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## Introduction

*Earth is the cradle of humanity, but one cannot live in a cradle forever.*  
(Konstantin E. Tsiolkovsky)

Space exploration has always fascinated humankind. It has inspired the works of philosophers such as Lucretius, Kepler, and Kant and modern works of fiction by Jules Verne, Isaac Asimov, Arthur C. Clark, Fred Hoyle, and Italo Calvino. These works are not only pleasant entertainment but also ways to expand our imagination. They allow us to explore human responses to future scientific developments and to speculate on how they might develop. In the second half of the twentieth century, space exploration moved away from the realm of pure imagination. Sputnik and Soviet astronauts (beginning with Yuri Gagarin) orbiting the Earth and American astronauts landing on the Moon created an atmosphere of optimism. Optimism pervaded science, the public, and the arts, as Stanley Kubrick's film *2001: A Space Odyssey* explored the possible origins and fate of humankind in space.

After the optimism of the 1960s, human space exploration entered a state of flux. Humanity's presence in space centred on suborbital flights and short-term residence on the International Space Station. Paraphrasing Tsiolkovsky, humanity still lives in the cradle. Space agencies have been conducting robotic space exploration with great success. Many think of scientific research as space exploration's main goal. They are losing sight of other equally important goals: those of an economic, commercial, or cultural nature. And, in the longer term, spreading out into space may perhaps guarantee the survival of the human race. As physicist Stephen Hawking once said:

The long-term survival of the human race is at risk as long as it is confined to a single planet. Sooner or later, disasters such as an asteroid collision or nuclear war could wipe us all out. But once we spread out into space and establish independent colonies, our future should be safe. As there isn't anywhere like Earth in the solar system, we would have to go to another star.

This book develops a scenario for human space exploration. Scenarios are not forecasts but rather ways to understand the dynamics shaping the future by identifying the primary driving forces at work today. Analyses of such scenarios do not rely on extrapolations from the past. They consider possible developments and turning points, which may or may not be connected to the past. Scenarios allow for qualitative changes not included in quantitative extrapolations of past trends. This is particularly important when analysing

scientific and technical progress. Often, forecasts of these events are made obsolete by unpredictable innovations and scientific breakthroughs.

Our scenario examines: (i) the history of human space exploration from its beginning up to now; (ii) its short to medium-term prospects; and (iii) the possible longer-term developments. History helps us to understand better the motivations and constraints—technical, political, and economical—that shaped space exploration. The short to medium-term prospects enable us to identify the driving forces that will shape its next phase. While science and technology define the limits of what is possible: transforming these possibilities into reality depends on the economic and political benefits resulting from human space exploration. The economic benefits fall into three categories: direct effects measured by revenues generated by using space resources and related services and products; consumer welfare effects measured by the benefits to consumers beyond the value they paid for those products and services; and economic effects that arise from the efficiencies generated by those products and services.

Political benefits come in terms of international cooperation and world political stability. International cooperation is a necessary condition for human space exploration: the financial resources required for it are too large for any single nation to afford. If private companies are to seize the opportunities arising from space exploration, certainty over property rights and the uses of space resources are needed. This would involve extensive international cooperation. But we are struggling to find ways to cooperate. We are far from an advanced level of civilization in which international relations are solely based on cooperation and not conflict. Tensions arising from the control of natural resources, economic inequalities, and racial and religious conflicts are among the obstacles to international cooperation. Doubts exist whether we will be able soon to achieve such a civilization.

Despite this note of pessimism, the situation may not be hopeless. Michael Tomasello [1](#) argues that *Homo heidelbergensis* developed abilities to cooperate through mimicry and gesturing in the search for food. Later on, *Homo sapiens* expanded cooperative capabilities through common cultural backgrounds centred on conventions and norms. Through these arguments, Tomasello proposes that humans can continue to develop because they can absorb and share knowledge. The human race has thus the ability to find solutions to problems it has itself created, and, through this process, to reach the stars.

To ease reading, all technical details have been placed in footnotes. However, it is not necessary to read these in order to understand the text; they are there for the curious reader who wishes to know more.

## Reference

Tomasello M. A natural history of human thinking. Cambridge, MA: Harvard University Press; 2014.