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**Previewing the James Webb
Space Telescope (JWST)**

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JWST Mid-infrared Instrument-(Retd)

Pandemic lockdown over, this was the first live meeting held for over a year. Those who still preferred to quarantine at home were welcomed on-line, leaving the speaker with a diminished audience. Thankfully, his presentation suited in-house and on-line attendees.

He outlined UK involvement in space-related projects, with a brief history of a factory built in Stevenage. Over 70 years ago it was opened as a supplemental manufacturing site for the nearby de Havilland Comet production line at Hatfield. Aviation expanded into 'aerospace' in the 1960s and the site became the hub for many UK programs. The largest of these was the UK 'Blue Streak' medium-range ballistic missile project which was cancelled in the 1960s (and, as the first stage of the ELDO launcher, it can be seen at the National Space Centre in Leicester). Stevenage became the home for many other projects, and has evolved, taking responsibility for systems for space-related systems often managed worldwide. Throughout most of the new millennium Stevenage was the site where UK industry contributed to projects such as the James Webb Space Telescope (JWST).

For several years the speaker was the European Consortium project manager for the JWST mid-infrared instrument, and it was from this background that he reviewed the aims. He described the unique aspects of a 'telescope' that has been designed to gather information from a spectrum other than that of an optical telescope. Several companies from collaborating nations have contributed sensor, processing and telemetering elements that will produce images that will show, for the first time, activity that astronomers have not been able to visualise. These will be from the era shortly after what we refer to as 'the Big Bang' - the event that all scientists believe was the moment when 'space' as we know it was created from a singularity that we have never seen. It is believed to have occurred, using the Earth calendar, nearly 14 billion years ago.

The Hubble Space Telescope, launched on 24 April 1990, has improved the detail of stellar objects within, and beyond, our galaxy. Astronomical researchers still need to have access to data that will allow examination of deeper space. Especially they have wished to see (if it is possible) the first stars and galaxies born after the 'Big Bang.' This led to a specification for a larger and unique space 'telescope'. The project was first proposed in the mid 1990's and its launch was planned to be in 2007. However, this timescale proved not to be achievable, but the programme was expanded and retained.

Scientists were aware by now that it was possible to launch to a suitable place, called Lagrange Point L2: one of five sites where a satellite (in this case the JWST) will remain in a relative fixed position. Point L2 is 1.5 MKms from the Earth and, if a spacecraft there can be shielded from Sun, Earth and Moon emissions, it would allow radiation captured from deep space over billions of years ago to be pin-pointed and collected without terrestrial interference. The JWST project is a joint-team project managed by NASA with US, European (including UK) and Canadian teams responsible for components of the whole system.

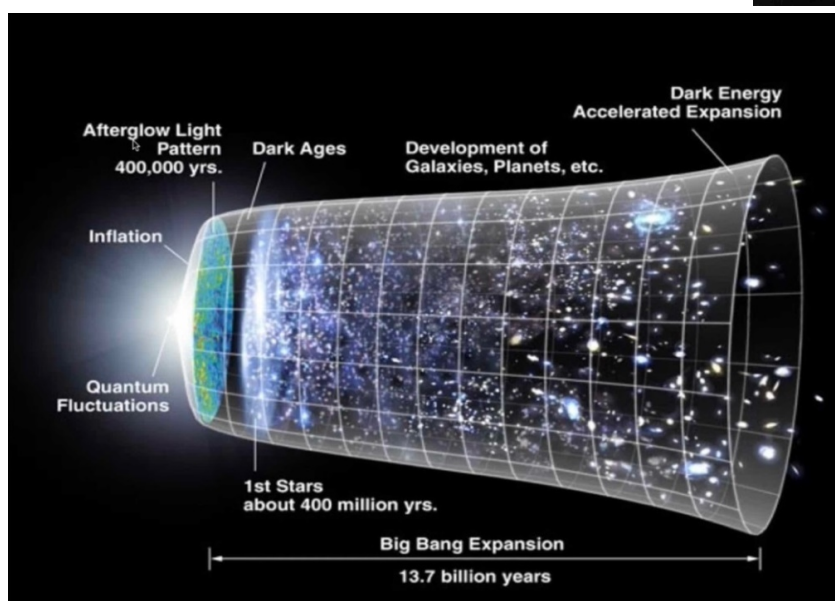
It is named after James Webb, the NASA administrator from 1961 to 1968. Throughout his period in office, programmes key to US exploration of space began to reach beyond close earth orbits. Apollo, conducted over 50 years ago, placed 'man on the Moon' and he later encouraged and supported un-manned programs that looked deeper into space, the most notable being the Hubble Space Telescope and Chandra X-ray Observatory. He did not live to see what finally emerged from his 'large scale' approach, but his name was much honoured at NASA. His successor announced that the latest telescope, able to look beyond the

galaxy and designed to reveal the first stars and galaxies to form, would be named the "James Webb Space Telescope."

James Webb is seen here with President John Kennedy who appointed him as NASA Administrator in 1961. He managed NASA during the period of early manned flights, and throughout the development of the Apollo program.



To detect radiation from deeper space (i.e. further back in space and time than Hubble can) requires JWST to conduct Infra-red observations with wavelengths between 0.6 and 28 microns by instruments operating at temperatures of 40K (-233C) and colder.

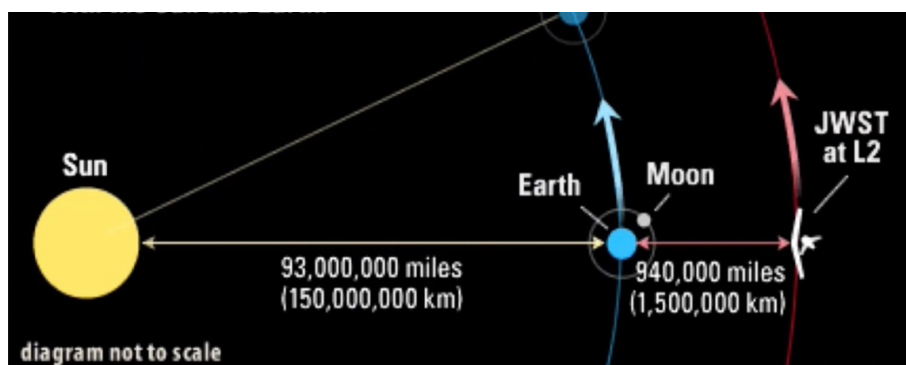


Astronomical research has suggested the expansion rate of the universe places the Big Bang singularity at around 13.8 billion years ago. This is a schematic diagram of the universe since that time. The diameter shown is representative of the universe expanding over time. The horizontal scale represents time.

The JWST has sensors that should be able to detect events as early as when the first stars were being formed.

To minimise the possibility of sensors

being affected by radiation from the sun and earth the JWST will be in an orbit around a location almost 1.5 million km away from the Earth, and directly on a straight line from the sun that passes through the Earth. This is referred to as the Lagrange 2 (L2) point. A general description of a Lagrange point is that the gravitational and centrifugal force of two large bodies, much larger than the satellite, will maintain its position relative to the Earth and Sun.



The day of our meeting happened to be the date when the completed JWST was arriving at the ESA launch site at Kourou in French Guiana. The complete satellite had been assembled in the US, and moved by sea from the US west coast, and through the Panama Canal. It was in a container with all the elements in place, and stowed as they will be when launched. The telescope primary mirror is large at 6.5m diameter and has to be launched as folded up to fit in the 5m diameter Ariane 5.

The telescope was undergoing pre-launch tests soon after arrival, and current plans are that the launch will take place 18th December 2021. The launch site is almost equatorial, and following the the trajectory will take less than 2 days to reach the same distance from Earth as the Moon's orbit. Thereafter it will take another 27 days to reach Lagrange L2.



The photograph to the left shows the complete assembly before it was ready to leave the test facilities in the US. The upper section is open, showing the hexagonal sections of the telescope antenna. The right hand side is hinged and would have been turned through 180° in preparation for the journey to Kourou.

The photograph **below** shows a full-scale mock-up, shown here at the NASA Goddard facility. It reveals the considerable size of the JWST when the telescope antenna and the multi-plate sun shield components have been fully deployed.

It is larger than the Hubble telescope, in use already using visible wavelength sensors to gather high-resolution images.



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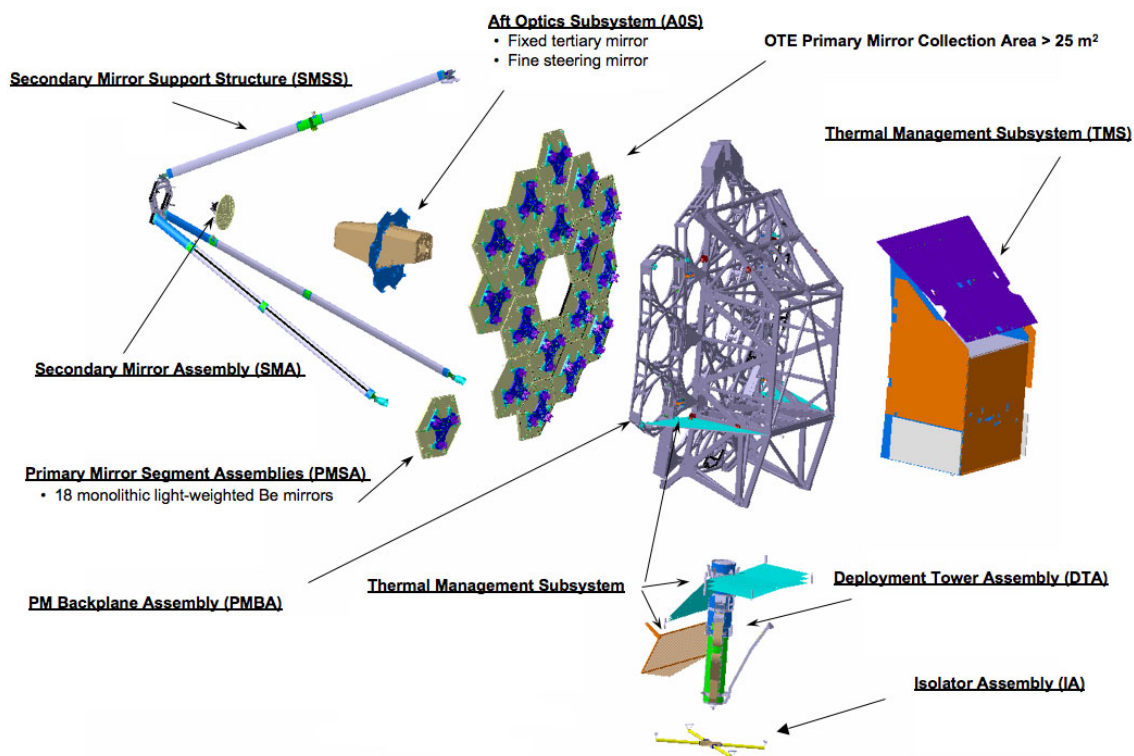


Diagram of the sensor elements on the JWST

The overall telescope design is a 3-mirror anastigmat mirror system, widely used in astronomical observatories. The primary (large) mirror collects light that is reflected onto a much smaller, secondary mirror, mounted ahead of the main mirror. The secondary mirror has a curved surface that reflects the light back towards the main mirror, and then via a tertiary and steering mirror system concentrates it to be received by a cluster of imaging sensors (ie the instruments) mounted behind the primary mirror.

The telescope's primary mirror has a 25m² surface area that has a thin gold coating (the thickness is only 100×10^{-9} metres (1,000 angstroms)). Overall the coating mass is only 48.25 grammes (about the same as that of a golf ball).

There are three major instruments on JWST plus the Canadian contribution of the Fine Guidance Sensor (FGS) that allows Webb to point precisely so that it can obtain high-quality images. FGS also incorporates a Near Infrared Imager and Slitless Spectrograph. All the instruments have been designed to meet lightweight optic requirements and have been assembled throughout the countries engaged.

Near infra-red camera (NIRCam) This US-developed sensor has been created by the University of Arizona, with Lockheed-Martin's Advanced Technology Center (Palo Alto, California).

Near Infra-red spectrograph (NIRSpec) The European Space Agency at ESTEC (Noordwijk, Netherlands) used a development team that included Airbus Defence and Space (Ottobrunn and Friedrichshafen, Germany), and the Goddard Space Flight Center (NASA) with École Normale Supérieure de Lyon (France).

Mid-InfraRed Instrument (MIRI) This was developed as a collaboration between NASA and a consortium of European agencies and institutes. Our speaker was the European Consortium Project Manager based at Airbus Stevenage. Because they work in the mid-infrared the MIRI detectors need to operate at around 7 degrees Kelvin and MIRI uses a US-supplied helium gas mechanical cooler to achieve this. The cryocooler is located on the warm side of the 'sun shield' in the spacecraft 'bus'.

Our speaker provided much data across all aspects of the project. His perspectives were routed around the work conducted in Europe, and also revealed how essential it is to develop and certify their contributions. He stressed that we must not expect images to be released immediately JWST is in place and all systems have begun to provide data. The first fully commissioned and calibrated science data is expected to be available by April 2022 but some early images may be publicly released before this.

Many thanks to all those who did join in on what was a very informative and pleasant presentation. Due to what we hope are residual consequences of recent social distancing rules, attendance figures were 26 in the auditorium and joined by 18 more on-line. John Thatcher's closing comment illustrates what the project has set out to provide to everyone.

"We will literally see our Universe in a whole new light!"

Notes by Mike Hirst