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The Universe through the eyes of Hubble Space Telescope

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Abstract:

Hubble telescope, is known as Cassegrain reflector consists of two mirrors which are primary and secondary. This paper deals in the study of investigation of early history and launching of Hubble Space Telescope which was later known as James Webb Space Telescope. The most efficient group of astronomers and engineers are examining the universe through Hubble Space Telescope whose successor was placed at the Space Telescope Science Institute, situated in Baltimore. during1980s, the concept of successor use to work in the range of optical, ultraviolet and infrared wavelengths which were later considered impractical somewhere. Through this paper, researchers can have a broad horizon of knowledge regarding, how the planned destiny of the Next Generation Space Telescope were closely related to that of their parents.

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

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Introduction

Hubble Telescope was launched in 1990, but its story was written long before the discovery of space shuttle.

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, National Aeronautics and Space Administration (NASA) 2006,** introduced the first ever 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 resulted in the huge loss of space shuttle and its crew in 1986. After which the Hubble was designed simply only for visit of the astronauts, prior to the introduction of Hubble, NASA started to build a camera of second generation that could replace the main camera, sent along with the telescope. According to suggestion of the optical experts, they should have developed tools like corrective optics that could be attached into the camera to simultaneously counter the errors in the Hubble mirror. The work was paced up by NASA on a Wide Field Planetary Camera 2 (WFPC2) and related engineers and scientists designed a mechanical structure which was named as Corrective Optics Space Telescope Axial Replacement (COSTAR) that locate the corrective optics present in the light paths with the other instruments.

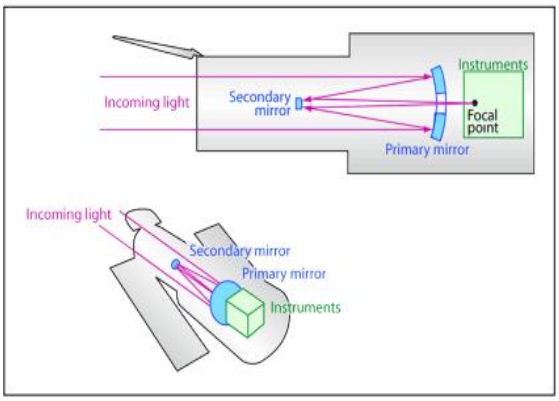

Figure 1 – Diagrammatic representation of light's path inside the Hubble Space Telescope

In 1999, the servicing mission has improved many of the subsystems of Hubble that includes the central computer which is a newly developed system which is used for recording solid states and helps to replace the magnetic tape drives whereas gyroscopes are needed for pin pointing controls.

Then in 2008, the final servicing mission anchored two more new instruments viz. Cosmic Origins Spectrograph (COS) and Wide Field Camera 3 (WFC3). The COS technique is considered as the most efficient ultraviolet spectrograph for Hubble space telescope. The scrutiny of the instrument in the cosmic web takes place which is a large scale representation of the universe, determined by dark gravity matter and after which tracing is done by the galaxies and intergalactic spatial distribution. A new camera i.e., WFC3 is sensitive covering a wide range of wavelengths including visible, infrared and UV light. While the repairing of STIS which was installed in 1997, stopped working in 1997. After getting repaired, the instrument was then used for the purpose of studies involving high resolution in VIS and UV light and galaxies which distant.

Figure 2 – Hubble Space Telescope

The Hubble Project

The project i.e., Hubble Space Telescope was a result of International co-operation between the European Space Agency (ESA) and National Aeronautics and Space Administration (NASA) which has an agreement on partnership between ESA and NASA, signed on 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 STSI, Baltimore are majorly accountable to operate the scientific issues of the Observatory under this telescope and then 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

During the launch of HST i.e., Hollow Space Telescope, the 1980's it was seen that the universe is decelerating and the rate of expansion was considered as an uncertain phenomena. Only Black holes were traced at the core of major 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 curbs to be placed on some of the associated parameters such as deceleration parameters and the critical density.

• The factors and properties of the intergalactic medium is generally determined by discovering the adsorption marks in the UV spectra having a large number of quasars which is caused by the material that intervenes along the beam line (pencil beam) to each quasar.

• Survey galaxy demographics and of many other objects of interest having regions of deep imaging the unremarkable. The project is recognized as Medium Deep Survey (MDS).

All these vital points were observed and were incorporated in 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 altitude control is done with the help of wheels and simply known 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 upto six batteries which eventually works as a powerhouse during the orbital night. This combination of thermal controls help in vigilant management of environment of the tools.

This telescope works in lower earth orbits, with 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 is stored on-board and which is transmitted to the NASA at a regular basis Tracking Data Relay Satellite System (TDRSS) where it is transmitted 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 switched HSP to COSTAR i.e., Corrective Optics Space Telescope Axial Replacement that assist the optics and provides a spherical anomaly corrected which is fed to the existing first generation telescope. With the aid of improved solar arrays, the switch allowed for HST are to realize its predicted working.

In Servicing Mission 2, to achieve the required stability, the primary and secondary mirrors of this telescope are heated, with standard control temperature conditions at a set point of 21oC.Due to the gradient present across the mirrors from the front to back, the actual temperatures which are calculated near the surface of primary mirror the inner and outer edges that shows temperature between 14oC and 16oC and are stable at 1oC. The surface at the secondary mirror is stable and observed, cooler at the surface as compared to the point of control. Simultaneously, the temperatures are quite stable for a figure whose changes are not observable all kind of observations are then compared with the varying focus anomalies.

The Servicing mission 3B is considered as a landmark in the history of ACS installation which is an efficient and powerful modern imager whose sensitivity of product and field of view is greater than the normal cameras.

The Intended servicing mission 3 is divided into two separate missions.

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

This program of repair represented a major step towards the ability to work 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, implementation, processing, distribution and complex science products availability. The implementation and development of "parallel observations" that takes benefit of the spatial HST sharing at the focal plane that can assist various instruments to record images at the same time.

Post observation of ground system, the scientific data model which is considered as a pipeline to generate calibrated products of science and is an integral HST

observatory. On the Fly Re-processing (OTFR) was executed at middle of the operation where the request of data from the archive automatically be reduced again that uses the current knowledge of calibrated products.

For the investigation of important key of scientific queries and produce results of high quality to the public and HST is efficiently used for science programs of high magnitude that is usually run by teams that provide 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).

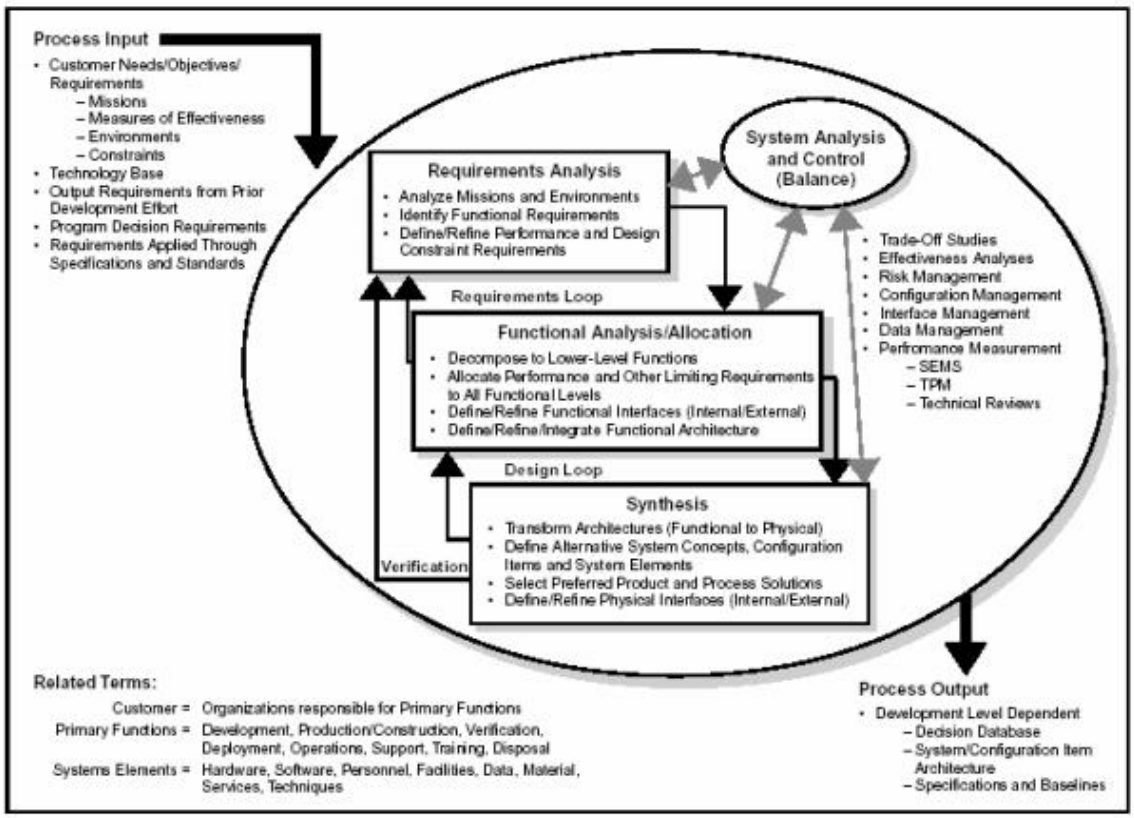

Figure 3 – The system Engineering Process presented by the Defense Acquisition University

According to the **Scientific staff of the Space Telescope Science Institute**, the Hubble images are considered to be stable and it is responds to all the wavelengths from the Ultraviolet to the near IR waves. All these wavelengths are obstructed by the atmosphere and are not approachable from earth. The stability of Hubble is the main reason as it is used for the detection and observation of the atmosphere and surroundings of other celestial bodies such as Osiris. Then in 2015, Roth et al, published a paper on Limitation on an exosphere at Ceres. In 1994, Benedetti et al, stated that the technology of Virtual Environment (VE) is used to build a Hubble Space Telescope (HST) model and then all wear and tear of tools are repaired at the time of the repair and maintenance mission of December 1993 that is conducted by the National Aeronautics and Space Administration (NASA).

Conclusion

Prior to the launch of Hubble Space Telescope which took place in 1990, the number of astronomers and engineers that belonged to US and Europe were planning about the appropriate successor of HST. The development of any other successor was likely to be few years away. This was also accepted widely throughtout the world. Therefore, the failure of spherical aberration of Hubble posed a significant effect at which the plans were being implemented for the Next Generation Space Telescope. Critically, the building dynamics i.e., Next Big Machine and the offspring's fate was attached closely to that of its originator. 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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