This Hubble Space Telescope image shows the nearby, barred spiral galaxy M83 ablaze with star formation. The newest stars are forming largely in clusters on the edges of dark, spiral dust lanes. Ultraviolet radiation emitted by these stars causes surrounding gas clouds to glow in pinkish hydrogen light. In 2014, this mosaic was the subject of a citizen-science project called Star Date: M83, in which volunteers analyzed individual Hubble images of the galaxy to provide age estimates of star clusters in M83.
More productive than ever, the Hubble Space Telescope is boldly opening new discovery space for astrophysics. Hubble is expanding the cosmic frontier with its multi-year Frontier Fields campaign, which made significant progress in 2014. Taking advantage of its exquisite imaging and the magnification due to gravitational lensing by massive galaxy clusters, Hubble observes previously unseen populations of galaxies and maps dark matter.

In 2014, Hubble successfully executed a large reverberation mapping program that stressed the scheduling ability by requiring one orbit per day for 179 consecutive days.

Another successful observing campaign targeted Kuiper Belt Objects in support of the New Horizons mission. Following a pilot program of about 40 orbits, the main program of about 140 orbits had to be implemented on extremely short notice and in a very compact time frame.

To celebrate Hubble’s 24th anniversary in space, a mosaic of a small portion of the Monkey Head Nebula unveiled a collection of carved knots of gas and dust silhouetted against glowing gas. This also marked the beginning of planning for a number of worldwide activities to celebrate Hubble’s silver anniversary in 2015.

More than 1,000 proposals have been submitted in each of the past 5 years, with an oversubscription rate of greater than 5:1. Observatory science productivity, data return, and archive usage are near all-time highs. During Hubble’s lifetime, 12,700 refereed papers based on Hubble data have been published, with more than 820 added in 2014.
Above: This image of Abell 2744, taken as part of the Frontier Fields program, includes light from very distant galaxies that has been amplified by gravitational lensing.

Below: NGC 5548 is part of a large reverberation mapping project designed to estimate the masses of black holes at the centers of active galactic nuclei.

Above: In 2014, Hubble discovered two potential Kuiper Belt objects for the New Horizons mission to visit after its encounter with Pluto in mid-2015.

Below: For Hubble’s 24th anniversary, the WFC3 instrument captured an infrared view of a small portion of the Monkey Head Nebula (top), which the WFPC2 instrument had previously imaged in visible light (bottom).
STScI began several initiatives in 2014 to begin shifting the JWST conversation from building the observatory to using it. At the Lunar and Planetary Science Conference and Division of Planetary Science meeting in 2014, STScI led various workshops and town halls to engage the science community and organize focus groups, and to set up an external advisory panel to provide us with recommendations on maximizing JWST solar system science. At the January 2015 AAS meeting, STScI organized a town hall session and presented the JWST science timeline to the community (e.g., the timing of the Early Release Science program and Cycle 1 Call for Proposals in 2017) and organized a workshop to begin training the community on how to use data analysis tools for JWST. STScI continues to support the work of our senior JWST Advisory Committee, which made several recommendations in 2014 on ways to maximize JWST science. The letters from the committee are all posted at http://www.stsci.edu/jwst/advisory-committee. STScI also participated and organized meetings for the JWST Science Working Group.

Many aspects of the Science Operations Center (SOC) for JWST saw major milestones in 2014. The overall System Design Review 1 was successfully presented to an external committee and NASA stakeholders, key JWST science preparation tools like the Exposure Time Calculator and Astronomer’s Proposal Tool saw major progress, and the Institute created and completed Data Analysis Use Case workflows to help define priorities for data analysis tools. The first schematic designs for the JWST flight operations at STScI were also reviewed and are now being finalized. STScI scientists and engineers were also heavily involved in major JWST development work, such as the testing of all four JWST science instruments at the Goddard Space Flight Center (GSFC).

STScI scientists and educators continue to communicate the story and science behind JWST to the astronomical community and the general public. During the year, scientists were involved in dozens of professional and public JWST talks across the nation. Working with our partners at NASA, GSFC, and Northrop Grumman, STScI led major initiatives at the 2014 USA Science & Engineering Festival and the 2014 South by Southwest Interactive Festival. STScI also substantially grew the JWST STEM Innovation Program and launched a new website for the projects. The program, in which students actively participate in an interdisciplinary project related to JWST’s science, technology, or engineering, is now being completed in all 50 U.S. states.
Rachel Osten, Deputy Project Scientist for JWST, discusses the mission’s capabilities at a recent meeting of the American Astronomical Society.

Children pose with the projects they created as part of the JWST STEM Innovation Program (SIP)

STScI’s JWST booth at the 2014 South by Southwest Interactive Festival
Wide-Field Infrared Survey Telescope (WFIRST) Preformulation

WFIRST was the highest-ranked large space-mission concept in the 2010 Astronomy & Astrophysics Decadal Review. It will provide fundamental new constraints on dark energy, galaxy and stellar evolution, and the demographics and properties of exoplanets.

- WFIRST-AFTA (Astrophysics-Focused Telescope Assets) is currently in NASA preformulation, and is being studied for launch in the mid-2020s. It implements the WFIRST science program on an existing 2.4-meter-diameter mirror donated to NASA by the United States National Reconnaissance Office.

- With almost 100 times the field of view of Hubble, WFIRST-AFTA will produce large-scale maps of the night sky at Hubble resolution. With its wide-field, near-infrared imaging camera and visible-light coronagraph, it will build on Hubble’s legacy through deep, wide surveys and a competed General Observer program.

- STScI is participating in planning for the science operations of the mission, in collaboration with NASA’s Goddard Space Flight Center (Greenbelt, Maryland), NASA’s Jet Propulsion Laboratory (La Cañada Flintridge, California), the Infrared Processing and Analysis Center (Pasadena, California), and other partners.

- Work has started at STScI to create simulated data and to study guiding operations, grism spectral analysis software, telescope scheduling efficiency, coronagraphic post-processing, and advanced wavefront control. Also, two STScI astronomers have continued to contribute to the work of the NASA Science Definition Team.
The planned layout of the 18 4k x 4k detectors of the WFIRST-AFTA Wide Field Imaging camera is superposed here on a color-composite Digitized Sky Survey (DSS) image of the Orion Nebula. The entire nebula can be imaged with just a few mosaicked exposures. The image was created with a customized implementation of the footprint functionality in the Mikulski Archive for Space Telescopes (MAST), developed as part of STScI’s WFIRST mission support activities.

This diagram compares WFIRST’s field of view to those of the James Webb Space Telescope and Hubble Space Telescope.
The Mikulski Archive for Space Telescopes (MAST) archives data from 18 active or legacy telescopes or missions including HST, Kepler, and GALEX. Planning and development needed to process and archive JWST and TESS data is underway. In the future, STScI will become the public archive for PanSTARRS as well, providing public access to this valuable resource and to a variety of HST, JWST, and TESS projects.

As of the end of 2014, MAST holdings were 317 TB. In 2014, MAST distributed over 220 TB of data. The Kepler and follow-on K2 mission data have been extremely popular. While the Kepler/K2 holdings are just under 20 TB in size, in 2014 MAST distributed over 62 TB of data, more than three times the volume in a single year. Through the lifetime of the Kepler mission, MAST has distributed over 265 TB of Kepler data, 13 times the size of the current Kepler holdings.

The HST Archive ingested almost 10 TB of data in 2014, bringing its total size over the lifetime of the Hubble mission to almost 106 TB. Archive users retrieved more than 101 TB of Hubble data during 2014, leading to retrievals exceeding ingest by a factor of more than ten.

MAST also archives community-contributed science-ready products, and these products are also heavily retrieved. MAST currently holds over 7 TB of these “high-level science products” and on average distributes over 25 TB a year of these products.

Over half the yearly Hubble publications are based on archival data, and are not written by the team that submitted the original observing proposal. (See HST Papers in Refereed Literature on page 1.) Hence, the existence of an effective archives contributes greatly to the mission’s overall science productivity. However, MAST is not just the Hubble archive. To date, MAST data have contributed to more than 8,300 papers from other astrophysics missions.

Complete, full-depth mosaics of the first two Frontier Fields clusters and their associated parallel fields.
The Community Missions Office brings the cumulative science system expertise and experience of the Institute to other community-led astronomy missions. It fosters partnerships between mission teams and STScI staff, develops tools to communicate with the science community, and more.

- The Kepler mission’s Data Management Center (DMC) is hosted at STScI and holds approximately 20 TB of data, available through MAST. Kepler completed its primary mission to determine the fraction of stars that have planets in 2013 but is continuing the search, in a more limited mode, for another two years. The Kepler DMC continues to be heavily used by the community. Since the spacecraft’s launch in 2009, users of the public Kepler archive have retrieved more than 575 million datasets.

- The Transiting Exoplanet Survey Satellite (TESS) is an Explorer-class mission scheduled for launch in 2017. It will survey roughly 500,000 nearby stars to search for planets, ranging from Earth-sized to gas giants, orbiting a wide range of stellar types and orbital distances. STScI will host the TESS science archive, help manage its guest investigator program, and participate in the TESS public outreach program.

- The public science archive for the Panoramic Survey Telescope & Rapid Response System (Pan-STARRS) will be hosted at STScI. Pan-STARRS data consist of multi-wavelength images of the sky taken at multiple epochs. The survey, being done using a telescope located in Hawaii, has completed its mapping of 75% of the sky. The public archive will contain over 2 petabytes of data and is currently scheduled to be available in 2015.

- The search for potentially habitable worlds beyond the solar system will require a space-based telescope significantly larger than Hubble that can perform very high contrast imaging. STScI is participating in studies of advanced instrument concepts that are capable of blocking the light from stars, allowing us to then detect and measure properties of potential planets in orbit around those stars. STScI is also participating in concept studies of telescopes optimized for exoplanet direct imaging.
Science Activities

STScI provides an intellectually rich and diverse environment where experts visit the Institute to collaborate with the staff, conduct workshops, and present their latest findings.

2014 Bahcall Lecture
by Brian Greene

Habitable Worlds
Across Time and Space
Spring Symposium, 2014

Hubble Fellows Symposium
Space Telescope Science Institute
10-12 March 2014

Welcome to the Cosmic Distance Scale
April 13 – April 2, 2014
The Office of Communications and Public Outreach (CPO) continues to focus its efforts on creating new and innovative partnerships to share the wonders of the Hubble mission and the promise of JWST. In 2014, CPO reached both surrounding communities and diverse audiences through a new partnership with the Maryland Out of School Time Network (MOST). CPO staff provided a series of student workshops for Baltimore City youth as part of the Baltimore Reads summer program sponsored by MOST and the Weinberg Foundation. This enabled CPO to extend the reach of Hubble and Webb within local communities while supporting structured out-of-school-time activities that have been shown to have a positive effect on at-risk youth.

Through another new partnership with TeacherTube, LLC, CPO will be able to post visualizations, videos, and other content to the TeacherTube site, making it more widely available to users. STScI will have its own Partner Channel — potentially expanding CPO’s user base via TeacherTube’s 1.3-million–member network. In addition, CPO was able to bring both the present and future of astronomy to thousands in attendance at the 2014 South by Southwest Gaming Expo, the USA Science and Engineering Festival, and the Astronomy Night on the Mall event.

CPO’s ViewSpace multimedia display continues to reach a broad cross-section of the public through its usage in hundreds of venues throughout the U.S. In 2014, CPO published new ViewSpace programs about Frontier Fields observations, extrasolar planets, and anticipated findings from JWST.

Additionally, CPO continues to expand the JWST STEM Innovation Project (SIP) — an interdisciplinary, standards-based project that focuses on the engineering aspects and potential scientific discoveries of JWST. Currently, over 500 schools throughout all 50 states have been recruited to participate in the SIP.

A fifth-grade student at Checotah Middle School in Checotah, Oklahoma, poses with her SIP project — a model of JWST. Other students at Checotah Middle School created a variety of JWST-inspired projects, such as models, poetry, and essays. Checotah Middle is the first school in Oklahoma to complete SIP projects.

Baltimore City youth, participating in the Baltimore Reads summer program, explore Hubble images and learn about the various characteristics of planets and objects in our solar system.
The Office of Communications and Public Outreach’s News Office is at the heart of STScI’s public outreach activities as both the point of contact for translating and communicating HST science accomplishments to the public and as a content driver for educational activities. A total of 39 HST science press releases were issued in FY14, resulting in continuous monthly coverage of HST research. The press releases generated 5,122 online news stories in newspapers, magazines, and on broadcast media, reaching an average potential audience of 260 million people per release. Top stories included the most comprehensive picture of the evolving universe assembled through multiple-wavelength Hubble Ultra Deep Field (HUDF) observations, the discovery of a disintegrating asteroid that superficially looks like a comet, and measurements of the shrinkage of Jupiter’s Great Red Spot that reveal it is at the smallest size it has ever been observed.
The Youth for Astronomy & Engineering (YAE) program in the Office of Communications and Public Outreach engages and mentors students in the Maryland community, primarily in Baltimore City, through a variety of workshops, events, and partnerships during the year. Students are exposed to hands-on activities related to science and engineering as well as experiences that represent the work done by astronomers and engineers. Highlights for the year 2014 include two spring “Women’s Science Forum with Parent Workshop” events for middle- and high-school girls as well as their parents; one spring “Hispanic Science & Engineering Forum” for middle- and high-school students; two summer “Family Night at the Institute” events; two fall “Parent & Daughter/Son Evening Under the Stars” events; six “YAE Astronomy Club” fall/spring sessions; six “YAE Engineering Club” fall/spring sessions; and in the winter 2014, the YAE Program, by special invitation, took students to attend the White House Office of Science and Technology’s Computer Science Film Fest.

In partnership with the Office of Communications and Public Outreach’s Education Program, YAE sponsored an Educator’s Workshop for middle-school teachers. Educators participated in talks on different science topics, engaged in hands-on science activities, and learned ways to bring the knowledge gained in the workshop as well as the hands-on activities back to their classrooms.

The YAE program’s continued partnership with the U.S. Dream Academy, a national after-school program for at-risk children, resulted in two additional STEM events hosted at Pimlico Middle School in Baltimore. Other partnerships included the YAE program’s collaboration with the Mayor’s Office “YouthWorks” program in Baltimore City in which the YAE program was able to provide summer work experience for two youths who actively participated in the YAE program throughout the year. In addition, the YAE program partnered with Maryland’s Division of Rehabilitation Services (DORS) in Baltimore City, which provides programs and services that help youth and young adults with physical and mental disabilities get work experience. The YAE program provided work experience and STEM engagement to over 20 recipients in the DORS program throughout the year.

The YAE program, existing for nine years, has begun to see under-represented students who have continued to participate in the YAE program events enter college, majoring in astronomy or physics. The YAE program is working with these students, connecting them with other programs within the Institute, such as the Summer Student Program, as a continued effort to foster and sustain interest in astronomy.
The Institute remained flexible in responding to the various challenges encountered in FY14 while adhering to the FY14 guideline budgets.

STScI worked closely with the HST and JWST projects to identify the impact of schedule and requirement changes, and consistently submitted requested documentation on time and in compliance with all contract requirements.

For Hubble, FY14 ended with a 0.13% underrun compared with the year's guideline and mid-year rebaseline, and for Webb the variance was an underrun of 1.11%.

STScI provided $32.2M in grant funding to support HST researchers, including Hubble Fellows, throughout the U.S.

The web-based Space Telescope Grants Management System was successfully launched in January 2014, giving users quick and easy access to their grant information.

From the 2014 Report of the HST Senior Review Panel:

- “Hubble is operating at or near the highest level of performance and scientific productivity in its history.”
- “The Senior Review Panel strongly and unanimously recommends [Hubble’s] continued long-term operation.”

From the NASA Evaluation of STScI’s Performance under the HST Contract in 2014:

- “The nation looks with interest to the Hubble mission as a source of pride and inspiration for scientific and engineering accomplishments. The dedicated people that make up the AURA team have once again met this challenging trust.”

From the NASA GSFC Evaluation of STScI’s JWST Contract:

- “I commend AURA for the accomplishment of the key events and the numerous technical, science, public outreach, and business achievements.”
- “AURA’s in person astronomical community public and educational outreach efforts have all been outstanding this period.”
- “I am especially pleased with the excellent support provided to the Integrated Science Instrument Module (ISIM) Cryo-Vac (CV) #2 test. AURA provided over 200 more shifts than planned in the test director, test conductor, test operator, and ground segment and operations (GS&O) roles, as well as provided off-line support.”
- “Overall, I am very pleased with AURA’s performance during this twenty-third evaluation period. I commend AURA for many areas of excellent performance. I appreciate AURA’s contribution and look forward to a continued productive relationship as the ongoing challenges are met with the development of the JWST S&OC.”
In 2014, STScI remained committed to diversity and inclusion. These objectives are essential elements of a leading-edge, world-class workplace able to achieve excellence in astronomical research. This commitment was demonstrated through our efforts to develop, attract, and retain broadly diverse and talented professionals now and in the future, and to build a culture where they can thrive.

Our existing team and work environment are our priority. We optimize the inclusiveness of our organizational culture and team by:

• providing policies, practices, and programs that address a diverse array of staff needs, demonstrate respect for difference, and ensure fair treatment;
• offering training, mentoring, and coaching opportunities to improve interpersonal, leadership, and cultural skills essential to guide us forward; and
• soliciting feedback for multiple internal/external committees and employee groups to continuously assess our progress.

Our Future of the Workplace (FOTW) Committee met in January of 2014 to evaluate the internal climate at STScI. Their final report included the following:

This committee represents a positive and important collaboration between internal staff and external colleagues, giving the Institute a flexible and forward looking way of consistently moving the Institute toward the best practices in workforce development, climate, mentoring, etc. The goal is to maintain the Institute’s status as one of the best places to work in astronomy. One of the most satisfactory comments heard during this meeting was that staff concerns and requests made through the Focus groups had been heard and that employees had noticed that several of the FOTW Committee recommendations from past years had been implemented and had made an impact.

We expanded and fortified partnerships with educational institutions, career development consortiums for students from under-represented groups and individuals with disabilities, veterans’ associations, research centers, professional associations, and government agencies. This enabled us to integrate resources and provide career opportunities to a broader audience.

STScI outreach and education programs target strategic points in STEM career identification in order to develop and reinforce the abilities of the next generation of professionals and ensure a diverse pipeline of capable and innovative talent. Opportunities offered start with the early discovery of career paths through our K-12 education and community outreach programs, to career focus with our summer student research programs for undergraduates, through career choice via internships and research assistance opportunities.

Members of our science staff engage participants at a Baltimore high school STEM Career Day for young women.
Using the Hubble Space Telescope, astronomers recently searched for water vapor in the atmospheres of three gas-giant planets orbiting stars similar to the Sun. However, they reported in 2014 that the spectroscopically surveyed planets have only one-tenth to one one-thousandth the amount of water predicted by standard planet-formation models. This suggests that some Earth-size exoplanets may not have as much water as expected, and the search for water-bearing terrestrial worlds may be more challenging than once thought.