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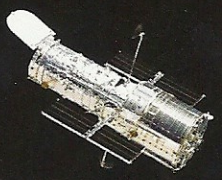


"Tin Can In Space"

2015 JUN

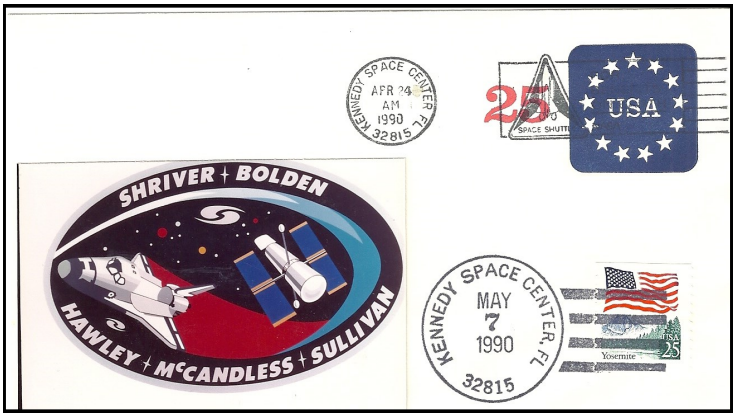
ASTRO SPACE STAMP SOCIETY

A Short History of Hubble

Umberto Cavallaro, editor of our Italian sister paper* AdAstra *explains how NASA/ESA's Hubble Space Telescope is the greatest leap forward in astronomy since Galileo

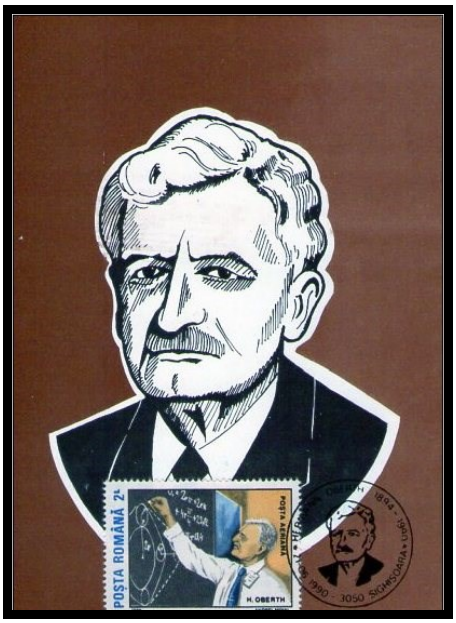
The Hubble Space Telescope (HST) is the most famous – and probably most successful – space observatory ever flown.

HST is a cooperative NASA/ESA programme conceived in order to operate a long-lived space-based observatory for the benefit of the international astronomical community.



The 11 ton telescope was placed into a 570 km high orbit around Earth by the Space Shuttle in April 1990. Circling our planet every 96 minutes, the HST has so far (at spring 2015) travelled more than 6.5 billion km, has marked the most significant advance in astronomy since Galileo's telescope, and helped to determine the age and size of the Universe. Hubble's discoveries have revolutionised nearly all areas of astronomy, from planetary science to cosmology and led to significant changes in our basic understanding in astronomy.

The Hubble pre-history



The idea of sending into space a telescope able to look into the universe from above the distortion of the Earth's atmosphere was first proposed by German rocket scientist Hermann Oberth (one of the fathers of modern rocketry, together with Robert Goddard and Konstantin Tsiolkovsky) in his book "*Die Rakete zu den Planeträumen*" (*Rockets into Interplanetary Space*), as early as 1923: long before the first satellite was launched.

His heritage was developed in the States by the astrophysicist Lyman Spitzer who developed in 1946 a realistic plan for placing a large telescope in space, and described in detail the advantages in his paper entitled *"Astronomical Advantages of an Extra-Terrestrial Observatory".*

He would work for the next decades to explain his vision to the scientific community – that often was against the idea of a space telescope, concerned that the cost would reduce funding for ground-based astronomy – and for lobbying for his idea with the U.S. Congress, so becoming instrumental in the design and development of the Hubble Space Telescope.

Soon after it was set up in 1958, NASA established a set of scientific objectives that included an astronomical observatory and consequently carried out studies with the OAOs (Orbiting Astronomical Observatories) , the four small satellites that, launched from 1966 onward, increased in the astronomical community awareness of the benefits of orbiting telescopes.

ESA-NASA cooperation

Cooperation with ESA (European Space Agency) was first formally raised in 1973 when the Astrophysics Working Group recommended that Europe should consider and explore the possibility of participating with NASA in what was then known as the *'Large Space Telescope*' (LST). At that time Europe had something of a lead in the area of photon-counting imaging system that, developed by the University College London, was in routine use for optical astronomy, and would appear very appropriate in order to exploit the LST's potential to the full.

In 1976 NASA formally invited Europe to take a share in the LST and to contribute 15% of the costs. ESA requested, in return, to have a guaranteed share of 15% of the available observing time; NASA accepted the principle, and in October 1976 ESA approved the European financial contribution.

After the Tempel-2/Halley cometary project was aborted, the plans for co-operative utilisation of the Shuttle/ Spacelab system were frustrated, and the joint ISPM mission was unilaterally abandoned by NASA as a consequence of budget cuts by the newly elected President, the *Large Space Telescope* remained the only ESA/NASA co-operative project, with ESA regarded as a

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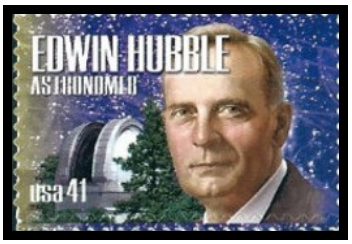
"junior partner", according to ESA historians .

But the precise instrument to be built by Europe was in some doubt, as was the question of what size of telescope, if any, the US Congress would fund .

In July 1977 the American Congress approved funding for the *Large Space Telescope.* On the NASA side, it was decided to reduce the size of the Telescope's primary mirror from 3 m to 2.4 m for cost reasons. The term "*Large*" was dropped from the Telescope's name, which NASA later changed to the *'Hubble Space Telescope'* in honour of Edwin P Hubble, (1889 –1953), one of the great American pioneers of modern astronomy (USA 2008) who identified galaxies outside the Milky Way and discovered that the Universe is expanding.



The Memorandum of Understanding (MoU) between ESA and NASA was signed in October that year and would last 11 years after launch (expiring in April 2001, later replaced by a new agreement)

NASA chose Marshall Space Flight Center in Huntsville, Alabama, as the lead NASA field centre for the design, development, and construction of the Hubble Telescope. Marshall delegated Perkin-Elmer Corporation (now, Hughes Danbury Optical Systems) the task of developing the Optical Telescope Assembly and the Fine Guidance Sensors.

Lockheed Missiles and Space Company (now, Lockheed Martin) was selected by Marshall to build the cylindrical casing and the internal support systems (the Support Systems Module) and assembling the telescope together.

Goddard Space Flight Center in Greenbelt, Maryland, was designed to be the lead in scientific instrument design and ground control for the space observatory. Proposals were received from the scientific community and judged, and five science instruments were selected as the initial instruments that would be aboard the Space Telescope to study the Universe in infrared, visible or ultraviolet light. The devices were the Faint Object Camera (FOC), the Wide Field/ Planetary Camera, the Faint Object Spectrograph, the High Resolution Spectrograph, and the High Speed Photometer.

FOC was the main contribution of Europe, together with the solar array. The 318-kg FOC – which was not affected by the hairbreadth defect in the surface of the primary mirror and was removed as planned from Hubble in early 2002 and replaced by the more powerful *Advanced Camera for Surveys* – was one of the most crucial components on board, being an optical and ultraviolet camera able to count the individual rays of light (or light particles, i.e. photons) as they arrived. The resolution of FOC was stunning: the camera was built by Dornier in Germany and Matra in France, with British Aerospace making the photon detector assembly therein. The detector was designed to identify very faint UV light from 115 to 650 nanometers in wavelength, sensitive enough to pick up a single candle light at 40.000 km . FOC has taken, since, thousands of pictures of outstanding quality and scientific interest.

By contrast the two solar arrays, provided by ESA were the largest attachment to the spacecraft and were required to produce 5kW of electricity. Each had 24.380 cells and the overall span was 33 sqm.

The Johnson Space Center in Houston, Texas, and the Kennedy Space Center in Florida supplied Space Shuttle support. In all, dozens of contractors, a handful of universities, and several NASA centres, spanning 21 states and 12 other countries worldwide, made the dream of a telescope above the clouds and in space a reality.

Seven years of delays

Hubble was originally scheduled for launch on the Space Shuttle in December 1983 but the launch date had been put back at least five times, both because of NASA technical and budgetary limitations, resulting in a three-year delay overall .

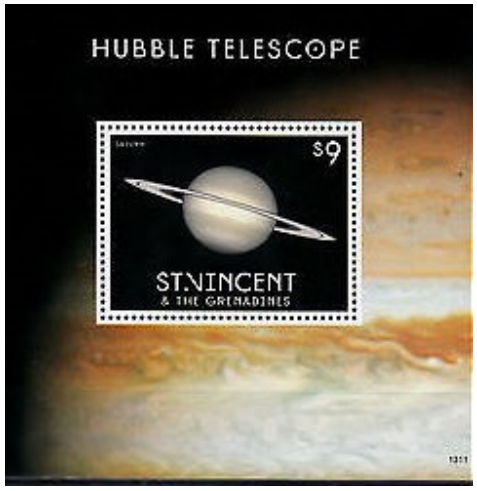
Its launch was eventually scheduled for October 1986 but the *Challenger* accident caused a further delay which had several repercussions on the ESA elements of the HST. The solar arrays had been delivered and installed in final flight configuration in early 1986. There was some concern as the further delayed launch date would coincide with a period of maximum solar activity, thereby exposing the HST, at its planned orbital altitude of approx. 600 km, to the resulting expansion of the Earth's outer atmosphere and the corrosive effects of atomic oxygen. The silver interconnects between the cells of the solar arrays would be particularly vulnerable. In addition, NASA's planned power utilization had increased, thus requesting improvements in power generation. The decision was therefore taken to remove the solar arrays from the HST and bring them back to Europe for upgrading. The two array wings were reworked in the course of 1988, with new blankets fitted with high-performance and atomic-oxygen-resistant cells and interconnects. The arrays were returned to the United States and re-fitted to the Telescope in early 1989.

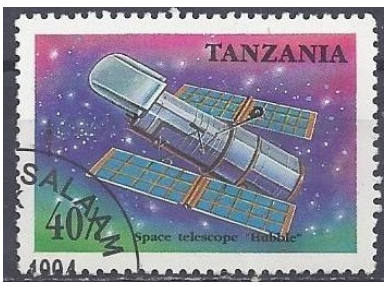
The telescope was finally launched by the Shuttle Discovery STS-31 on 24 April 1990, thus joining, to the benefit of the astronomy community at large, the European Hipparcos, the first astrometric satellite already in orbit. Also was in orbit – launched by ESA from Kourou on top an Ariane rocket – Giotto, the Halley/Grigg-Skjellerup mission originally conceived as the ESA contribution to the joint ESA/NASA cometary mission to be launched on the Space Shuttle, and cancelled by NASA at the end of 1979 with the cost of the shuttle programme soaring.

USA 2000

St Vincent & G 2013

Australia 2007
Austria 2009
St Tome & P 2010
Tanzania 1994
Bulgaria 1991





A page from your editor's 2014BTA Cup winning entry on 50 years of space walking

EVA is 50

Launch, maintenance and repair of the Hubble Space Telescope (HST).

New Glasses for Hubble Space Telescope

Shuttle Mission STS-61/Endeavour 2-12 Dec 1993

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Designer: Karl Tanner

Hubble Mission STS-82/Discovery

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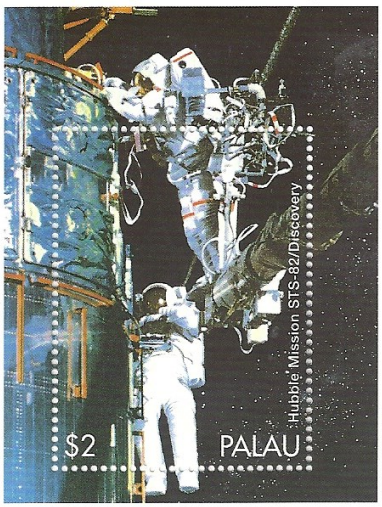

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Designer: Karl Tanner

Second servicing mission
February 11-21,1997
Astronauts Mark Lee and
Steven Smith patching Hubble's insulation

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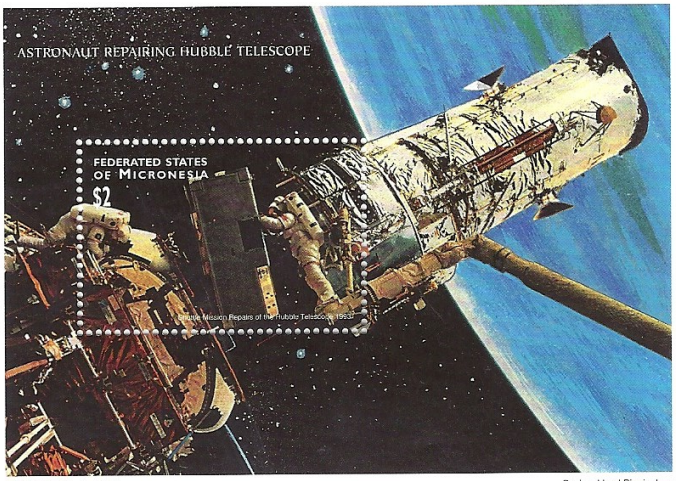

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Design: Lloyd Birmingham

Flawed mirror and consternation.

When the first pictures returned, the scientific community realized that the image quality obtained by Hubble Telescope was drastically lower than expected, initially causing severe consternation amongst NASA, the scientific community and the general public.

Analysis of the flawed images showed that the cause of the problem was that one lens was out of position by 1.3 mm and consequently the primary mirror had a variation from the prescribed curve by about 2,2 nanometers, thus severely reducing the usefulness of the telescope for faint objects. It was also realized that final tests had correctly reported spherical aberration, but the warning was overlooked and ignored by Perkin-Elmer. This led to heavy criticism by NASA for its managerial failings and the organisation was blamed for not supervising adequately the project and not involving the optical designers in the construction and verification of the mirror. On the other hand NASA itself was criticized for not adequately managing the quality control.

Repairing Hubble mirror to restore NASA's image

Except for the explosion of *Challenger* that killed its crew of seven in 1986, no single event had damaged NASA's reputation and its own sense of achievement more than the discovery that, after more than a decade of development, the $1.6 billion Hubble Space Telescope had been launched with a serious manufacturing error in the curvature of its main mirror .

It would have been impossible to replace the mirror in orbit, and too expensive to bring the telescope back to Earth for a refit.

Fortunately one of the innovative ideas behind Hubble were the Servicing Missions planned for keeping the observatory and its instruments in prime scientific condition. Periodic visits by astronauts were planned for replacing some instruments with state-of-the-art versions. Originally, telescope maintenance visits were planned for every 2.5 years and a larger overhaul was envisaged every five years, when HST would have been brought back to the ground. This plan was changed somewhat over time and a servicing scheme that included Space Shuttle Servicing Missions every three years was finally decided upon.

This proved to be invaluable in this case. NASA considered at least 28 proposals for the repairs. At the end, new optical components were studied and designed with exactly the same error but in the opposite sense, acting as "spectacles" to be added to the telescope to correct the spherical aberration. This way the first maintenance mission by Space Shuttle 'Endeavour' STS-61, in December 1993, fully restored Hubble's functionality .

A quarter century of success in engineering, science and culture

Hubble has since far exceeded expectations and currently generates 844 gigabytes of data per month giving astronomers detailed information on supernovae, and galaxies in various evolutionary states. Because of its versatility, the Hubble Observatory has made contributions to almost every branch of astronomy: from the studies of our own solar system, to the detailed observations of extrasolar planets, to the census of stellar populations in nearby galaxies, to the deepest views of the distant Universe. The telescope was also instrumental in the discovery of dark energy, a little-known but ubiquitous force that works against gravity and contributes to the ongoing expansion of the universe.

According to the statistics released by NASA as of its 24th anniversary (April 2014) Hubble has made more the 1 million observations and observed 38,000 celestial targets. More than 100 terabytes of data has been accumulated so far. About 4,000 astronomers from all over the world have used the telescope to probe the universe. Astronomers using Hubble data have published more than 11,000 scientific papers, making it one of the most productive scientific instruments ever built

One of the most popular and stunning images taken by Hubble is the so-called "Pillars of Creation" which, taken in 1995, is reproduced and is so popular that it has appeared everywhere, including in movies and television shows, and even on a postage stamp. (USA 2000)

It shows never-before-seen details of three giant columns of cold gas from a cluster of young, massive stars in a small region of the Eagle Nebula, or M16 as it looked about 7,000 years ago because the nebula is 7,000 light-years away from Earth.

1. Project RAND Report, Douglas Aircraft Co., September 1946; see "*Lyman Spitzer, Jr., The Man Behind the Machine*" in *hubblesite.org;* see also Denise Applewhite, "*Lyman Spitzer Jr.*", in *www.spitzer.caltech.edu*
2. See "*Orbiting Astronomical Observatory*", in *en.wikipedia.org*
3. R.J. Laurance, "*The History of the Hubble Space Telescope and ESA's Involvement*", in ESA Bulletin, n. 61 (February 1990), p.9-11
4. According to ESA historians, in those years very little had survived of the ambitious plans for scientific cooperation which ESA and NASA had been discussing about fifteen years earlier. The