EUROPEAN SPACE AGENCY

NGST

OBSERVING THE FIRST LIGHT IN THE UNIVERSE

The Next Generation Space Telescope (NGST) follows the highly successful Hubble Space Telescope (HST) with a scheduled launch late in this decade. NGST will be larger and more powerful than Hubble.

The primary mirror will be 8 metres in diameter and capable of gathering ten times more light than Hubble. NGST will be launched into a special orbit that will keep it 1.5 million km from Earth (four times the distance to the Moon). By remaining in the shadow cast by a huge sunshield, NGST and its instruments will gradually cool to -240° C, giving the telescope an extraordinary sensitivity over a wide range of wavelengths in the infrared region of the spectrum.

ESA's active participation in Hubble from the very beginning has not only been hugely beneficial scientifically to European astronomers, but has also promoted competitiveness and cross-border collaboration within European science as a whole. Since 1997, NASA and ESA – joined by the Canadian Space Agency (CSA) – have collaborated on this worthy successor.

The most important goal for NGST is to see light from the very first stars and galaxies forming after the Big Bang – objects which are beyond the reach of today's telescopes.

esa

NGST spacecraft study: TRW/Ball

THE SCIENCE

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NGST is intended to solve outstanding key questions concerning our place within the evolving Universe.

In order to guide the design of the telescope and its instruments, five general topics have been identified as the core scientific themes for NGST.

1. Cosmology and the Structure of the Universe

How large and how old is the Universe and what is its ultimate fate?

NGST will help us to determine the geometry of the Universe and enable us to establish whether the Universe will continue to expand forever. Today we see indications that the expansion is actually accelerating, rather than decelerating under the influence of gravity from its constituent matter. NGST will be able to observe supernovae in the remote past. By using these "standard candles" of known brightness, astronomers will be able to measure the size and geometric structure of the Universe.

NGST will also be uniquely powerful for studying the effects of the mysterious dark matter. We know that this strange form of matter constitutes more than 90% of the mass of the Universe. Although NGST, like other telescopes, can only observe luminous objects, it will be able to detect subtle distortions in the shapes of the most distant galaxies caused by the gravitational deflections of the intervening mass which cannot be seen directly.

2. Origin and Evolution of Galaxies

What were the first sources of light in the Universe, and how and when did galaxies like our own Milky Way form?

We live on the threshold of being able to see the first luminous objects in the Universe. For the first time in human history we have the opportunity to investigate the origin of galaxies directly. The term "dark ages" is used today to describe the epoch shortly after the beginning of the Universe when the microwave background radiation was emitted - up to the period where stars and galaxies became common. This period lasted some 1-2 billion years, but the first objects to illuminate the darkness are too faint to be detected by present-day telescopes.

One of the main strengths of NGST lies in its ability to probe the infrared region of the spectrum with exquisite sensitivity. This will enable it to see further than optical telescopes and catch the feeble, redshifted light from the most distant objects.

3. History of the Milky Way and its Neighbours

How old are the stars in our Milky Way and its neighbours - and what do these stars tell us of their origins?

The stars in our "local" Universe - in our own galaxy and in its neighbours - represent a fossil record of their evolutionary history. NGST will be able to read this fossil history for a large number of our neighbouring galaxies, extending significantly the work started on our nearest companions by Hubble.

In addition to acting as a time machine for the study of the most remote galaxies in the distant past, NGST will also be able to decipher the history of our surroundings.

4. Birth and Formation of Stars

How and where do stars form, and what determines how many form and their masses?

Stars are the "witches' cauldrons of the Universe" - they transform the simple light elements into heavier elements and spread them among the stars. The heavier elements are crucially important for the creation of planets, and in turn, also for life itself. The birth of the first stars triggered the continuing chain of cosmic recycling to which we owe our existence. The processes by which stars, their surrounding protoplanetary discs and planets themselves are made remain poorly understood.

Using the infrared part of the spectrum, NGST will be able to penetrate the dusty envelopes around newborn stars and take a closer look at the stars themselves. NGST will also have the sensitivity to study very small objects that are not massive enough to become stars. These objects - brown dwarfs and Jupiter-sized planets - will become targets for intensive study with NGST.

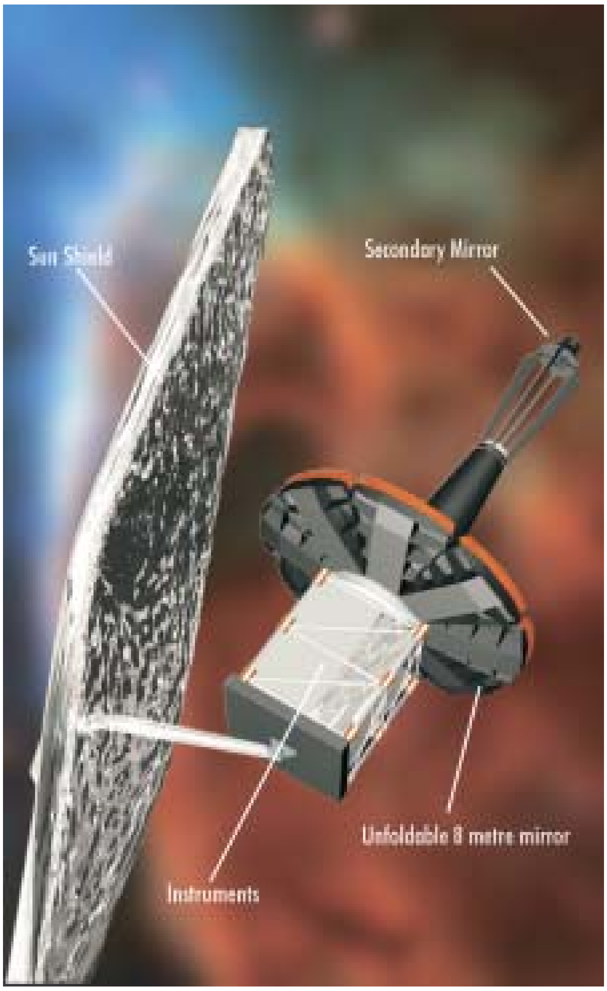
5. Origin and Evolution of Planetary Systems

Where and how do planetary systems form and evolve?

Until recently the only planetary system we could study was our Solar System. Now astronomers have found a number of signatures of other such systems. Although the planets themselves are difficult to image directly, the high resolution of NGST will make it possible to see how other planetary systems form, and in this way enable us to piece together a picture of how other solar systems evolve.

THE TECHNOLOGY

There is no doubt that building NGST will be a considerable technological challenge.



Infrared astronomy needs cold instruments

The expansion of the Universe means that the further back astronomers look in time, the more light gets shifted to longer wavelengths. Longer wavelengths mean redder light, and ultimately the light from the most remote objects in the Universe will be in the infrared when it is received.

Observing infrared light is not easy – all objects in the Universe emit infrared light, also known as heat radiation – even telescopes. Optical telescopes are put in dark places for the best results and infrared ones need to be kept as cold as possible in order not to confuse the observations with infrared radiation from instruments and telescope structures. In NGST the instruments will have to be cooled to –240° C. How will it be possible to cool very advanced electronic and mechanical parts to a temperature where metal is as brittle as glass? Let alone make every component work under these extreme conditions for five to ten years?

Far away

NGST will be placed 1.5 million km away from the disturbing radiation of the Earth at the so-called L2 point. L2 is a nearly stable point in the direction opposite the Sun where the system of forces from the Sun and the Earth keeps an object rotating around the Sun in synchronisation with the Earth. However this remote location also puts very strict constraints on the specifications of NGST and in particular on its weight and the communication systems.

Bigger is better

The collecting area of NGST is one of its most important advantages. Even though Hubble only has 1/17 the collecting area of today's largest ground-based telescopes, its images are much sharper and fainter objects can be detected than is possible from the ground. One can only imagine what a telescope with ten times the collecting power of Hubble will be able to do scientifically.

One of the major technological challenges will be to pack an 8 metre telescope into a small rocket with a diameter of 5-6 metres. The only way to solve the problem is to divide the mirror into several parts and to fold it up like the petals of a flower during launch. When the mirror is unfolded on the way to L2, ultra-precise mechanisms will adjust the position of each petal with extreme accuracy. Some of the scientists working on the construction of NGST have described it as "a bit like designing a ship in a bottle".

Technological challenges

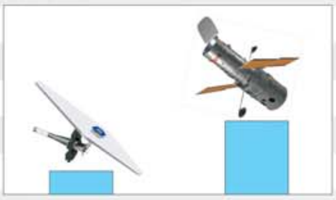
- Folding up a large, very accurate 8 metre mirror, fitting it into a rocket with a diameter of 5-6 metres, and unfolding and adjusting the mirror petals to high accuracy after launch.
- Cooling instruments and mechanisms to –240° C and making them work at such extreme temperatures. It will also be a challenge to prevent the electronics from radiating heat and thus heating up the instrument bay.
- Constructing the large telescope, the very large sunshade (the size of a tennis court), and the large instruments with a total weight of less than 3300 kg (less than 1/3 of Hubble's weight). The mirror will have to have a surface density similar to that of a coin so as not to be too heavy.
- Designing and manufacturing the new very sensitive instruments and detectors. NGST has to be extremely reliable and stable, despite utilising new and innovative technology. In the L2 orbit approximately 1.5 million kilometres from Earth it is not possible for astronauts to perform service missions as has been done with Hubble.
- Constructing, launching and operating NGST at a cost significantly below that of its predecessors.

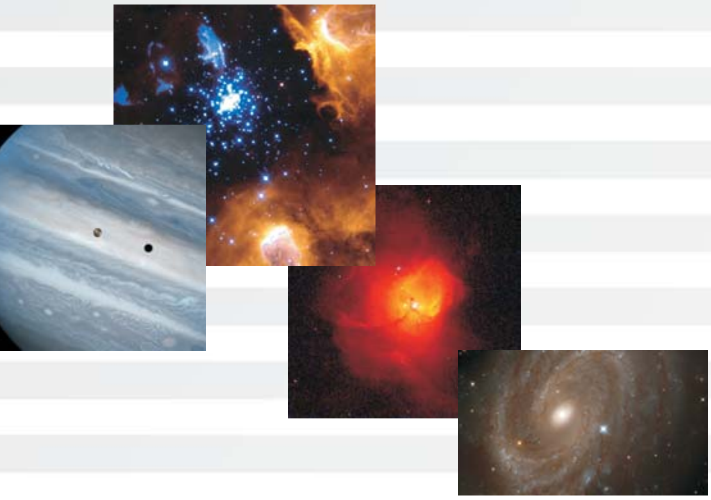
THE HERITAGE FROM HUBBLE

Hubble and NGST compared in size and weight

SIZE

WEIGHT





Ground-based and space-based astronomy

Hubble has been very successful as the first large-scale space-based observatory. Compared to the many 8-10 metre telescopes which already exist or are being built today, Hubble is certainly not very large – its light-collecting surface is almost 20 times smaller than the largest telescopes on Earth.
However, one of the biggest challenges to ground-based astronomy is the degradation of images by the Earth's atmosphere, whereas space-based observatories enjoy the perfect clarity of space.

Space observatories like Hubble and NGST work closely together with their ground-based counterparts in an extremely fruitful collaboration. The big telescopes can gather more light in a shorter time, which is essential for applications such as spectroscopy where the composition of stars, galaxies and other objects are investigated. Space-based observatories allow a closer look at the structure of objects, and big ground-based telescopes deliver the key to their composition. Together the two types of telescopes are highly productive and complementary, enabling astronomers to determine the true nature of the observed objects.

Experiences from Hubble

NGST will benefit from experience gained with Hubble – both in terms of the operation of a large space-based observatory and the science it can carry out. Although NGST will mainly be sensitive to wavelengths beyond the reach of Hubble and groundbased telescopes, NGST's main scientific areas will largely be the logical extension of areas where Hubble already has proved successful.
Hubble's deep imaging has lifted a corner of the veil hiding the remote parts of the Universe. NGST will continue the scientific strategies of Hubble and continue to expand our horizons in terms of distance and time.

Comparisons of Hubble and NGST

	HUBBLE	NGST
DIAMETER OF MAIN MIRROR	2.4 m	8 m
LOCATION	Low Earth orbit (600 km)	Far from Earth in L2 (1.5 million km)
LAUNCH	Space Shuttle	Unmanned launcher
WEIGHT	11 tonnes	3 tonnes
LIFETIME	20 years	5-10 years
SERVICING MISSIONS	5-6 planned	No
OPERATING TEMPERATURE	20° C	-240° C
MIRROR	Rigid, heavy, ceramic	Deployable, thin, active, light
WAVELENGTH RANGE	0.1 - 2.5 microns (100 - 2,500 nm)	0.6 - 28 microns (600 - 28,000 nm)
RESOLUTION	0.05 arcseconds (at 500 nm)	0.05 arcseconds (at 2 microns)