European space exploration: strategic considerations of human versus robotic exploration

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Space activities belong to three main categories, all with strong societal and cultural implications. Moving progressively outwards from the Earth, these are: (a) scientific, political and commercial activities dealing with the Earth, for example meteorology, climate, resources, communications, navigation, and surveillance; (b) activities related to the exploration of the solar system, typically scientific, and which may be either automated/robotic or manned; (c) astronomical research beyond the solar system, where all telescopes and associated operations are currently (and preferentially) automated/robotic.

European policies and activities are rather well focused and organised on the first and last of these three categories, with the selection of missions in each of the areas being determined by evolving scientific developments and commercial priorities. But after more than 50 years of space missions, with new countries entering the field, with the US having signalled its intent to continue human space flight (at least in the context of the International Space Station, by extending its operational lifetime to 2024), and with scientific, commercial, political, and popular interest all on the ascendancy, the category related to solar system exploration is in a **more uncertain state**.

The reason for this present uncertainty and potential controversy is tied to the fact that, while deep space activities are restricted to purely `robotic' (i.e. automated) observatories, the future exploration of the inner solar system may develop via **robotic or manned missions** (or some mixture of the two). Since manned missions come with substantial financial implications, as well as severe restrictions due to the hostile environment coupled with the required mission durations, their selection implies particularly significant challenges and consequences for their implementation. This is further complicated by the fact that arguments for human space flight typically embrace both objective as well as more subjective considerations.

The report underlines the fact that the case for the augmented **scientific exploration of the solar system** is very strong. Specifically, there are numerous candidate bodies whose more detailed investigation would substantially advance scientific enquiry, ranging from the inner and outer solar system planets and their moons, to asteroids and comets. Their further exploration will be central to understanding many details of the formation and evolution of the solar system, as well as providing more detailed insight into questions of the origin and presence of life elsewhere in the solar system and beyond. The report also summarises some of the arguments for the **economic and societal benefits of funding pure science** (and, specifically in this context, of space science missions).

Still more complex considerations are involved in pursuing a programme of **human space flight**. These include scientific (including life and engineering sciences), technological, economic, and cultural reasons, more subjective aspects such as curiosity and exploration, political considerations such as national prestige and international cooperation, as well as the broader benefits of an increasing public and political awareness of space exploration.

In an atmosphere of competition for prestige, and industrial interests, there are substantial financial stakes. Politicians, advisory bodies, and funding authorities may find it difficult to penetrate the various arguments put forward to justify future space exploration, especially in the area where automated/robotic missions and human spaceflight overlap. To provide some guidance on such a costly but strategic issue, this report examines various issues related to attempts to balance or prioritise, within the context of solar system exploration, automated/robotic versus human missions.

The report gives an overview of the most important scientific targets of solar system exploration, and indicates some possible component missions in the future exploration of the Moon and Mars. The report notes that European funding in automated/robotic exploration is already stretched when compared with scientific aspirations, the more so in the presence of international competition. Accordingly, the report argues, any increased emphasis on human space flight should not be to the detriment of the existing budget for scientifically-driven robotic missions. Indeed, from the perspectives of astronomy or solar system

related science alone, it is difficult to justify a human presence in the exploration of space, whatever the advantages of such ambitious programmes in other areas of engineering, technology or society.

Taking account of these various complexities, the report addresses: (a) the requirements of **fundamental research** driven by scientific enquiry; (b) strategies for contributing to solar system exploration with **robotic missions**; (c) the added value associated with **human space flight**; (d) the **applied science questions** (e.g. space medical and biotechnology sciences) which must be pursued in the context of human space flight; (e) the ongoing **International Space Station** programme spanning fundamental physics, astronomy, and technology, as well as medical, biological, and material sciences; (f) the context of **very large international collaborations** in space exploration and associated infrastructures, not only in order to minimise costs, but also explicitly through the development of international cooperation; (g) some considerations on the question of risk that may be considered in the context of future human space flight exploration programmes.

A number of general recommendations related to the future European space exploration programme are presented, underpinned by the importance of Europe **remaining at the forefront of scientific and technological capability in space**. It is argued that a strategic plan for the cost share between robotic and manned missions in European space exploration, capitalising on technological advance and international cooperation, but without negatively impacting the future of pure scientific research, is highly desirable.

The current considerations may be of interest for various broad audiences, including the European Space Agency (notably for the directorates of *Science and Robotic Exploration* and *Human Spaceflight and Operations*); national governments in their role of funders of research and as funders and members of ESA; the European Parliament and the European Commission; as well as for the media, general public, and younger generations, where interest and excitement in questions of space and space exploration is intense and broad ranging.

The full report is available from the EASAC website: www.easac.eu

EASAC

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Its mission reflects the view of academies that science is central to many aspects of modern life and that an appreciation of the scientific dimension is a pre-requisite to wise policy-making. This view already underpins the work of many academies at national level. With the growing importance of the European Union as an arena for policy, academies recognise that the scope of their advisory functions needs to extend beyond the national to cover also the European level. Here it is often the case that a trans-European grouping can be more effective than a body from a single country. The academies of Europe have therefore formed EASAC so that they can speak with a common voice with the goal of building science into policy at EU level.

Through EASAC, the academies work together to provide independent, expert, evidence-based advice about the scientific aspects of public policy to those who make or influence policy within the European institutions. Drawing on the memberships and networks of the academies, EASAC accesses the best of European science in carrying out its work. Its views are vigorously independent of commercial or political bias, and it is open and transparent in its processes. EASAC aims to deliver advice that is comprehensible, relevant and timely.

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