

All About European Space Agency (Facilities, Research Centres and Programs)



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Chapter- 1

European Space Agency



Owner	18 European states
Established	1975
Headquarters	Paris
Primary spaceport	Guiana Space Centre
Administrator	Jean-Jacques Dordain
Budget	▲€3.99 billion / \$5.43 billion US dollars (2011)
Official language(s)	English, French and German

The **European Space Agency (ESA)**, established in 1975, is an intergovernmental organisation dedicated to the exploration of space, currently with 18 member states. Headquartered in Paris, ESA has a staff of more than 2,000 with an annual budget of about €3.99 billion / \$5.43 billion US dollars (2011).

ESA's space flight program includes human spaceflight, mainly through the participation in the International Space Station program, the launch and operations of unmanned exploration missions to other planets and the Moon, Earth observation, science,

telecommunication as well as maintaining a major spaceport, the Guiana Space Centre at Kourou, French Guiana, and designing launch vehicles. The main European launch vehicle Ariane 5 is operated through Arianespace with ESA sharing in the costs of launching and further developing this launch vehicle.

ESA science missions are based at ESTEC in Noordwijk, Netherlands, Earth Observation missions at ESRIN in Frascati, Italy, ESA Mission Control (ESOC) is in Darmstadt, Germany, the European Astronaut Centre (EAC) that trains astronauts for future missions is situated in Cologne, Germany, and the European Space Astronomy Centre is located in Villanueva de la Cañada, Spain.

History

Foundation



ESTEC buildings in Noordwijk. ESTEC was the main technical centre of ESRO and remains so for the successor organization, ESA

After World War II, many European scientists left Western Europe in order to work either in the United States or the Soviet Union. Although the 1950s boom made it possible for Western European countries to invest in research and specifically in space

related activities, Western European scientists realised solely national projects would not be able to compete with the two main superpowers. In 1958, only months after the Sputnik shock, Edoardo Amaldi and Pierre Auger, two prominent members of the western European scientific community at that time, met to discuss the foundation of a common western European space agency. The meeting was attended by scientific representatives from eight countries, including Harrie Massey (UK).

The Western European nations decided to have two different agencies, one concerned with developing a launch system ELDO (European Launch Development Organization) and the precursor of the European Space Agency, ESRO (European Space Research Organization). The latter was established on 20 March 1964 by an agreement signed on 14 June 1962. From 1968 to 1972, ESRO carried out numerous successful projects. Seven research satellites were brought into orbit, all by US launch systems. Ariane did not exist at that time.

ESA in its current form was founded in 1975, when ESRO was merged with ELDO. ESA had 10 founding members: Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom. ESA launched its first major scientific mission in 1975, Cos-B, a space probe monitoring gamma-ray emissions in the universe first worked on by ESRO.

End of space race



Mock-up of the Ariane 1

Beginning in the 1970s, when the space race between the US and the Soviet Union had cooled down and space budgets were cut dramatically in both countries, ESA established itself as a forerunner in space exploration. ESA joined NASA in the IUE, the world's first high-orbit telescope, which was launched in 1978 and operated very successfully for 18 years. A number of successful Earth-orbit projects followed, and in 1986 ESA began Giotto, its first deep-space mission, to study the Comets Halley and Grigg-Skjellerup. Hipparcos, a star-mapping mission, was launched in 1989 and in the 1990s SOHO, Ulysses and the Hubble Space Telescope were all jointly carried out with NASA. Recent scientific missions in cooperation with NASA include the Cassini-Huygens space probe, to which ESA contributed by building the Titan landing module Huygens.

As the successor of ELDO, ESA has also constructed rockets for unmanned scientific and commercial payloads. Ariane 1, launched in 1979, brought mostly commercial payloads into orbit from 1984 onward. The next two developments of the Ariane rocket were intermediate stages in the development of a more advanced launch system, the Ariane 4, which operated between 1988 and 2003 and established ESA as the world leader in commercial space launches in the 1990s. Although the succeeding Ariane 5 experienced a failure on its first flight, it has since firmly established itself within the heavily competitive commercial space launch market with 40 successful launches as of 2009. The successor launch vehicle of Ariane 5, the Ariane 6 is already in the definition stage and is envisioned to enter service in the 2020s.

The beginning of the new millennium saw ESA become, along with agencies like NASA, JAXA, ISRO and Roscosmos, one of the major participants in scientific space research. While ESA had relied on cooperation with NASA in previous decades, especially the 1990s, changed circumstances (such as tough legal restrictions on information sharing by the United States military) led to decisions to rely more on itself and on cooperation with Russia. A recent press issue thus stated:

Russia is ESA's first partner in its efforts to ensure long-term access to space. There is a framework agreement between ESA and the government of the Russian Federation on cooperation and partnership in the exploration and use of outer space for peaceful purposes, and cooperation is already under way in two different areas of launcher activity that will bring benefits to both partners.

Most notable for its new self-confidence are ESA's own recent successful missions SMART-1, a probe testing cutting-edge new space propulsion technology, the Mars Express and Venus Express missions as well as the development of the Ariane 5 rocket and its role in the ISS partnership. ESA maintains its scientific and research projects mainly for astronomy-space missions such as Corot, launched on 27 December 2006, a milestone in the search for extrasolar planets.

Mission statement

Since the Cold War ended with the fall of the Soviet Union's "iron curtain", space agencies around the world had to refocus and revise their visions and goals. In an interview with JAXA, the Japanese national space agency, Jean-Jacques Dordain ESA's Director General (since 2003) outlined briefly the European Space Agency's mission:

Today space activities are pursued for the benefit of citizens, and citizens are asking for a better quality of life on earth. They want greater security and economic wealth, but they also want to pursue their dreams, to increase their knowledge, and they want younger people to be attracted to the pursuit of science and technology.

I think that space can do all of this: it can produce a higher quality of life, better security, more economic wealth, and also fulfil our citizens' dreams and thirst for knowledge, and attract the young generation. This is the reason space exploration is an integral part of

overall space activities. It has always been so, and it will be even more important in the future.

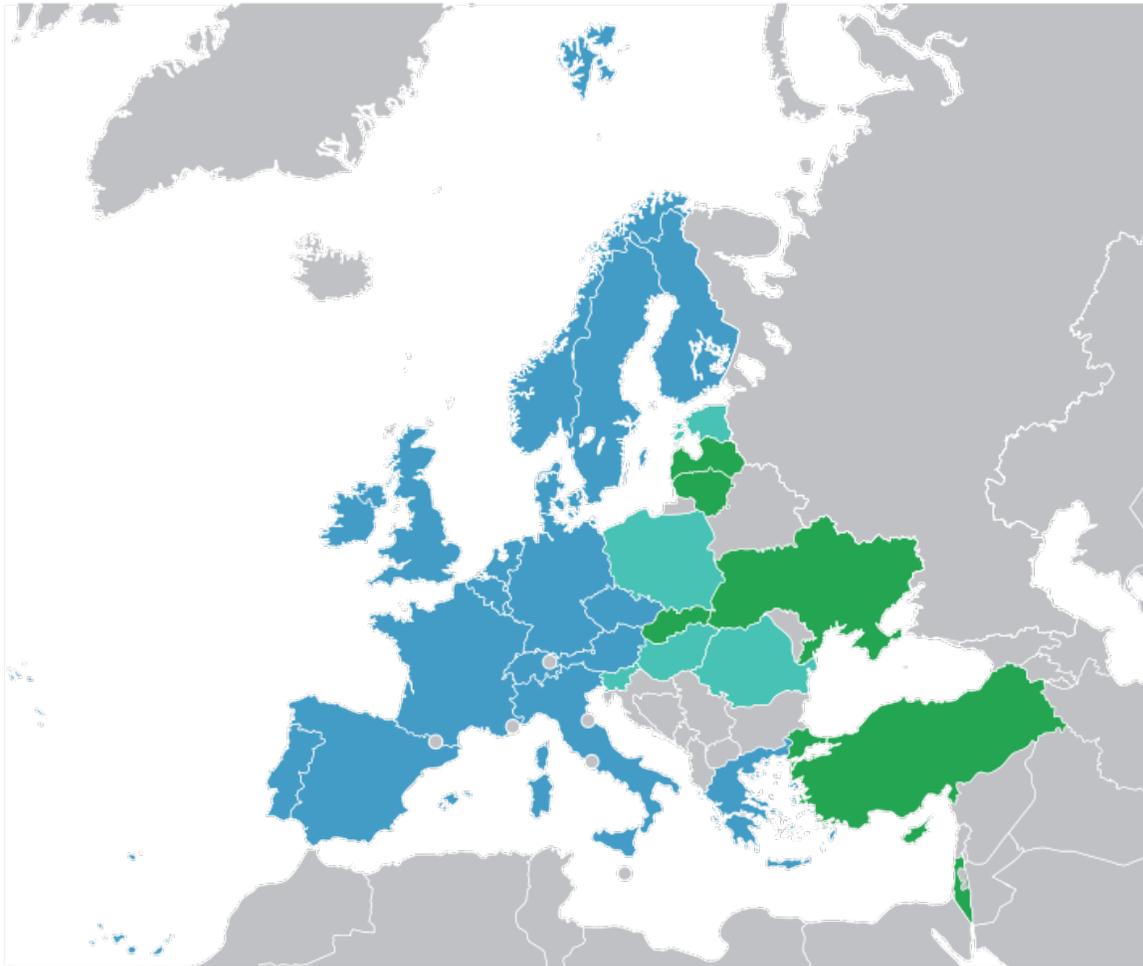
Article II, Purpose, Convention of establishment of a European Space Agency, SP-1271(E) from 2003 also defines ESA's mission statement:

ESA's purpose shall be to provide for, and to promote, for exclusively peaceful purposes, cooperation among European States in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems:

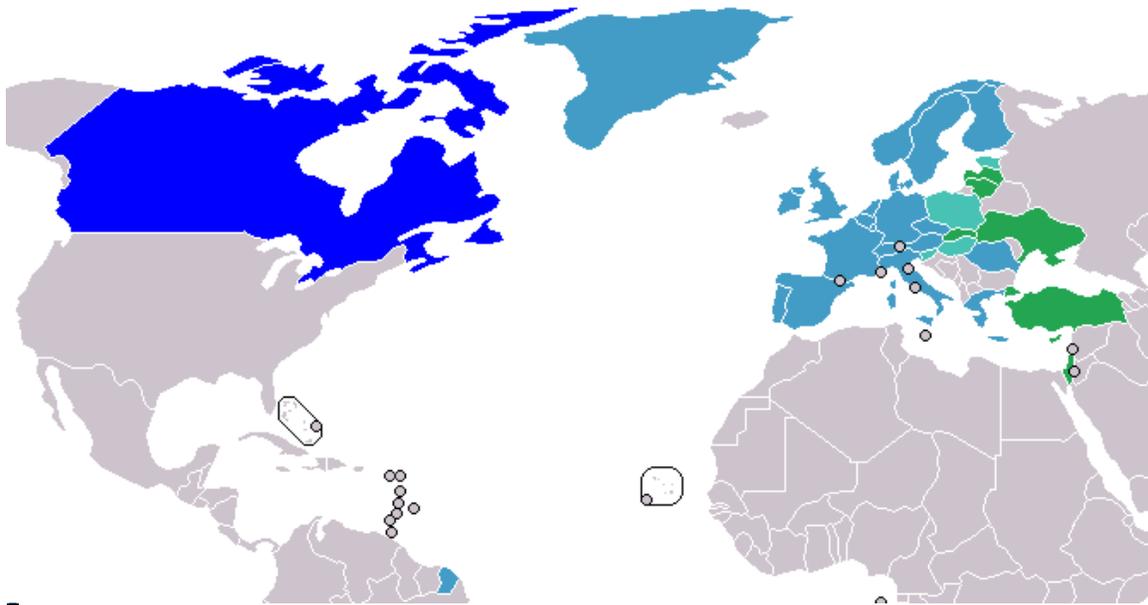
- by elaborating and implementing a long-term European space policy, by recommending space objectives to the Member States, and by concerting the policies of the Member States with respect to other national and international organisations and institutions;
- by elaborating and implementing activities and programmes in the space field;
- by coordinating the European space programme and national programmes, and by integrating the latter progressively and as completely as possible into the European space programme, in particular as regards the development of applications satellites;
- by elaborating and implementing the industrial policy appropriate to its programme and by recommending a coherent industrial policy to the Member States.

Member countries and budget

Membership and contribution to ESA



- ESA member countries
- ECS states
- signed Cooperation Agreement



- ESA member countries
- ESA associate members
- ECS states
- signed Cooperation Agreement

ESA is an intergovernmental organisation of 18 member states. Member states participate to varying degrees in the mandatory (25% of total expenditures in 2008) and optional space programmes (75% of total expenditures in 2008). The total budget in 2010 amounted to about €3.7 billion. The 2008 budget amounted to €3.0 billion and the 2009 budget to €3.6 billion.

The following table gives an overview of all member states and adjunct members and their contributions to ESA in 2011:

Member state	ESA membership	National Program	Contr. (mill. €)	Contr. (%)
 France	30 October 1980	CNES	751.4	18.8%
 Germany	30 October 1980	DLR	713.8	17.9%
 Italy	30 October 1980	ASI	380.0	9.5%
 United Kingdom	30 October 1980	UKSA	265.3	6.6%
 Spain	30 October 1980	CDTI	201.9	5.1%
 Belgium	30 October 1980	BELSPO	164.8	4.1%
 Netherlands	30 October 1980	NSO	84.2	2.1%
 Switzerland	30 October 1980	SSO	96.2	2.4%
 Sweden	30 October 1980	SNSB	59.9	1.5%
 Denmark	30 October 1980	DTU Space	31.2	0.8%

 Ireland	10 December 1980	EI	15.6	0.4%
 Norway	30 December 1986	NSC	63.2	1.6%
 Austria	30 December 1986	FFG	54.0	1.3%
 Finland	1 January 1995	TEKES	20.1	0.5%
 Portugal	14 November 2000	FCT	15.8	0.4%
 Greece	9 March 2005	ISARS	14.9	0.4%
 Luxembourg	30 June 2005	Luxinnovation	11.5	0.3%
 Czech Republic	8 July 2008	CSO	10.4	0.3%
Associate Members				
 Canada	1 January 1979	CSA	20.5	0.5%
Total Members and Associates			2,975.0	74.5%
 European Union	28 May 2004	ESP	777.9	19.5%
ECS states	various	various	7.9	0.2%
Other income	—	—	233.0	5.8%
Total ESA			3,993.8	100.0%

1. ^{^ a b c d e f g h i j k} Founding members drafted the ESA charter which entered into force on 30 October 1980.
2. [^] Ireland is considered an initial signatory, but since it was a member of neither ESRO nor ELDO (the precursor organizations to ESA) the Convention entered into force when the last of the other 10 founders ratified it.
3. ^{^ a b c d e f g} Acceded members became ESA member states upon signing an accession agreement.
4. [^] Canada is an associated member of ESA.
5. [^] Framework Agreement establishing the legal basis for cooperation between ESA and the European Union came into force in May 2004.

Associate Members

Currently the only associated member of ESA is Canada. Previously associated members were Austria, Norway and Finland, all of which later joined ESA as full members.

Canada

Since 1 January 1979, Canada has had the special status of a Cooperating State within ESA. By virtue of this accord, the Canadian Space Agency takes part in ESA's

deliberative bodies and decision-making and also in ESA's programmes and activities. Canadian firms can bid for and receive contracts to work on programmes. The accord has a provision ensuring a fair industrial return to Canada.

Budget appropriation and allocation

The budget of ESA was €2.977 billion in 2005, €2.904 billion in 2006 and grew to €3.018 billion in 2008 and €3.600 billion in 2009. Every 3–4 years, ESA member states agree on a budget plan for several years at an ESA member states conference. This plan can be amended in future years, however provides the major guideline for ESA for several years. The last major conference was held at the end of 2008, setting the budget for the years to 2012.

The 2011 funding allocations for major areas of ESA activity are shown on the pie-chart on the right. The section called 'Other' includes Technology Development, Space Situational Awareness and spending related to European Cooperating States.

Countries typically have their own space programmes that differ in how they operate organisationally and financially with ESA. For example, the French space agency CNES has a budget double the amount it contributes to ESA. Several space-related projects are joint projects between national space agencies and ESA (e.g. COROT). Also, ESA is not the only European space organisation (for example European Union Satellite Centre).

Enlargement

After the decision of the ESA Council of 21/22 March 2001 the procedure for accession of the European states was detailed as described here. Nations who want to become a full member of ESA do so in 3 stages. First a Cooperation Agreement is signed between the country and ESA. In this stage, the country has very limited financial responsibilities. If a country wants to cooperate more fully with ESA, it signs a European Cooperating State (ECS) Agreement. The ECS Agreement makes companies based in the country eligible for participation in ESA procurements. The country can also participate in all ESA programmes, except for the Basic Technology Research Programme. While the financial contribution of the country concerned increases, it is still much lower than that of a full member state. The agreement is normally followed by a Plan For European Cooperating State (or PECS Charter). This is a 5-year programme of basic research and development activities aimed at improving the nation's space industry capacity. At the end of the 5-year period, the country can either begin negotiations to become a full member state or an associated state or sign a new PECS Charter. ESA is likely to expand quite rapidly in the coming years. Many countries, most of which joined the EU in both 2004 and 2007, have started to cooperate with ESA on various levels:

Applicant state	Cooperation Agreement	ECS Agreement	PECS Charter(s)	ESA Convention	National Program
 Hungary	April 1991	7 April 2003	1st: 5		HSO

			November 2003 2nd: 26 September 2008		
 Romania	December 1992	17 February 2006	16 February 2007	20 January 2011	ROSA
 Poland	28 January 1994	27 April 2007	28 April 2008		CBK-PAN
 Turkey	15 July 2004				TÜBİTAK
 Estonia	26 June 2007	10 November 2009			through MoEC
 Ukraine	25 January 2008				SSAU
 Slovenia	28 May 2008	22 January 2010	30 November 2010		through MoHEST
 Latvia	23 July 2009				through MoES
 Cyprus	27 August 2009				through MoCW
 Slovakia	28 April 2010				through MoE
 Lithuania	7 October 2010				through MoE
 Israel	30 January 2011				ISA

Romania signed the ESA Convention on 20 January 2011 and will become the 19th member of ESA once it deposits its instrument of ratification with the government of France. This is due to happen later in 2011.

Possible future cooperation

The political perspective of the European Union (EU) is to make ESA an agency of the EU by 2014.

So far the only two EU member states that have not signed an ESA Cooperation Agreement are Bulgaria and Malta. Both of them, however, have already announced their intention to join ESA.

-  Bulgaria on 9 April 2009 announced their intention to participate in the activities of ESA through IKI-BAN.
-  Malta on 20 June 2009 announced their intention to participate in the activities of ESA through the Malta Council for Science and Technology.

Launch vehicle fleet

ESA has made great progress towards its goal of having a complete fleet of launch vehicles in service, competing in all sectors of the launch market. ESA's fleet will soon consist of three major rocket designs, Ariane 5, Soyuz-2 and Vega. Rocket launches are carried out by Arianespace, which has 23 shareholders representing the industry that manufactures the Ariane 5 as well as CNES, at the spaceport in French Guiana. Because many communication satellites have equatorial orbits, launches from French Guiana are able to take larger payloads into space than from more northerly spaceports. In addition, equatorial launches give spacecraft an extra 'push' of nearly 500 m/s due to the higher rotation velocity of someone standing on the equator than near the Earth's axis where rotation velocity approaches nil.

Ariane 5



An Ariane 5

The Ariane 5 rocket is the primary launcher of ESA. Its maximum estimated payload is 6–10 tons to GTO and up to 21 tons to LEO. The launch craft has been in service since 1997 and replaced Ariane 4. The Ariane rocket exists in several specifications, the heaviest being Ariane 5 ECA, which failed during its first test flight in 2002, but has since made twenty-two consecutive successful flights.

ESA's Ariane 1, 2, 3 and 4 launchers (the latter of which was ESA's long-time workhorse) have been retired.

Soyuz

Soyuz-2 (also called the Soyuz-ST) is a Russian medium payload (ca. 3 metric tons to GTO) launcher to be brought into ESA service in April 2010. ESA has entered into a €340 million joint venture with the Russian Federal Space Agency over the use of the Soyuz launcher. Under the agreement, the Russian agency manufactures Soyuz rocket parts for ESA, which are then shipped to French Guiana for assembly. ESA benefits because it gains a medium payload launcher, complementing its fleet while saving on development costs. In addition, the Soyuz rocket—which has been the Russian's space launch workhorse for some 40 years—is proven technology with a good safety record, which ESA might use for launching humans into space. Russia also benefits in that it gets access to the Kourou launch site. Launching from Kourou rather than Baikonur will allow the Russians to almost double the Soyuz payload (3.0 tonnes vs. 1.7 tonnes to GTO), because of Kourou's closer proximity to the equator. Both agencies benefit from the long term strategic cooperation, which is also intended to enable future joint technology developments. Maiden launch is planned for third quarter 2011.

Vega

Vega is ESA's small payload (ca. 1.5 metric tons to 700 km orbit) launcher; its first launch is planned for 2010 or early 2011. The leading ESA member state for the *Vega* Programme is Italy, contributing 65% of the costs. *Vega* itself has been designed to be a body launcher with three solid propulsion stages and an additional liquid propulsion upper module to place the cargo into the exact orbit intended. For a small-cargo rocket it is remarkable that *Vega* will be able to place multiple payloads into orbit.

Vega's first and main stage (P80) is a direct modification of the Ariane 5 EAP (solid boosters) developed by CNES, the French space agency.

Human space flight

History



Ulf Merbold became the first ESA astronaut to fly into space.

At the time ESA was formed, its main goals did not encompass human space flight, rather it considered itself to be primarily a scientific research organisation for unmanned space exploration in contrast to its American and Soviet counterparts. It is therefore not surprising that the first non-Soviet European in space was not an ESA astronaut on a European space craft: It was Czechoslovak Vladimír Remek who in 1978 became the first non-Soviet European in space (the first European in space being Yuri Gagarin of the Soviet Union) — on a Soviet Soyuz spacecraft, followed by the Pole Mirosław

Hermaszewski and East German Sigmund Jähn in the same year. This Soviet cooperation programme, known as Intercosmos, primarily involved the participation of Eastern bloc countries, however in 1982, Jean-Loup Chrétien became the first western European on a flight to the Soviet Salyut 7 space station.

Because Chrétien did not officially fly into space as an ESA astronaut, but rather as a member of the French CNES astronaut corps, the German Ulf Merbold is considered the first ESA astronaut to fly into space. He participated in the STS-9 Space Shuttle mission that included the first use of the European built Spacelab in 1983. STS-9 marked the beginning of an extensive ESA/NASA joint partnership that included dozens of space flights of ESA astronauts in the following years. Some of these missions with Spacelab were fully funded and organizationally and scientifically controlled by ESA (like separate two by Germany and one by Japan) with European astronauts as masters not a guests on a board. Beside paying for Spacelab flights and seats on the shuttles, ESA continued its human space flight cooperation with the Soviet Union and later Russia, including numerous visits to Mir.

During the latter half of the 1980s, European human space flights changed from being the exception to routine and therefore, in 1990, the European Astronaut Centre in Cologne, Germany was established. It selects and trains prospective astronauts and is responsible for the coordination with international partners especially with regards to the International Space Station. As of 2006, the ESA astronaut corps officially includes 12 members, including nationals from all the large Western European countries except the United Kingdom.

In the summer of 2008 ESA started to recruit new astronauts so that final selection would be due spring 2009. Almost 10,000 people registered as astronaut candidates till the registration ended in June 2008. 8,413 fulfilled the initial application criteria. Of the applicants 918 were chosen to take part in the first stage of psychological testing which narrowed down the field to 192. After two stage psychological tests and medical evaluation in early 2009 as well as formal interviews, six new members of the European Astronaut Corps were selected: five men and one woman.

Astronaut Corps

The astronauts of the European Space Agency are:

-  Jean-François Clervoy
-  Samantha Cristoforetti
-  Frank De Winne
-  Pedro Duque
-  Reinhold Ewald
-  Léopold Eyharts
-  Alexander Gerst
-  Christer Fuglesang
-  André Kuipers
-  Andreas Mogensen
-  Paolo Nespoli
-  Claude Nicollier
-  Luca Parmitano
-  Timothy Peake
-  Thomas Pesquet
-  Thomas Reiter
-  Hans Schlegel
-  Gerhard Thiele
-  Michel Tognini
-  Roberto Vittori

-  Umberto Guidoni
-  Philippe Perrin

1. ^{^ a b c d e} have visited Mir
2. ^{^ a b c d e f} 2009 selection
3. ^{^ a b c d e f g h i j k} have visited the International Space Station
4. ^{^ a b c d e} retired now

Manned launch vehicles

In the 1980s France pressed for an independent European manned launch vehicle. Around 1978 it was decided to pursue a reusable spacecraft model and starting in November 1987 a project to create a mini-shuttle by the name of Hermes was introduced. The craft itself was modelled comparable to the first proposals of the Space Shuttle and consisted of a small reusable spaceship that would carry 3 to 5 astronauts and 3 to 4 metric tons of payload for scientific experiments. With a total maximum weight of 21 metric tons it would have been launched on the Ariane 5 rocket, which was being developed at that time. It was planned solely for use in Low-Earth orbit space flights. The planning and pre-development phase concluded in 1991; however, the production phase was never fully implemented because at that time the political landscape had changed significantly. With the fall of the Soviet Union ESA looked forward to cooperation with Russia to build a next-generation human space vehicle. Thus the Hermes program was cancelled in 1995 after about 3 billion dollars had been spent.

In the 21st century ESA started new programs in order to create its own manned spacecraft, most notable among its various projects and proposals is Hopper, whose prototype by EADS, called Phoenix, has already been tested. While projects such as Hopper are neither concrete nor to be realised within the next decade, other possibilities for human spaceflight in cooperation with the Russian Space Agency have emerged. Following talks with the Russian Space Agency in 2004 and June 2005, a cooperation between ESA and the Russian Space Agency was announced to jointly work on the Russian-designed Kliper, a reusable spacecraft that would be available for space travel beyond LEO (e.g. the moon or even Mars). It was speculated that Europe would finance part of it. However, a €50 million participation study for Kliper, which was expected to be approved in December 2005, was finally not approved by the ESA member states. The Russian state tender for the Kliper project was subsequently cancelled in the summer of 2006.

In June 2006 ESA member states granted 15 million to the Crew Space Transportation System (CSTS) study, a two-year study to design a spacecraft capable of going beyond Low-Earth orbit based on the current Soyuz design. This project is pursued with Roskosmos instead of the previously cancelled Kliper proposal. A decision on the actual implementation and construction of the CSTS spacecraft is contemplated for 2008, with the major design decisions being made before the summer of 2007. In mid-2009 EADS Astrium was awarded a €21 million study into designing a manned variation of the

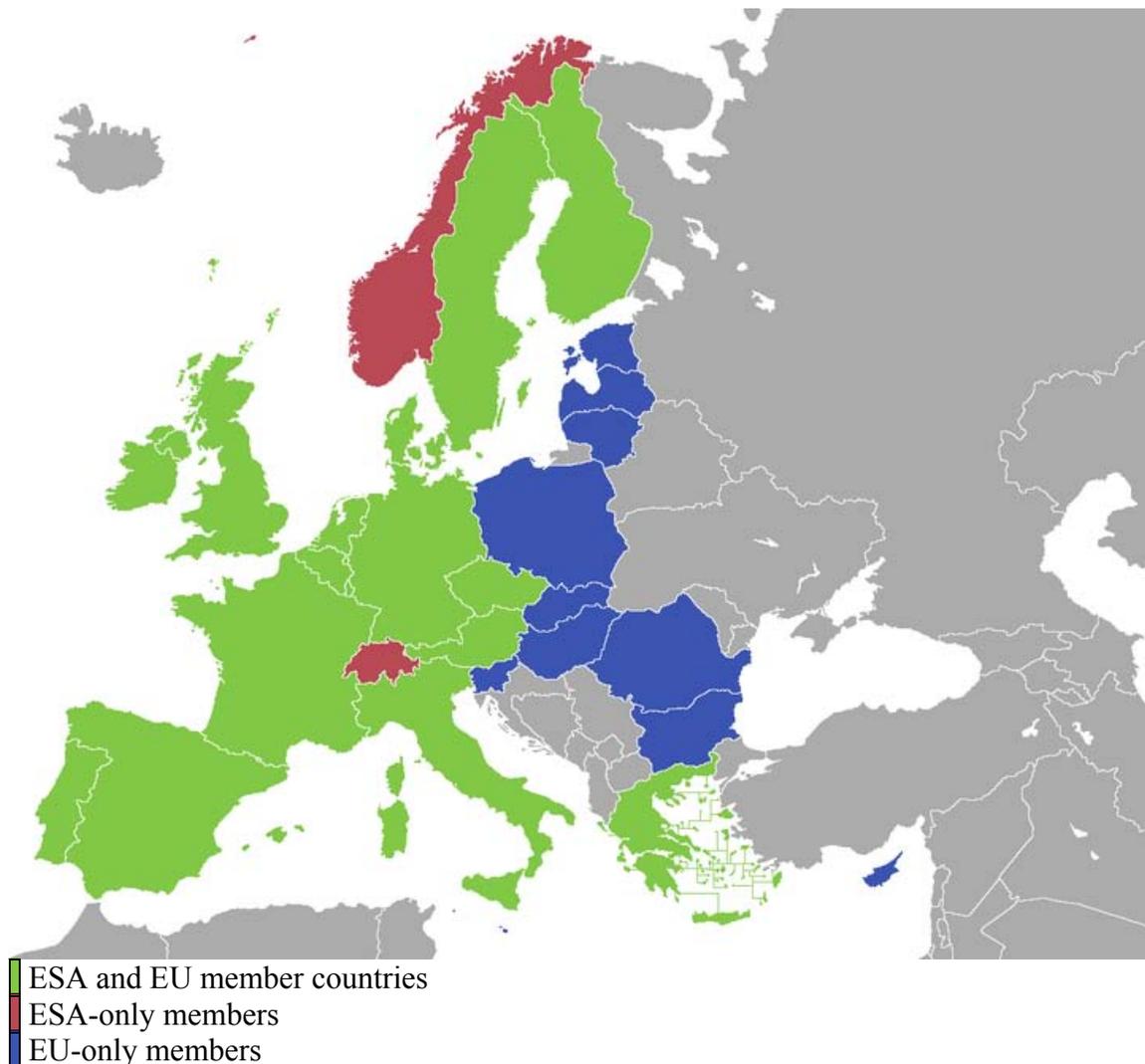
European ATV vehicle which is believed to now be the basis of the Advanced Crew Transportation System design.

Cooperation with other countries and organisations

ESA has signed cooperation agreements with the following states that currently neither plan to integrate as tightly with ESA institutions as Canada, nor envision future membership of ESA: Argentina, Brazil, China, India (for the Chandrayan mission), and Russia.

Additionally, ESA has joint projects with the European Union, NASA of the United States and is participating in the International Space Station together with the United States (NASA), Russia and Japan (JAXA).

European Union



ESA is not an agency or body of the European Union (EU), and has non-EU countries Switzerland and Norway as members. There are however ties between the two, with various agreements in place and being worked on, to define the legal status of ESA with regard to the EU. There are common goals between ESA and the EU, and ESA has an EU liaison office in Brussels. On certain projects, the EU and ESA cooperate, such as the upcoming Galileo satellite navigation system. Space policy has since December 2009 been an area for voting in the European Council. Under the European Space Policy of 2007, the EU, ESA and its Member States committed themselves to increasing coordination of their activities and programmes and to organising their respective roles relating to space.

Former Italian astronaut Umberto Guidoni, during his tenure as a Member of the European Parliament from 2004 to 2009, stressed the importance of the European Union as a driving force for space exploration, "since other players are coming up such as India and China it is becoming ever more important that Europeans can have an independent access to space. We have to invest more into space research and technology in order to have an industry capable of competing with other international players."

An independent report on the future of ESA, requested by its director-general, recommends further integration of ESA into the structures of the EU. Space policy would be decided by the European Council and ESA would be the *de facto* space agency of the European Union, not excluding the possibility of making it a formal EU agency. This would also help with co-operation between space policy and environmental or security policy, Galileo itself has a security dimension.

The first EU-ESA International Conference on Human Space Exploration took place in Prague on 22 and 23 October 2009. A road map which would lead to a common vision and strategic planning in the area of space exploration was discussed. Ministers from all 29 EU and ESA members as well as members of parliament were in attendance. If a roadmap is accepted at the November 2010 Brussels conference as planned, it is estimated that an additional €3 billion annually would be made available for European space exploration activities by the European Commission. The political perspective of the European Union (EU) is to make ESA an agency of the EU by 2014, although this date may not be met.

National space organisations of member countries

- The *Centre National d'Études Spatiales* (CNES) (National Centre for Space Study) is the French government space agency (administratively, a "public establishment of industrial and commercial character"). Its headquarters are in central Paris. CNES is the main participant on the Ariane project. Indeed CNES designed and tested all Ariane family rockets (mainly from its centre in Évry near Paris)
- The UK Space Agency is a partnership of the UK government departments which are active in space. Through the UK Space Agency, the partners provide delegates

to represent the UK on the various ESA governing bodies. Each partner funds its own programme.

- The Italian Space Agency (*Agenzia Spaziale Italiana* or ASI) was founded in 1988 to promote, coordinate and conduct space activities in Italy. Operating under the Ministry of the Universities and of Scientific and Technological Research, the agency cooperates with numerous entities active in space technology and with the president of the Council of Ministers. Internationally, the ASI provides Italy's delegation to the Council of the European Space Agency and to its subordinate bodies.
- The German Aerospace Center (DLR) (German: *Deutsches Zentrum für Luft- und Raumfahrt e. V.*) is the national research centre for aviation and space flight of the Federal Republic of Germany and of other member states in the Helmholtz Association. Its extensive research and development projects are included in national and international cooperative programmes. In addition to its research projects, the centre is the assigned space agency of Germany bestowing headquarters of German space flight activities and its associates.
- The Instituto Nacional de Técnica Aeroespacial (INTA) (National Institute for Aerospace Technique) is a Public Research Organization specialized in aerospace research and technology development in Spain. Between other functions, it serves as a platform for space research and acts as a significant testing facility for the aeronautic and space sector in the country.

NASA

ESA has a long history of collaboration with NASA. Since ESA's astronaut corps was formed, the Space Shuttle has been the primary launch vehicle used by ESA's astronauts to get into space through partnership programs with NASA. In the 1980s and 1990s, the Spacelab program was an ESA-NASA joint research program that had ESA develop and manufacture orbital labs for the Space Shuttle for several flights on which ESA participate with astronauts in experiments.

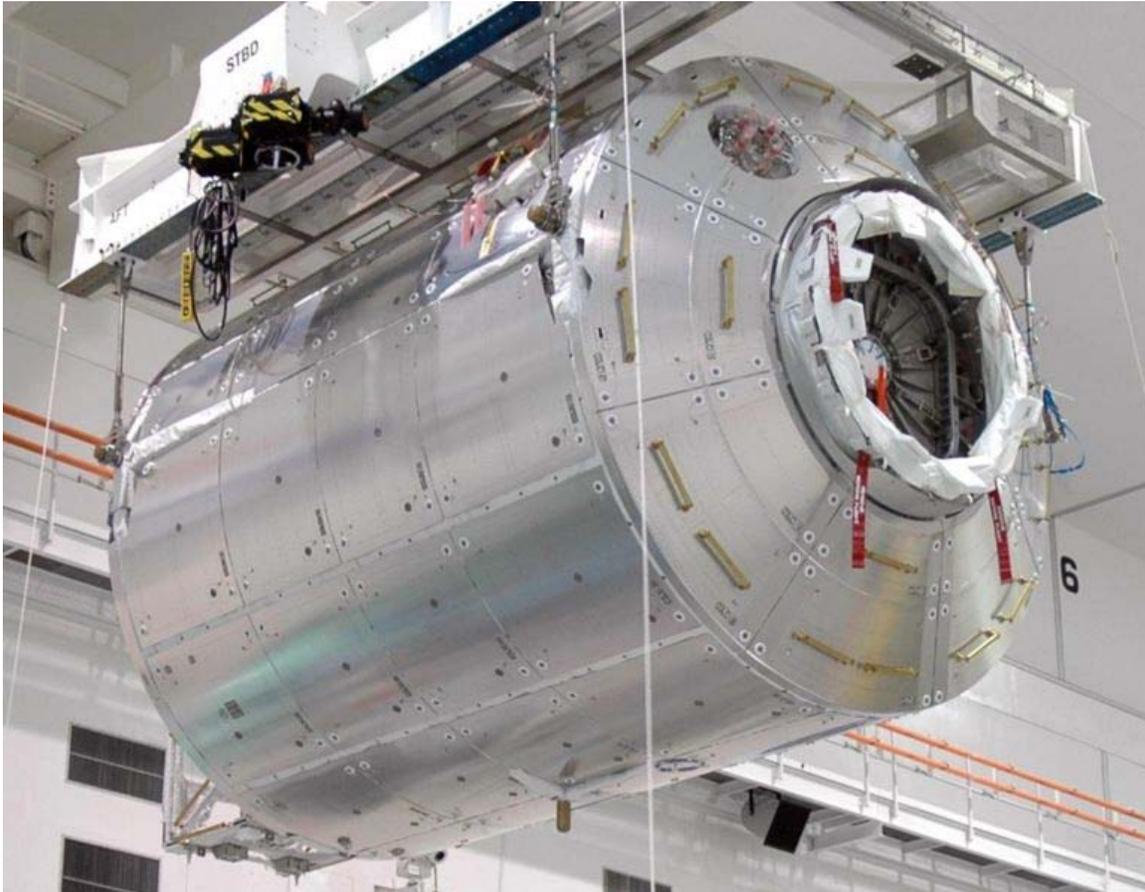
In robotic science mission and exploration missions, NASA has been ESA's main partner. Cassini-Huygens was a joint NASA-ESA mission, the Infrared Space Observatory, INTEGRAL, SOHO, and others. Also, the Hubble space telescope is a joint project of NASA and ESA. Future unmanned projects that are in development right now and are ESA-NASA joint projects include the James Webb Space Telescope or the Laser Interferometer Space Antenna. NASA and ESA will also likely join together for a Mars Sample Return Mission.

Cooperation with other space agencies

Since China has started to invest more money into space activities, the Chinese Space Agency has sought international partnerships. ESA is, beside the Russian Space Agency, one of its most important partners. Recently the two space agencies cooperated in the development of the Double Star Mission.

ESA entered into a major joint venture with Russia in the form of the CSTS, the preparation of French Guyana spaceport for launches of Soyuz rockets and other projects. With India ESA agreed to send instruments into space aboard the ISRO 's Chandrayaan in 2008. ESA is also cooperating with Japan, the most notable current project in collaboration with JAXA is the BepiColombo mission to Mercury.

International Space Station



ISS module Columbus at Kennedy Space Center

With regard to the International Space Station (ISS) ESA is not represented by all of its member states: 10 of the 18 ESA member countries currently participate in the project. ESA is taking part in the construction and operation of the ISS with contributions such as Columbus, a science laboratory module that was brought into orbit by NASA's STS-122 Space Shuttle mission and the Cupola observatory module that was completed in July 2005 by Alenia Spazio for ESA. The current estimates for the ISS are approaching €100 billion in total (development, construction and 10 years of maintaining the station) of which ESA has committed to paying €8 billion. About 90% of the costs of ESA's ISS share will be contributed by Germany (41%), France (28%) and Italy (20%). German ESA astronaut Thomas Reiter was the first long-term ISS crew member.

As of 2008, the spacecraft establishing supply links to the ISS are the Progress, Soyuz and Space Shuttle. ESA has developed the Automated Transfer Vehicle (ATV) for ISS resupply. Each ATV has a cargo capacity of 7,667 kilograms (16,900 lb). The first ATV, *Jules Verne*, was launched on 9 March 2008 and on 3 April 2008 successfully docked with the ISS. This manoeuvre, considered a major technical feat, involved using automated systems to allow the ATV to track the ISS, moving at 27,000 km/h, and attach itself with an accuracy of 2 cm. No other spacefaring nations or space agency currently possess this level of autonomy in rendezvous and docking activities, considered key to future space exploration. With the Space Shuttle reaching its retirement age in 2010, until NASA has a replacement for it such as COTS the ATV together with Progress, Soyuz and the Japanese transporter HTV will be the only links between Earth and the ISS.

Miscellaneous

Languages

According to Annex 1, Resolution No. 8 of the *Convention for the establishment of a European Space Agency*, English, French and German may be used in all meetings of the Agency, with interpretation provided into these three languages. All official documents are available in English and French with all documents concerning the ESA Council being available in German as well.

Facilities

- Headquarters of ESA, Paris, France
- European Space Operations Centre (ESOC), Darmstadt, Germany
- Centre Spatial Guyanais, Kourou, French Guiana
- European Space Research and Technology Centre (ESTEC), Noordwijk, The Netherlands
- ESA Centre for Earth Observation (ESRIN), Frascati, Italy
- European Astronaut Centre (EAC), Cologne, Germany
- European Space Astronomy Centre (ESAC), Madrid, Spain
- ESTRACK European Space Tracking Network
- European Robotics and Climate Change Centre, Harwell Science and Innovation Campus, United Kingdom

Chapter- 2

ESRO

**European Space Research Organisation
Conseil Européen de Recherche Spatiale**



Owner	10 European states
Established	1964
Headquarters	Paris, France
Primary spaceport	Esrangle, Guiana Space Centre

The **European Space Research Organisation (ESRO)** was an international organisation founded by 10 European nations with the intention of jointly pursuing scientific research in space. It was founded in 1964. As an organisation ESRO was based on a previously existing international scientific institution, CERN.

The ESRO convention, the organisations founding document outlines it as an entity exclusively devoted to scientific pursuits. This was the case for most of its lifetime but in the final years before the formation of the European Space Agency (ESA), ESRO began a

programme in the field of telecommunications. Consequently, ESA is not a mainly science focused entity but concentrates on telecommunications, earth observation and other application motivated activities. ESRO was merged with ELDO in 1975 to form the European Space Agency.

The founding of ESRO

Origin

The origins of a joint European space effort are generally traced back to a number of initiatives taken in 1959 and 1960 by a small group of scientists and science administrators, catalysed by two friends, physicists and scientific statesmen, the Italian Edoardo Amaldi and the Frenchman Pierre Victor Auger. Neither Amaldi nor Auger was a stranger to the cause of scientific collaboration on a European scale. Indeed it was they who, in the early 1950s, were key actors in the process which led to the setting up of CERN, the European Organisation for Nuclear Research. Now, as the decade drew to a close, they turned their attention to space. Success was rapid. Within a year of the first formal discussions being held amongst scientists, European governments had set up a European Preparatory Commission for Space Research (COPERS) to explore the possibilities for a joint space research effort.

The European Preparatory Commission for Space Research

The COPERS held its first session in Paris on 13 and 14 March 1961. Its first task was to create the organs needed to define the scientific programme and the necessary infrastructure of the envisaged organisation, to draw up its budget, and to prepare a Convention for signature by those member state governments who wished to join it. To this end the meeting first elected its "bureau": chairman Harrie Massey, vice-chairmen, Luigi Broglio and Hendrik van de Hulst, and executive secretary Pierre Auger, all men who had played an important role in the debates in 1960 and, Auger apart, still active and eminent European space scientists. It then established two working groups. The first was the Interim Scientific and Technical Working Group (STWG). Its task was to prepare the scientific programme for the future space organisation, paying particular attention to the technical and financial implications of its proposals. Lamek Hulthén, from the Royal Institute of Technology in Stockholm, was nominated chairman of this group; Reimar Lüst from the Max-Planck-Institut für Physik und Astrophysik in Garching, near Munich was appointed its coordinating secretary. The second was the Legal, Administrative and Financial Working Group (LAFWG). Its chairman was initially left open, though it was recommended that he be someone from the German Federal Republic. Alexander Hocker, a senior bureaucrat from Bad-Godesberg who was the chairman of the CERN Finance Committee at the time, took on this task. All Member States were to be represented on both working groups, which were empowered to set up subgroups to facilitate their work.

The Blue Book

By the third meeting of COPERS on 24 and 25 October 1961 in Munich, the STWG had prepared a 77 page document outlining the future European Space Research Organisation. The so called Blue Book was divided into 5 parts, each devoted to one of the following subjects:

- a general outline of ESRO
- ESRO's scientific programme
- its technology centre
- data handling
- ranges and vehicles

The Blue Book foresaw the firing of some 435 sounding rockets and the successful development and launching of 17 satellites in the 8 years covered by the ESRO Convention, namely 11 small satellites, 4 space probes, and 2 large satellites. It was assumed that 2 launchings would be required to orbit one successful spacecraft, so the number of satellite and space probes launchings budgeted for was doubled. The total cost of the satellite programme was estimated at 733.5 Million F, of which 450 Million F was for launchers and launch operations and 283.5 Million F for spacecraft development.

It should be noted that the Blue Book was more a manifesto of interests and expectations than a concrete working hypothesis. It only reflected the intentions and hopes of important sectors of the European scientific community while ignoring their lack of capacity to fulfill these intentions. The fact that transforming the manifesto into a true operational programme would be a long and laborious process and the results sometimes disappointing.

Organisation and functioning

The Auger years (1964-67)

The ESRO Convention entered into force on 20 March 1964. The ten founding states were Belgium, Denmark, France, (Federal Republic of) Germany, Italy, Netherlands, Spain, Sweden, Switzerland and the United Kingdom. Two other countries which had participated in the early COPERS activities, Austria and Norway, decided not to join the new organisation but retained an observer status. The first meeting of the Council opened in Paris three days later with Harrie Massey in the Chair. Pierre Auger was appointed ESRO's first Director General.

The Legislative arm

At the decision making level (the "Legislative" in the ESRO jargon), the supreme governing body was the Council, made of delegations from its Member States. Each member state had one vote in the Council, where it could be represented by not more than two delegates, one of whom was generally a scientist, the other an important national

science administrator. One or more advisers were usually included national delegations. The main tasks of the Council were to determine the Organisation's scientific, technical and administrative policy; to approve its programme and annual work plans; and to determine its level of resources both annually, and every third year for the subsequent three-year period. The Council was advised by two subordinate bodies, the Administrative and Finance Committee (AFC) and the Scientific and Technical Committee (STC).

The Executive arm

At the executive level, ESRO was managed by a Directorate based in Paris, including the Director General assisted by a Scientific Director, a Technical Director and a Head of Administration. The directors of ESRIN, ESDAC and ESLAB reported to the Scientific Director; the director of ESTEC, who had also responsibility for ESRANGE and ESTRACK, reported to the Technical Director. The "Executive", as it was eventually called, was responsible for the implementation of approved programmes within the established financial envelope and under general control from the Scientific and Technical Committee. It was also called to perform feasibility studies of space missions proposals coming from the scientific community and recommended by the STC, in view of their eventual adoption in the programme.

The *Bannier* report and its consequences

Only two years after the formation of ESRO, problems with its structure became painfully obvious. By mid-1966 it had climbed to 50%, placing enormous pressure on the operational programme. For this reason the Council set up a group of experts led by J.H. Bannier to investigate and solve the problem. Bannier quickly relieved the pressure on the AFC by raising the limit below which the Executive could award contracts without having to seek committee approval. He further increased the role of the Executive by transferring certain competencies from the Legislative to the Directorate. But this was only a stop-gap measure.

Bannier realised that the entire structure of ESOC had to be changed. Firstly, they were emphatic that the executive function of the organisation should be clearly separated from the policy and the planning function. Secondly, as far as the scientific programme was concerned, they recommended that there be a clear institutional distinction drawn between spacecraft development and spacecraft operation after launch. To achieve these objectives, the Bannier group suggested that ESRO's top management structure be completely changed. The dichotomy between scientific and technical directorates was, in Bannier's view, wrong in principle for an organisation like ESRO. To overcome it, he suggested that the two posts be abolished. In its stead a new structure was proposed. It comprised the Director General (DG) plus four directors, two of whom were essentially responsible for policy-making and two for policy execution. A new post was to be created in the first category, a so-called Director of Programmes and Planning (DPP), whose task it would be to prepare draft programmes of the Organisation, based on the scientific, technical, financial and time implications of the different proposals. The second

member of the directorate concerned with forward planning would be the Director of Administration (DA) whose task it would be to prepare policy on the future needs of personnel, finance and contracts, and to organise and implement the necessary procedures to maintain an a posteriori control over the Organisation's functioning. The two posts in the Directorate having executive authority would be filled by the director of ESTEC and of ESDAC, which was to be renamed ESOC, the European Space Operations Centre. As for ESRIN, the Bannier group judged its research to be marginal to the major activities of the Organisation. Its director, they felt, should not be a member of the directorate but should rather report directly to the DG.

Facilities and establishments

European Space Research and Technology Centre

The European Space Research and Technology Centre (ESTEC) was to be a facility at the very core of ESRO. Its responsibilities included the engineering and testing of satellites and their payloads, the integration of scientific instruments in these payloads, and making arrangements for their launch. In some cases member states were to produce the scientific instruments for ESRO or produce them as part of their own national effort and compensate ESTEC for its service. In practise, national organisations simply used ESTEC as a service organisation and left it to pay for their efforts from the ESRO budget. After the Bannier Report the facility gained overall executive authority for spacecraft development and was merged with ESLAB. The satellite control centre was also moved to ESOC. ESTEC was originally to be located in Delft (Holland) but because of unforeseen difficulties, Noordwijk was chosen instead.

ESLAB

The situation with ESRO's laboratory, ESLAB was similar. It lacked the staff to function as an independent organisation. But this wasn't surprising since the ESRO Convention describes ESLAB's role in the following manner:

...to undertake joint research programmes on the minimum scale deemed necessary by the Council [...] to complete or complement the scientific studies carried out in Member States.

– *ESRO Convention*

This meant that ESLAB was little more than a venue for visiting scientists. ESLAB's role was later expanded. It acted as the interface between national scientific groups and ESTEC engineering groups as well as conducted its own research within the scope of the large astronomical satellite project. After the Bannier Report ESLAB was merged with ESTEC.

ESRANGE

In 1964 ESRANGE was established as an ESRO sounding rocket launching range located in Kiruna (Sweden). This location was chosen because it was important to carry out a sounding rocket programme in the auroral zone, and essential that ESRO equip itself with a suitable range in the northern latitudes. Access to Kiruna was good by air, road and rail, and the launching range was relatively close to the town of Kiruna. Finally and perhaps decisively, ESRANGE could be located near Kiruna Geophysical Observatory (subsequently renamed the Swedish Institute of Space Physics). In 1972 ownership and operations of the range was transferred to the Swedish Space Corporation.

ESTRACK and ESDAC

Space science data handling has two aspects. Firstly, it requires the setting up of a network of tracking and telemetry stations which can receive signals from spacecraft (ESTRACK). This network comprised four stations situated in the following locations:

- Redu (Belgium)
- Fairbanks (Alaska)
- Spitsbergen (Norway)
- Falkland Islands

Secondly, it requires a central facility which edits and processes the information from the tracking network. The facilities at the centre, initially labelled ESDAC (European Space Data Acquisition Centre), were essentially a large mainframe computer or computers, which was made available both to its in-house staff and to visiting scientists and fellows who wished to use them to analyse and study the recovered data. ESDAC was later renamed ESOC, the European Space Operations Centre. ESOC is located in Darmstadt (Germany). After the Bannier Report it gained overall executive authority for spacecraft operation. ESOC's director also became responsible for ESRANGE and for ESTRACK.

ESLAR

ESLAR, a laboratory for advanced research was created in 1966 mainly to break the political deadlock over the location of ESLAB. Later renamed ESRIN, and acronym for European Space Research Institute, ESLAR was based in Frascati (Italy). The ESRO Convention describes ESRINs' role in the following manner:

...to undertake laboratory and theoretical research in the basic physics and chemistry necessary to the understanding of past and the planning of future experiments in space.

– *ESRO Convention*

The facility began acquiring data from environmental satellites in the 1970s.

ESRO headquarters

ESRO headquarters was home to the Executive arm of ESRO. After the Bannier Report it became responsible for policy, planning and *a posteriori* control.

Scientific activities

The ESRO convention outlined the organisation as one which would be solely devoted to space science. As a consequence, scientific work was the main area of ESROs early operations. As the organisation and its capabilities matured it shifted from a strictly scientific programme to one where applicational activities played a more dominant role.

Sounding rockets

The fact that sounding rockets are relatively inexpensive, have a short lead time, provide a test bed for more ambitious project and have a low risk of failure made them an ideal first project for the newly formed European Space Research Organisation.

The first two ESRO sounding rockets were launches from the Salto di Quirra range in Sardinia on 6 and 8 July 1964. They released a payload of barium and ammonia into the ionosphere. The first launch from ESRANGE was made in November 1966. From this point onward the frequency of sounding rocket launches increased dramatically. The Norwegian base in Andøya was also used as a launch site.

The British Skylark (83) and French Centaure (64) were the main rockets utilised for the programme. The American Arcas (14), French Béliet (4) and Dragon (2), British Petrel (1) and German/Swiss Zenit (1) were also used. In total, the program oversaw the launch of 168 sounding rockets with an average success rate of 75%. During the course of the programme, the size and payload of the sounding rockets used by ESRO increased from 2.7 to 5.55 m (in length) and from 140 to 310 kg respectively.

About half of the 168 sounding rockets were dedicated to ionospheric and auroral studies, about a quarter to atmospheric physics and the rest to solar, stellar and gamma-ray studies. While the number of launched rockets was lower than foreseen, the project exceeded expectations due to higher than anticipated payload capacity and longer range of the rockets.

Original satellite programme

The Blue Book foresaw the launching of 11 small satellites, 4 space probes, and 2 large satellites. These ambitions were never realized mainly due to financial troubles. The programme went through many revisions and in the end only a handful of projects produced concrete results. These were the two small, non-stabilised satellites ESRO I and ESRO II, launched in 1968 and renamed after launch Aurorae and Iris respectively; the two small highly eccentric orbit satellites HEOS-A and HEOS-A2, launched in 1968 and

1972 and then renamed HEOS-1 and HEOS-2; the medium size, stabilised satellite TD-1, launched in 1972; and the small satellite ESRO IV, also launched in 1972, which replaced the second satellite of the TD series (TD-2). All of these were multi-experiment satellites, i.e. the spacecraft carried a payload comprising several instruments provided by different research groups.

ESRO I and ESRO II

These were small, non-stabilised spacecraft, carrying very simple experiments designed to measure the radiation environment around the spacecraft. They represented the direct satellite descendants of the experience gained with the sounding rocket experiments. ESRO I's origin in the sounding rocket programme was particularly obvious. It studied auroral phenomena and the polar ionosphere. ESRO II was dedicated to the fields of solar astronomy and cosmic rays. Sometimes the two satellites are also referred to as ESRO-1A or Aurora and ESRO-2B Iris respectively.

HEOS-A

Later renamed as HEOS-A, the first highly eccentric orbit satellite was designed to make measurements of plasma, magnetic field and cosmic ray particles. There were disagreements over the cost of this project. Since the existing ESTRACK grid had been designed with low orbit satellites in mind it would be insufficient for tracking and receiving data from a satellite in a highly eccentric (escape) orbit. A solution was found in the form of upgrading an ELDO facility in Australia and integrating it at a relatively low cost.

The TD programme

Named after the workhorse medium launch system used by ESRO at the time, the Thor Delta, the TD programme initially foresaw the launch of 3 satellites: TD-1, TD-2 and TD-3. TD-1 was devoted to stellar astronomy, TD-2 was to be devoted to solar astronomy while TD-3 was to study the ionosphere. Later TD-2 and 3 were merged to save funds. But subsequent financial difficulties and political disagreements led to the abandonment of the TD-2/TD-3 spacecraft. Later some of the experiments destined for launch aboard the TD-2/TD-3 were flown on the ESRO IV satellite.

LAS

The Large Astronomical Satellite was to be an orbiting observatory with the mission of providing basic knowledge about celestial objects through the use of a high-resolution ultraviolet spectrometer. The project started in the late 1950s and was cancelled in 1968 because of the lack of financial support and political squabbles.

Second generation satellites

COS-B

COS-B was the first successful ESRO science satellite. The mission was first proposed by the scientific community in the mid 1960s, approved in 1969 and launched in 1975. It was shut off in 1982 after contributing a great deal of scientific data on cosmic gamma rays, which continues to be analysed today. This was the first ESRO satellite which carried only one experiment.

GEOS

GEOS was a geostationary multi-experiment satellite dedicated to magnetospheric research. The instruments for this project were provided by multiple European institutions. When GEOS was launched in 1977, the launcher malfunctioned and the planned orbit was not achieved. A modified qualification model of the same payload was successfully launched in 1978 and remained in operation until 1982 when it was turned off.

The first package deal

This was the name of a policy shift negotiated by ESRO members in 1971 which drastically reduced scientific funding in favor of application activities doubling the overall budget. This first led to a change in the administrative structure and a 50% reduction of the scientific staff. Given the new budgetary environment, LPAC had to choose which two missions to fly among the five which had been planned thus far. It eventually chose HELOS, renamed Exosat, and the IMP-D, renamed ISEE-2, projects.

Exosat

ISEE-2

This satellite was the second of 3 International Sun-Earth Explorer (ISEE) spacecraft. The project was a cooperative effort between NASA and ESRO (later ESA) designed to study the interaction between the Earth's magnetic field and the solar wind. The program used three spacecraft, a mother/daughter pair (ISEE-1 and ISEE-2) and a heliocentric spacecraft (ISEE-3, later renamed ICE). The instruments on board ISEE-2 were designed to measure electric and magnetic field properties.

The second package deal

This new ESRO policy, negotiated in 1973, gave the organisation overall responsibility for the development of the European Ariane launcher. This task was entrusted to CNES. The second package deal enabled ESRO to enter into cooperation with NASA on the Spacelab project as well as manage the MAROTS maritime satellite navigation project. This agreement made funding easier and more flexible for the contributing nations which

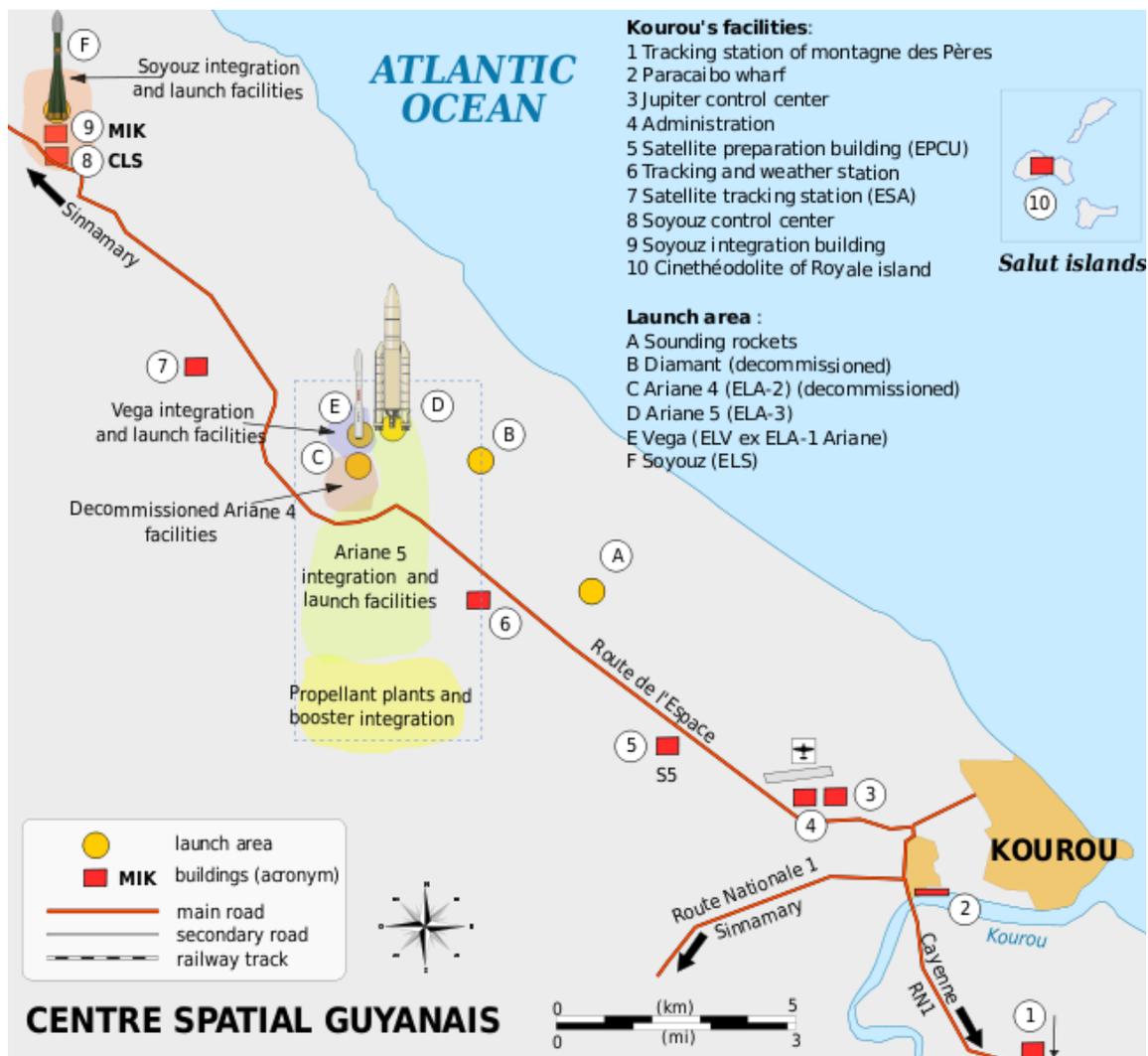
led to a doubling of the organisation's overall budget. ESRO also participated in the International Ultraviolet Explorer mission with NASA under these policy guidelines.

Telecommunications Satellite Programme

The first step towards an telecommunications program within ESRO was made in the end of 1966 when the European Conference on Satellite Communications requested that the organisation examine the potential for a European telecom satellite project. Although studies were carried out at this early stage as well as during the subsequent 5 years the ESRO council would not approve research and development activities until 1971 when the first package deal took effect. The delay was due to ESRO's rigid decision making structure and the unfavorable political situation which existed among ESRO members at the time. These problems were largely done away with as part of the 1971 policy change which, among other things, outlined a fully voluntary mechanism for application project financing. Under the first package deal ESRO pursued a project to establish a European satellite system by the early 1980s in partnership with the European Conference of Postal and Telecommunications Administrations and the European Broadcasting Union. ESRO merged with ELDO to form the European Space Agency in 1975 before the first satellite of the effort, the Orbital Test Satellite, would be successfully launched in 1978.

Chapter- 3

Guiana Space Centre



Map of Guiana Space Centre

The **Guiana Space Centre** or, more commonly, **Centre Spatial Guyanais (CSG)** is a French spaceport near Kourou in French Guiana. Operational since 1968, it is particularly suitable as a location for a spaceport due to its proximity to the equator, and that launches are in a favourable direction over water. The European Space Agency, the French space agency CNES, and the commercial Arianespace company conduct launches from Kourou.

The location was selected in 1964 to become the spaceport of France. When the European Space Agency (ESA) was founded in 1975, France offered to share Kourou with ESA. Commercial launches are bought also by non-European companies. ESA pays two thirds of the spaceport's annual budget, and has also financed the upgrades made during the development of the Ariane launchers.

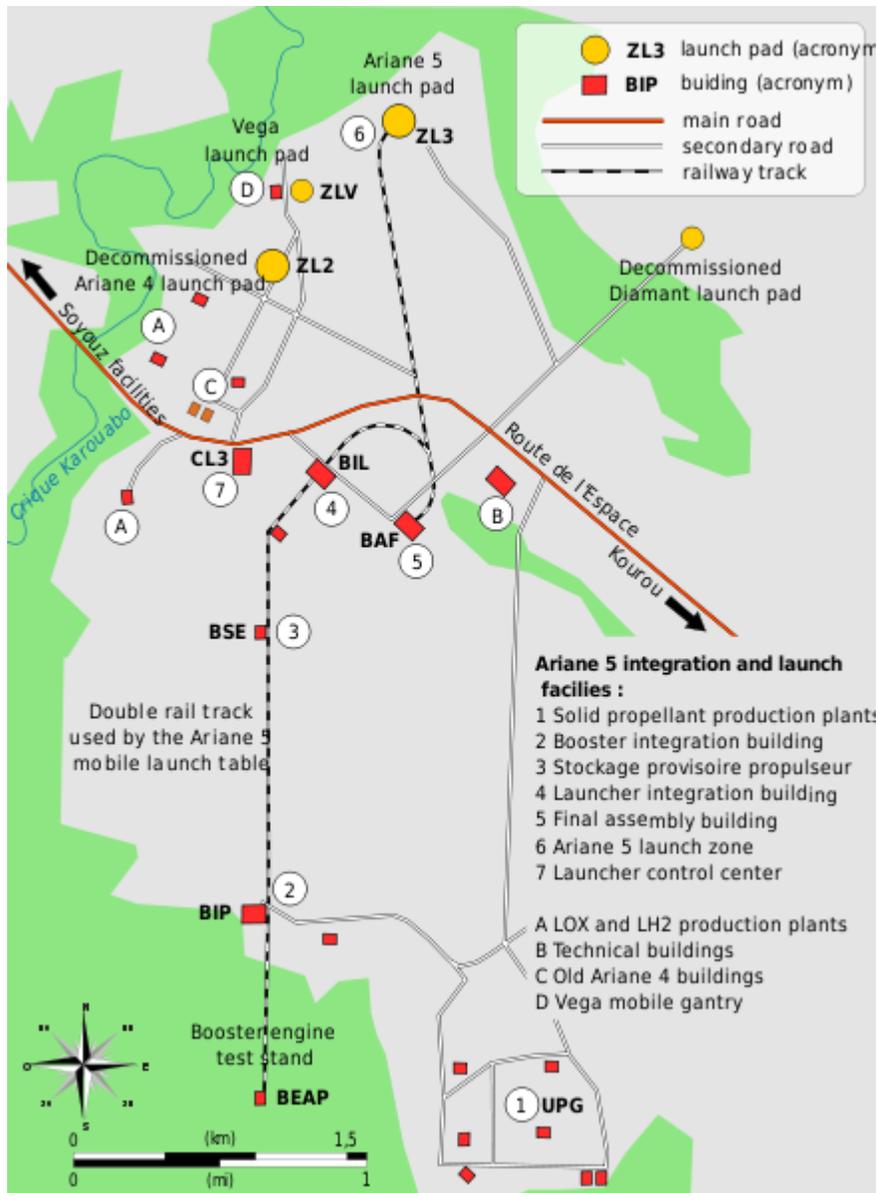
Facilities



The now-decommissioned *ELA 2 - l'Ensemble de Lancement Ariane 2 Ariane 4* launch site



The final assembly building for Ariane 5



ELA-3 map

Kourou is located approximately 500 kilometres (310 mi) north of the equator, at a latitude of $5^{\circ}10'$. At this latitude, the Earth's rotation gives a velocity of approximately 460 metres per second (1,000 mph; 1,700 km/h) when the launch trajectory heads eastward. The proximity to the equator also makes maneuvering satellites for geosynchronous orbits simpler and less costly.

The ground facilities at Guiana Space Centre (GSC) include launcher (French: *l'Ensemble de Lancement*) and satellite preparation buildings, launch operation facilities and a solid propellant factory. The GSC facility covers a total of 850 square kilometres (330 sq mi).

ELV (CECLES/ELA-1)

Originally built in the 1960s under the name of CECLES (French: *Conférence Européenne de Construction de Lanceurs et d'Engins Spatiaux*, English: *European conference on construction of launchers and spacecraft*), the ELV pad (French: *l'Ensemble de Lancement Vega*) located at  $5^{\circ}14'10''\text{N } 52^{\circ}46'30''\text{W} / 5.236^{\circ}\text{N } 52.775^{\circ}\text{W}$ was designed for the Europa-II rocket. One Europa-II was launched from the site, before the programme was cancelled.

The pad was demolished, and subsequently rebuilt as the first launch complex for Ariane rockets. Renamed *ELA* (later redesignated *ELA 1*), it was used for Ariane 1 and Ariane 2 and 3 launches until being retired in 1989.

As of 2008, ELV-1 is being rebuilt to support launches of the Vega rocket, back under the current designation of ELV.

ELA 2

The ELA 2 pad (French: *l'Ensemble de Lancement Ariane 2*), located at  $5^{\circ}13'55''\text{N } 52^{\circ}46'34''\text{W} / 5.232^{\circ}\text{N } 52.776^{\circ}\text{W}$ had been used for Ariane 4 launches until 2003.

ELA 3

As of 2008, ELA 3 (French: *l'Ensemble de Lancement Ariane 3*), located at  $5^{\circ}14'17''\text{N } 52^{\circ}45'40''\text{W} / 5.238^{\circ}\text{N } 52.761^{\circ}\text{W}$, is currently active for Ariane 5 launches. These facilities cover an area of 21 square kilometres (8.1 sq mi).

ELS / Soyuz at CSG

ESA is currently building ELS (French: *l'Ensemble de Lancement Soyouz*) for launching Russian-built Soyuz-2 rockets. The first Soyuz launch from ELS has been postponed several times. The current target date for the first launch is April 2011.

ELS is located on the territory of Sinamary commune, 27 km (17 mi) from Kourou harbor. It is 10 km (6.2 mi) north of the site used for the Ariane 5 launches. Under the terms of the Russo-European joint venture, ESA will augment its own launch vehicle fleet with Soyuz rockets—using them to launch ESA or commercial payloads—and the Russians will get access to the Kourou spaceport for launching their own payloads with Soyuz rockets. Russia will use the Guiana Space Centre in addition to Baikonur Cosmodrome. The Guiana location has the significant benefit of greatly increased payload capability, owing to the near equatorial position. A Soyuz rocket with a 1.7 tonnes to geostationary transfer orbit (GTO) performance from Baikonur, will increase its payload potential to 2.8 tonnes from the Guiana launch site.

The rocket assembly procedures will differ from ones used at Baikonur. Traditionally, the Soyuz is being fully assembled in horizontal position, then transported to a launch pad and erected for launch. In ELS only the rocket will be assembled in horizontal position, then transported and erected. Then a spacecraft will be transported to the pad separately and attached to the rocket. To protect from dust and wind, the launch pad will have a closed gantry. The gantry will be able to move away from the pad for launch.

The ELS project is being co-funded by Arianespace, ESA, and the European Union, with CNES being the prime contractor. The project has a projected cost of approximately €320 million, where €120 million are allocated for modernizing the Soyuz vehicle. The official opening of the launch site construction occurred on 27 February 2007. Excavation work however, had previously begun several months beforehand. As of May 2008, groundworks were still continuing but the flame pit was substantially complete, along with the shell of the Soyuz assembly building. Equipment manufactured in Russia had arrived in French Guiana by July 2008, with Russian technicians performing the equipment installation at ELS.

In November 2007, reports emerged attributed to Vladimir Grezdilov, general director of the Mir company, of thefts from the Soyuz site near Sinnamari, which could cause delays to its completion and the first launches. Grezdilov said that the local security company was involved.

In February 2009 ESA reported from Samara, Russia that the launchers destined for the ELS were being built.

On May 21, 2009 Russian news agency ITAR-TASS reported that the first two Soyuz-ST to be launched at ELS have been built, tested and prepared for delivery to ELS.

On August 25, 2009 the general director of the Progress design bureau Alexander Kirilin said that the first launch of the Soyuz-ST from the Kourou space center was postponed for the beginning of April 2010. He informed that the first three rockets had been built and would be shipped on November 1, 2009 by sea.

On September 13, 2010 Spaceflight Now reported that after several delays in the construction of a mobile gantry the launch pad had been finished, and the first flight of the Soyuz is expected to occur in early 2011. By October 2010, 18 launch contracts have been signed. Arianespace has ordered 24 launchers from Russian industry, with the first two already delivered to CSG.

On January 14, 2011 BBC reported that the Soyuz launch complex will have its qualification review in April with the expectation for the first Soyuz to lift-off sometime between 15 August and 15 September [of 2011].

Final assembly building

Astrium assembles each Ariane 5 launcher in the Launcher Integration Building. The vehicle is then delivered to the Final Assembly Building for payload integration by Arianespace. The Final Assembly Building is located 2.8 kilometres (1.7 mi) from the ELA-3 launch zone. The mobile launch table completes the trip with an Ariane 5 in about one hour. It is then secured in place over the launch pad's flame ducts.

Launch safety



Ariane IV launched from the Guiana Space Centre on 10 August 1992

Fire safety is ensured by a detachment of the Paris Fire Brigade. Safety around the base is ensured by French Gendarmerie forces, assisted by the 3rd Foreign Infantry Regiment of the French Foreign Legion.

Before and during launch windows, CSG facility security is significantly enhanced by anti-personnel and anti-aircraft measures, the exact configurations of which are classified by the French military. All entrants to the launch complex are also subject to checks for proof of permission to enter the facility.

The Guiana Space Centre (as per CNES) also holds the *Îles du Salut*, a former penal colony including the infamous Devil's Island. Now a tourist site, the islands are under the launching trajectory for geosynchronous orbit and have to be evacuated during launches.

Early launches

- 10 March 1970 - The first Diamant-B launched the DIAL/MIKA and DIAL/WIKA satellites. DIAL/MIKA failed during launch, but entered orbit with a total mass of 111 kg. DIAL/WIKA provided data for about two months after launch.

Recent launches

- 5 October 2007 - An Ariane 5 GS launched from CSG carrying Intelsat 11 and Optus D2.
- 9 March 2008 - An Ariane 5 launched carrying the ATV (Automated Transfer Vehicle) *Jules Verne* in preparation for docking with the ISS. This was the first launch of the ESA unmanned resupply craft.
- 18 April 2008 - An Ariane 5 launched carrying Vinasat-1 - Vietnam's first satellite.
- 14 August 2008 - An Ariane 5 carrying Superbird 7 for Mitsubishi Electric Corporation and AMC-21 for SES Americom
- 20 December 2008 - An Ariane 5 carrying HOT BIRD 9 AND W2M for Eutelsat
- 14 May 2009 - An Ariane 5 carrying the ESA's Herschel and Planck space telescopes
- 1 July 2009 - An Ariane 5 carrying TerreStar-1, the heaviest commercial telecommunications satellite ever launched

Chapter- 4

Esrange



The BLAST payload and high altitude balloon shortly before launch.



Skylark rocket launch at Esrange on May 2, 2005.

Esrange Space Center (short form *Esrange*) is a rocket range and research centre located outside the town of Kiruna in northern Sweden. It is a base for scientific research with high altitude balloons, investigation of the aurora borealis, sounding rocket launches, and satellite tracking, among other things. Located 200 km north of the Arctic Circle and surrounded by a vast wilderness, its geographic location is ideal for many of these purposes. Richard Branson of Virgin Galactic has looked into the option of using this site for launching space tourism, starting in 2011. The local hotel Aurora has been used by tourists since December 2007, who want to spend time at the only rocket base allowing tourists to sleep in the hotels, which are normally meant for scientists and engineers.

Esrange was built in 1964 by ESRO, the *European Space Research Organisation*, which later became European Space Agency by merging with ELDO, the European Launcher Development Organisation. In 1972, ownership was transferred to the newly started Swedish Space Corporation.

In 2007, it was proposed that Spaceport Sweden be co-located with Esrange at Kiruna.

History

In 1964 ESRANGE was established as an ESRO sounding rocket launching range located in Kiruna (Sweden). This location was chosen because it was generally agreed that it was important to carry out a sounding rocket programme in the auroral zone, and for this reason it was essential that ESRO equip itself with a suitable range in the northern latitudes. Access to Kiruna was good by air, road and rail, and the launching range was relatively close to the town of Kiruna. Finally and perhaps decisively, ESRANGE could be located near Kiruna Geophysical Observatory (subsequently renamed to Swedish Institute of Space Physics). In 1972 ownership and operations of the range was transferred to the Swedish Space Corporation.

Name

The name of the facility was originally ESRANGE, which was an abbreviation for *ESRO Sounding Rocket Launching Range*.

When Swedish Space Corporation took over the range, Esrange (with capital 'E' only) became a name only.

Esrange Space Center is the name that is currently used for the facility.

Rocket activities

There had been Swedish rocket activities previously, mainly at Kronogård (18 launches in the period 1961-1964). However, the rocket activity in Sweden did not gain thrust until after ESRO established Esrange in 1964.

During the period 1966-1972 ESRO launched more than 150 rockets from Esrange. Most of these were Centaure, Nike Apache, and Skua rockets reaching 100–220 km altitude. They supported many branches of European research, but the emphasis was on atmospheric and ionospheric research.



A vast uninhabited area north of the range is used as an area where the sounding rockets can land. Spread throughout this area are small shelters, like the one shown in this picture. When a launch campaign is planned, people are asked to visit such shelters and listen to the radio. This shelter is at Vassejávri, around 10 km west of Järämä (Sweden).



Interior of such a shelter

In 1972 the management of Esrange was transferred to the Swedish Space Corporation (SSC). Gradually the smaller rockets were complemented by larger rockets reaching higher altitudes, achieving weightlessness for a few minutes when the rocket is above the parts of the atmosphere giving an appreciable friction. Three main programmes, Texas, Maser, and Maxus currently dominate the rocket activities at Esrange and support microgravity research for ESA and DLR:

Programme	Rocket motor	Peak altitude	Payload mass	Microgravity time	Period	Launches	Customers
Texus	Skylark 7, VSB-30	250–300 km	330–400 kg	6 minutes	1977-	47	DLR and ESA
Maser	Black Brant, Skylark 7, VSB-30	250–300 km	330–400 kg	6 minutes	1987-	11	ESA
Maxus	Castor 4B	700–720 km	800 kg	12–13 minutes	1991-	7	ESA and DLR
Mini-Texus	Nike Orion	120–150 km	160–200 kg	3–4 minutes	1993–1998	6	DLR and ESA

Esrange has four launch pads:

- Aries launcher
- Centaure launcher
- MRL Launcher (used for the Black Brant)
- Skylark launch tower (used for the Maxus and Skylark)

Balloon activities

Since 1974, more than 500 high-altitude balloons have been launched from Esrange for research purposes. The launch pad can handle balloons with volumes exceeding 1 million cubic meters.

Satellite services

The arctic latitude of Esrange makes it very suitable for communication with satellites in polar orbits. Satellite services began in 1978.

Satellite control services

A number of telecommunication satellites have been controlled through Esrange:

- Tele-X (1989–1998)
- Sirius-1 (1995–2003)
- Sirius-2 (1997–2009)
- Sirius-3 (1998-)
- Sirius-4 (2008-)

All the research satellites of the Swedish space programme have received control commands through Esrange:

- Viking (1986–1987)
- Freja (1992–1996)
- Astrid-1 (1995)
- Astrid-2 (1998–1999)
- Odin (2001-)

Ground station services

Data have been received at Esrange from more than 50 satellites, including SPOT 1-5, Landsat 2-7, ERS 1-2 and Envisat.

Chapter- 5

European Space Operations Centre



The ESOC Main Control Room (MCR) in Darmstadt, Germany.



Centre in Darmstadt, Germany.



Entrance to the ESOC.

The **European Space Operations Centre (ESOC)** is responsible for controlling ESA satellites and space probes. The centre is located in Darmstadt, Germany. It is Mission Control for most of the space projects of the ESA. ESOC also houses the Ground Facilities Control Centre (GFCC) that is responsible for remote operation of the ESTRACK network of Ground Stations and antennas.

Currently ESOC is operating the following spacecraft: ERS-2, XMM-Newton, the four Cluster spacecraft, Envisat, INTEGRAL, Mars Express, Rosetta, Venus Express, GOCE, Herschel, Planck, and Cryosat-2

Recent high-profile missions that were controlled from ESOC include SMART-1 and Huygens.

Projects under preparation include: LISA Pathfinder, ADM-Aeolus, SWARM, the Sentinel series and Gaia.

Recently controlled through LEOP, and then handed over to EUMETSAT was MetOp-A.

This centre is also responsible for the development of the technology infrastructure it requires to support existing and planned missions. Arguably its most important

technology asset is the Space Control and Operations Software (SCOS 2000), an adaptable software infrastructure for monitoring and controlling the various spacecraft.



European Space Operations Centre, Darmstadt, Germany-main gate.



European Space Operations Centre, Darmstadt, 1/2 scale mockup of XMM-Newton satellite.



European Space Operations Centre, Darmstadt, entrance.

History

Space science data handling has two aspects. Firstly, it requires the setting up of a network of tracking and telemetry stations which can receive signals from spacecraft (ESTRACK). This network comprised four stations situated in the following locations:

- Redu (Belgium)
- Fairbanks (Alaska)
- Svalbard (Norway)
- Falkland Islands

Secondly, it requires a central facility which edits and processes the information from the tracking network. The facilities at the centre, initially labelled ESDAC (European Space Data Acquisition Centre), were essentially a large mainframe computer or computers, which was made available both to its in-house staff and to visiting scientists and fellows who wished to use them to analyse and study the recovered data. ESDAC was later renamed ESOC, the European Space Operations Centre. ESOC is located in Darmstadt (Germany). After the Bannier Report it gained overall executive authority for spacecraft operation. ESOC's director also became responsible for ESRANGE and for ESTRACK.

Chapter- 6

European Space Research and Technology Centre

European Space Research and Technology Centre



ESTEC buildings in Noordwijk, Netherlands

Abbreviation	ESTEC
Location	Noordwijk, Netherlands
Parent organization	European Space Agency

The **European Space Research and Technology Centre (ESTEC)** is the European Space Agency's main technology development and test centre for spacecraft and space technology. It is situated in Noordwijk, South Holland, in the western Netherlands.

At ESTEC, about 2500 engineers, technicians and scientists work hands-on with mission design, spacecraft and space technology. ESTEC provides extensive testing facilities to verify the proper operation of spacecraft, such as the Large Space Simulator (LSS), acoustic and electromagnetic testing bays, multi-axis vibration tables and the ESA Propulsion Laboratory (EPL). Prior to the launch of almost all equipment that ESA launches is tested in some degree at ESTEC.



ESA-ESTEC-escape



ESA-ESTEC3



ESA-ESTEC4



ESA-ESTEC5



ESA-ESTEC6



ESA-ESTEC7

The Space Expo is ESTEC's visitors center. It has a permanent exhibition about space exploration.

Activities

- Future mission assessment
- Current project support
- Test Center
- Operations

History

The European Space Research and Technology Centre was to be a facility at the very core of ESRO. Its responsibilities included the engineering and testing of satellites and their payloads, the integration of scientific instruments in these payloads, and making arrangements for their launch. In some cases member states were to produce the scientific instruments for ESRO or produce them as part of their own national effort and compensate ESTEC for its service. In practise, national organisations simply used ESTEC as a service organisation and left it to pay for their efforts from the ESRO budget. After the Banner Report the facility gained overall executive authority for spacecraft

development and was merged with ESLAB. The satellite control centre was also moved to ESOC. ESTEC was originally to be located in Delft (South Holland) but because of unforeseen difficulties, Noordwijk was chosen instead.

Chapter- 7

European Astronaut Centre, European Space Astronomy Centre & ESA Centre for Earth Observation

European Astronaut Centre



Entrance of the EAC on the campus of the German Aerospace Center in Porz, Cologne

The **European Astronaut Centre (EAC)** is a centre of the European Space Agency and home of the European Astronaut Corps. It is located in Cologne, Germany, and is subdivided into four separate arms, these being Training, Medicine, Education and PR, and Astronaut Management. It provides training facilities to the European astronauts, particularly regarding ESA hardware for the ISS such as Columbus and the ATV. The overall European Astronaut Centre organisation is also in charge of the organisation of the training of European astronauts in the centers of other partners, such as the United

States (Johnson Space Center), Russia (Star City) Canada (Saint-Hubert) or Japan (Tsukuba).

The Medical Operations arm (the Crew Medical Support Office) concentrates on providing health related support to the European astronauts and their families. Astronaut management supports and directs the careers and mission placements of the astronauts, and Education and PR are involved in activities related to education and outreach and the appropriate representation of the European astronauts and their space activities to the public.

European Space Astronomy Centre

The **European Space Astronomy Centre (ESAC)** is the ESA's centre for space science, which means Astronomy as well as Solar System exploration. It is located in Villanueva de la Cañada, close to Madrid in Spain and hosts the science operation centres for all ESA astronomy and planetary missions together with their scientific archives.

Space telescopes are humankind's eyes in the heavens: from their superior observing positions high above the Earth's atmosphere, they provide us with astounding views of the Universe. ESAC is where those views are first studied – data on black holes and distant galaxies, from neighbouring planets and even from planets far beyond the Solar System are beamed back to the Madrid countryside. ESAC is thereby the 'home' of ESA's space-telescope and planetary missions, the place from where their science operations are conducted, and where all of the scientific data that they produce are archived and made accessible to the world. ESAC is therefore one of ESA's centres of excellence for space science. Missions represented a ESAC include (in alphabetical order) AKARI, Gaia, Herschel, INTEGRAL, LISA Pathfinder, Mars Express, Planck, Rosetta, Venus Express, and XMM-Newton.

In addition to deep space and solar system exploration ESAC hosts the data processing of SMOS, a satellite observing the earth, as well as the Space Situation Awareness (SSA) programm.

ESA's deep-space antenna in Europe, located in Cebreros, Avila, is an essential support to the activities of ESAC. Inaugurated in September 2005, Cebreros features a new, highly accurate pointing control system and a 35-metre antenna that allow ESA to gather data from distant missions to Mercury, Venus, Mars and beyond.

ESAC is also involved in ESA missions conducted in collaboration with other space agencies. One example is Akari, a Japanese-led mission to carry out an infrared sky survey, launched on 21 February 2006. Future collaborative programmes also include the NASA-led James Webb Space Telescope, the successor to the Hubble Space Telescope.

In addition, ESAC also hosts the Spanish Laboratory for Space Astrophysics and Fundamental Physics (LAEFF), an innovative research facility aimed mainly at

encouraging young Spanish scientists to enter the fields of astrophysics and fundamental physics.

The ESAC centre in Villafranca del Castillo, within the town limits of Villanueva de la Cañada, is located 30 km west of Madrid in the Guadarrama Valley. Evergreen oaks and the ruins of a nearby 15th century castle make a spectacular backdrop for the high-tech vista of ESA's large antennas and modern buildings. The Cebreros site is in Avila, about 90 km from Madrid and 65 km from ESAC.

ESA Centre for Earth Observation

Coordinates:  41°49'37"N 12°40'27"E / 41.8269472°N 12.6741222°E



European Space Agency

The **ESA Centre for Earth Observation** (also known as **ESRIN**) located in Frascati, Italy, is one of the five specialised centres of the European Space Agency (ESA) located across Europe. Among other things the establishment currently hosts the ESA development team for the Vega Launcher.

History

ESLAR, a laboratory for advanced research was created in 1966 mainly to break the political deadlock over the location of ESLAB. Later renamed ESRIN, and acronym for European Space Research Institute, ESLAR was based in Frascati (Italy). The ESRO Convention describes ESRINs' role in the following manner:

...to undertake laboratory and theoretical research in the basic physics and chemistry necessary to the understanding of past and the planning of future experiments in space.

– *ESRO Convention*

The facility began acquiring data from environmental satellites in the 1970s.

Chapter- 8

Aurora Programme

The **Aurora programme** is a human spaceflight programme of the European Space Agency (ESA) established in 2001 with the primary objectives of creating, and then implementing, a European long-term plan for exploration of the Solar System using robotic spacecraft and human spaceflight. A secondary objective is to search for life beyond the Earth.

Member states commit to participation in the Aurora programme for five-year periods (the first is 2005-2009), after which they can change their level of participation or pull out entirely.

In the early years the Aurora Programme planned for flagship missions such as ExoMars and NEXT., and arrow missions for key technology demonstrations, such as Earth re-entry vehicle/capsule and Mars aerocapture demonstrator.

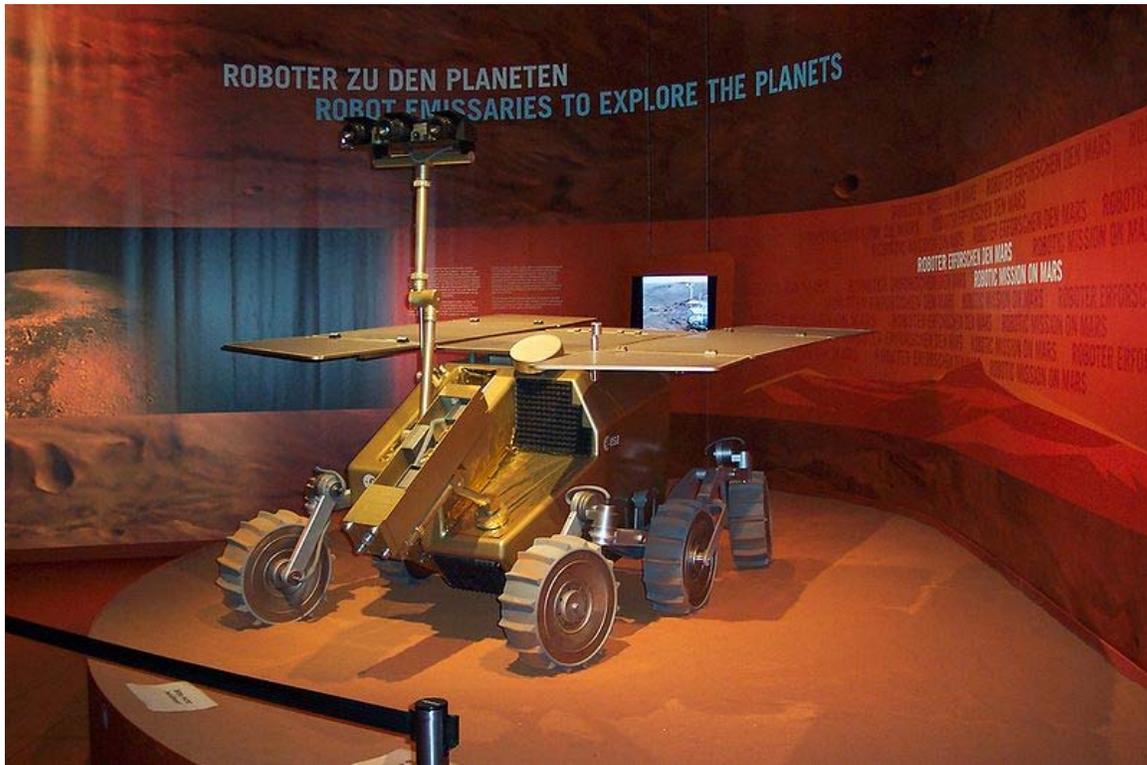
In recent years ESA has increasingly used the name **Aurora Exploration Programme**, or simply **Exploration Programme**. Although human spaceflight has remained a long-term goal of the programme, with some basic technology development in this area, the thrust has been on implementation of the ExoMars mission and preparations for an international Mars Sample Return Mission. Due to funding shortages on both sides of the Atlantic, these plans for robotic exploration of Mars are currently (2009) increasingly made in cooperation with NASA.

At a meeting in Plymouth on 2009 June 29–30 ESA and NASA created a Mars Exploration Joint Initiative (MEJI) with the aim of planning collaborative Mars missions for 2016, 2018 and 2020, and leading to the return of samples from Mars in the 2020s. The previous main effort of the Aurora Programme, the ExoMars mission, is not explicitly part of the MEJI collaboration and unlikely to be implemented as originally foreseen, but major parts of its science instruments are likely to be embedded in the MEJI collaboration. However, the Italian Space Agency (ASI), a major financier of the Aurora programme, has voiced scepticism regarding the proposed MEJI collaboration, in particular its lack of independent European demonstration of key capabilities for future planetary exploration.

The Aurora programme has currently two planned missions, both in collaboration with NASA. These are planned for launch in 2016 and 2018.

The text below is completely out of date, but shows some of the historical development of the Aurora Programme.

Missions



ExoMars model.

The first decade is planned to focus on robotic missions.

Flagship missions

ESA describes some Aurora programme missions as "Flagship" missions. The first Flagship mission is ExoMars, a robotic mission to Mars. It will involve development of a Mars orbiter, a descent module and a Mars rover.

Flagship missions planned as part of Aurora include (as of September 30, 2005):

- *ExoMars*, consisting of an unmanned orbiter and rover, launching in 2016
- a robotic *Mars Sample Return Mission*, to be conducted jointly with NASA, delayed until at least 2016

Arrow missions

Arrow missions are technology demonstrator missions focused on developing a certain technology needed for the Flagship missions. Approved Arrow missions so far (as of January 30, 2003):

- *Earth re-entry vehicle/capsule*, a step in the preparations for the *Mars Sample Return* mission.
- *Mars aerocapture demonstrator*, to further develop the technologies for using a planet's atmosphere to brake into orbit. This particular mission seems to have been revised into an expanded mission to demonstrate "aerobraking/aerocapture, solar electric propulsion and soft landing" to be launched in 2018.

Call for ideas on NEXT mission

On 9 March 2007, ESA invited proposals for its Next Exploration Science and Technology (NEXT) mission, which might launch in 2015-2018. NEXT would demonstrate key enabling capabilities, such as descent and precision landing, needed for a future Mars sample return mission.

Timeline

The proposed Aurora roadmap (as of September 30, 2005. This roadmap can, and most likely will, go through revisions):

- 2007 – Earth re-entry vehicle/capsule
- 2014 – Human mission technologies demonstrator(s) to validate technologies for orbital assembly and docking, life support and human habitation
- 2016 – Mars Sample Return mission with NASA
- 2018 – A technology demonstrator for aerobraking/aerocapture, solar electric propulsion and soft landing (formerly envisaged as a smaller Arrow-class mission to be launched in 2010)
- 2018 – ExoMars, a Mars rover. The scientific objectives include exobiological studies as well as study of the surface of Mars.
- 2024 – Human mission to the Moon
- 2026 – Automatic mission to Mars
- 2030/2033 – First human mission to Mars, as a split mission

Only ExoMars has been formally approved during the December 2005 Ministerial conference, which will postpone to a later date or cancel altogether the Earth re-entry vehicle/capsule, which was proposed for 2007.

The human part of the programme has been challenged by the main ESA contributors (France, Germany and Italy), making it quite possible that the whole Aurora Programme will be refocused on robotic-only exploration of Mars.

- 2013 – ExoMars, a Mars rover. The scientific objectives include exobiological studies as well as study of the surface of Mars.
- 2016? – Mars Sample Return mission with NASA
- 2018? – A technology demonstrator for aerobraking/aerocapture, solar electric propulsion and soft landing (formerly envisaged as a smaller Arrow-class mission to be launched in 2010)
- 2026? – Automatic mission to Mars

Chapter- 9

Galileo (Satellite Navigation)



Galileo logo

Galileo is a global navigation satellite system (GNSS) currently being built by the European Union (EU) and European Space Agency (ESA). The €5.3 billion project is named after the famous Italian astronomer Galileo Galilei. One of the political aims with Galileo is to provide a high-accuracy positioning system upon which European nations can rely independent from the Russian GLONASS and US GPS systems, which can be disabled for commercial users in times of war or conflict.

When in operation, it will use the two ground operations centers, one near Munich, Germany, and another in Fucino, Italy and will consist initially of 18 satellites by 2015. An additional €1.9 billion is planned to be spent bringing the system up to the full complement of 30 satellites (27 operational + 3 active spares). The first experimental satellite, GIOVE-A, was launched in 2005 and was followed by a second test satellite, GIOVE-B, launched in 2008. The first four operational satellites for navigation will be launched in 2011 and once this In-Orbit Validation (IOV) phase has been completed, additional satellites will be launched. On 30 November 2007 the 27 EU transportation

ministers involved reached an agreement that it should be operational by 2013, but later press releases suggest it was delayed to 2014.

The navigation system is intended to provide measurements down to the metre range as a free service including the height (altitude) above sea level, and better positioning services at high latitudes compared to GPS and GLONASS (though with recent upgrades to GPS similar accuracy levels are reached). As a further feature, Galileo will provide a global Search and Rescue (SAR) function. To do so, each satellite will be equipped with a transponder, which is able to transfer the distress signals from the user's transmitter to the Rescue Co-ordination Centre, which will then initiate the rescue operation. At the same time, the system will provide a signal to the user, informing him that his situation has been detected and that help is on the way. This latter feature is new and is considered a major upgrade compared to the existing GPS and GLONASS navigation systems, which do not provide feedback to the user. The use of basic (low-accuracy) Galileo services will be free and open to everyone. The high-accuracy capabilities will be available for paying commercial users and for military use.

History

In 1999, the different concepts (from Germany, France, Italy and the United Kingdom) for Galileo were compared and reduced to one by a joint team of engineers from all four countries. The first stage of the Galileo programme was agreed upon officially on 26 May 2003 by the European Union and the European Space Agency. The system is intended primarily for civilian use, unlike the United States system, which the U.S. military runs and uses on a primary basis. The U.S. reserves the right to limit the signal strength or accuracy of GPS, or to shut down public GPS access completely (although it has never done the latter), so that only the U.S. military and its allies would be able to use it in time of conflict. Until 2000, the precision of the signal available to non-U.S.-military users was limited (due to a timing pulse distortion process known as *selective availability*). The European system will only be subject to shutdown for military purposes in extreme circumstances. It will be available at its full precision to both civil and military users.

The European Commission had some difficulty getting money for the project's next stage, after several allegedly "per annum" sales projection graphs for the project were exposed in November 2001 as "cumulative" projections (which for each year projected, necessarily included all previous years of sales). The attention that was brought to this multi-billion euro exponentially growing error in sales forecasts resulted in a general awareness in the Commission and elsewhere that the program did not have near the return on investment that had been presented to the investors and decision-makers up until that point. Additionally, following the September 11, 2001 attacks, the United States Government wrote to the European Union opposing the project, arguing that it would end the ability of the United States to shut down satellite navigation in times of military operations. On 17 January 2002 a spokesman for the project stated that, as a result of U.S. pressure and economic difficulties, "Galileo is almost dead." A few months later, however, the situation changed dramatically. Partially in reaction to the pressure exerted by the U.S. Government, European Union member states decided it was important to

have a satellite-based positioning and timing infrastructure that the US could not easily turn off in times of political conflict.

The European Union and the European Space Agency agreed in March 2002 to fund the project, pending a review in 2003 (which was finalised on 26 May 2003). The starting cost for the period ending in 2005 is estimated at €1.1 billion. The required satellites (the planned number is 30) will be launched throughout the period 2006–2010 and the system will be up and running and under civilian control from 2010. The final cost is estimated at €3 billion, including the infrastructure on Earth, which is to be constructed in the years 2006 and 2007. The plan was for private companies and investors to invest at least two-thirds of the cost of implementation, with the EU and ESA dividing the remaining cost. An encrypted higher-bandwidth *Commercial Service* with improved accuracy would be available at an extra cost, with the base *Open Service* freely available to anyone with a Galileo-compatible receiver. Costs for the project have run 50% over initial estimates.

In June 2004, in a signed agreement with the United States, the European Union agreed to switch to a modulation known as BOC(1,1) (Binary Offset Carrier 1.1) allowing the coexistence of both GPS and Galileo, and the future combined use of both systems. The European Union also agreed to address the "mutual concerns related to the protection of allied and U.S. national security capabilities."

Early 2007, the EU had yet to decide how to pay for the system and the project was said to be "in deep crisis" due to lack of more public funds. German Transport Minister Wolfgang Tiefensee was particularly doubtful about the consortium's ability to end the infighting at a time when only one testbed satellite had been successfully launched.

Although a decision was yet to be reached, on Friday the 13th of July 2007 EU countries discussed cutting €548m (\$755m, £370m) from the union's competitiveness budget for the following year and shifting some of that cash to other parts of the financing pot, a move that could meet part of the cost of the union's Galileo satellite navigation system. European Union research and development projects could be scrapped to overcome a funding shortfall.

In November 2007, it was agreed to reallocate funds from the EU's agriculture and administration budgets and to soften the tendering process in order to invite more EU companies.

In April 2008, the EU transport ministers approved the Galileo Implementation Regulation. This allowed the €3.4bn to be released from the EU's agriculture and administration budgets. This will allow the issuing of contracts to start construction of the ground station and the satellites.

In June 2009, the European Court of Auditors published a report, pointing out governance issues, substantial delays and budget overruns that led to project stalling in 2007, leading to further delays and failures.

In October 2009, the European Commission cut the number of satellites from 28 to 22, with plans to order the remaining six at a later time. It also announced that the first OS, PRS and SoL signal will be available in 2013 and the CS and SOL sometime later. Current budget for 2006-2013 period planned for €3.4 billion was also considered as insufficient. The think tank Open Europe has estimated the total cost of Galileo from start to completion, and then running it over a 20 year period, at a staggering €22.2 billion — a cost which will be borne entirely by taxpayers. Under the original estimates (from 2000) this cost would have been €7.7 billion, of which only €2.6 billion was to be borne by taxpayers and the rest by private investors.

In November 2009, a ground station for Galileo was inaugurated near Kourou (French Guiana).

The launch of the first two of four in-orbit validation (IOV) satellites is currently planned for the end of April 2011, while the launch of full operational capability (FOC) satellites is planned to start in late 2012.

As of March 2010 it was verified that the budget for Galileo would only be available to provide the 4 IOV and 14 FOC satellites by 2014, with no funds currently committed to bring the constellation above this 60% capacity. Paul Verhoef, the then current satellite navigation program manager at the European Commission indicated that this limited funding would have serious consequences commenting at one point "To give you an idea, that would mean that for three weeks in the year you will not have satellite navigation" in reference to the currently proposed 18 vehicle constellation.

In December 2010 EU ministers in Brussels have voted Prague (Czech Republic) as the headquarters of the Galileo project.

International involvement

In September 2003, China joined the Galileo project. China was to invest €230 million (USD 302 million, GBP 155 million, CNY 2.34 billion) in the project over the following years.

In July 2004, Israel signed an agreement with the EU to become a partner in the Galileo project.

On 3 June 2005 the EU and Ukraine signed an agreement for Ukraine to join the project, as noted in a press release.

As of November 2005, Morocco have also joined the programme.

On 12 January 2006, South Korea joined the programme.

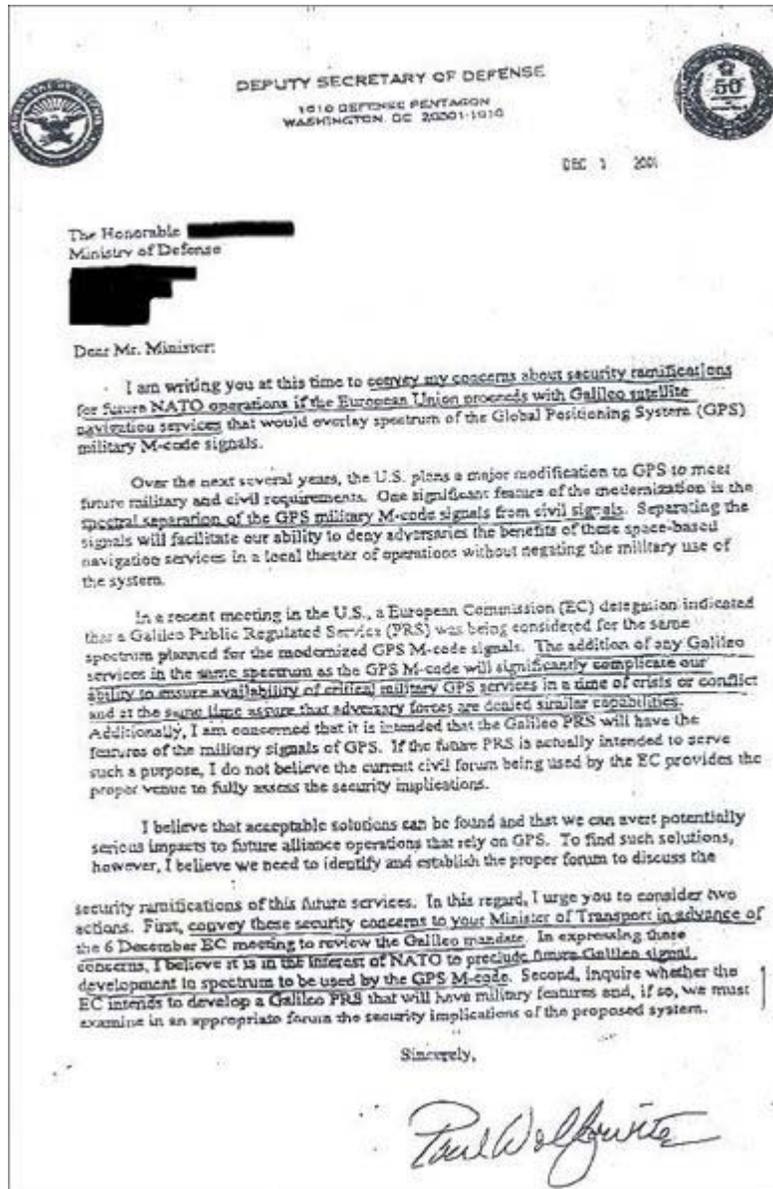
In November 2006, China abandoned the programme and decided to develop an independent global navigation system: Beidou navigation system.

On 30 November 2007, the 27 member states of the European Union unanimously agreed to move forward with the project, with plans for bases in Germany and Italy. Spain did not approve during the initial vote, but approved it later that day. This greatly improves the viability of the Galileo project: "The EU's executive had previously said that if agreement was not reached by January 2008, the long-troubled project would essentially be dead."

On 3 April 2009, Norway too joined the programme pledging €68.9 million toward development costs and allowing its companies to bid for the construction contracts. Norway while not a member of the EU is a member of the ESA.

Political implications of Galileo project

Tension with the United States



Letter from Paul Wolfowitz to the Ministers of the Member State of the European Union from December 2001 as part of the US-lobbying campaign against Galileo

Galileo is intended to be an EU GNSS civilian system that allows all users access to it. GPS is a US GNSS military system that provides location signals that have high accuracy to US military users, while also providing somewhat accurate location signals to others. The GPS had the capability to block the "civilian" signals while still being able to use the "military" signal (M-band). A primary motivation for the Galileo project was

international concern that the US could deny others access to GPS during political disagreements.

Since Galileo was designed to provide the highest possible accuracy (possibly even greater than GPS) to anyone, the US was concerned that an enemy could use Galileo signals in military strikes against the US (some weapons like missiles use GNSS systems for guidance). The frequency initially chosen for Galileo would have made it impossible for the US to block the Galileo signals without also interfering with their own GPS signals. The US did not want to lose their GNSS capability with GPS while denying enemies the use of GNSS. Some US officials became especially concerned when Chinese interest in Galileo was reported.

Some US officials have threatened to shoot down Galileo satellites in the event of a major conflict in which Galileo was used in attacks against American forces. The EU's stance is that Galileo is a neutral technology, available to all countries and everyone. Originally, EU officials did not want to change their original plans for Galileo, but have since reached a compromise, that Galileo was to use a different frequency. This allowed the blocking/jamming of one GNSS system without affecting the other, giving the US a greater advantage in conflicts in which it has the electronic warfare upper hand.

GPS and Galileo

One of the reasons given for developing Galileo as an independent system was that GPS is widely used worldwide for civilian applications, which until 2000 had Selective Availability (SA) enabled (and could be re-enabled). This could intentionally render the locations given via GPS inaccurate. Galileo's proponents argued that civil infrastructure, including aeroplane navigation and landing, should not rely solely upon GPS.

On May 1, 2000, SA was disabled by the then President of the United States Bill Clinton, and in late 2001, the entity managing the GPS confirmed that they never intend to enable selective availability again. Though Selective Availability still exists, on 19 September 2007, the US Department of Defense announced that the new GPS satellites will not be capable of implementing Selective Availability. This means the next wave of Block IIF satellites launching in 2009 will not support SA. As old satellites are replaced in the GPS modernization program, SA will cease to exist. The modernization programme also contains standardized features that allow GPS III and Galileo systems to inter-operate, allowing a new receiver to utilise both systems to improve accuracy. By combining GPS and Galileo, it can create an even more accurate GNSS system.

Final system description

Galileo satellites

- 30 in-orbit spacecraft (including 3 spares)
- orbital altitude: 23,222 km (MEO)

- 3 orbital planes, 56° inclination, ascending nodes separated by 120° longitude (9 operational satellites and one active spare per orbital plane)
- satellite lifetime: >12 years
- satellite mass: 675 kg
- satellite body dimensions: 2.7 m x 1.2 m x 1.1 m
- span of solar arrays: 18.7 m
- power of solar arrays: 1,500 W (end of life)

Services

The Galileo system will have five main services:

- **Open Access Navigation:** This will be 'free to air' and for use by the mass market; Simple timing and positioning down to 1 metre.
- **Commercial Navigation (Encrypted):** High accuracy to the centimetre; Guaranteed service for which service providers will charge fees.
- **Safety Of Life Navigation:** Open service; For applications where guaranteed accuracy is essential; Integrity messages will warn of errors.
- **Public Regulated Navigation (Encrypted):** Continuous availability even in time of crisis; Government agencies will be main users.
- **Search And Rescue:** System will pick up distress beacon locations; Feasible to send feedback, confirming help is on its way.

Other secondary services will also be available.

The concept

Each satellite will have two types of atomic clocks 4 in total (2 rubidium frequency standards and 2 passive hydrogen masers) - critical to any sat-nav system and a number of other components. These clocks will provide an accurate timing signal for a receiver to calculate the time that it takes the signal to reach the target. This information is used to calculate the position of the receiver by trilaterating the difference in received signals from multiple satellites.

Satellite system

Galileo satellite test beds: GIOVE



GIOVE-A was successfully launched 28 December 2005.

In 2004 the Galileo System Test Bed Version 1 (GSTB-V1) project validated the on-ground algorithms for Orbit Determination and Time Synchronisation (OD&TS). This project, led by ESA and European Satellite Navigation Industries, has provided industry with fundamental knowledge to develop the mission segment of the Galileo positioning system.

- GIOVE-A is the first GIOVE (Galileo In-Orbit Validation Element) test satellite. It was built by Surrey Satellite Technology Ltd (SSTL), and successfully launched on 28 December 2005 by the European Space Agency and the Galileo Joint. Operation of GIOVE-A ensured that Galileo meets the frequency-filing allocation and reservation requirements for the International Telecommunication Union (ITU), a process that was required to be complete by June 2006.
- GIOVE-B, built by Astrium and Thales Alenia Space, has a more advanced payload than GIOVE-A. It was successfully launched on 27 April 2008 at 22:16 UTC (4.16 a.m. (Baikonur time) aboard a Soyuz-FG/Fregat rocket provided by Starsem.

A third satellite, GIOVE-A2, was originally planned to be built by SSTL for launch in the second half of 2008. Construction of GIOVE-A2 was terminated due to the successful launch and in-orbit operation of GIOVE-B.

The GIOVE Mission segment operated by European Satellite Navigation Industries is exploiting the GIOVE-A/B satellites to provide experimental results based on real data to be used for risk mitigation for the IOV satellites that will follow on from the testbeds. ESA organised the global network of ground stations to collect the measurements of GIOVE-A/B with the use of the GETR receivers for further systematic study. GETR receivers are supplied by Septentrio as well as the first Galileo navigation receivers to be

used to test the functioning of the system at further stages of its deployment. Signal analysis of GIOVE-A/B data has confirmed successful operation of all the Galileo signals with the tracking performance as expected.

In-Orbit Validation (IOV) satellites

These testbed satellites will be followed by four IOV Galileo satellites that will be much closer to the final Galileo satellite design. The launch of the first pair of satellites is scheduled in April 2011. Once this In-Orbit Validation (IOV) phase has been completed, the remaining satellites will be installed to reach the Full Operational Capability.

Full Operational Capability (FOC) satellites

On 7 January 2010, it was announced that the contract to build the first 14 FOC satellites was awarded to OHB System and Surrey Satellite Technology Limited (SSTL). Fourteen satellites will be built at a cost of 566M euros (\$811M; £510M). The first two are expected to be ready in October 2012. Arianespace will launch the satellites for a cost of 397M euros (\$569M; £358M).

The European Commission announced also that the contract of 85 million euros for the System support covering industrial services required by ESA for integration and validation of Galileo System was awarded to Thales Alenia Space. Thales Alenia Space subcontract performances to Astrium GmbH and security to Thales Communications.

Science projects using Galileo

In July 2006, an international consortium of universities and research institutions embarked on a study of potential scientific applications of the Galileo constellation. This project, dubbed GEO6, is a 360-degree study oriented to the scientific community in its broader sense, aiming to define and implement new applications of Galileo.

Among the various GNSS users identified by the Galileo Joint Undertaking, the GEO6 project addresses the Scientific User Community (UC).

The GEO6 project aims at fostering possible novel applications within the scientific UC of GNSS signals, and particularly of Galileo.

The AGILE project is an EU-funded project devoted to the study of the technical and commercial aspects of Location-based Services (LBS). It includes technical analysis of the benefits brought by Galileo (and EGNOS); also studying the hybridisation of Galileo with other positioning technologies (network-based, WLAN, etc.). Within these project, some pilot prototypes were implemented and demonstrated.

On the basis of the potential number of users, potential revenues for Galileo Operating Company or Concessionaire (GOC), international relevance, and level of innovation, a

set of Priority Applications (PA) will be selected by the consortium and they will be developed within the time frame of the same Project.

These applications will help to increase and optimise the use of the EGNOS services as well as the opportunities offered by the Galileo Signal Test-Bed (GSTB-V2) and the Galileo (IOV) phase.

Coins



European Satellite Navigation commemorative coin

The European Satellite Navigation project was selected as the main motif of a very high value collectors' coin: the Austrian European Satellite Navigation commemorative coin, minted on 1 March 2006. The coin has a silver ring and niobium “pill”, colour gold-brown. In the reverse, the niobium portion depicts navigation satellites orbiting the Earth. The ring shows different modes of transport (an aeroplane, a car, a container ship, a train and a lorry) for which satellite navigation was developed.

Chapter- 10

Global Monitoring for Environment and Security

Global Monitoring for Environment and Security (GMES) is a joint initiative of the European Commission and European Space Agency, which aims at achieving an autonomous and operational Earth observation capacity.

The objective is to rationalize the use of multiple-sources data to get a timely and quality information, services and knowledge, and to provide autonomous and independent access to information in relation to environment and security. In other words, it will pull together all the information obtained by environmental satellites, air and ground stations to provide a comprehensive picture of the "health" of Earth.

Main users of GMES will be policy-makers. GMES should allow them to prepare national, European and international legislation on environmental matters (including climate change) and to monitor the implementation of this legislation.

GMES builds upon 4 pillars: the space component (observation satellites and associated ground segment with missions observing land, atmospheric and oceanographic parameters), in-situ measurements (ground-based and airborne data gathering networks providing information on oceans, continental surface and atmosphere), data harmonization and standardization, and services to users.

The geo-spatial information services offered by GMES can be grouped into six main interacting themes: land, ocean, emergency response, atmosphere, security and climate change. The first three GMES services under the land, ocean and emergency response themes and two additional services addressing the atmosphere and security themes were unveiled at the GMES Forum held in Lille in September 2008. Currently in their pre-operational phase, it is foreseen that these services enter into a EU-wide operational phase by 2011, with the objective to be fully operational by 2014.

GMES is fast moving towards an operational phase. The key to providing operational GMES services is to have an appropriate governance and business model structure in place which supports provisioning of these services.

GMES is the European Union contribution to the Global Earth Observation System of Systems GEOSS.

History

19 May 1998: institutions involved in the development of space activities in Europe give birth to GMES through a declaration known as "The Baveno Manifesto". At that time, GMES stands for "Global Monitoring for Environmental Security"

Year 1999: the name is changed to "Global Monitoring for Environment and Security", thus illustrating that the management of the environment also has security implications.

Year 2001: at the occasion of the Gothenburg Summit, the Heads of State and Government request that "*the Community contribute to establishing by 2008 a European capacity for Global Monitoring for Environment and Security*".

October 2002: the nature and scope of the "Security" component of GMES are defined as addressing prevention of and response to crises related to natural and technological risk, humanitarian aid and international cooperation, monitoring of compliance with international treaties for conflict prevention, humanitarian and rescue tasks, peacekeeping tasks and surveillance of EU borders.

February 2004: the Commission Communication "*GMES: Establishing a GMES capacity by 2008*" introduces an Action Plan aimed at establishing a working GMES capacity by 2008. In 2004, a Framework Agreement is also signed between EC and ESA, thus providing the basis for a space component of GMES.

May 2005: the Commission Communication "*GMES: From Concept to Reality*" establishes priorities for the roll-out of GMES services in 2008, the initial focus being on land monitoring, marine monitoring and emergency response services, also known as Fast Track Services (FTS). Later services, also known as Pilot Services, are expected to address atmosphere monitoring, security and climate change.

June 2006: the EC establishes the GMES Bureau, with the primary objective of ensuring the delivery of the priority services by 2008. Other objectives of the GMES Bureau are to address the issues of the GMES governance structure and the long-term financial sustainability of the system.

May 2007: adoption of the European Space Policy Communication, recognising GMES as a major flagship of the Space Policy.

September 2008: official launch of the 3 FTS services and 2 Pilot services in their pre-operational version at the occasion of the GMES Forum held in Lille, France.

November 2008: the Commission Communication "*GMES: We care for a Safer Planet*" establishes a basis for further discussions on the financing, operational infrastructure and effective management of GMES.

May 2009: the Commission Proposal for a Regulation on "*the European Earth Observation Programme (GMES) and its initial operations (2011-2013)*" proposes a legal basis for the GMES programme and EC funding of its initial operations.

November 2010: the regulation on "*the European Earth Observation Programme (GMES) and its initial operations (2011-2013)*" entered into force.

From R&D to operational services

Over the last decades, European and national institutions have made substantial R&D efforts in the field of Earth observation. These efforts have resulted into tremendous achievements but the services and products developed during this period have limitations which are inherent to R&D activities (e.g. lack of service continuity on the long-term).

GMES has been conceived to move from R&D to operational services. The transition to operational services follows a phased approach:

- **2008 – 2010:** GMES pre-operational services (FTS and Pilot services)
- **2011 – 2013:** GMES initial operations
- **From 2014:** GMES fully operational services

The development of the five services is being realised by a series of projects launched by the European Commission and partly funded through the EU's 7th Framework Programme (FP7). These projects are *geoland2* (land), *MyOcean* (marine), *SAFER* (emergency response), *MACC* (atmosphere) and *G-MOSAIC* (security).

- **geoland2** started on 1 September 2008. The project covers a wide range of domains such as land use, land cover change, soil sealing, water quality and availability, spatial planning, forest management, carbon storage and global food security.
- **MyOcean** started on 1 January 2009. It covers themes such as maritime security, oil spill prevention, marine resource management, climate change, seasonal forecast, coastal activities, ice survey and water pollution.
- **SAFER** started on 1 January 2009. The project addresses three main domains: civil protection, humanitarian aid and Security crises management.
- **MACC** started on 1 June 2009. The project will continue and refine the products developed in the projects *GEMS* and *PROMOTE*.
- **G-MOSAIC** started on 1 January 2009. Together with the **LIMES** project (co-funded by the European Commission under FP6), *G-MOSAIC* specifically deals with the Security domain of GMES addressing topics such as Support to Intelligence & Early Warning and Support to Crisis Management Operations operations.

Space missions

ESA is currently developing five types of new satellites called Sentinel to meet the needs of the GMES programme. The Sentinel missions include radar and super-spectral imaging for land, ocean and atmospheric monitoring. The Sentinel missions will have the following objectives:

- Sentinel 1 will provide all-weather, day and night radar imaging for land and ocean services. The first Sentinel-1 satellite is planned for launch in 2012;
- Sentinel 2 will provide high-resolution optical imaging for land services (e.g. imagery of vegetation, soil and water cover, inland waterways and coastal areas). Sentinel-2 will also provide information for emergency services. The first Sentinel-2 satellite is planned for launch at the end of 2012;
- Sentinel 3 will provide ocean and global land monitoring services. The first Sentinel-3 satellite is planned for launch at the end of 2012;
- Sentinel-4, embarked as a payload upon a Meteosat Third Generation Satellite, will provide data for atmospheric composition monitoring. It will be launched in 2017;
- Sentinel-5 will also provide data for atmospheric composition monitoring. It will be embarked on a post-EUMETSAT Polar System (EPS) spacecraft and launched in 2019;
- Sentinel-6 is the intent to sustain high precision altimetry missions following the Jason-2 satellite.

Before the Sentinel missions provide data to GMES, numerous existing or planned space missions provide or will provide data useful to the provision of GMES services. These missions are often referred to as "*GMES Contributing Missions (GCMs)*".

ERS: The European Remote Sensing Satellite ERS-1 (1991-2000) was ESA's first Earth observation satellite. ERS-2, launched in 1995, provides data related to ocean surface temperature, winds at sea and atmospheric ozone.

ENVISAT: Launched in 2002, Envisat is the largest Earth Observation spacecraft ever built. It carries sophisticated optical and radar instruments among which the Advanced Synthetic Aperture Radar (ASAR) and the Medium Resolution Imaging Spectrometer (MERIS). Envisat provides continuous observation and monitoring of the Earth's land, atmosphere, oceans and ice caps. ESA Member States have unanimously voted to extend the Envisat mission through to 2013.

Earth Explorers: Earth Explorers are smaller research missions dedicated to specific aspects of our Earth environment. Earth Explorer missions focus on the atmosphere, biosphere, hydrosphere, cryosphere and the Earth's interior with the overall emphasis on learning more about the interactions between these components and the impact that human activity is having on natural Earth processes. There are 6 missions selected for implementation:

- GOCE (Gravity Field and Steady-State Ocean Explorer), launched on 17 March 2009
- SMOS (Soil Moisture and Ocean Salinity), launched on 2 November 2009
- CryoSat-2 (measurement of the thickness of floating ice), scheduled for launch on 25 February 2010.
- Swarm (high-precision and high-resolution measurements of the strength and direction of the Earth's magnetic field), scheduled for launch in 2011
- ADM-Aeolus (Atmospheric Dynamics Mission), scheduled for launch in 2011
- EarthCARE (Earth Clouds, Aerosols and Radiation Explorer), scheduled for launch in 2013

MSG: the Meteosat Second Generation is a joint project between ESA and EUMETSAT.

MetOp: MetOp is Europe's first polar-orbiting satellite dedicated to operational meteorology. MetOp is a series of three satellites to be launched sequentially over 14 years from October 2006. The series will provide data for both operational meteorology and climate studies.

SPOT: SPOT (Satellite Pour l'Observation de la Terre) consists of a series of earth observation satellites providing high resolution images of the Earth. SPOT-4 and SPOT-5 include sensors called VEGETATION able to monitor continental ecosystems.

TerraSAR-X: TerraSAR-X is an Earth observation satellite providing high quality topographic information. TerraSAR-X data has a wide range of applications (e.g. land use / land cover mapping, topographic mapping, forest monitoring, emergency response monitoring and environmental monitoring)

COSMO-SkyMed: the COntstellation of small Satellites for the Mediterranean basin Observation is an Earth observation satellite system which will include four satellites equipped with synthetic aperture radar (SAR) sensors. Applications include seismic hazard analysis, environmental disaster monitoring and agricultural mapping.

DMC: The Disaster Monitoring Constellation (DMC) consists of five remote-sensing satellites. The constellation provides emergency Earth imaging for disaster relief under the International Charter for Space and Major Disasters.

JASON-2: The JASON-2 satellite provides precise measurements of ocean surface topography, surface wind speed and wave height; as this type of measurement is a crucial requirement for the GMES Marine Services the European Commission has included this type of mission in its latest communication on the future GMES Space Component as Sentinel 6

PLEIADES: The PLEIADES constellation consists of two satellites providing very high resolution images of the Earth

Data provided by non-European satellite missions (e.g. LANDSAT, GOSAT, RADARSAT) can also be used by GMES.

In-Situ Coordination

GMES In-Situ Coordination (GISC). GISC is a FP7 funded initiative, will last for three years (January 2010 – December 2012) and is coordinated by the European Environment Agency (EEA).

In-situ data are all data from sources other than Earth observation satellites. Consequently all ground-based, air-borne, and ship/buoy-based observations and measurements that needed to implement and operate the GMES services are part of the in-situ component. In-situ data are indispensable; they are assimilated into forecasting models, provide calibration and validation of space-based information, and contribute to analysis or filling gaps not available from space sources.

The goal of GISC is to develop an innovative and sustainable framework for open access to in-situ data for GMES.

GISC objectives will be achieved by:

- documenting the in-situ data needs and data requirements
- cooperating with the users, stakeholders, and service providers
- exploring and determining methods to enable networks to provide the required in-situ data for GMES
- exploring approaches to the integration of in-situ assets and networks into long-term sustainable frameworks for GMES services
- providing 'quick-wins'

GISC is undertaken with reference to other initiatives, such as INSPIRE (Infrastructure for Spatial Information in Europe) and SEIS (Shared Environmental Information System) as well as existing coordination and data exchange networks. The coordinated access to data will retain the capacity to link directly data providers and the service providers because it is based on the principles of SEIS and INSPIRE. The implementation of INSPIRE is embedded in the synergies and meta-data standards that are used in GISC. Data and information will aim to be managed as close as possible to its source in order to achieve a distributed system, by involving countries and existing capacities which maintain and operate the required observation infrastructure.

Other relevant initiatives

Other initiatives will also facilitate the development and functioning of GMES services:

- INSPIRE: this initiative aims at building a European spatial data infrastructure beyond national boundaries.
- Urban Atlas: Compiled from thousands of satellite photographs, the Urban Atlas provides detailed and cost-effective digital mapping, ensuring that city planners have the most up-to-date and accurate data available on land use and land cover. The Urban Atlas will enable urban planners to better assess risks and opportunities, ranging from threat of flooding and impact of climate change, to identifying new infrastructure and public transport needs. All cities in the EU will be covered by the Urban Atlas by 2011.
- SEIS: The Shared Environmental Information System (SEIS) is a collaborative initiative of the European Commission and the European Environment Agency (EEA) to establish together with the Member States an integrated and shared EU-wide environmental information system.

GMES is one of three related initiatives that are the subject of the GIGAS (*GEOSS, INSPIRE and GMES an Action in Support*) harmonization project under the auspices of the EU 7th Framework Programme.

Chapter- 11

Other European Space Agency Programs

Cosmic Vision

The **Cosmic Vision** is the paraphrasing name given to the roadmap for scientific space based missions of the European Space Agency (ESA) in the time frame between 2015 and 2025.

The initial call of ideas and concepts was launched in 2004 with a subsequent workshop held in Paris to define more fully the themes of the Vision under the broader headings of Astronomy and Astrophysics, Solar System Exploration and Fundamental Physics.

By early 2006 the formulation for a 10-year plan based around 4 key questions emerged:

- What are the conditions for planet formation and the emergence of life?
- How does the Solar System work?
- What are the fundamental physical laws of the Universe?
- How did the Universe originate and what is it made of?

In March 2007 a call for mission ideas was formally released, which yielded in 19 astrophysics, 12 fundamental physics and 19 solar system mission proposals.

Medium-size missions (M)

M-class projects will usually be relatively stand-alone ESA projects. M-missions have an ESA cost ceiling of 470 million euro. The two first M-class missions, M1 and M2, are planned for launch in 2017-2018. There are currently three candidates undergoing definition studies for these two slots:

- Euclid, a proposed mission to study dark energy and dark matter
- Plato, a proposed mission to search for new exoplanets and measure stellar oscillations

- Solar Orbiter, a proposed mission for close-up observations of the sun

The selection of two of the above candidates for implementation as M1 and M2 is expected to be made in September/October 2011.

The third M-class mission, M3, is planned for launch in 2022. ESA released a call for missions proposals for M3 in July 2010.

Large missions (L)

L-class projects will often be carried out in collaboration with other partners and should have an ESA cost not exceeding 900 million euros. The first large mission, L1, is planned for launch in 2020. There are currently three candidates for L1:

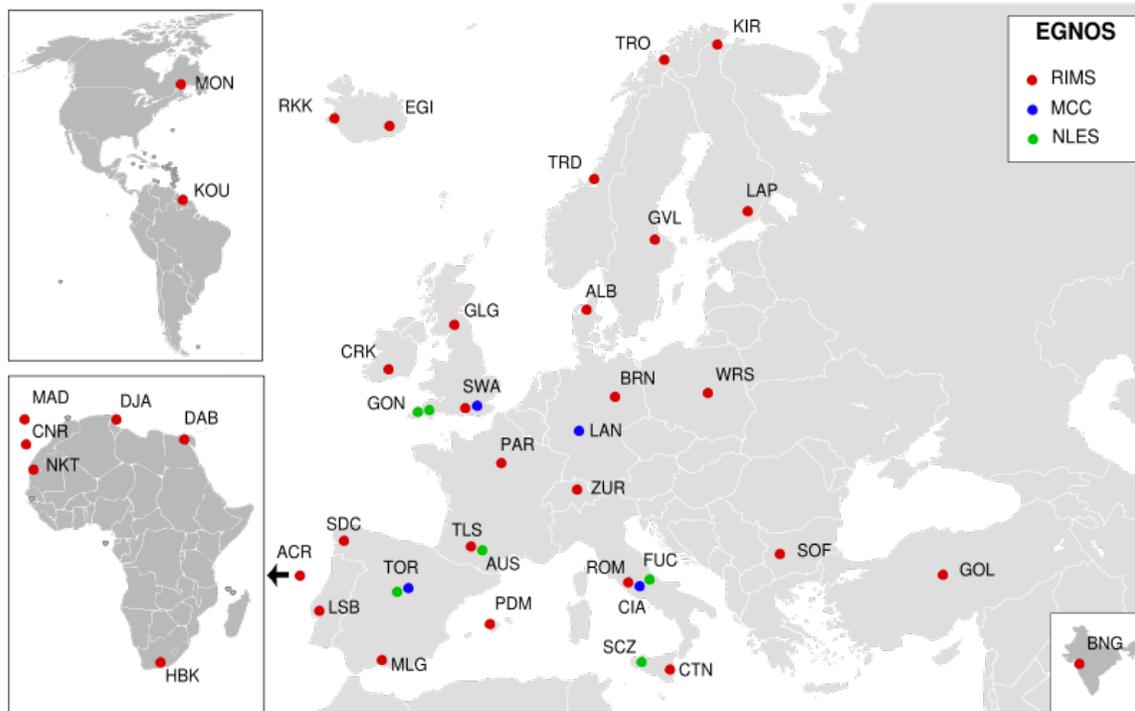
- Europa Jupiter System Mission/Laplace, a proposed mission to study the Jovian system (with NASA)
- LISA, a proposed gravitational wave observatory (with NASA)
- IXO, previously XEUS, the proposed International X-ray Observatory (with NASA and JAXA)

The process for selection of one of the candidates for implementation as L1 started in October 2010.

European Geostationary Navigation Overlay Service



EGNOS logo



Map of the EGNOS ground network

The **European Geostationary Navigation Overlay Service (EGNOS)** is a satellite based augmentation system (SBAS) under development by the European Space Agency, the European Commission and EUROCONTROL. It is intended to supplement the GPS, GLONASS and Galileo systems by reporting on the reliability and accuracy of the signals. The official start of operations was announced by the European Commission on 1 October 2009.

According to specifications, horizontal position accuracy should be better than seven metres. In practice, the horizontal position accuracy is at the metre level. The EGNOS system consists of three geostationary satellites and a network of ground stations.

The system started its initial operations in July 2005, showing outstanding performances in terms of accuracy (better than two metres) and availability (above 99%); it is intended to be certified for use in safety of life applications in early 2011. A commercial service is under test and will also be made available in 2011.

Similar service is provided in North America by the Wide Area Augmentation System (WAAS), and in Asia, notably Japan, by the Multi-functional Satellite Augmentation System (MSAS).

On 28 July 2005, the European Space Agency announced it had signed a contract with an operating company, European Satellite Services Provider, to run EGNOS. As of July 2005, EGNOS has been broadcasting a continuous signal, and at the end of July 2005 the system was again used to track cyclists in the Tour de France road race.

Initial work to extend EGNOS coverage to the Southern Africa region is currently being undertaken.

Satellites

Similarly to WAAS, EGNOS is mostly designed for aviation users which enjoy unperturbed reception of direct signals from geostationary satellites up to very high latitudes. The use of EGNOS on the ground, especially in urban areas, is limited due to relatively low elevation of geostationary satellites: about 30° above horizon in central Europe and much less in the North of Europe. To address this problem, ESA released in 2002 SISNeT, an Internet service designed for continuous delivery of EGNOS signals to ground users. First experimental SISNeT receiver was created by the Finnish Geodetic Institute. The commercial SISNeT receivers have been developed by Septentrio.

Satellite Name & Details	NMEA / PRN	Location
Inmarsat 3-F2 (Atlantic Ocean Region-East)	NMEA #33 / PRN #120	15.5°W
ARTEMIS	NMEA #37 / PRN #124	21.5°E
Inmarsat 4-F2 (Europe Middle East Africa)	NMEA #39 / PRN #126	25°E
Inmarsat 3-F1 (Indian Ocean)	NMEA #44 / PRN #131	64.5°E
Astra 4B (a.k.a Sirius 5 or SES-5)	launch in 2011	5.0°E
Astra 5B	launch in 2013	31.5°E

Ground stations

More than 40 ground stations are linked together to create EGNOS network which consists:

34 **RIMS** (**R**anging and **I**ntegrity **M**onitoring **S**tations) - receiving signals from US GPS satellites,

4 **MCC** (**M**ission **C**ontrol **C**enters) - data processing and differential corrections counting,

6 **NLES** (**N**avigation **L**and **E**arth **S**tations) - accuracy and reliability data sending to three geostationary satellite transponders to allow end-user devices to receive them.

Future Launchers Preparatory Programme

The **Future Launchers Preparatory Programme (FLPP)** is a European Space Agency (ESA) program that aims to develop a "Next Generation Launcher" carrier rocket as a successor to Ariane 5. The program began in February 2004, and the NGL is foreseen to become operational around the year 2020. A secondary aim of the FLPP is to enhance the reliability and competitiveness of ESA launchers, including those operational today.

Expectations

The FLPP is expected to harmonise European launcher technology development activities and steer the restructuring of the European launcher industrial sector, optimizing the use of available resources, and leading to more cost-effective launchers.

Current status

Presently the program is divided into periods: the first covering 2004 to 2006 and the second from 2006 to 2009. During these periods, the FLPP will conduct technology activities to foster new technology capabilities within Europe. The following types of technology activities are foreseen;

- system studies
- ground tests
- in-flight tests e.g. the Intermediate eXperimental Vehicle (IXV)

Living Planet Programme

The **Living Planet Programme** is a program within the European Space Agency and part of the Global Monitoring for Environment and Security (GMES) programme. LPP consists of research missions under Earth Observation, whereas the Earth Watch is to make applicable the Earth Observation data in weather forecasting or resource management.

Currently there are eight Earth Observation missions in progress:

- GOCE – Gravity Field and Steady-State Ocean Circulation Explorer - was launched on March 17, 2009.
- SMOS – Soil Moisture and Ocean Salinity satellite will study ocean salinity and soil moisture; it was launched in 2 November 2009.

- CryoSat is designed to map the Earth's ice cover. CryoSat-1 was lost in 2005 when the Russian SS-19 "Rockot" malfunctioned and was terminated. CryoSat-2 was launched 8 April 2010.
- Aeolus – Atmospheric Dynamics Mission will use an innovative laser to measure winds. Due for launch in 2011.
- Swarm – is a trio of satellites to map the Earth's magnetism. Due for launch in 2012
- EarthCARE – Earth Clouds Aerosols and Radiation Explorer will examine the formation and effects of clouds. Due for launch in 2013.
- 7th Earth Explorer mission was in January 2009 decided to be one of the following three missions BIOMASS (global measurements of forest biomass), CoReH2O (snow, ice and water cycle key characteristics observations) or PREMIER (atmospheric processes linking trace gases, radiation, chemistry and climate) selected out of six missions. Scheduled to launch in 2016.
- 8th Earth Explorer mission is open to ideas from the scientific community. Due to launch in 2018.