European Space Agency

Aurora

European Space Exploration Programme

EXECUTIVE SUMMARY

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1. What is Aurora?

A European Space Exploration Programme based on a road map culminating in a voyage by European astronauts to Mars by 2030, with a return to the Moon in the meantime!

Aurora was presented as a response to the mandate from Ministers, received by ESA in 2000, to prepare for the next steps in human exploration. The programme and its principle were unanimously approved at the ESA Council at Ministerial Level held in Edinburgh in 2001.

Conceived after a broad survey conducted with the scientific and industrial communities, Aurora defines and will implement the European strategy for the exploration of the Solar System and of those planets that may harbour life forms. Aurora is currently in its preparatory phase.

Between now and 2015, Aurora will feature robotic missions both to the Moon and to Mars, in preparation for human missions to both targets. The final goal is to allow European astronauts to reach Mars as part of an international endeavour by the end of the third decade. The work carried out in the framework of Aurora will provide the basis for defining the European participation in that endeavour, taking due account of Europe's strategic industrial, scientific and technological interests. It is expected that such a decision will be taken around 2015.

In summary, Aurora proposes a stepwise build-up of capabilities and knowledge, in a non-binding framework of international cooperation, until the go-ahead decision is taken.

Aurora is:

- an inspiring objective for present and future generations, a key asset for education;
- an irreplaceable source of innovation and research in technology, planetary science, astrobiology, and life sciences, offering valuable spin-offs for the Earth and featuring a strong interdisciplinary approach;
- a powerful tool for peaceful international cooperation, and for European identity building;
- an extension of Europe's human space flight programmes, with its industrial relevance and implications;
- an affordable objective.

2. Why should Europe do it?

The desire to explore is a fundamental heritage of the European people. Exploration has always been both inspirational and utilitarian: to discover what is "out there", but also to find new resources; to understand the motion and essence of stars and planets, but also to find ways to guide ships at sea and produce accurate maps.

As Europe continues to assert itself both economically and politically as a leading world power, it cannot leave space exploration to the other space-faring powers, Russia, the United States, Japan and now China, without participating significantly.

Space remains a highly strategic asset in industrial, political, technological and economic terms. Europe's competitiveness rests on its technological capabilities and their constant advancement. Space exploration by its very nature ranks among the most effective ways of achieving this. It also heightens the appeal of peaceful science and technology to society at large and to the younger generations. It offers the most interesting, inspiring and affordable "high visibility" endeavour with which to reaffirm Europe's values and capabilities.

3. How should Europe do it?

3.1. The road map:

Europe's first attempt to visit the Red Planet is the Mars Express mission, carrying a suite of instruments including the Beagle-2 lander. The first European mission to reach the Moon will be Smart-1, launched in September 2003. The experience gained through these two robotic missions is paving the way for the first steps in Aurora. Similarly, the International Space Station (ISS) is giving Europe indispensable experience in human space flight.

The ISS will most likely be in operation for another 10-15 years. It is a unique facility for training humans to occupy deep space over long periods of time. The Moon is a logical step in the same direction. Europe needs to be in a position to stimulate and join such a venture and to do so from a position of strength whenever the time is ripe for taking the decision to go. Landing European astronauts on Mars is the final goal.

The preparation for that ultimate step will be through technology preparation and robotic missions that Europe can easily lead, building technological and political credibility as it goes along, and establishing itself as an indispensable partner in the human exploration of the Red Planet.

Aurora's preliminary road map will evolve as the programme unfolds as a result of the new knowledge and of joint work with international partners.

As currently envisaged, the first decade will include development and launch of the first robotic missions and development and test of the human technologies. The second decade will include a number of Technology Demonstration missions, undertaken either autonomously or with ISS support, to prepare the landing of astronauts on the Moon and the testing of in-situ technologies that are deemed necessary for the later human Martian expedition. The third decade will see the deployment of human size missions to the Red Planet. Figure 1 illustrates the range of missions envisaged in the programme.

In parallel the programme is also addressing the ethical, societal and legal issues connected with planetary exploration and the search for life.

3.2. The technologies Europe must have

The technologies that are needed to explore the Red Planet with robots, thus paving the way for human explorers, and those necessary to sustain humans for years in hostile environments, offer challenges to the brilliant minds of European scientists and engineers. These can be as diverse as:

- Power and propulsion systems including hydrogen storage - a key technology for the future "hydrogen economy"- fuel cells, CO^2 conversion and nuclear power generation;
- Life support and recycling systems;
- Long-term habitability module design, psychological effects;
- Assembly in Low Earth Orbit;
- Rendezvous and Docking in Mars orbit;
- Image recognition, automatic precision navigation and landing;
- Radiation protection, countermeasures against prolonged exposure to micro-gravity effects, health monitoring;
- Bio-detection, bio-protection and sterilisation techniques;

All of these activities are also being pursued through earthbound research. What the space challenge brings is an additional set of constraints that force the creativity and inventiveness of researchers. These constraints (low power, low mass, extreme reliability and autonomy) make these solutions attractive for many other earthbound applications.

3.3. The robotic missions

Aurora's robotic missions are categorised as 'Flagship' or 'Arrow', the former being major missions with a clear and self-contained capability demonstration and knowledge acquisition goal, while the latter are limited cost missions, intended mainly for technology demonstration.

A draft baseline scenario has been defined by ESA on the basis of a wide-ranging call for ideas. The Exploration Programme Advisory Committee (EPAC) has endorsed its objectives and approach. So also has the Aurora Board of Participants (ABP).

Consequently, the first three robotic missions in the scenario have been approved for industrial studies.

Two Flagship class missions are envisaged:

- ExoMars, due to be launched in 2009, featuring an orbiter and a large rover carrying 40kg of astrobiology instruments. Over 580 scientists from 30 countries have responded to the instruments call for ideas;
- Mars Sample Return, featuring four elements: Orbiter and the Earth Re-entry Module, due to be launched in 2011, and Descent and Ascent Modules, due to launch in 2013.

In further Arrow class categories, the following technology demonstrator mission was approved:

- A Re-entry Vehicle demonstrator.

A new Arrow mission will be selected in 2004, with possible candidates being international cooperation on one of the planned lunar missions or a technology-driven Martian micro-mission.

3.4. The structure of the programme

Aurora is built as an envelope programme based on successive five-years periods. Each Member State will be committing itself only to each programmatic period of five years and will be able to change the level of its participation or pull out at the end of each period. Whenever the decision is taken to go ahead with the human missions to the Moon and Mars, a different programmatic framework will have to be set up to implement it.

The programme will develop the technologies for exploration, in parallel to the robotic missions described above. Preparatory technologies and in-flight demonstrations will offer unique opportunities for first-class science.

Member States will choose their level of participation in the envelope according to the rules of optional programmes, and determine their share of participation in specific missions, robotic and human, within the limits of their overall participation. This will allow countries, which have developed strong competences during ISS development, to build on that investment and countries which have not participated in human space-flight programmes to steer their participation towards robotic missions or technology.

3.5. The approach to international cooperation

Returning humans to the Moon and landing them on Mars is clearly a worldwide endeavour for humankind and not for any one country alone. The world has changed. The number of space-faring nations has increased, as well as the number of potential partners. Indeed, Europe with ESA does offer a unique framework to undertake an exploration

programme based on multinational cooperation. ESA provides proven and powerful competence for leading and organising multilateral efforts, capitalising on its history of reliability as an international partner.

By being at the forefront of the conception of human exploration of the Solar System, Europe and in particular the ESA Member States will reap enormous benefits in foreign relations while guaranteeing their own role in the implementation. With Aurora, Europe has a unique window of opportunity to take a key role in that endeavour, cooperating with the US, Russia, Japan and China, as well as with all other space-faring nations that might be interested in joining, initiating very early in the process the international framework that will eventually make it possible.

Europe is already moving ahead with significant cooperation with the US, Russia, Japan and China and implementing cooperation activities with India and South America. It also has long-standing special cooperation with Canada, which is participating in the Aurora programme.

Aurora is proposing a stepwise build-up of capabilities, in a non-binding framework of international cooperation, until the decision to go-ahead is to be taken. This may well take a decade, during which each potential international partner will be able to decide its level of interest in the project and the most useful participation content.

3.6. Building public awareness

Intrinsic to Aurora is the aim of serving as a tool for inspiring and motivating the younger generation to renew its interest in scientific and technological subjects. ESA is already creating a university network and building the public awareness necessary to establishing a truly European framework for the Aurora missions.

In that context, ESA is seeking the support of the European Union as mentioned in the Commission's White Paper on Space and could contribute significantly to strengthening the European Research Area. The first robotic missions of ESA to Mars and the Moon - Mars Express and Smart-1 - will of course constitute excellent opportunities to attract the attention of the European public and to motivate their interest in the challenge of later human exploring of the Solar System as proposed by Aurora.

4. The key role of science in Aurora

The Moon and Mars are the first two Solar System objects that humans may realistically be expected to visit this century. Having set a planned date for the first human mission to Mars, Aurora is on course to pursue an aggressive schedule of robotic missions to these two destinations, in particular through landers, and of human missions to LEO.

While the driving requirement for these missions is the demonstration of technologies and the acquisition of the knowledge necessary for the next steps, it is clear that scientific

investigations will have to be conducted in the lunar and Martian sciences as well as in the life sciences and human physiology. Even though science will not be the driver for these missions it will nevertheless be an indispensable tool. Indeed, the first two robotic missions under the Aurora near-term plan (ExoMars and Mars Sample Return) have both a capability demonstration and a knowledge-acquisition dimension that make them very appealing from a scientific point of view.

The scientific return under Aurora therefore appears very high. Whenever scientific investigation is identified as a necessary element, its selection and implementation should follow the processes already operative for science missions i.e.: call for proposals and competitive selection process for science experiments.

5. How much will Aurora cost the European taxpayer?

The Aurora programme has a thirty-year outlook with a pattern of five- year funding periods. Presently subscribed by 10 ESA countries (including Canada), the preparatory phase is due to finish in late 2004 and will result in an updated Programme Proposal for the 2005-2009 period and a strategy document containing the long-term plans for exploration: the "European Framework for Exploration".

The cost of the 2005-2009 period is estimated at €900m. This estimate still needs to be consolidated with respect to:

- industrial cost estimates (technical studies are still ongoing);
- cost of launchers for the two robotic missions foreseen in this period;
- share of funding between Aurora and other Agency programmes, concerning the scientific instruments and the human-related technologies.

For the later phases, cost estimates are at this stage just guesses. The scenario for a human mission to Mars is still to be established and this should be achieved in the 2005-2009 period. It is to be expected that the European participation will be fixed as a share of the overall cost.

The percentage of the ESA budget devoted to human spaceflight has constantly grown on average since 1975, and in 2003 it is about 25% of the total ESA budget. The above percentage does not include national funding (all the habitats flown in the Shuttle were built in Europe; and with the logistic modules, the nodes, the cupola and soon the ATV and Columbus, the share of European hardware on the ISS is larger than most people realise). It is foreseen that the overall Aurora programme in the future should have a similar percentage, enabling it to fulfil a significant role within a very affordable budget.

It is worth recalling that considering the completion of ISS hardware development, the Aurora request (i.e. around €900m) over the next five years is on average less than 7% of ESA's total budget, therefore representing a very gradual start of activities.

6. When should Europe do it: what are the next steps?

The decision on the first development period for the Aurora Programme (2005-2009) is to be taken at the next Ministerial meeting. However, the date of this event has now slipped towards the end of 2004 or early 2005, which makes it necessary for the Executive to ask for a €25m bridging phase to support the activities in 2004. The decision to fund the continuation of the programme in 2004 is to be taken by the Aurora Board of Participants and Council in December 2003 and in any case no later than March 2004. This will also be the ideal time for Member States not yet participating in the programme to join and be party to the definition of the development activities.

7. Conclusion

Space and exploration retain their strategic importance as sources of inspiration, innovation and economic development, providing lasting spin-offs for daily life. The coupling of these two concepts into the Aurora programme, represents a unique opportunity for Europe to show its scientific, technical and industrial maturity and to be regarded as a key player in future international co-operative space ventures.

All the robotic demonstrations and/or missions envisioned in the first phase of the programme are presently under study by ESA and European industry, following the recommendations of the EPAC and ABP at the end of 2002.

Through the technological development and these first missions, Aurora will contribute to raising the living standards of Europe's citizens. At the same time, it will contribute to retaining Europe's present workforce and further enhancing its skills. It will offer European academia and research centres unique opportunities for first-class science and research.

Europe has set itself ambitious goals responding both to the political challenge of the Lisbon Declaration stating that Europe should become "*the most dynamic knowledge-based economy" in the 21st century"* and to the more immediate objectives of its space policy as presented in the White Paper on Space. The Aurora programme is a comprehensive and coherent response to both challenges. The vision enshrined in the programme is the continuation of Europe's historical tradition of exploration and discovery and is an essential element of any European space strategy.

Figure 1. The Aurora Draft Long Term Plan