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The Universe through the eyes of Hubble Space Telescope

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Abstract:

Hubble is a telescope design which is known as Cassegrain reflector which has two mirrors: primary and secondary. This paper studies the investigation of the early history and the launching of Hubble Space Telescope which is later after investigation called as James Webb Space Telescope. In order to do a planning for successor t0o the Hubble Space Telescope, the initial ideas for such a Next Generation Space Telescope. The most important group of astronomers and engineers are examining the universe through Hubble Space Telescope such as the successor was based at the Space Telescope Science Institute, Baltimore. In 1980s, the successor concepts would work in optical, ultraviolet and infrared wavelengths that are later considered as politically unrealistic. Through this paper, researchers can also explore how the planned fortunes of the Next Generation Space Telescope were linked intimately to that of the parent i.e., the Hubble Space Telescope.

Keywords: *Hubble Space Telescope, Next Generation Space Telescope*

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Introduction

In 1990, the Hubble Space Telescope was launched and the story this telescope started long before the introduction of space shuttle Discovery.

In the astronomical research, telescopes have been used as tools for years and sophisticated, refined devices for the purpose to measure the sky. This science Astronomy is considered as the first science during ancient period of Babylon and Greece about 2,000 years ago. One of the first suggestion was given by the German Rocket Scientist i.e., Hermann Oberth whose idea came just two decades after the airplane that is powered had thrashed off the run way for a very few seconds of flight. But the time, when Oberth gave the suggestion was the age of wood and cloth biplanes, airships and the flying boats.

Then, In 1957 , Sputnik's first planet's orbit was introduced and this war technology finally found an appropriate use and then proved that the spaceflight was more than a theoretical possibility that indicates Space Age had Begun (Usher and Christensen, 2014).

Hubble has provided us most of the haunting challenges to humans who are working in space and are successful in meeting all those issues around the technology. After its launch in 1990, the visit through the Hubble is around four times by astronauts that fixes, restore and also requires equipment upgradation. It has also been used in the research field, as with the help of Hubble, most of the data is generated for number of scientific papers whose topics ranges from solar system discovery in formation to the precise measurement of the universe's age.

According to **Lyman Spitzer in 1946 in National Aeronautics and Space Administration (NASA) 2006,** introduced the first articulated scientific and technical rationale for the purpose of space astronomy. When the researchers started working on the Hubble space telescope, the technology needed should be well advanced. Then the turmoil of the Hubble design culminated with the huge loss of space shuttle challenger and its related crew in 1986, January. The Hubble was simply designed to be visited by the astronauts, so even before the introduction of Hubble, NASA started to building a second generation camera that replaces the main camera that was launched along with the telescope. As per the suggestion of the optical experts, they could built corrective optics that is incorporated into the camera to counteract the flaw in the Hubble mirror. The work was accelerated by NASA on the Wide Field Planetary Camera 2 (WFPC2) and related engineers and scientists of Hubble designed a mechanical fixture called Corrective Optics Space Telescope Axial Replacement (COSTAR) that deploys the corrective optics in the light paths to the other instruments.

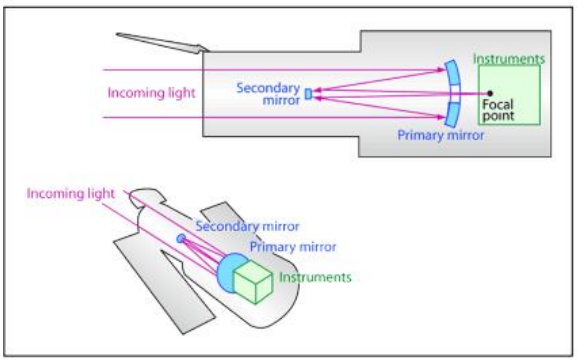

Figure 1 – Diagrammatic representation of light's path inside the Hubble Space Telescope

In 1999, the servicing mission has improved many of the subsystems of Hubble that includes the central computer which is a new solid state recording system for data to replace the magnetic tape drives and the requirement of the gyroscopes are needed to pointing control.

Then in 2008, the final servicing mission install two new instruments i.e., Cosmic Origins Spectrograph (COS) and Wide Field Camera 3 (WFC3). The COS technique is considered as the most profound ultraviolet spectrograph for Hubble. The probing occurs in the instrument in the cosmic web which is the large scale structure of the universe whose structure is determined by the dark gravity matter and then the tracing is done by the galaxies and intergalactic spatial distribution. A new camera i.e., WFC3 is sensitive that covers wide range of wavelengths that includes infrared visible and UV light. At the time of repairing of STIS which is installed in 1997 and then working stopped in 1997. And then when it got repaired, so the instrument is then used for the purpose of high resolution studies in VIS and UV light and galaxies which are at distance.

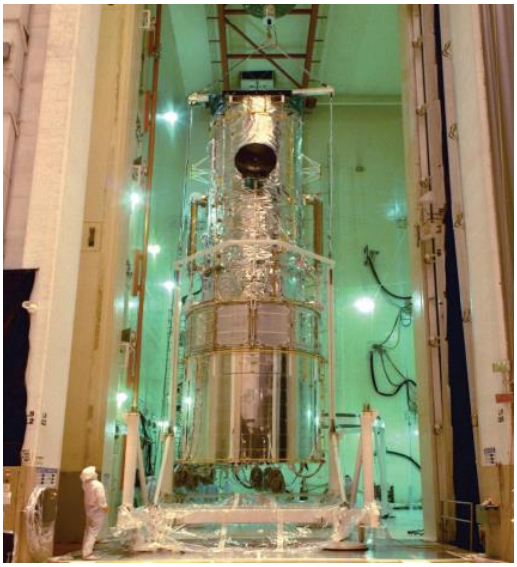

Figure 2 – Hubble Space Telescope

The Hubble Project

The project i.e., Hubble Space Telescope is of International co-operation in between the European Space Agency (ESA) and National Aeronautics and Space Administration (NASA) which has an agreement of partnership between ESA and NASA that was signed on 7 October, 1977.

The two pairs of Solar panels are provided by ESA and other one is the scientific instruments of Hubble along with the other components. In this Hubble Project,15 Scientists of Europe origin at the Space Telescope Science Institute in Baltimore which is majorly responsible to operate the scientific problems of the Observatory of Hubble and then is managed by the AURA i.e., Association of Universities for Research in Astronomy for the organization NASA.

The ST-ECF i.e., The Space Telescope European Coordinating Facility which is hosted at the European Southern Observatory (ESO) (Nicollier 2000).

Scientific Goals

At the time of launch of HST i.e., Hollow Space Telescope, the 1980's universe is decelerating and the rate of expansion was greatly considered as uncertain. Only Black holes were suspected at the center of the galaxies. The top three fundamental projects which are established for HST are,

• The distance scale is calibrated by the determination of Hubble constant which is H0. This is done by HST usage that observes "standard candle" objects beyond the galaxy that largely improves the knowledge of the rate of expansion of universe and its age. In case the determination of H0 is accurate, it would allow tighter constraints to be placed on some of the associated parameters such as deceleration parameters and the critical density.

• The properties of the intergalactic medium is determined by observing the adsorption signature in the UV spectra having a large number of quasars that causes by the material that intervenes along the beam line (pencil beam) to each quasar.

• Demographics of survey galaxy and of the other objects of interest having deep imaging of regions in the sky that are unremarkable. The project is recognized as Medium Deep Survey (MDS).

All these important observations were front –loaded into the initial part of the HST mission.

Design of HST

Brief Overview of Spacecraft

The spacecraft includes telescope of 2.5 m diameter and consists of two cylindrical parts having larger diameters. The "section of equipment" contains subsystems as powder, logic and reaction. The execution of attitude control is done by wheels and simply sensed by the inertial navigation combination, interferometric nulling i.e., FGSs and the matching of star field i.e., FHSTs. A pair of large solar arrays that provides power and are rotatable, can charge 6 batteries for power during the orbital night. This active and passive combinations of thermal control provides the careful management of the environment for the instruments and optics.

This telescope operates in low earth orbit, has an altitude that varies from 616 km to 565 km. During the launch time, the efficiency values were 35% and after the observation of target it occulted the earth anywhere that is between zero and approximately 50 % of an orbit. The data of science and engineering is stored on-board and which is transmitted periodically to the NASA Tracking Data Relay Satellite System (TDRSS) where it is sent to the ground.

Primary Mirror:
- 2400 mm diameter circular annulus sandwich design, with 600 mm central opening.
- Corning ultra-low expansion (ULE) glass, MgF_2 coating over Al. Hyperboloid: 11040 mm radius of curvature, 5520 mm focal length (f_1')
- Conic constant K_1 = -1.0022985 (spec, [14]), -1.0144 (as built, [15])

Note the significant difference between the primary mirror's as-built, and design value for K, which will be discussed later.

Secondary Mirror:
- 281 mm diameter (310 mm with housing)
- Schott Zerodur glass, with MgF_2 coating over Al. Convex hyperboloid: -1358 mm radius of curvature,
- Conic constant K_2 = -1.496 [16]

System:
- Focal length (system) f' = 57600 mm, focal ratio (system) = f/24, focal ratio (primary mirror) = f/2.3, (magnification = 10.43)
- Mirror separation, t = 4906.9 mm, Central obscuration = 33% (diametric)
- Focal surface images ~28 arcmin on sky (~ diameter full moon) at a plate scale from 3.60 - 3.37"/mm
- MgF_2 coating thickness is sized to boost UV response but throughput cuts off sharply at ~115 nm.

Table 1- Optical Parameters for HST

The Servicing missions and capabilities which have expanded capabilities

The Servicing mission 1 has exchanged the HSP for the COSTAR i.e., Corrective Optics Space Telescope Axial Replacement that deploys the optics and provides a spherical aberration corrected feed to the existing first generation. With the help of improved solar arrays, the replacements allowed for HST are to realize its intended performance.

In Servicing Mission 2, to achieve the required mirror figure stability, the primary and secondary mirrors of HST are heated, with controlled temperature conditions at a set point of 21oC.Because of the gradient present across the mirrors from front to back, the actual temperatures which are measured near the primary mirror surface on the inner and outer edges that indicates temperature between 14oC and 16oC and are stable at 1oC. The mirror surface at the secondary position is stable and considered as cooler at the surface than the point of control. Simultaneously, the temperatures are stable enough for a figure of constant mirror whose changes or alterations are not observable during the aberrations of monitoring which are then compared with the varying focus aberration.

The Servicing mission 3B is considered as a milestone for the ACS installation which is a powerful modern imager whose sensitivity of product and field of view is many times greater than the cameras which are existing.

The Intended servicing mission 3 is categorized into two separate missions for over two years.

Servicing mission 4 was introduced in 2004 and after the loss of the Shuttle Columbia it was considered as canceled.

This program of repair represented a major step forward in the ability to perform on – orbit spacecraft servicing.

Advances in observation, analysis and archiving of HST

HST is used for the significant and major advancement in the technology to analyze data, processing, distribution and high level science products availability. The implementation and development of "parallel observations" that takes advantages of the spatial HST sharing at the focal plane that allows the multiple instruments to image the sky at one time.

During the post observation ground system, the science data model which is considered as a pipeline to generate calibrated products of science and is an integral HST observatory operations part from the onset. The On the Fly Re-processing (OTFR) was executed at mid of the mission where the request of data from the archive automatically be reduced again that uses the current knowledge of calibrated products.

For the investigation of key scientific questions and disseminate results of high quality to a large audience and the time of HST is increasingly used for long term or science programs of high volume that is usually run by teams that provides community feedback (Lallo , 2-31).

According to the **NASA Systems Engineering Process**, which is best explained in "NASA Systems Engineering Handbook" which is published in 1995. The NASA position that is announced related to this document that it does not represents the current process or practices but is useful as an educational tool for developing systems engineer. This handbook published is evolving over time in 1989 and have an extensive effort that results in the initial draft in 1992 (September).

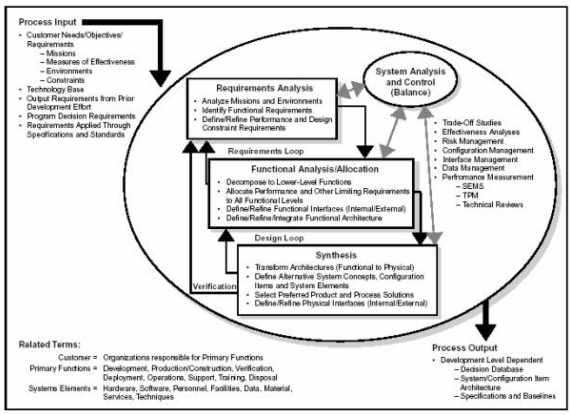

Figure 3 – The system Engineering Process presented by the Defense Acquisition University

According to the **Scientific staff of the Space Telescope Science Institute**, the Hubble images are considered to be stable and it is sensitive to all the wavelengths from the Ultraviolet to the near IR All these wavelengths are blocked by the atmosphere and are inaccessible from earth. The stability of Hubble is the main reason as it is used for the detection of the atmosphere of extra-solar planets such as Osiris. Then in 2015, Roth et al, published a paper on Constraints on an exosphere at Ceres from Hubble Space Telescope Observations. In 1994, Benedetti et al, the technology of Virtual Environment (VE) is used to construct a Hubble Space Telescope (HST) model and then all the elements are repaired during the repair and maintenance mission of December 1993 that is conducted by the National Aeronautics and Space Administration (NASA).

Conclusion

Before the launch of Hubble Space Telescope in 1990, number of astronomers and engineers belonging from US and Europe thinking about the possible successor of HST. The launch of any other successor was likely to be few years away was also accepted widely. Therefore, the failure of spherical aberration of Hubble had a serious pace effect at which the plans were advancing for the Next Generation Space Telescope. Critically, the building dynamics i.e., Next Big Machine and the offspring's fate was tied intimately to that of the parent. In this, the Hubble Space Telescope is described in detail associated with its working and requirements. The researchers are also finding the ways in future for the better performance by Hubble Space Telescope.

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