Historian Corner

By Barb Sande
barbsande@comcast.net

ANNOUNCEMENT: MARK YOUR CALENDARS!!!

The Titan Panel Discussion in honor of the 15th anniversary of the end of the program has been scheduled for Thursday, October 15 from 1:00 to 3:00 pm MDT via a Zoom teleconference (virtual panel). There are ten volunteers currently enlisted to participate in the panel, including Norm Fox, Bob Hansen, Ken Zitek, Ralph Mueller, Larry Perkins, Dave Giere, Dennis Brown, Jack Kimpton, Fred Luhmann, and Samuel Lukens. If you want to call into the panel discussion to hear the roundtable, please RSVP to me at the email above (emails only for RSVP, no phone calls). There are limitations to Zoom attendance for meetings. The details of the meeting will be emailed to the attendees at a later date (Zoom link).

Program Profile

This 2020 Q3 issue profiles the Hubble Space Telescope (HST) in honor of its 30th anniversary in orbit. For the MARS STAR in Q4, please come back to explore the "successful failure" that was the Apollo 13 mission.

Mission Overview and Introduction

On April 24, 2020, NASA, the European Space Agency, the Space Telescope Science Institute (STScI), astronomers and space science organizations around the world, and enthusiastic public supporters in many nations gathered on-line to celebrate thirty years of operations for the extraordinary Hubble Space Telescope. HST has changed our view of the universe in so many ways through its various instruments, scientific discoveries, and beautiful imaging. HST is a resounding success and may eventually celebrate a total of 40 or even 50 years in operation. HST is also the only Space Telescope deployed so far that was maintained and repaired on-orbit; this capability was, unfortunately, lost with the end of the Space Shuttle program in 2011 (more on the servicing missions later in this article). In 2017, there were talks about using Dream Chaser, the commercial crew vehicle built by Sierra Nevada, in a possible servicing mission to HST. However, no follow-on plans have been developed.

Hubble Space Telescope Mission
- Launched: 04/24/1990 12:33:51 UTC
- STS-31 (Discovery) LC-39B KSC
- Deployed 04/25/1990
- HST in-service date 05/20/1990
- Crew: Loren Shriver, Charles Bolden, Bruce McCandless, Steven Hawley and Kathryn Sullivan
- STS-31 landed 04/29/1990 Edwards AFB

HST Orbital parameters:
- Low Earth Orbit (roughly circular orbit)
- Perigee: 537.0 km (333.7 miles)
- Apogee: 540.9 km (336.1 miles)
- Inclination: 28.47 degrees
- Period: 95.42 minutes

HST Mission:
- On-going optical (near-infrared to UV wavelength) astronomical observations of the universe
- End of HST mission estimated to be 2030-2040
- Estimated costs of the HST program (including replacement instruments and five servicing missions) = ~ $10 billion – does not include on-going science

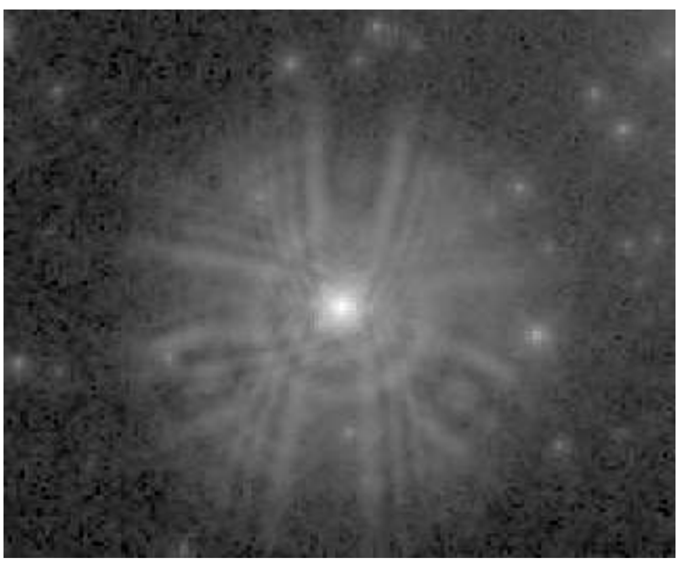
Connection to Lockheed Martin:
- Lockheed Sunnyvale built and integrated the main HST spacecraft and systems
- Martin Marietta/Lockheed Martin provided six external tanks and associated subsystems for the shuttle launches supporting the HST program.
-

HST 30th Anniversary Image: The Cosmic Reef
Image Credit: NASA, ESA and STScI

Development, Launch, Deployment, Disaster

Orbiting space telescopes have long been in the plans and dreams of astronomers and NASA and much earlier versions included the Orbiting Astronomical Observatories (OAO-1 and OAO-2). The concept of a Large Space Telescope with a 3-meter (9 feet, 11 inch) mirror was pursued and developed in the 1970s, with contracts going to Lockheed for the Spacecraft and Perkin-Elmer for the critical Optical Telescope Assembly in 1983. Initial budget constraints then limited the primary mirror to 2.4 meters (7 feet, 10 inches). A decision was made to name the Large Space Telescope after Edwin Hubble, an American astronomer who discovered the expanding universe and formulated Hubble's constant or law - a roughly linear relationship between the distances of galaxies and their radial velocities that is used to measure the age of the universe. Spacecraft systems and integration would be managed by Marshall Space Flight Center (MSFC) and the instruments would be under the purview of Goddard Space Flight Center (GSFC), which also manages ground control operations for the STScI. The ESA would also participate as a partner in the HST program. Delays and overruns occurred, but the HST was finally ready for possible launch in October, 1986. Sadly, the Challenger accident required the launch to be postponed for several years, necessitating storing the completed spacecraft. HST finally made the shuttle manifest on Discovery in 1990 (see launch details in the overview).

Within a few weeks of deployment of HST, astronomers were aghast to realize that, although the initial images were sharper in most respects than ground-based telescopes, the telescope failed to achieve a final sharp focus (see image below for an example) and the Point Spread Function was over a radius of more than 1 arcsecond, when the requirements were 0.1 arcseconds or less. An investigation revealed that the primary mirror had been polished into the wrong shape, resulting in severe spherical aberration. Observations were still possible with bright point sources and ground image reprocessing, but the HST was declared by the public and media to be a disaster. It became the target of jokes on late night shows and in comedy movies. If you have seen "Naked Gun 2 ½: The Smell of Fear", this screwball comedy displays a photo of HST along with other disasters (Lusitania, Edsel, Hindenburg) in a bar scene.



Star Image from HST showing Spherical Aberration Effects
Image Credit: NASA, ESA, STScI

The causal investigation, led by Lew Allen from JPL, revealed that a reflective null corrector test tool at Perkin-Elmer was incorrectly assembled, resulting in the critical fine grind of the mirror being done precisely, but in an incorrect shape. Testing with conventional null correctors noted the spherical aberration, but those results were dismissed. A system-level optical test at Lockheed was also canceled due to schedule constraints. NASA considered options such as retrieving the telescope and returning it to Earth and replacing the Perkin-Elmer Optical Telescope Assembly with a back-up built by Kodak, but that was considered prohibitively expensive and difficult.

Design Solution, First Servicing Mission, Success

The ultimate design solution for eliminating the spherical aberration was brilliant and used two instruments for replacement on HST on the first servicing mission. In essence, the Wide Field and Planetary Camera 2 design was modified to include an inverse error of the spherical aberration in the relay mirrors directing light onto four Charge-Coupled Device (CCD) chips. The Corrective Optics Space Telescope Axial Replacement (COSTAR) instrument corrected the error for three other on-board instruments (the Faint Object Camera, Faint Object Spectrograph and the Goddard High Resolution Spectrograph). The COSTAR placement required the sacrifice of the High Speed Photometer instrument. On future missions, all other instruments would be replaced with upgraded versions with optical corrections thus eliminating the need for COSTAR after all the upgrades were completed.

Because of the optical aberration, the first servicing mission became a higher priority and would require specialized training to do the instrument replacements and integration. STS-61 (Endeavour) was launched on December 2, 1993 from LC-39B and had a crew of seven veteran astronauts (Richard Covey, Ken Bowersox, Kathryn Thornton, Claude Nicollier (ESA), Jeffrey Hoffman, Story Musgrave, and Thomas Akers). After capturing HST on the second day in orbit with the robotic arm, the remaining eight days of the mission required five long EVAs to do the instrument swaps, perform other HST maintenance, including solar array replacements, and complete system checks. The orbit of HST was also boosted. Endeavour landed at KSC after a very successful and complex mission on December 23, 1993.

The resulting HST images, after the first servicing mission, were extremely sharp and the success of the design solutions and the mission was lauded by the astronomical community. Now the large orbiting telescope was truly functional and the scientific discoveries began in earnest. Later in this article, a top-level overview of the HST science projects and discoveries will be explored.

Summaries of HST Servicing Missions 2, 3A, 3B, 4

Four more servicing missions were performed for HST before the shuttle program ended. These missions are summarized below.

HST Servicing Mission 2
Launched: 02/11/1997 08:55:17 UTC
STS-82 (Discovery) LC-39A KSC
Crew: Ken Bowersox, Scott Horowitz, Joseph Tanner, Steven Hawley, Gregory Harbaugh, Mark Lee, Steven Smith

- Five lengthy EVAs required
- Goddard High Resolution Spectrograph (GHRS) replaced with Space Telescope Imaging Spectrograph (STIS)
- Faint Object Spectrograph (FOS) replaced with Near Infrared Camera and Multi-Object Spectrometer (NICMOS)
- Other maintenance and replacements were performed (Fine Guidance Sensor, Solid State Recorder, Reaction Wheel Assembly, insulation repair, orbit boost)

Landed 02/21/1997 at KSC

HST Servicing Mission 3A
Launched: 12/20/1999 00:50:00 UTC
STS-103 (Discovery) LC-39A KSC
Crew: Curtis Brown, Scott Kelly, John Grunsfeld, Jean-Francois Clervoy (ESA), Michael Foale, Steven Smith, Claude Lecollier (ESA)

- Mission moved up to 1999 after three of six gyroscopes failed on HST (3B mission split out)
- Three lengthy EVAs required
- All six gyroscopes replaced
- Fine Guidance Sensor replaced
- HST main instrument computer replaced (new computer was 20 times faster and had six times the memory size as the original unit)
- Other maintenance performed (Voltage and Temperature improvement kit installed, new S-Band transmitter installed, outer insulation replaced, spare solid state recorder)

Landed 12/28/1999 at KSC

HST Servicing Mission 3B
Launched: 03/01/2002 11:22:02 UTC
STS-109 (Columbia) LC-39A KSC
Crew: Scott Altman, Duane Carey, John Grunsfeld, Nancy Currie, Richard Linnahan, James Newman, Michael Massimino

- 3B mission split out from more urgent 3A mission in 1999
- Five lengthy EVAs required
- Advanced Camera for Surveys (ACS) installed
- New rigid solar arrays installed
- New Power Control Unit (PCU) installed
- Cryocooler installed to return NICMOS instrument to service
- Other routine maintenance performed on HST
- Last successful flight of Columbia, which disintegrated on re-entry on February 1, 2003

Landed 03/12/2002 at KSC

HST Servicing Mission 4
Launched: 05/24/2009 18:01:56 UTC
STS-125 (Atlantis) LC-39A KSC
Crew: Scott Altman, Gregory Johnson, Michael Good, Megan McArthur, John Grunsfeld, Michael Massimino, Andrew Feustel

- Mission originally planned for 2005, canceled by NASA Administrator after Columbia failure
- Lengthy political and scientific community negotiations resulted in the agreement to do the servicing mission in 2008 or 2009
- Five lengthy EVAs required
- Cosmic Origins Spectrograph installed
- Wide Field Camera 3 installed
- Removed COSTAR
- Advanced Camera for Surveys repaired
- Space Telescope Imaging Spectrograph repaired
- Soft-Capture mechanism installed for eventual safe de-orbiting
- All six gyroscopes replaced again
- Fine Guidance Sensors replaced again
- Other critical maintenance of spacecraft and instruments performed to allow operations for several more years
- IMAX camera included on the mission (movie: *IMAX: Hubble 3D*)
- Last flight of Atlantis

Landed 05/24/2009 at Edwards Air Force Base

NOTE: I was thrilled to be a team member on an independent Mission Success review of the safety requirements and mission objectives for HST Servicing Mission 4 at the Lockheed Martin facility supporting GSFC in Greenbelt, Maryland, so I have a little bit of personal interaction with the HST mission!

Technical Description of HST Optics, Current Instruments, Spacecraft Systems

Be prepared, class – this section is rather dry, but crucial to understanding the full history of HST. HST is a Cassegrain Reflector telescope of the Richey-Chrétien design. This means that the telescope functions with a hyperbolic primary mirror (2.4 meter or 7.8 feet) reflecting off a hyperbolic secondary mirror (0.3 meter or 12 inches) to minimize the off-axis errors (coma) found in parabolic mirror systems. Most large ground-based optical telescopes are of this design. The mirrors are made with a special glass coated with aluminum and a compound that reflects ultraviolet light. HST operates from near-infrared to ultraviolet light frequencies, which led to the very precise polishing requirement of 10 nanometers (the aberration error was in the perimeter of the primary mirror, which was too flat by only 2200 nanometers or less than the width of a human hair).

Currently, there are four functioning instruments, one instrument in hibernation (NICMOS) and three fine guidance sensors used in HST positioning and observing. All of the current instruments have corrective optics to eliminate the spherical aberration of the primary mirror:

Advanced Camera for Surveys (ACS): This is a third-generation axial instrument designed by a team at Johns-Hopkins University and assembled and tested at

Ball Aerospace and GSFC. The ACS was installed during HSM-3B and repairs were done where possible during HSM-4. ACS has three independent, high-resolution channels covering ultraviolet to near-infrared spectra, a large detector area, and quantum efficiency (incident photon to converted electron sensitivity). The High-Resolution channel has been disabled since 2007, but the Wide Field Channel (WFC) and Solar Blind Channel (SBC) continue to operate. The WFC has two CCDs for a total of 16 megapixels; the SBC is a low-background photon counting device optimized in ultraviolet ranges. The ACS also has 38 filters and dispersers.

Cosmic Origins Spectrograph (COS): This ultraviolet spectrograph is optimized for high sensitivity and spectral resolution of large scale structures in the universe. The COS was installed during HSM-4 and was built and designed by the University of Colorado and Ball Aerospace. The COS has two channels: Far Ultraviolet (90-250 nm wavelengths) and Near Ultraviolet (170-320 nm wavelengths), with a selection of diffraction gratings. Obtaining absorption spectra of interstellar and intergalactic gas forms the basis of the COS science programs.

Wide-Field Camera 3 (WFC3): This is the most technologically advanced instrument on HST that takes images in the visible spectrum. It was installed during HSM-4 and has two independent light paths: A UV and optical channel using CCDs for wavelengths from 200-1000 nm and a near infrared detector array covering wavelengths from 800-1700 nm. The optical channel has a field of view of 2.7 by 2.7 arcseconds; the CCDs are each 2048X4096 pixels. The near infrared channel has a field of view of 135 by 127 arcseconds; this channel is a pathfinder for the James Webb Telescope. WFC3 was built at GSFC and Ball Aerospace.

Infrared image of Horsehead Nebula (in Orion Great Nebula M42) using WFC3
Image credit: NASA, ESA, STScI

Space Telescope Imaging Spectrograph (STIS): This combination spectrograph and imaging camera was designed and built by GSFC. It was installed during HSM-2 and operated until 2004. A lengthy EVA during HSM-4 repaired the instrument, which has now been functional again since 2009. The STIS has three 1024X1024 detector arrays covering spectra wavelengths from 160 nm to 1030 nm (near-UV to near-infrared). Imaging is primarily focused on UV light.

Near Infrared Camera and Multi-Object Spectrometer (NICMOS): This instrument, designed at the University of Arizona and built by Ball Aerospace, is designed to image and perform spectral analyses of infrared wavelengths (0.9 to 2.4 micrometers). The instrument is dormant at this time, but could be utilized again; WFC3 performs some of the same observations. HST is a warm telescope, making true infrared wavelength observations to be limited in their quality. NICMOS was installed during HSM-2 and went into a dormant stage in 2009 after experiencing a start-up anomaly during a software upload in 2008.

Fine Guidance Sensors (FGS): Three FGS on HST are used for pointing the telescope in space and for astrometry (tracking precise movements of stellar bodies). The FGS were built by Perkin-Elmer and have been refurbished and replaced during servicing missions. The FGS are used in conjunction with the six gyroscopes and the main computer to ensure accurate pointing and tracking.

Spacecraft Systems: HST is operated from the ground and has four high-gain communications antennas, two rigid solar arrays (provided by ESA), parallel main computers (instrument processing and pointing control/system functions), thermal protection, solid state recorders, instrument microprocessors, batteries, and a sun filter door that can be opened or closed on the telescope depending on orientation and exclusion zones. The computers were upgraded from DF-224 and NSSC-1 designs to 25 Mhz-Intel based 80486 processors during HSM-3A.

General Layout of HST
Image Credit: NASA, ESA

Major Projects and Scientific Results

STScI is responsible for the scientific operation of the telescope and delivery of data products. STScI is located in Baltimore, Maryland on the campus of Johns Hopkins University. The European Space Astronomy Centre helps coordinate observation times for European astronomers. GSFC supports the STScI on a 24/7 basis.

Scheduling time on the telescope is very complex. Many astronomical targets are occulted, or not visible, during half the orbit of HST (in a low-earth orbit). Observations cannot take place when HST is passing through the South Atlantic Anomaly zone. There are sizeable exclusion zones for the Sun, Moon and Earth (the requirement is that no direct sunlight is allowed on any part of the OTA). Earth and Moon avoidance keep bright lights out of the Fine Guidance Sensors; they can be observed if those sensors are turned off. There is a Continuous Viewing Zone at roughly 90 degrees to the plan of Hubble's orbit, which minimizes occultation delays depending on the observation requested. Proposals for observations are solicited each year (HST is on a yearly observation "cycle" schedule) and several amateur astronomers have successfully submitted proposals that resulted in unique observations and discoveries.

The important discoveries from HST include:

1) Age of the universe: The Hubble constant was constrained using accurately measured distances to Cepheid variable stars, resulting in an estimated age of 13.7 billion years (+/- 10%).
2) Expansion of the universe: Observations of distant supernovae from the High-z Supernova Search Team and the Supernova Cosmology Project resulted in the surprising discovery that expansion of the universe is accelerating. Two Nobel prizes were awarded for these discoveries. The acceleration is most likely caused by dark energy (or is it? Dark energy is still controversial).
3) Black holes: Observations established the prevalence of black holes in the center of nearby galaxies and concluded that black holes are probably common to all galactic structures. The masses of the black holes and the properties of the galaxies are closely related.
4) Deep Field investigations: Discoveries of the most far-flung objects in our universe were done in the Deep Field, Ultra Deep Field and Extreme Deep Field observations. Images reveal galaxies billions of light years away, including GN-z11, which is estimated to be 13.4 billion light years away, only 400 million years after the Big Bang. Gravitational lensing resulting from nearer objects have also expanded the deep-field observations. Just recently, another deep field investigation looking for first-generation stars did not find them, pushing back the timeline for the evolution of the Universe (galaxies formed even earlier than previously thought).
5) Solar System discoveries: HST has observed Pluto and Eris and found five new Kuiper Belt objects for the New Horizons mission to select from for its fly-by in 2019. HST was able to image the collision of Comet Shoemaker-Levy with Jupiter in 1994 after HSM-2 restored the sharp optics. HST also discovered that Ganymede, the largest moon in the Solar System in orbit around Jupiter, has a subsurface ocean (based on observations of the aurorae of the moon).
6) Other observations: HST has helped determine the mass of the Milky Way galaxy (1.5 trillion solar units, with a radius of 129,000 light years), found evidence for extrasolar planets, observed optical counterparts of gamma-ray bursts, and used observations of a reappearing supernova to characterize dark matter distribution.
7) New projects: Other new HST projects include the Cosmic Assembly Near-Infrared Extragalactic Legacy Survey, the Frontier Fields program, and the Cosmic Evolution Survey. These surveys rely on deep-field observations and gravitational lensing to see the faintest galaxies in the distant universe.

HST observations have resulted in over 15,000 papers in peer-reviewed journals and thousands of citations. Ground-based telescopes, at much cheaper costs, have exceeded many of HST capabilities, but some observations were only possible with a space-based platform. The orbit of HST will eventually decay, probably between 2028 and 2040. A soft-capture mechanism was installed to provide for assist by another servicing mission (robotic or human) to allow for controlled re-entry. HST will be replaced by the problematic James Webb Telescope, which has seen many years of delays and cost overruns and will not launch any earlier than March 2021. The amazing legacy of HST is firmly established, however, and it is one of the most popular programs that NASA has sponsored. Take a look at this recent ultra-deep space image, taken using the ACS and WFC3 in 2014, and ponder how vast our universe is and how HST has redefined our place in the cosmos.

Ultra Deep Field using ACS and WFC3 2014
Image Credit: NASA, ESA, STScI

References for HST Article

NASA Hubblesite: https://hubblesite.org
Space Telescope Science Institute (STScI): https://www.stsci.edu/
Hubble History Timeline: https://www.nasa.gov/content/goddard/hubble-history-timeline
Wikipedia (HSM missions and mission overview) https://en.wikipedia.org/wiki/Hubble_Space_Telescope

On This Date in History

This section has milestones retrieved from publicly available information for LM, ULA and heritage programs from 10 to 60 years ago (2010, 2000, 1990, 1980, 1970, and 1960). Delta launches prior to the formation of ULA, unless it included an LM or heritage company payload or upper stage, are not listed. No classified programs are identified, even if the program is now considered unclassified. The events reflect milestone activity in the quarter previous to the release of the MARS STAR -- where appropriate, key press releases are also included; significant milestones are in bold. There will be gaps if no events occurred in that decadal year for that month (no events April 2000, April 1980, May 1990, May 1970, June 2010, and June 1970). The list is not intended to be all-inclusive due to historical record inaccuracies.

Events in April (10 to 60 years ago)

- 04/05/2010: STS-131 (Discovery) launched, LC-39A, KSC; Leonardo ISS module, seven astronauts
- 04/01/2010: Lockheed Martin Press Release: World's First Weather Satellite Launched 50 years ago today and Lockheed Martin has been Involved from the very Beginning
- **04/13/2010: Lockheed Martin Press Release: Space Foundation Honors Hubble Servicing Mission Team that Extended Life of the Orbiting Observatory**
- 04/14/2010: Lockheed Martin Press Release: Lockheed Martin Completes Work on First U.S. Air Force Advanced EHF Satellite
- **04/22/2010: USA-212 (X-37B) launched by ULA Atlas V-501, LC-41, CCAFS. Maiden flight of Atlas V 501 and X-37B**
- 04/11/1990: USA-56,-57,-58 launched by GD Atlas-E/Altair 3-E, SLC-3W, VAFB
- **04/25/1990: LM Hubble Space Telescope launched by STS-31 (Discovery); six astronauts**
- 04/26/1980: Navstar 6 launched by GD Atlas E/F-SGS-1, SLC-3E, VAFB
- **04/11/1970: Apollo 13 launched by Saturn V (C-5), LC-39A, KSC; successful failure – crew performed lunar free return after explosion in Service Module. This mission will be profiled in the Q4 2020 MARS STAR.**
- **04/01/1960: RCA Tiros-1 launched by Thor DM-18 Able II, LC-17A, CCAFS; partial failure before design life in orbit – first weather satellite**
- 04/08/1960: GD SM-65D Atlas launched, LC-11 CCAFS; launch failure
- 04/08/1960: MM HGM-30A Titan I launched, LC-16, CCAFS
- 04/15/1960: Discover 11 launched by Thor DM-18 LM Agena-A, LC-75-3-5
- 04/18/1960: Lockheed UGM-27 Polaris A1 launched, USNS Observation Island, ETR; launch failure
- 04/21/1960: MM HGM-30A Titan I launched, LC-15, CCAFS
- 04/22/1960: GD SM-65D Atlas launched, LC-576B-2, VAFB
- 04/26/1960: Lockheed UGM-27 Polaris A1 launched, LC-29A, CCAFS
- 04/28/1960: MM HGM-30A Titan I launched, LC-16, CCAFS
- 04/29/1960: Lockheed UGM-27 Polaris A1 launched, LC-29A, CCAFS
- 04/30/1960: Lockheed UGM-27 Polaris A1 launched, LC-25A, CCAFS

Events in May (10 to 60 years ago)

- 05/06/2010: Lockheed Martin Press Release: NASA, Lockheed Martin Team Launch Orion Crew Safety to New Heights (Orion abort test)
- 05/14/2010: STS-132 (Atlantis) launched, LC-39Am KSC; Rassvet ISS module, six astronauts.

- 05/28/2010: GPS IIF launched by Delta IV-M+ (4,2), LC-27B, CCAFS
- 05/03/2000: GOES-11 launched by LM Atlas IIA, LC-36A, CCAFS
- 05/08/2000: DSP-20 launched by LM Titan IVB (402/IUS), LC-40, CCAFS
- 05/19/2000: STS-101 (Atlantis) launched, LC-39A; Spacehab, seven astronauts
- 05/24/2000: Eutelsat W4 launched by LM Atlas IIA, LC-36B, CCAFS
- 05/29/1980: RCA NOAA-B launched by GD Atlas E/F-Star-37S-ISS, SLC-3W, VAFB (launch failure)
- 05/06/1960: GD SM-65D Atlas launched, LC-576B-2, VAFB; launch failure
- 05/13/1960: MM HGM-30A Titan I launched, LC-15, CCAFS
- 05/18/1960: Lockheed UGM-27 Polaris A1 launched, LC-25B, CCAFS
- 05/20/1960: GD Atlas SM-65D launched, LC-12, CCAFS
- 05/23/1960: Lockheed UGM-27 Polaris A1 launched, USNS Observation Island, ETR
- 05/24/1960: Midas-2 launched by GD Atlas LV-31 Lockheed Agena A, LC-14, CCAFS
- 05/27/1960: MM HGM-30A Titan I launched, LC-16, CCAFS

Events in June (10 to 60 years ago)

- 06/30/2000: TDRS-H launched by LM Atlas IIA, LC-36A, CCAFS
- 06/08/1990: USA-59,-60,-61,-62 launched by MM Titan TIV-A (405), LC-41, CCAFS
- 06/23/1990: Intelsat 605 launched by MM Commercial Titan III, LC-40, CCAFS
- 06/18/1980: Classified launch by MM Titan III(23D), SLC-4E, VAFB
- 06/07/1960: Lockheed UGM-27 Polaris A1 launched, LC-25A, CCAFS; launch failure
- 06/11/1960: GD SM-65D Atlas launched, LC-11, CCAFS
- 06/22/1960: GD SM-65D Atlas launched, LC-14, CCAFS
- 06/23/1960: Lockheed UGM-27 Polaris A1 launched, USNS Observation Island, ETR
- 06/23/1960: Lockheed UGM-27 Polaris A1 launched, LC-25B, CCAFS
- 06/24/1960: MM HGM-30A Titan I launched, LC-15, CCAFS
- 06/28/1960: GD SM-65D Atlas launched, LC-12, CCAFS
- 06/29/1960: Discoverer 12 launched by Thor DM-18 Lockheed Agena A, LC-75-3-4, VAFB; launch failure

Reference websites:
https://nssdc.gsfc.nasa.gov/planetary/chronology.html#2014
https://en.wikipedia.org/wiki/Timeline_of_spaceflight
https://www.ulalaunch.com/missions
https://news.lockheedmartin.com/news-releases?year=2020
https://space.skyrocket.de
http: www.astronautix.com

Next Edition

Check back in the next MARS STAR for a program profile of the Apollo 13 mission! Future editions will include more Apollo missions, the first shuttle launch, and other significant milestones.

Barb Sande, MARS STAR and MARS Facebook Page Historian. Contact me at barbsande@comcast.net or 303-887-8511 or find MARS Associates on Facebook