 (L2). The simulation is set against an accurate backdrop of our solar system, and allows users to view Webb alongside Hubble and the Wide Field Infrared Survey Telescope (WFIRST) in a 360-degree experience.

By pointing two hand-held controllers, users can zoom in and zip around Webb, Hubble, and WFIRST, comparing one to another, as well as familiar items that provide real-world context. With a little practice (no previous experience is required), virtual explorers can touch information hubs to learn more about Webb and the people behind it. The setting includes imagery from NASA missions, allowing users to explore the planets up close, including Earth 1 million miles away. The experience is immersive, breathtaking, and—warning—potentially habit-forming.

The VR experience, which is developed in partnership with staff at Northrop Grumman, has two primary objectives: to showcase Webb’s scientific capabilities as an observatory, and allow users to better visualize astrophysical concepts studied by Webb, beginning with the earliest days of a solar system. Future planned modules will expand the astrophysical scenes to other science topics, including galaxy structures.
In the same VR experience, participants can soar high above a protoplanetary disk deep in the heart of the Orion Nebula, and dive into the swirling dust to explore interactive labs (virtual laboratories within the disk) that help them understand this complex environment. Within the labs, users can experiment with gas, ice, and dust until the elements begin to form planetesimals, modify light sources to experience how different types of energy impact molecules emanating from within the disk, or drop mysterious planets throughout the disk to see how distance and composition affect planet formation. Users will not only learn, but also experience the science.

Our team selected virtual reality technology specifically to communicate science stories that are very difficult to describe. This captivating environment engages audiences in topics as broad as quantum mechanics, Newtonian gravity, collision physics, gas viscosity, and wavelengths of light while exploring an astrophysical scene based on realistic, cutting-edge science. Starting in 2018, the experience will be brought to large public events and be updated to include new experiences that entice new and existing users alike.

Contributing to a Cultural Shift

Catherine Riggs’ varied career experience has served her well. As a legislative assistant to the Baltimore City Council president in the 1990s, she was the first woman in the history of Baltimore City to read bills on the floor during legislative sessions. She also served at CitiFinancial as the operations coordinator for the business division before joining the institute to support the Business Resource Center in 2007. There, she assisted in planning large, detailed events, including the Telescope Allocation Committee, which selects astronomers’ proposals for Hubble observations.

Quickly after Riggs began, her managers and colleagues noticed her attention to detail and, particularly, how quickly she adapted. Several managers banded together to create a position to fully employ her skills as a documentation specialist. “From there, it morphed into a position as a software engineer,” Riggs explains. Although she had no prior engineering experience, she took evening courses to master the skillset, eventually earning a degree in computer information systems.

Today, she manages the database that houses the requirements for the command team, including test cases and tests that address requirements, script development tools, and documentation. “In addition to importing and exporting data, I’m frequently tweaking the code to create requested reports,” Riggs says. Topics range from target acquisition to spectroscopy for NASA’s James Webb Space Telescope.

Our Commitment to All Staff

Why we are committed to creating a culture that is inclusive and responsive to the needs of our employees.

We have committed ourselves to create a work culture that is inclusive and responsive to the needs of our employees. To this end, we embrace inclusion in our continued pursuit of excellence in space science and exploration. To be able to help humanity explore the universe and serve the widest audience possible, we understand that we need to include a broad range of ideas and insights. We know and have witnessed that knowledge, discovery, and innovation come from all backgrounds. Our success depends on teamwork from individuals with diverse talents, experiences, identities, beliefs, and perspectives to work together to achieve this excellence. With this understanding, we endeavor to make the faces of those who enable our success more reflective of the global community we serve. Engaging more viewpoints from diverse backgrounds and our differences do not hinder us, but rather are sources of enrichment for our scientific missions. An important outcome of this work is the Invision working group, an institute-wide committee constituted by the director to establish, monitor, and uphold a civil and inclusive environment for a diverse staff. The working group develops and ensures our policies and practices create a welcoming and productive work environment. Below, we profile one of the many employees who has contributed to this ongoing endeavor.
OUR DIVERSITY AND INCLUSION STATEMENT

We embrace inclusion in our bold pursuit to help humanity explore the universe. We value and rely on the contributions from a diverse workforce and community. We respect and celebrate the attributes, identities, beliefs, expertise, and perspectives that make each individual uniquely who they are. We believe at our core that these differences enable excellence and promote our collective success. We take actions to make our aspirations for a truly representative workforce a reality.

A Passion to Give Back

Riggs, who also has a paralegal degree, describes herself as an advocate for the underdogs. “I hate to see anyone mistreated,” she explains. “I’m moved to step in.” When she heard about CASA (Court Appointed Special Advocates for children), she signed up immediately. “It’s hard, emotional work,” she admits. “But it’s also very rewarding.”

One case centered on a child who refused to speak to anyone. Riggs bought the girl a journal, and kept coming back to visit. “Slowly, she came out of her shell,” she says. Her progress was much more than conversation; the girl was eventually able to join a therapeutic group home and attend a public school, earning her diploma at 18. The best part? “She still calls me periodically to say hello,” Riggs says, and smiles.

Over the years, her volunteer work has paralleled her contributions at the institute. “Today, the culture is much more inclusive,” she shares. “I have always had a group of advocates at the institute. I had a very courageous manager hire me into the engineering division. She set the standard, because she would not tolerate any type of mistreatment on her team. At that point, I knew I had to make a difference.”

Working to Connect Colleagues

Riggs started small. By being open to conversations with her colleagues, she was able to breakdown misconceptions. “I initiated a lot of communication and interaction,” she says. “I asked a lot of questions, which allowed our team to have important conversations.” When a civility group was created, her manager immediately asked her to join. Her response then, and to each subsequent committee, was a resounding yes. Riggs knows that by giving back, she will see important, incremental changes.

She contributed to the COED (Civility in Operations and Engineering Division) Working Group from 2014 to 2017, where she helped run a survey to identify pain points and connect staff to new resources. One of the most rewarding outcomes was the department’s creation of a mentor program, which pairs longtime employees with junior employees. Through monthly lunches, colleagues learn about one another’s skills and review career options. “Not only do they share ideas and resources, it’s increased communication within the division,” Riggs says.

Her current role on the institute’s Invision committee focuses on establishing and upholding a civil and inclusive environment for a diverse staff through a variety of initiatives. But, as Riggs shares, everyone at the institute has a voice. “We’re all individually accountable. Together, we will propel the movement to achieve our goals more quickly.”

NOTABLE HUBBLE RESEARCH

In 2017, astronomers reported new findings about the Hubble Frontier Fields clusters Abell 2744 and MACS 0416 in the Astrophysical Journal, which went on to be cited 40 times in the same year. The researchers’ results found galaxies intrinsically fainter than any observed before during the early universe’s epoch of reionization. These faint galaxies may be an important source of photons needed to ionize the hydrogen gas between galaxies. Their number counts of very faint galaxies as function of luminosity provided strong statistical evidence against a decline in faint galaxies down to the faintest levels probed. This suggests that very faint galaxies are a primary contributor to reionization and that astronomers have not yet probed the limits of low-mass galaxy formation.
BY THE NUMBERS
NASA's Hubble Space Telescope continued to break records.

We're pleased to report that our flagship mission, NASA's Hubble Space Telescope, is in high demand. The latest cycle of requests for its time led to an oversubscription of five to one. In 2017, the institute provided over $30 million in grant funding to support Hubble general observers and archival researchers throughout the U.S. Refereed scientific publications continue to grow year over year.