Enabling the sustainable space era by developing the infrastructure for a space economy

In response to the ESA Voyage 2050 call

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Introduction and vision

The true space era can only begin once we learn how to live and thrive in space without further straining Earth. That is, once we are able to start a space-based economy. Moreover, our planet is one of many places in space, so by learning how to start self-sustained human activities in space, we will advance towards a zero footprint economy back on Earth, which is a worthy legacy for the future generations. This can be done in a global community context by engaging and coordinating experts outside the traditional academic fields, training new professionals, organizing workshops and conferences, and developing discussion forums and citizen science initiatives.

The synergies between this vision and current grand challenges on Earth are numerous. By researching new methodologies without the need to satisfy the immediate economic incentive, we will obtain breakthroughs on a broad range of disciplines (e.g., spin-offs of space race or computing sciences). These include new definitions of cost & value detached from Earth's one, which will lead to novel economic and legislative frameworks.

Space endeavours are traditionally associated to governments, elites and scientists. As a result, the citizens are usually relegated to bystanding roles, and a lot of creative power remains latent. We need to break this stand-off and tap into the collective intelligence of societies and its citizens. In addition to partnerships with classic actors, the new space exploration era beyond the next decade must enable citizen participation (companies, individuals, schools, associations, towns) through the use of cooperation, co-creation, and citizen science tools. Last but not least, the inspirational value of space coupled to its radically different system of values once we are in space will be a powerful playground to attract young minds into pure, applied and social sciences.

Beyond the pragmatic use of developing a space-based economy; doing this will be essential to reach significant advances in all traditional pure scientific endeavors. That is, once we are unbound to Earth resources and infrastructure, we can proceed to truly revolutionary advances such as

- Gigantic >20m class telescopes, possibly reaching the 100m apertures and beyond. This will enable extremely high resolution imaging that is not imaginable today. This includes direct imaging and precision spectroscopy of nearby exoplanets, many of them potentially habitable, to the point where details on their surface (continents, ice-caps, oceans, could bands) can be resolved.

- Arrays of antennas for radio observations on the far side of the moon and in deep space will enable access to all sorts of astrophysical phenomena and the very early universe (dark ages between cosmic microwave background, and first stars), and extreme physics (black hole high resolution imaging around numerous nearby galaxies, and even galactic stellar blackhole and neutron star objects)

- Direct easy access to geologic record in other solar system bodies (moon, Mars, asteroids and beyond) will enable access to pristine records of the Solar System at a completely different level of measurement and human experience.

- Astrobiological experiments in space and other relevant solar system environments, including the moon, Mars, asteroids, deep space and beyond. Current experiments on how life develops in space, and how complex chemistry occurs are broadly limited to a handful of experiments that can be done on the ground.

The scale of large scientific facilities is at the level of large civil infrastructures such as the Panama channel upgrade (~17 Bn USD) or the high speed train HS2 in the UK (50-100 Bn). At this level of investment, there has to be -at least- some prospect of economic return. Therefore, when looking on what would be relevant three decades from now, it is of essential to equate in the future scenarios on how the world economics and geopolitics are likely to evolve.

In this white letter we advocate for an aggressive development of the technologies and infrastructures needed to develop a space-based economic and industrial base. After this is started, scientific exploration can expand and reach a whole new level.

Proposed plan

First 5 years

Start a vigorous multidisciplinary programme to bring professionals from traditionally non-space disciplines into the endeavour. These includes (but it is not limited to) architects, Chemists, Industrial Engineers, Manufacturing Engineers, Material sciences, Mining engineers, artificial intelligence experts, sociologists, biologists, economists just to mention a few.

5-10 years

The task is daunting, and a roadmap would need to be defined first. During the first ~5 years, a programme of multidisciplinary conferences and workshops endorsed by ESA should enable first contacts with the different communities so synergies can appear. Similarly, these need to be couple to both governments (member states, but also EU), and the broader society. Any space based endeavour for either scientific or economic activities require massive amounts of public support.

Begin developing small mission programmes and demonstrators to raise technology readiness levels of different aspects. Involve the broader society in the decision making with intense consultation with the stakeholders (governments and industry) so the developed infrastructure satisfies the economic primer.

10-20 years

Deploy a research station on the moon, and develop it into the first industrial facility beyond Earth. Some obvious science cases can immediately begin by the mere fact of having a human presence on the Moon, such as sample collection and other geologic studies, construction of a Moon based observatory (small telescopes and antenna arrays first), and astrobiology and human physiology studies. In the mid term (~5 years), the 'base' can be operated as a service provider for all sorts of experiments (public, governmental or private) approaching the model of the Antarctica research stations and/or large observatories on Earth. More importantly, the main goal of this first facility is to start testing and developing all the in-situ-resource-utilization (ISRU) processes to be able to produce self sustaining infrastructures on the Moon itself, and prepare for Mars as the next logical step. Once self sustainability is achieved and excedents start to be produced, the true space era expansion can begin.

20-30 years

Permanent, self-sustaining self-replicating infrastructure is deployed on Mars. Again, obvious science can begin right away, but more importantly, having a destination enables the begin of economic activities between Earth orbit and Mars; further boosting moon activities and start exploration/exploitation of Asteroids. Achieving self-replicating capabilities ensures that expansion in Mars and the Solar system becomes independent of Earth economics. At that point, and given that there will be excedent, the space infrastructure should be able to start feeding resources back to Earth; while expanding human activities in the Solar System. Next generation space mega projects (>100m telescope, >10^6 m baseline radio-arrays, etc) can also start at this point

Conclusions

Given the current emergency situation on Earth and the uncertainties on the mid term stability of western economies, we find it might be very unwise to maintain the current approach of planning for one shot L-class which -at best- will satisfy a small part of the already small scientific elites. Incremental experiments (such as M and S-class missions, say <1 Bn EUR scale) should be able to proceed, but efforts at a larger scale start to compete with crucial civil infrastructures and these are bound to suffer from uncertainties of the world's geopolitics and economy.

There are world-wide efforts devoted on how to solve the climate crisis/catastrophe, especially among the younger generations. After interacting with stakeholders (politicians, journalists, architects, etc…) beyond classic academic backgrounds, we find that long term support for large scale space scientific activities is unlikely, even not morally justifiable. In this sense, when planning for large scale scientific endeavours beyond the 2030 horizon, these need to be part of the 'Solution' to the world's problems.

In terms of missions to implement this vision, we envisage a roadmap starting with community gathering activities of multidisciplinary nature, supported by seed level research grants to draft a roadmap within the next 5 years. We can then establish a first Moon infrastructure (~2030's) dedicated mostly to develop & test industrial & manufacturing capabilities in space with the sight set on Mars. By ~2040, we may be able to deploy a self-sustainable and self-replicating infrastructure on Mars. This will open up the space between Earth and Mars to human economic activities, at which point the nascent space economy can start feeding back to Earth's; and a new generation of space mega-projects (current concepts, or yet to be conceived) can begin.