DESIGN FOR RESILIENCE IN THE SPACE ECOSYSTEM

A COSMOPOLITAN APPROACH

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Design for resilience in the space ecosystem:
A cosmopolitan approach

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Giulia Calabretta (Chair)
Erik Tempelman (Mentor)

With the collaboration of

Stefan Frey (Vyoma Space)
Chris J. M. Verhoeven (TU Delft Space Institute)

To my network.

To any dear soul who dedicated me one moment of care,
contributing to make this day possible.

"The exploration and use of outer space,
including the moon and other celestial bodies,
shall be carried out for the benefit and in the
interests of all countries, irrespective of their
degree of economic or scientific development,
and shall be the province of all mankind."

Outer Space Treaty, Art. I
UN General Assembly, 19 December 1966

Design for resilience in the space ecosystem

A cosmopolitan approach

EXECUTIVE SUMMARY

As history demonstrates, a slight instability in a socio-technical system can become a landslide for its economy. One factor in particular is often enough to cause a prosperouse regime to fall overnight: Lack of democracy.

The so-called "New Space" economy is reaching maturity and its stakeholders are looking forward to unprecedented opportunities. Nevertheless, some oddities in the ecosystem are emerging and their cost is becoming weighty. On the one hand, the democratic accessibility to space is quickly making the Low Earth Orbit (LEO) overcrowded, a big risk considering that a system for space traffic management is still missing. On the other hand, the recent world geopolitical polarisation is putting at stake the principle of peaceful use of outer space, since satellites are becoming more and more strategic military assets. By pursuing the current development model, a short term consequence will be the rising frequency of expensive manoeuvres to avoid collisions in LEO. On the long term, new collisions might make some strategic orbits inaccessible, or even make some services out of reach. A miserable legacy for the future generations of space citizens. It is time to assess **the failure of markets and states in the management of orbital resources**: Without contrasting trends the New Space democratic dream may fall soon.

Outer space has become a non-cooperative game for a few players with infinite resources, in an environment with limited resources.

The findings presented in this report highlight how the space debris issue represents the first case of a tragedy of the commons happening beyond our planet's boundaries. In fact, a scenario of hyper congested orbits is becoming hard to avoid. Although policy makers are nudging operators towards responsible behaviours, imposing strict regulations is difficult on a global scale and - anyway - they alone are not enough to stop the so-called "free riders", as recent conflicts are demonstrating. Missions to actively remove debris are being tested by some companies but the roadmaps are too long to achieve a significant impact any time soon. A few governments are contributing through the money of mostly unaware taxpayers, yet it is still uncertain who will fund these activities in the future. Finally, besides all these mitigation strategies, there is still no plan to prepare, respond and recover from an actual disaster scenario, like an rapid increase of massive fragmentation events. The purpose of this graduation project is not to suggest such a plan, rather to present an alternative development model for the space economy to become more **resilient** in the face of disruptive events, which are becoming particularly recurrent in this era of human history. As a result of six months of conversations and co-creation activities with a wide network of companies, lawyers and researchers, I propose in this report a **cosmopolitan approach** to face the space debris threat.

The necessity to raise awareness among the civilian society is urged by many experts in the field, since this strategy has already proved effective for environmental issues, cultural initiatives and humanitarian emergencies on Earth. By conducting qualitative research I have proved that it can be valid also beyond the atmosphere: People's consideration for outer space changes radically after they become aware of its environmental issues, to the point of considering the orbit as "an extension of our planet" and taking ownership of the situation with a political attitude. In support of this strategy, Elinor Ostrom's empirical studies provide numerous examples of how some local communities around the world have actually been able to **self-manage global commons "beyond markets and states",** for many years or even centuries. The novelty of my approach bases on her principles and builds on **the decentralising power of cryptocommons**: digital tokens linked to real-value assets that enable communities of individuals to increase the sustainability of their micro economies, by rewarding them after specific positive behaviours.

Due to its intrinsic nature, the space ecosystem represents an ideal context to prove cryptocommons' potential. In spite of their recent conception and their scalability challenges, these new economic tools may offer unprecedented opportunities to make civilians co-owners of real world resource. This means not only **spreading benefits fairly among all contributors but also sharing risks and maintenance costs**. As every cosmopolitan approach, it presumes a good education about the concept of value among all the individuals involved and a redistribution of power within the ecosystem. Moreover, besides making economies objectively more democratic and fair (for policy makers' interest), it can represent a substantial source of profit for the most active players, capable of transforming an environmental burden like space debris into a profit opportunity. Such an innovation can trigger a new transition towards a more resilient state, a possible and desirable future whose characteristics are outlined in this report.

Space 5.0, a time when space is evolving from being dependent on the initiative of a few private and public actors, to a situation in which all the resources are managed on the basis of co-ownership, co-creation and co-responsibility with the whole civilian society.

To thrust the ecosystem in this direction, I have designed an innovative business concept that leverages the in-space observation technologies developed by Vyoma Space to provide an educational service for children. It consists in a metaverse of space: **A cultural social platform built in an immersive virtual environment, showing real-time data from space and aimed at educating the next generations of space citizens**. It can be accessed through the purchase of an non-fungible token (NFT) connected to the position of a piece of space debris. On the one hand the project is conceived as **non profit,** in collaboration with governmental and intergovernmental organisations (like UNOOSA and space agencies). It would be a concrete incentive for them, since the money raised is aimed at **funding R&D initiatives** to increase resilience in outer space, like debris removal missions. On the other hand, it can also represent **a commercial opportunity for operators**, who are invited to offer educational experiences to children and receive in exchange "space coins", that they can spend to **receive in-orbit services** (like satellite refuelling or maintenance) during their missions.

The main goal of this project is to make the exploitation of space sustainable, by accelerating the sustainability roadmaps for **debris offset**. The political implications would be to **make the space ecosystem more democratic** and to **incentivise governments to remove their derelict satellites**. This means cultural, financial and environmental benefits for all the stakeholders involved. Futhermore, the dynamics of such a social platform can also **inform policy makers on the actual needs and dreams of civilians concerning activities in space**. Finally, such a model of decentralised finance (DeFi) can open unprecedented perspectives to **overcome the dilemma of dealing with space resources**, like on asteroids or moon territories, since it would enable operators to share their benefits with all humankind without actually taking ownership, as stated in the Outer Space Treaty.

The project also demonstrates how design practice has the potential to open new perspectives on wicked problems, for space and many other sectors. **The strategic value of Design** lies in the ability to generate unexpected and relevant opportunities to achieve systemic resilience, by envisioning innovative uses of technologies, by unveiling latent human needs and by bringing benefits to multiple stakeholders at the same time.

Gianmarco Luggeri
Delft University of Technology

SUMMARY

RESEARCH

DESIGN

01
My space odyssey

First comes the network

Everything started in October 2021, when my academic mentors for this graduation project - Giulia, Erik and Chris - realised the complexity of the space debris issue in relation to the minimal time at my disposal, only 6 months. “This topic seems too much for a graduation thesis”, they said, “You’d better find a partner company, at least”. Fair enough.

By coincidence, Space Tech Expo (1) would take place a few weeks later in Bremen (Germany), so I got the chance to fully dive into the bastion of the European space industry. By coincidence, one day before the event opening, Russia decided to conduct an anti-satellite test (ASAT): a missile was shot to destroy one of its defunct satellites still in orbit, generating a huge cloud of fragments that whizzed alongside the International Space Station, threatening Russian, European and American astronauts’ life alike (2) . Inevitably, this terrible fact became the predominant topic of discussion among the visitors of the fair. At the time of writing a global war is knocking at the doors of Europe and it is heavily affecting space activities too: it’s safe to affirm that - by coincidence - that ASAT event didn’t change only the course of my graduation project, but also of space history.

Three days, a hundred stands visited and about fifty hands shaken (figuratively, Covid19 was still spread) earned me an accelerated degree in space business, technology and law, besides a wide network of experts willing to talk with a Strategic Design student (“you can make nice illustrations, right?”) and to actively support my cause. I am not sure this would have been so easy without Russia’s bombastic initiative. Anyway, that experience also earned me a partner company for this graduation, which was actually what I was there for.

Stefan is an expert of space debris, he knows how to mitigate the problem. With his colleagues Christoph and Luisa he founded Vyoma (3) , a startup that is going to be a game changer in the field. But he also understood the value that design can bring in such a technical industry and he was open to exploring a new path.

Giulia, Erik, Chris and Stefan were the first people to believe in my capabilities, this project would have never even started without them. They were followed by other experts and organisations from all over Europe, who contributed to inspire, define and validate my ideas (you can find a list below). Not less important, my friends and fellow design students provided me with priceless feedback and motivation during these busy months.

In conclusion, finding myself in the right place, at the right moment and with the right experts was only a coincidence, but it gave me the chance to start cultivating a network. More than a method, leading a conversation with this diverse group of people became determinant to move on in every step of my graduation journey. Hence my takeaway:

Your project is just as valuable as the people you involve.
Before planning how to do something, try asking “With whom?”

1. *Europe’s largest exhibition and conference for the space industry. In 2021, it took place from 16 to 18 November*
2. *Hennigan, W. J. (2021, November 15): "Astronauts Take Shelter Aboard ISS After Russian Anti-Satellite Test, U.S. Says.", www.time.com*
3. *For more info: www.vyoma.space*

My team

Academic supervisors

Giulia Calabretta (chair)

Associate Professor of Strategic Value of Design at TU Delft, Design and Engineering faculty

Erik Tempelman (mentor)

Associate Professor of Design for Manufacturing at TU Delft, Design and Engineering faculty

Collaborators

Stefan Frey (company mentor)

Astrodynamics specialist and founding member of the smart-space company Vyoma

Chris Verhoeven (couch)

Associate professor of microelectronics at TU Delft, part of the TU Delft Space Institute

Interviewees at every stage

The experts involved are representative of the following organisations

Research	Future vision	Design	Validation
nlr	 Marta Ferraz	VR ZONE	clearspace today
UNOOSA	SPACE GENERATION ADVISORY COUNCIL	TU Delft Design students	ASTROSCALE
Universiteit Leiden	esa	L'ATELIER BNP PARIBAS	Parlamentum Europaeum
DELFT BLOCKCHAIN LAB TU Delft	CRYPTO COMMONS ASSOCIATION	newzoo	MEDIA MONKS

Geographical distribution of my network for this project

People reached physically

People reached virtually

02

A new perspective on the space industry

Why Speculative Design methods

One thing I quickly understood in Bremen was that aerospace is a purely technology-driven industry in which designers are an extremely rare species. Most of the design activities are actually executed by engineers, including at the managerial level, whereas designers are mainly employed to create appealing visual presentations. In spite of this, as I have learnt at TU Delft, design can deliver a higher strategic value within organisations (1) , industries and society, especially in terms of radical innovation. But among the numerous aims and methods designers can pursue, which ones could bring the best value for aerospace and for this particular project?

Space debris is a wicked problem (2) that has been addressed by experts for many years. As a Strategic Designer with a humanistic background, my goal was not to show engineers a new kind of cleaning machine that could solve the issue forever. Rather, I was aware that I could provoke established thoughts and bring unexpected perspectives, by showing a new way of doing business in space and proposing a new vision for a sustainable future. My project brief was to use Vyoma technologies to design a service that could raise awareness about space debris among a wide audience of civilians, and to enable people to contribute through a collective action. For this purpose, I decided to adopt Speculative Design methods.

"This form of design thrives on imagination and aims to open up new perspectives on what are sometimes called wicked problems, to create spaces for discussion and debate about alternative ways of being, and to inspire and encourage people's imaginations to flow freely. Design speculations can act as a catalyst for collectively redefining our relationship to reality." (3)

Moreover, Speculative Design is best suited for long-term roadmaps like the ones on which space companies usually work on. For this, a designer can have three possible approaches (4) :

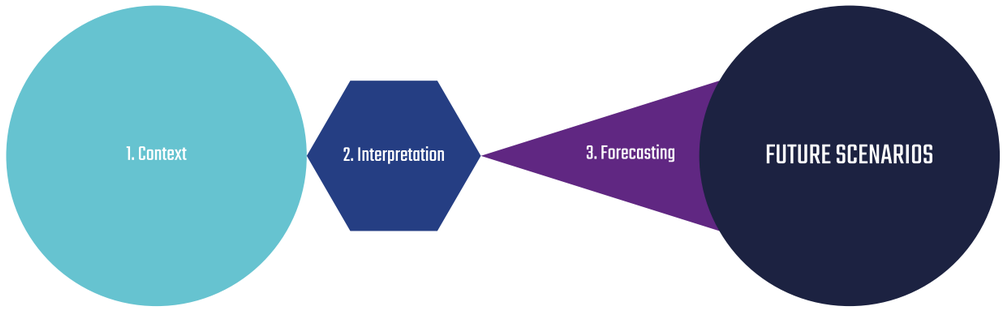
- ***Pragmatic***: focussed on keeping a business competitive within an industry.
- ***Progressive***: aimed at innovating and encouraging a new way of doing things.
- ***Civilisational***: re-conceptualising human activities in the whole society and working to create the foundations of the next level of world civilization and culture.

The last approach is the riskiest, hardest and least adopted overall. Nonetheless, it is the one that pursues the highest impact and the one in which designers can contribute at best, enhancing a higher degree of creativity and a primary focus on human factors. Aware of the great challenge, the civilisational approach is the one I have decided to adopt for this project.

1. *Rae, J. (2016): "Design Value Index Exemplars Outperform the S&P 500 Index (Again) and a New Crop of Design Leaders Emerge.", Design Management Review, volume 27, n.4, pages 4-11*
2. *Rittel, H.W.J & Webber, M.M. (1973): "Dilemmas in a general theory of planning", Policy Sciences, volume 4, pages 155–169*
3. *Dunne, A. & Raby, F. (2013): "Speculative everything: Design fiction and social dreaming", The MIT Press Cambridge, USA, page 2*
4. *Slaughter, R. (1999): "Futures for the Third Millennium: Enabling the Forward View", Prospect Media, Sydney, Australia*

Drawing from the foresight method as described by Joseph Voros [5] and thanks to the mentoring of the Futurist Scientist Marta Ferraz, I have preliminarily traced the following research process, in which every step helped me to answer a specific question:

1. ***Context***: What seems to be happening?
2. ***Interpretation***: What is actually happening?
3. ***Forecasting***: What might happen?



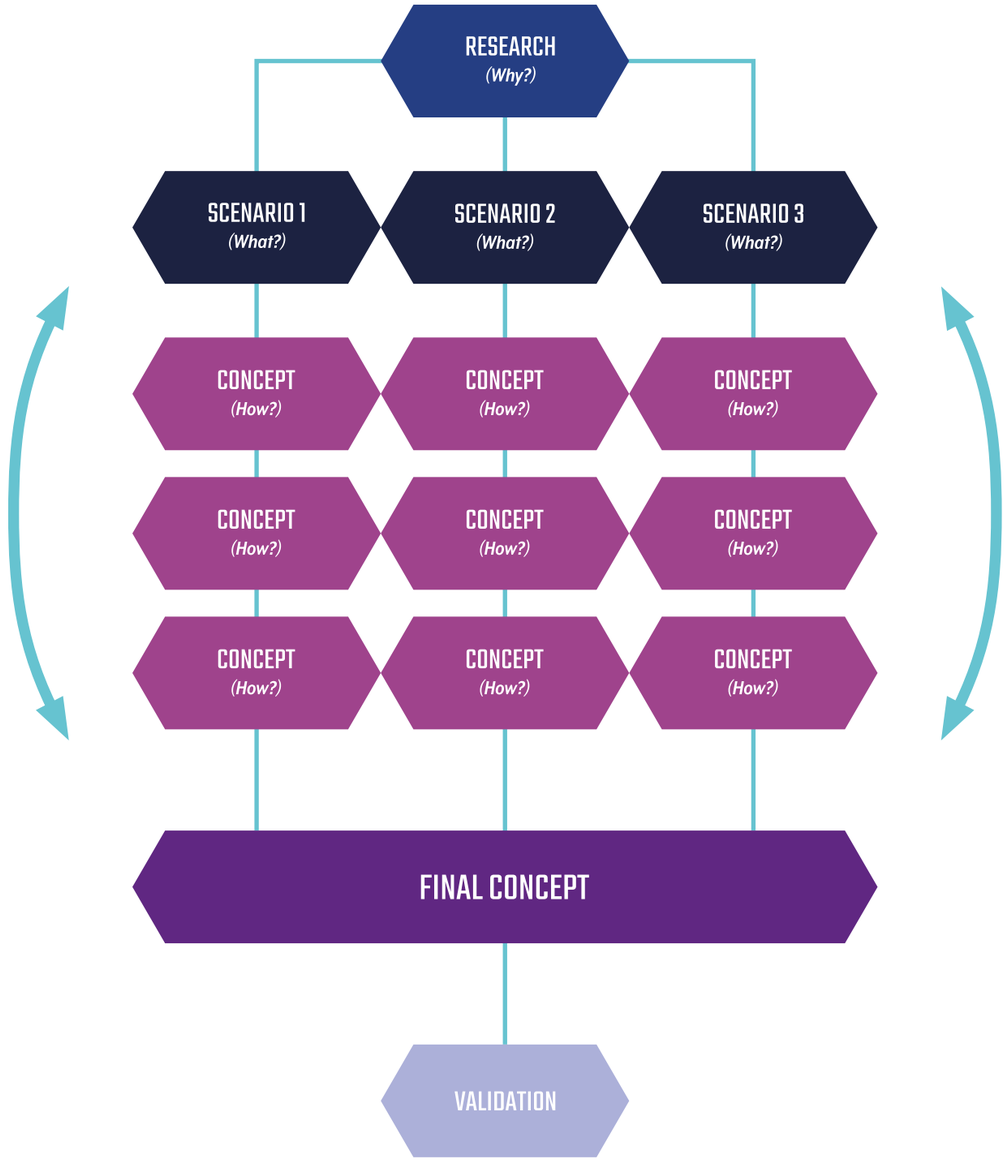
Following these 3 steps helped me to converge towards a generic design direction to present at the Mid-term graduation meeting and to envision possible scenarios for the future of outer space.

Most importantly, the main insights of this research made evident the reasons why the space industry urgently needs to intervene in the ecosystem that is being built right now and inspired me to envision an alternative future, based on a higher degree of resilience.

This was made possible by taking into consideration 3 hypothetical scenarios for an alternative future (what if ...?), stretching their consequences to the extremes (positive and negative) and building a compelling narrative for each of them.

The combination of these independent (but correlated) alternative ideas of future became the new context from which I started to design solutions, by asking how such scenarios could be achieved through the inception of a new kind of services into the present ecosystem. The resulting concept was finally validated through interviews with field experts.

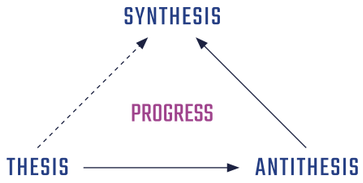
It goes without saying that this process was not linear at all. Iterations and questioning about the process itself happened all along the six-month journey, but this effort contributed to make the contents more coherent and consolidated the overall direction.



5. *Voros, J. (2005): "A generic foresight process framework", Faculty of Business and Enterprise, Swinburne University of Technology, Australia*

A transition theory for New Space

In order to elaborate an interpretation about the present state of the space ecosystem and to envision a better future condition, it is useful to adopt an historical perspective.



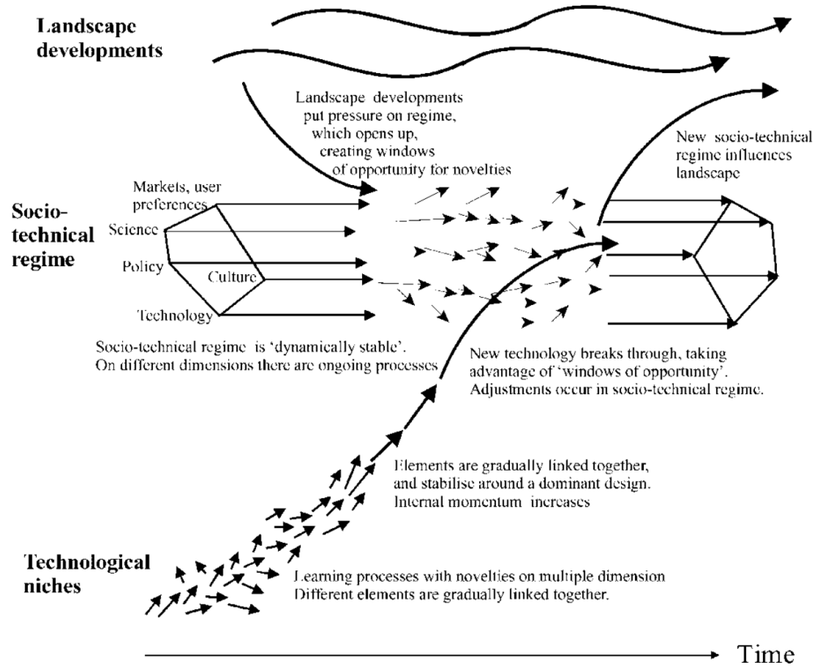
The German philosopher Hegel (6) believed that ideas, history and the whole reality itself don't develop in a linear way: a negative moment always comes to contrast the status quo, before the human intellect can conceive a synthesis of both the states and achieve progress. History is viewed as a dialectic process, in which a positive state is just as necessary and temporary as its opposite. This view helped me to frame the current space economy in a wider geo-political and socio-technical context, and aroused some questions:

Where does the so-called "New Space" come from? Is it the ultimate synthesis state of a past evolution, or an intermediary moment of a larger development process? If the former is true, how can we contrast the status quo? If the latter is true, how can we steer this process towards a more resilient state? What if both are true?

A more contemporary and empirical theory of transitions has been elaborated by Frank Geels (7) . The multilevel perspective (MLP) was initially applied to better understand technology transitions, it received numerous criticism and implementations, which made it quite popular, and today it can be considered one of the most adopted and comprehensive frameworks to address ecological issues (8) . It represents ecosystems as composed of 3 inter-embedded levels, whose elements can be reconfigured in order to achieve socio-technical transitions:

- ***Landscape*** is the most superficial and evident manifestation of an ecosystem, consisting of a "set of deep structural trends" and mainstream events (such as the price of goods, the market share, a catastrophic event in the news, ...). It is a consolidated context that is mainly passive and slow to change.
- ***Regime*** represents the underlying structure of the landscape, consisting of all the - explicit and implicit - relationships between a dominant community of actors who share the same direction, "the outcome of organisational and cognitive routines". This is the level on which incremental innovations are set to become consolidated in the landscape.
- ***Niches*** lie in the basements of the regime, where minorities of actors start to think and to do things differently. They are protected or isolated by the regime due to their low technical and economical performance and because of possible unintended consequences. This is the level from which radical innovations generate and grow.

6. *Hegel, G.W.F. (1807): "The phenomenology of Spirit"*
7. *Geels, F.W. (2002): " Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study", Research policy, vol. 31, n. 8/9, pages 1257-1274*
8. *Geels,F.W. (2011): "The multi-level perspective on sustainability transitions: Responses to seven criticisms", Environmental Innovation and Societal Transitions, volume 1, n. 1, pages 24-40*



© Geels, F.W. 2005. The Dynamics of Transitions in Socio-Technical Systems: A Multi-Level Analysis of the Transition Pathway from Horse-Drawn Carriages to Automobiles (1860–1930)

Niches are generated when evident shocks or subliminal frictions are observed in the landscape and instil a reaction in a minority of actors. From such moments several transition plots can happen (or not), depending on the attitude of the regime to coordinate or contrast the integration of the niche and on the niche strategy to achieve technology-market readiness (9) . A transition is accomplished when a niche becomes part of the regime and starts to affect the landscape significantly, so one has to look at niches to see what the future might hold.

Not only linear and rational factors are encompassed by this theory, such as cause-and-effect explanations, but also more complex and humanistic aspects, like the different roles that dominant actors are keen to play at every step following their own momentary interests. In this view, narratives are also considered an important factor of causality:

"Even when structural alignments raise the probability of transitions, actors may or may not take advantage of windows of opportunity" (10) .

Since design practice also makes a large use of narratives to exert its influence and spark a change in relevant actors, I have decided to adopt Geels' MLP as an interpretative framework for the change I want to inspire in the space ecosystem through this graduation project, for a more sustainable future. The MLP has also been integrated in my research method and used as a narrative structure to present my findings in the following chapter.

9. *Raven, R., Kern, F., Verhees, B., Smith, A. (2016): "Niche construction and empowerment through socio-political work. A meta-analysis of six low-carbon technology cases", Environmental Innovation and Societal Transitions, volume 18, pages 164-180*
10. *Geels, F.W. & Schot, J. (2010): "The Dynamics of Transitions: A Socio-Technical Perspective", Routledge, New York, USA*

“New Space” as a recurrent narrative

“New Space” is a not-so-new way to refer to space activities.

It started to be used from the 1980s when the very first private companies in the industry were founded (11) , and when the White House pushed NASA to start a new massively communicated series of missions to space, designed from the 1971, probably as an attempt to rehabilitate America’s post-Vietnam prestige (12) . This was advertised as the dream of a democratic access to space, not only for the unusual involvement of commercial partners but also for the recruiting of common civilians as part of the astronaut crew. This dream concretised in a 24-flight-per-year schedule, required very tight economical and technical constraints, caused a “go fever” inside the NASA teams and eventually crashed with the Challenger disaster in 1986, when a shuttle exploded in the atmosphere with 7 astronauts on board, including a high school teacher.

The crew of the space shuttle Challenger is seen in this 1986 file photo released by NASA

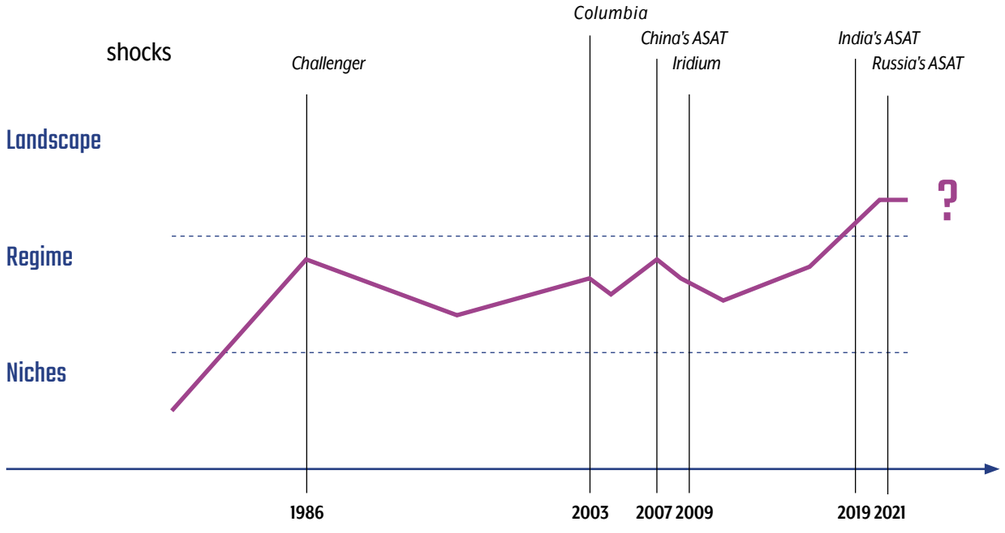
In spite of another similar fatal incident happened in 2003, the Columbia disaster, the enthusiasm around New Space revived from the early 2000s, when a few startups began to take the leadership and to make human space travel appetible again (13) .

11. *Bromberg, J.L. (1999): "NASA and the Space Industry", Johns Hopkins University Press, page 186*
12. *Logsdon, John. (1986): "The Space Shuttle Program: A Policy Failure?", Science*
13. *Denis, G., Alary, D., Pasco, X., Pisot, N., Texier, D., Toulza, S. (2020): "From new space to big space: How commercial space dream is becoming a reality", Acta Astronautica, volume 16, pages 431-443*

A new rush to space was officialised in 2017, when the former US President Trump signed a programme to bring American citizens to the Moon, to Mars and “perhaps some day, to many worlds beyond” (14) . Nevertheless, further recent incidents in orbit (like the Iridium-Cosmos collision) and anti-satellite tests (by order of China, India and Russia) are raising a widespread scepticism about the overall stability of the “New Space” ecosystem. Before talking about space tourism and colonisation of other planets, some important issues need to be solved in order to grant secure operativity for humans and artificial objects in space, without considering the defence of the natural environments.

If we look at the past 40 years, more than a radical paradigm shift, New Space appears like a recurrent narrative that hasn’t accomplished its promise yet: to truly democratise the access to outer space and to safeguard its environment for the future generations.

What is the change to be instilled in order to make this promise a present reality?



14. *Wang, J.R. (2017): "New Space Policy Directive Calls for Human Expansion Across Solar System", www.nasa.gov*

03

The step not taken towards resilience

Many experts have tried to define New Space and to point out the novelty it brings compared to the past regime. As a Strategic Designer my goal is rather to dig to the roots of the New Space culture, beneath the common definitions, in order to better understand its lead actors, the nature of its systemic problems and to find the seeds of a new transition. This research aims to open a novel perspective on the space debris issue, from which to envision a more resilient future for space and to design an intervention to steer the industry towards such a direction.

This chapter provides an explanation of the main thesis of this graduation project: *Why* the space ecosystem needs a cosmopolitan approach to achieve resilience.

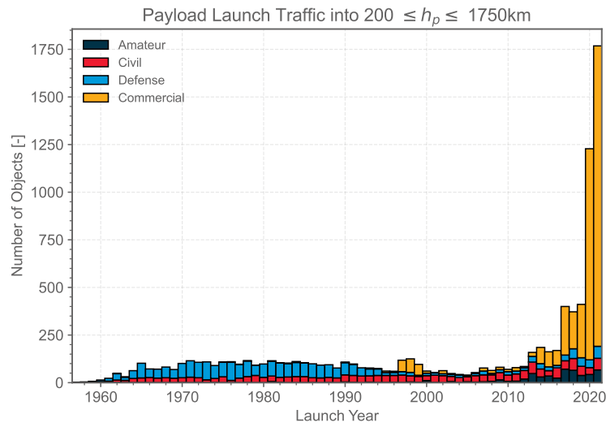
01

Landscape: What seems to be happening?

The rise of commercial companies

The abrupt development of technology in the last two decades has opened unprecedented opportunities also in the space industry and many achievements that were once unbelievable seem now possible, like landing humans on Mars. A renewed interest in space missions has attracted a massive number of private companies into the industry causing its population to change completely, such to mark the definitive advent of the so-called “New Space” (1) .

This transition started to become evident in the early 2000s, when the Silicon Valley most-prominent start-ups brought an agile attitude and fresh know-how, especially from the information technology sector. Hardware miniaturisation and decrease in launching costs have made satellite manufacturing cheaper and more functional, to the point that even academic institutions can afford conducting experiments with nano satellites in orbit nowadays.

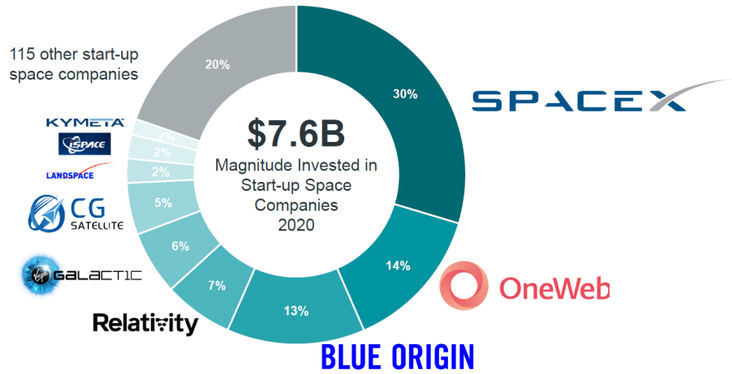


© ESA (2022): Space Environment Report

1. *Denis, G., Alary, D., Pasco, X., Pisot, N., Texier, D., Toulza, S. (2020): "From new space to big space: How commercial space dream is becoming a reality", Acta Astronautica, volume 16, pages 431-443*

Although the ultimate liability for all space activities shall always be on governments due to international law (2) , today commercial actors carry on the vast majority of the work and generate almost 80% of the total revenues in the market. They still collaborate in close partnership with governative space agencies like NASA and ESA, whose role has shifted from technology producers to funding entities and strategic consultants (3) .

In 2020 the global space industry tipped $447B value, 55% more than the previous decade. American venture capitalists have moved the majority of money and 57% of the total investments has been directed towards only three startups: SpaceX, OneWeb and Blue Origin (4) . Nations (USA on top, followed by China and EU) are supporting the private initiatives through their governative agencies, with a total of $90B in 2020. Interestingly, expenses in military missions have decreased constantly from the first era of rush to Space, and it is now globally stable at 35%.



9 companies accounted for 80% of start-up space investment in 2020, 3 companies accounted for nearly 60%

© Bryce Tech (2021): Update on Investment in Commercial Space Ventures

Looking at the future, Morgan Stanley estimates that the global space industry could generate revenue of more than $1 trillion or more by 2040 (5) . Possible game changers might also be new kinds of business like space tourism and resource mining on the Moon or on other celestial bodies.

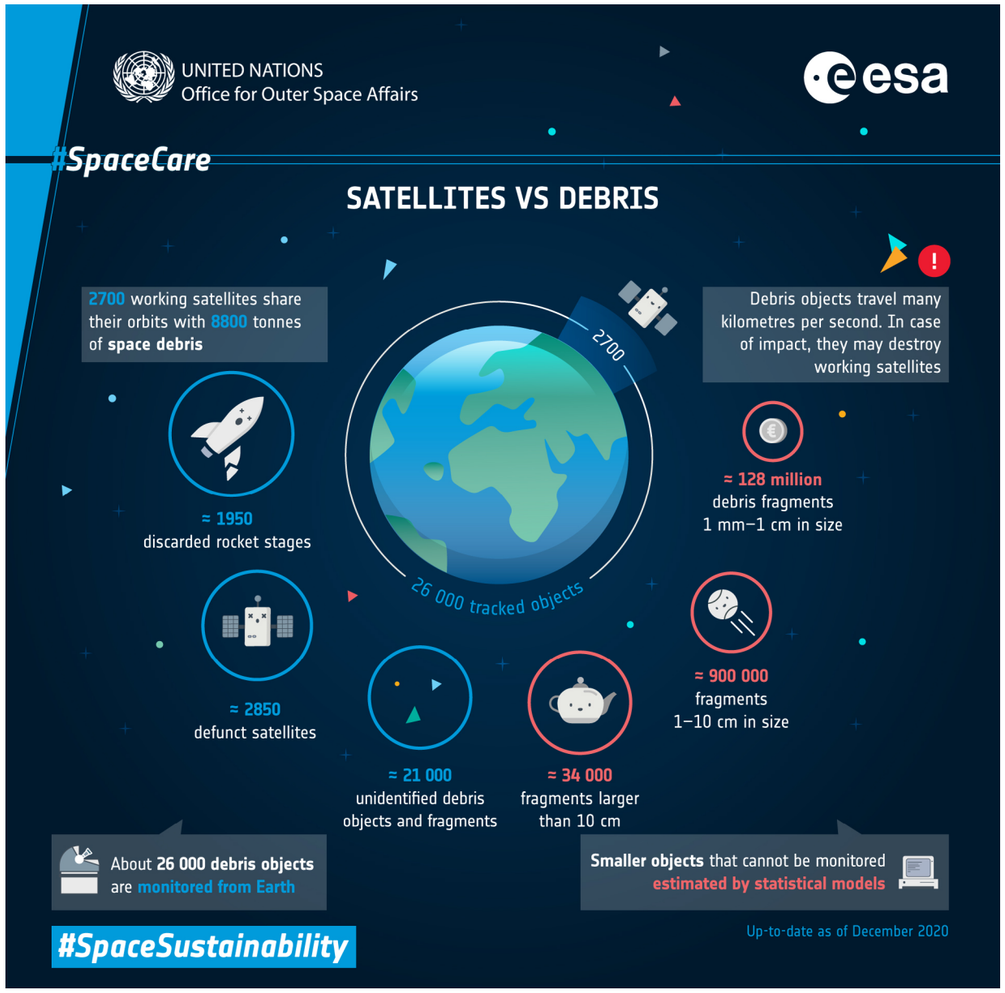
Beneath the howling enthusiasm and the bold promise of conspicuous returns on investments, one question is echoing more and more in the mission control rooms and in the space agencies offices:

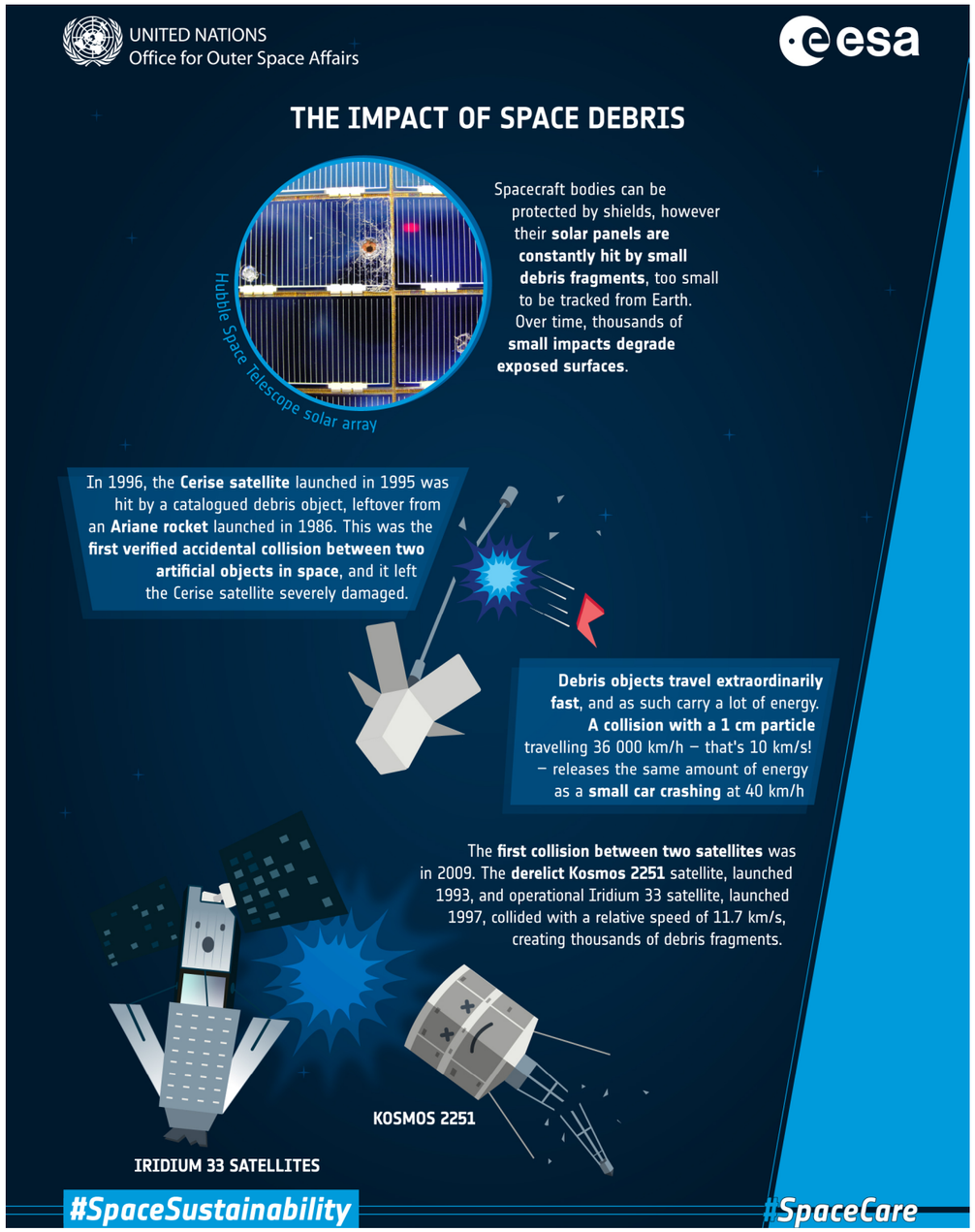
At what price does this prosperity come?

2. *United Nation, Office for Outer Space Affairs (1971): "Convention on International Liability for Damage Caused by Space Objects"*
3. *European Space Policy Institute (2019): "Evolution of the Role of Space Agencies"*
4. *Bryce Tech (2021): " Update on Investment in Commercial Space Ventures"*
5. *Morgan Stanley (2020): "Space: Investing in the final fronteer", www.morganstanley.com*

The threat of space debris

As a consequence of all the missions undertaken in space since the very beginning in 1957, hundreds of millions of artificial debris are now orbiting loose at high speed around Earth, more than 10.000 km/h. Only the ones bigger than 10 cm can be tracked with currently available technologies and they are more than 30.000, as the illustration below shows. Many of them fall and disintegrate in the atmosphere naturally, but many more remain in orbit for decades or longer. The ones ranging from 1 cm to 10 cm size, about one million, can cause the destruction of a satellite in case of collision, and the death of humans if any on board. Still, this is not the worst scenario.





In 1978 Donald J. Kessler, a former NASA's scientist, assumed that an escalation might happen if too many collisions occur in a busy orbit, a reaction chain that would raise the collision risk in that area to an extreme point of non return [6]. Earth might quickly become surrounded by billions of pieces of junk that would put active satellites out of use and make new operations on that altitude impossible. This scenario is called "Kessler syndrome" and its consequences might be terrible for humanity: no GPS to track and direct the global supply chain, no telecommunications for broadcast information and no planet observation systems to monitor climate change and mobility flows. Without considering that more ground infrastructures and activities are moving to space in these years, like mobile internet, which would be at risk too. In reality, it is not possible to predict precisely what effects such an event could produce, and the probabilities for it to happen seem very low today. Furthermore, debris could be considered a manageable issue if the situation in the busiest orbits around Earth stayed the same, or grew at a slow pace. Unfortunately, this is not the case.

UNOOSA, the UN Office for Outer Space Affairs, holds an official register of objects sent in space by all nations [7]. It says that more than 12.000 objects have been sent to space since 1957, more than 8.000 are still in orbit. Until 2016 about one or two hundred objects were launched every year, yet this number turned to 456 in 2017, and peaked at 1808 in 2022 [8]. This abrupt growth is due to the start of the so-called "mega constellation" projects, wide networks of small coordinated satellites aimed at bringing the internet to any part of the world. The biggest company currently in the whole space industry, SpaceX, expects to send around 42.000 within few years with its programme Starlink; OneWeb, its main competitor, 648; Amazon's constellation Kuiper has announced 3.236; also China is planning to build a 13.000-satellite constellation for its own internet provision. In order to provide an efficient signal, all these systems will have to be positioned in the Low Earth Orbit (LEO), between 160 and 2.000 km of altitude. Considering that a globally coordinated system of Space Traffic Management (STM) still doesn't exist ...

How could orbital traffic work with a hundred thousand satellites and millions of debris expected by 2030?

© ESA

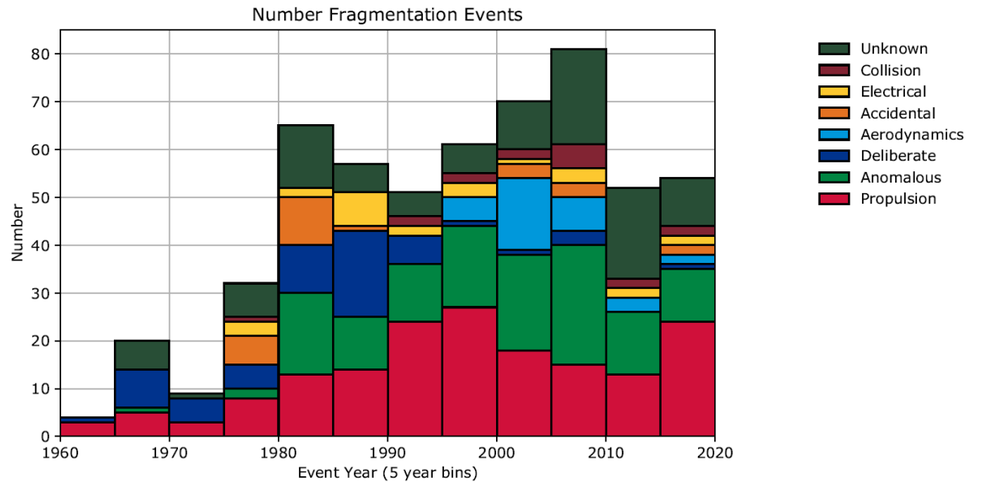
6. *Kessler, D.J. & Cour-Palais, B.G. (1978): " Collision frequency of artificial satellites: The creation of a debris belt", JGR Space Physics, volume 83, n. A6, pages 2637-2646*
7. *UNOOSA: "United Nations Register of Objects Launched into Outer Space", www.unoosa.org (updated on 21/04/2022)*
8. *ESA Space Environment Report 2022*

The operations to avoid a collision with another active satellite or with an inert debris are quite expensive, in terms of extra hours spent in elaborating the procedure, fuel and loss of data. To give an idea, nowadays each ESA satellite manoeuvres on average twice per year. As some authoritative experts have already warned (9) this development represents "a potential source of disruption to the long term sustainability of the space environment". Moreover they show that, even if all these constellations adopted reliable procedures to remove satellites quickly at the end of their mission, the proliferation of debris would still continue.

9. *Bastida Virgil, B. et al (2016): " Risk to space sustainability from large constellations of satellites", Acta Astronautica, vol. 126, pages 154-162*

If the scenarios presented still appear too hypothetical or far away in time, it would be worth contemplating present history facts. A collision event between two satellites has already happened in 2009, between the active Iridium against the derelict Kosmos, causing the spread of thousands of new debris pieces in only one second (10) . India and Russia executed anti-satellite tests respectively in March 2019 and in November 2021, with the latter causing astronauts of the International Space Station (ISS) to take shelter from a huge cloud of debris (11) . As the current war in Ukraine is demonstrating, the political tension between stakeholders is skyrocketing in the space sector too, mainly for military reasons (12) . As a consequence of a new cold war escalation, some geopolitical analysts are even raising the hypothesis that some superpower might decide to generate a Kessler scenario on purpose, in order to gain strategic advantages (13) .

More than a systemic problem, space debris appear like a global threat for humanity that could break out at any moment. So, stated the urgency, what is currently being done to address it?



© ESA (2022): Space Environment Report

10. *Kelso, T.S. (2009): "Analysis of the Iridium 33-Cosmos 2251 Collision", 19th AIAA/AAS Astrodynamics Specialist Conference. 135.*
11. *Hennigan, W.J. (2021, November 15): "Astronauts Take Shelter Aboard ISS After Russian Anti-Satellite Test, U.S. Says.", www.time.com*
12. *Heilweil, R. (2022): "The International Space Station isn't above global politics", www.vox.com*
13. *Miller, G.D. (2021): "Deterrence by Debris: The Downside to Cleaning up Space", Space Policy, volume 58, 101447*

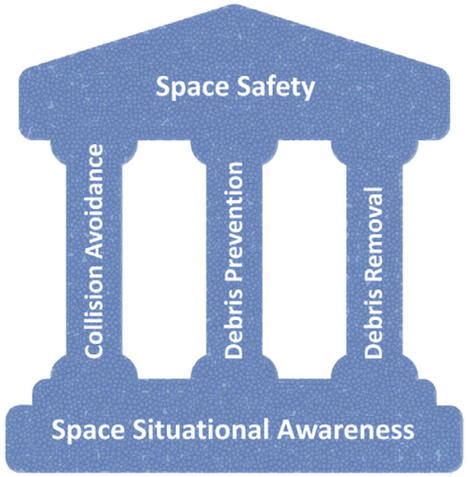
Towards a sustainable space domain

Especially after the Iridium-Kosmos collision, the issue has started to be taken more seriously. Following the example of the long-lasting US Space Surveillance Network, in 2009 ESA launched the Space Situational Awareness programme (SSA). SSA is meant as the ability to track, identify and predict man-made objects orbiting the Earth (from active satellites to loose paint chips), space natural environment (like meteorites, solar activity or man-made effects) and possible consequential threats for humans.

Developing technologies and data sharing practices to advance SSA capabilities is a necessary prerequisite to design interventions to grant a safer and more sustainable space domain in the short and long term [14] .

Overall, experts have pinpointed three possible scopes of intervention for a better space environment management [15] :

1. ***Preventing and mitigate debris production***
2. ***Avoiding collisions***
3. ***Removing the debris***



Maclay & McKnight (2020): A comprehensive framework for space safety in a congested environment, with SEM elements (prevention and removal) playing critical roles alongside STM (collision avoidance)

14. *Pelton, J.N. (2019): " A path forward to better space security: Finding new solutions to space debris, space situational awareness and space traffic management", The Journal of Space Safety Engineering, volume 6, pages 92-100*
15. *Maclay, T. & McKnight, D. (2020): " Space environment management: Framing the objective and setting priorities for controlling orbital debris risk" , Journal of Space Safety Engineering, volume 8, pages 93-97*

Scope 1) encompasses all those design and operational practices that should be put in place before the launch of objects in space, in order to prevent the generation of new debris and mitigate the growth of the issue. This scope is actually more political than technical. The UN Committee on Peaceful Uses of Outer Space (COPUOS) has already issued clear guidelines for the long-term sustainability of outer space activities [16] and ESA has proposed the adoption of a framework to rate the sustainability of space missions before and after the launch, in collaboration with other partners [17] . The ambitious goal set by UNOOSA on November 12th 2021 is to reach "Net Zero" generation of debris by 2030 [18] . Yet, the real challenge is to convince numerous governments to incorporate these recommendations within their local laws, as binding requirements for public and private actors to get licence to operate in space.

The highest achievement in this scope would be to induce satellite owners to mount specific standardised components that enable trackability and the provision of In-Orbit Services (IOS). IOS are a new generation of services aimed at refuelling, repairing and maintaining active satellites and at deorbiting objects at the end of their mission. IOS are still in a Technology Readiness Level 6, (TRL 6 out of 9: Technology Demonstration), they are expected to be fully operative around 2030 and they are considered a strategic advancement for the sustainability of future space activities [19] . Finally, mitigating the issue also entails banning ASAT tests, and it is good news that the US has given up this kind of harmful activities on April 18th 2022, encouraging other nations to join. An interesting tool that lawyers might deploy to achieve widespread adoption of all these initiatives is customary laws: in simple words, if a relevant number of nations enacts a rule and demonstrates its regular practical deployment, then the rule can be considered a reasonable universal principle and be imposed as a mandatory rule to other international actors, prevailing over individual vetoes.

International cooperation is an essential factor to maintain the sustainability of the space environment. Agreeing on mandatory rules and minimum requirements would also benefit scope 2), which has as its highest aspiration the creation of a globally shared system of Space Traffic Management (STM) in order to avoid collisions and make manoeuvres more efficient for everyone. The challenge here is to convince operators to be more transparent, to share data that are essential to avoid possible collisions with other operators and to do it in an effective way, as much automated as possible. An authoritative reference for this goal is CREAM, the ESA's Proposal for "Collision Risk Estimation and Automated Mitigation", which focuses on three objectives: (a) reducing manpower efforts in particular for large constellations, (b) reducing the number of false alerts, (c) reducing the time between manoeuvre decision and close approach [20] . A notable initiative in this direction is also the plan presented by the European Union on February 15th 2022 to elaborate a legislative proposal for a STM system in coordination with international partners by 2024 and to enhance European SSA technologies by 2025.

For scope 3), many solutions for active debris removal (ADR) have already been designed, but very few have been tested successfully so far. An example is the Astroscale mission ELSA-D, a robot created to dock a derelict satellite at the end of its mission and to deorbit it, by pushing its body away towards the so-called "graveyard orbit" or by decaying it towards Earth, to make it disintegrate in the atmosphere. Another complex demonstration is the ClearSpace-1 mission planned in 2026: a "tow-truck" for space, able to grasp big payloads with a claw and to drag it towards the atmosphere, where they would disintegrate together. For smaller pieces of debris, a promising

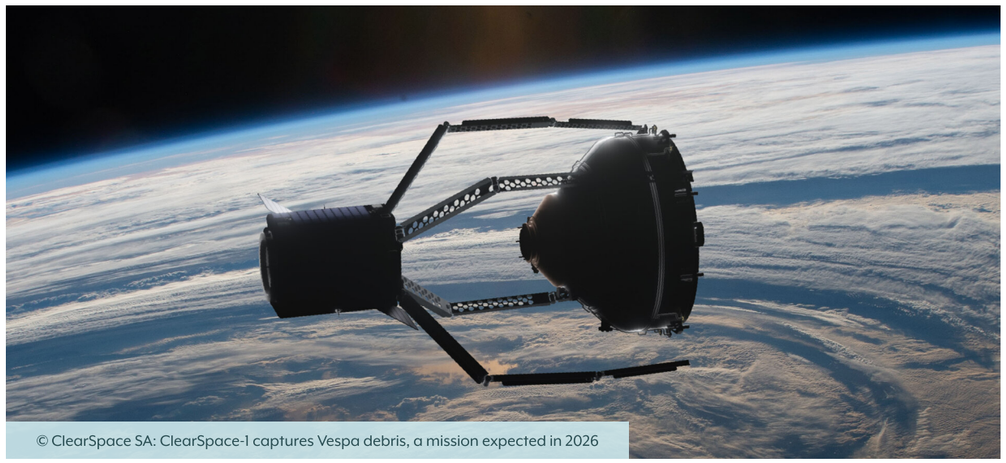
16. *UN Committee on the Peaceful Uses of Outer Space (2018): " Guidelines for the Long-term Sustainability of Outer Space Activities"*
17. *Flohrer, T., Lemmens, S.,Schmitz, F. (2021): "Framework for the space sustainability rating", Proc. 8th European Conference on Space Debris (virtual), Darmstadt, Germany*
18. *Peace Paris Forum, 4th edition, 20 April 2022 (parispeaceforum.org)*
19. *ESA, www.ideas.esa.int*
20. *Bastida Virgil, B., Floher, T., Krag, H., Merz, K., Lemmens, S. (2019): "CREAM - ESA's Proposal for Collision Risk Estimation and Automated Mitigation", The First International Orbital Debris Conference (IOC)*

technology could be able to zap them with a laser from a ground station in order to deviate its orbit. Although these missions may seem extremely complex, technology is not the main concern: the big problem is rather financial. Once the missions are proved feasible, they will be scaled and the cost to remove one piece may become a fraction of what it is now.

But how to finance a series of ADR missions, extensive enough to remove a sufficient number of dangerous objects and have a significant impact on the environment? And how to do it quickly enough before the traffic situation escalates? Who will (or should) pay for all this?

Few governments and space agencies are now financing these first testing missions through citizens' taxation, however it is still not clear who will pay to scale them in the long term. An option supported by some is to impose space operators mandatory insurance policies within the licensing price to finance ADR [21] . Nevertheless, this would reduce the accessibility to the most polluted orbits (often the most valuable) only to the few richest companies, since the premium to maintain those areas would be very high and satellites navigating cleaner orbits wouldn't care of contributing. Such a policy would lead to a monopoly in some orbits, which is against the OST principles of free accessibility to outer space and celestial bodies.

Overall the industry is now moving in the right direction to achieve sustainability in the New Space ecosystem. Yet, **sustainability might not be enough**. As stated before, space debris is a constant threat that can lead to a global disaster, it can occur suddenly at any moment and it can preclude space missions for many future generations. Currently humanity hasn't got any means to defend from such a contingency, or to remediate to an eventual catastrophe. Hence, what is needed is something more than sustainability: resilience. In practice this means accelerating all the roadmaps presented above (especially for debris removal), developing capabilities to detect a Kessler scenario on time and sharing a post-disaster vision in case it occurs. Finally, it is worth noting that the space sector has always operated with a top-down approach, deciding on missions without **involving the most important stakeholder: the civilian society**.



© ClearSpace SA: ClearSpace-1 captures Vespa debris, a mission expected in 2026

21. Wang, T. (2016): "A Liability and Insurance Regime for Space Debris Mitigation", Science & Global Security, volume 24, pages 22-36.

02

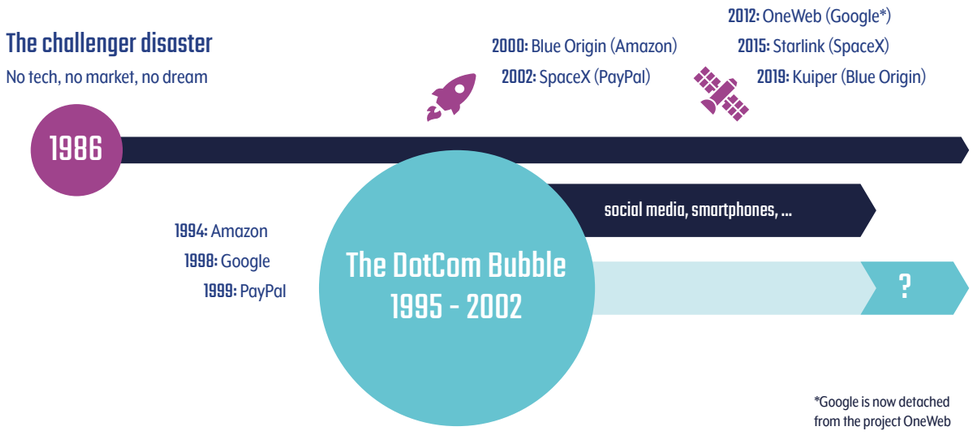
Regime:
What is actually happening?

The software is eating space: A game for few

In an interview for The Wall Street Journal in 2011, Marc Andreessen stated that "The software is eating the world" (22) . As an American blue chip investor, he meant this sentence as a rejoicing acknowledgment of facts and invited everyone to embrace a brave new world, since it is an established trend that could be observed in any sector. The space sector has been no different.

Today only three companies attract together more than 50% of the investments, in order:

- ***SpaceX***, founded by Elon Musk, founder of PayPal and Tesla, in 2002
- ***OneWeb***, founded by Greg Wyler while working for Google in 2015 (now detached)
- ***Blue Origin***, founded by Jeff Bezos, CEO and founder of Amazon, in 2000



22. Andreessen, M. (2011): "The software is eating the world", The Wall Street Journal

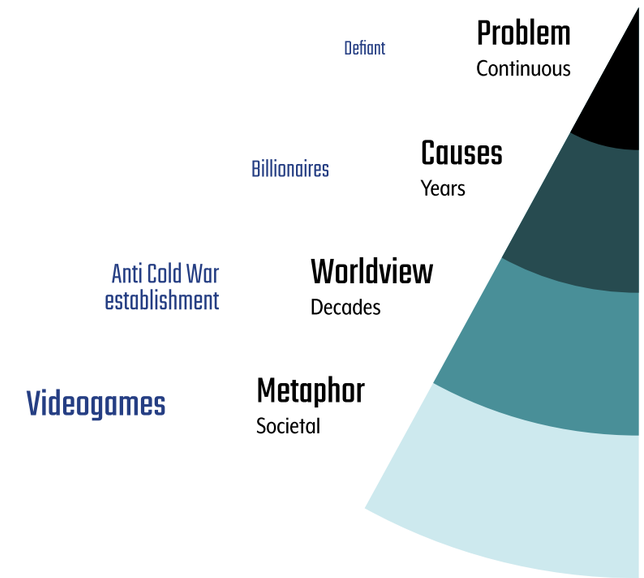
Notably, all these startups have originated from established software companies that are currently ruling the world economy (PayPal, Google, Amazon). Not surprisingly, all these companies have plans to build mega constellations to provide satellite internet to every corner of the world, probably to expand their digital empire. Moreover, it is interesting to align the timeline of the digital economy development with the one of New Space.

From this perspective, the Challenger disaster of 1986 can be identified as the endpoint of the past space regime, when the role of NASA started to be questioned and when space missions started to be seen as a life threatening unprofitable business. That was also the period when commercial companies started to be involved, marking the start of New Space, but it took almost 20 years for this trend to emerge. After the DotCom bubble, the few companies that survived were the ones to prove resilience and financial reliability, the ones that could bear a new massive round of investments to build the New Space economy. Nowadays the space private population is full of startups that offer software, cloud and AI-driven solutions, as I could also observe walking around the stands of Space Tech Expo.

Unfortunately, together with ingent capitals and reinvigorated dreams, the billionaires leading the biggest companies are also bringing problems to traditional scientific, governative and legal authorities. Elon Musk's personality is quite emblematic: his wealth is so big that he can joke about reigning over the planet Mars (23) , after becoming the richest man on Earth, and he is using Starlink technology to bother the Russian army during the war in Ukraine (24) . This defiant attitude is typical of the innovators enriched with the digital economy, who are setting the new rules of the world we live in today. From one side they push socio-technical progress, on the other side their megalomania leads them to impose their own vision and will with arrogance.

An interesting theory proposed by Italian philosopher and novelist Alessandro Baricco (25) suggests that the roots of the digital revolution, the nature of its leaders' mindset, might be found in a sense of exasperation with the establishments from Cold War times and in a boyhood spent with **videogames**.

It is not certain whether videogames have actually had an influence on their way of doing business, but it might be interesting to see what direction the gaming and internet industry is taking to foresee possible developments for the New Space economy.



23. Tangermann, V. (2021): "Elon Musk says he is now the "imperator of mars", www.futurism.com
24. Wadhva, V. (2022): " How Elon Musk's Starlink Got Battle-Tested in Ukraine", www.foreignpolicy.com
25. Baricco, A. (2020): "The Game: A Digital Turning Point", McSweeney's Publishing

Free riders: A tragedy of the commons

In 2019 Time magazine published a cover illustrated by Alessandro Gottardo that paid homage to another Time cover, illustrated by Robert Grossman in 1968 right after the Apollo 8 mission. The latest illustration is emblematic of New Space, for two reasons:

- First, it points out that the main difference in the last 50 years is in the lead actors, since private companies like SpaceX and BlueOrigin have entered the field and seem to run their own race, independently from nations.
- Second, it highlights that resource exploitation, like Moon mining, is still the aim of global superpowers, both public and private.

This time the race is not only to the Moon but to any valuable natural source of profit in space, and even a spot on an orbit can represent a strategic resource. In fact, another 'land rush' is occurring in LEO to gain the right to place numerous satellites on specific altitudes (26) . The richest companies in the industry are ready to launch hundreds of thousands satellites to build their mega-constellation and provide internet services. LEO is particularly attractive for its short distance from Earth surface, which enables transmitting signals to ground with low latency. The consequence of this "race for the spectrum" is a tragedy of the commons:

26. Boley, A.C., Byers, M. (2021): "Satellite mega-constellations create risks in Low Earth Orbit, the atmosphere and on Earth", Science Reports, volume 11, page 1064

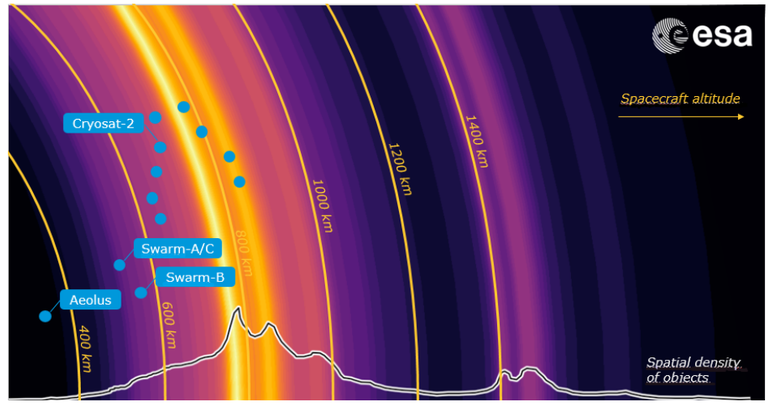
Outer space has become a non-cooperative game for a few players with infinite resources, in an environment with limited resources.

I have interviewed two space lawyers and they agreed on the thesis, stressing on one point:

"Space debris is a political issue, without international cooperation it will be hard to achieve progress in space environmental management" (27) .

Unfortunately the recent escalation in the global geopolitical polarisation is not helping, since satellites represent a military asset too. There is actually an open debate on the limitedness of the space environment and on whether the existing legislative framework is enough to safeguard it (28) . A constant orbit occupation by few actors clashes with some of the main principles of space law: the free accessibility to resources for any other player, the absence of ownership or sovereignty in space, the due regard towards other operators in orbit and the prohibition to contaminate the environment for a long time. Some other frameworks valid on Earth can be extended to limit resource exploitation in space, such as national laws, International Humanitarian Law and International Human Rights Law.

In spite of these arguments, some people maintain that outer space is so wide that it cannot be defined as a global common (29) . On April 20th 2022 the European Space Policy Institute published a report that proposes metrics to objectively calculate the orbital density threshold, the environmental capacity limit for some strategic areas in outer space (30) . This can represent a crucial step to enable more stringent rules, to design a globally coordinated STM system for LEO, to assign eventual sanctions for the so-called "free riders" or rewards for those who do more to maintain the shared resources. But will this be enough to achieve resilience?



27. Personal interview with a space lawyer (10/02/2022)
28. Hanlon, M.D & Autry, G. (2021): "Space law hasn't been changed since 1967", www.theconversation.com
29. Goehring, J.S. (2021): "Why Isn't Outer Space a Global Commons?", Journal of National Security, Law and Policy
30. European Institute of Space Policy (2022): "Space Environment Capacity"

The gap in the system: Participation

Until the end of the past century it was widely believed that communities of rational beings are not able to manage shared pools of resources in autonomy without depleting them, due to their natural “free rider” inclination and inability to coordinate. The solutions to avoid a tragedy of the commons were only more regulation or more privatisation by the government. Building on the game theory and of collective action, Elinor Ostrom proved how this dilemma can be overcome and opened a new path of research that gained her the Nobel prize for economy in 2009, the first woman in history. She travelled the world for many years and studied local communities that have been able to maintain environments autonomously for decades or even centuries, without a direct political intervention and allowing the members to profit from the resources at the same time, within specific limits. Examples are the meadow mountains of Switzerland and Japan, the irrigation systems in the Philippines, the forests of Nepal and the finishing communities of Canada. These groups base their local economy on a complex set of rules (explicit and implicit) and, although some cases are more successful than others, she was able to extrapolate 8 universal principles for the good design of global commons (31) .

I applied and analysed these principles in the context of outer space, where private ownership and national sovereignty are not allowed on the basis of binding international treaties.

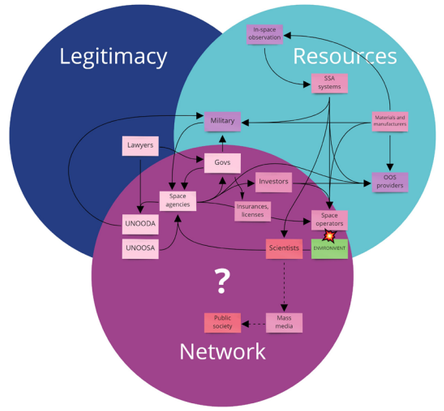
1. Clearly defined boundaries
2. Proportional equivalence
3. Participation
4. Monitoring
5. Graduated sanctions
6. Monitoring
7. Conflict resolution
8. Nested enterprises

While principles 6, 7 and 8 are well applied, the points 1, 2, 4 and 5 still need some work to be done within the international fora to coordinate space actors. However, the 3rd principle was the one that drew my attention and concern, Participation: “Individuals who get affected by the rules in the governance system must also have a say in making the rules”.

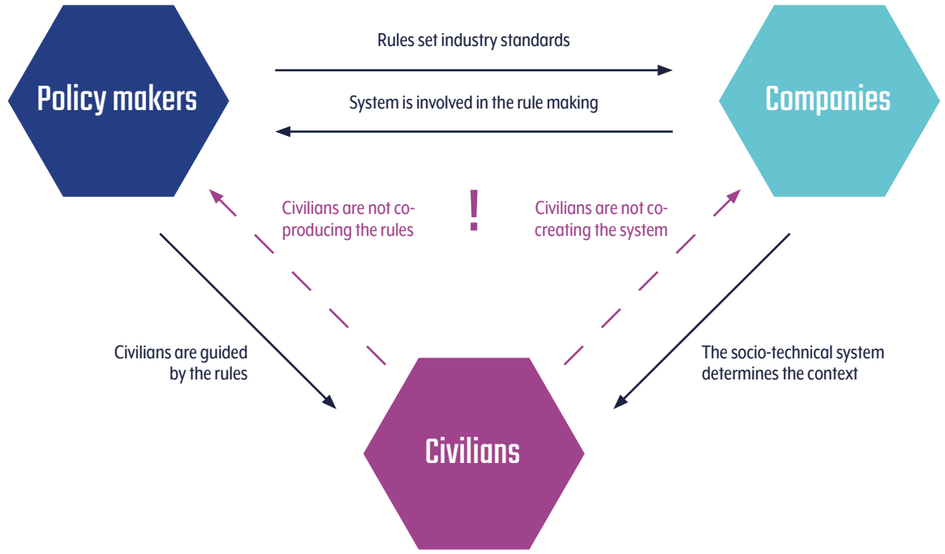
On one hand, private and public institutions are well involved in the decision making about the rules in space. On the other hand, a big part of the world population is paying governative taxes without having the right to influence the decisions about the space missions sponsored with that money, they receive the offer of satellite services like GPS without expressing their demand and they risk suffering the consequences of possible failures without being able to contribute to their mitigation. I am not claiming that space activities are not democratic. I argue that, within the current top-down approach, more participation of the civilian society might bring more balance in the system, indulge operators to behave more responsibly and contribute to build resilience in case of adversities in the ecosystem, like for example a Kessler scenario.

31. *Ostrom, E. (2010): "Beyond Markets and States: Polycentric Governance of Complex Economic Systems", The American Economic Review, volume 100, n. 3, pages 641-672*

A further argument in support of a cosmopolitan approach comes from a stakeholder analysis I made to visualise the power weight of the main actors and their interrelation. It appears evident that there is a gap at the bottom of the diagram, the actors with the networking power are not sending feedback to the other actors who have more legitimacy or resource power. According to Geels’ transition theory (32) this can bring disbalance in the dynamics of the ecosystem and eventually induce niche groups to push for a new transition.



At this moment the socio-technical system in space is mainly driven by startups and has gained too much power, hence the legal and governative authorities are trying to set new industry standards to safeguard the environment. Notably, the civilian society is not having any influence on the other two parties. Can this in fact lead to unexpected disruptions for all actors? If yes, in which transition direction can they push? Geels suggests that the answer may be in the niches.



32. *Geels, F.W. & Schot, J. (2010): "The Dynamics of Transitions: A Socio-Technical Perspective", Routledge, New York, USA*

03

Niches:
What might happen?

The collateral beauty of space tourism

One of the highest ambitions of mankind, after sending the first human to space, has been bringing more humans in space. Besides the promises to build stations on the Moon and enable life on Mars by the 2030s, the closest and most feasible business to enable a massive space civilization for now is space tourism. So far very few civilians have already experienced a journey beyond the atmosphere, from a period of 90 minutes to a maximum of 12 days, but some companies are already planning to open orbital hotels to host hundreds of tourists by 2025. The ticket for only a suborbital trip costs more than $200.000, but prices might decrease if the demand grows. However, philanthropic companies like Space For Humanity are offering some seats for free, by raising money through sponsorships and donations.

But what is the point of sending numerous people to space without any scientific purpose?

NASA/Bill Anders: "Earthrise", 24 December 1968, taken from Apollo 8

Although space tourism might seem an idle business, it depends on the way one looks at it.

The photograph “Earthrise”, taken by the astronaut William Anders on board of the Apollo 8 in 1968, has been considered "the most influential environmental photograph ever taken" (33) . It is believed that this picture instilled a new awareness, since humanity had never seen itself from outside. Probably because, actually, humanity can’t be seen from this picture: the planet showed itself in all its natural beauty and fragility, lonely, enveloped in a dark void, whereas all the big artificial things that civilization had built in history were not visible, and national borders either.

"But beyond this new consciousness, Earthrise instilled a sense of urgency for those who were already on the front lines battling pollution and making the case that our health and planet were in danger," said Kathleen Rogers on the 50th anniversary of the picture in 2018. Her organisation, Earth Day Network, has been the initiator of the initiative that is still celebrated internationally every year, since 1970. Today, companies like Space For Humanity are enabling influential world civilians to go to space and experience the so-called “overview effect”. They believe that such an experience would have the effect of getting people to reflect on the actual role of humanity in comparison to the whole universe, change their mindset and convince them to have a meaningful impact when they return home. Moreover, this perspective is supposed to arouse not only people’s care for the Earth environment, but also for the environment universally.

Besides this aesthetic and social purpose, space tourism is also helping the cause of space debris under the legal point of view. As a matter of fact, this issue is making outer space an unsafe place for both automated vectors and for humans. If orbits start to be inhabited by more people regularly, lawyers might soon be urged to create new legal frameworks focused on reinforcing safety in orbit and reducing risks for astronauts’ incolumity as much as possible.

Waiting for space tourism to be safer, some companies are offering VR experiences to make more people experience the overview effect without being physically there, like the Dutch programme SpaceBuzz aimed at “creating ambassadors of planet Earth”, starting from children.

© SpaceBuzz

33. *Life (2003): "100 Photographs that Changed the World"*

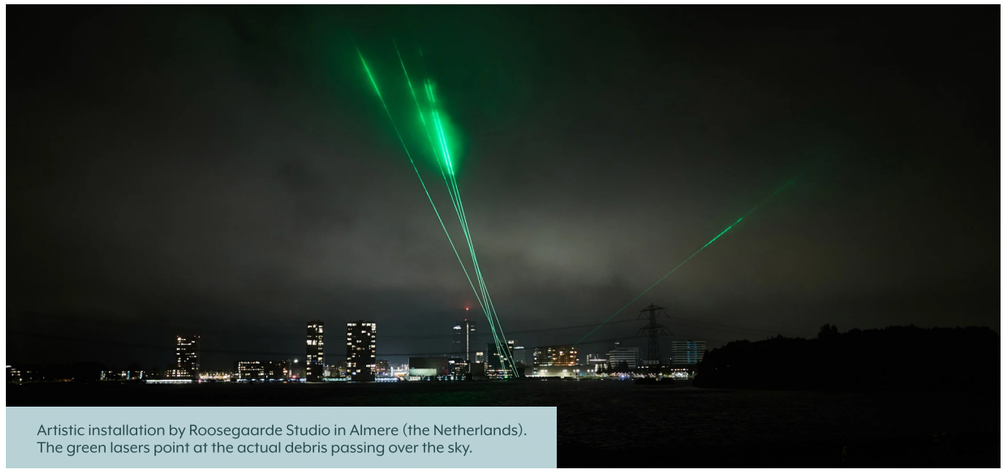
Advanced awareness in space with Vyoma

It's hard to deal with a problem if you cannot see it. In order to visualise the issue of space debris, several ground stations exist around the world equipped with advanced telescopes, laser and radar technologies. They are able to identify and track objects that are bigger than 10 cm also at high altitudes like GEO: a directory of more than 30.000 elements. Nevertheless what these SSA systems can actually see is just a bubble, which represents the approximate zone where the debris should be at a specific time. Unfortunately, this bubble is usually much bigger than the actual debris. In fact, this means that the space operators that use SSA services still rely on a big amount of approximation.

This causes three problems:

- The first one is that, if an active satellite is expected to encounter another object on its way (an inert debris or another active satellite), the standard procedure suggests performing a manoeuvre every time the probability of collision is 1 out of 10.000 (34) . This means that many times the manoeuvre is performed even if the two objects are actually very far away from each other, hence a lot of precious resources (fuel, data, hours spent by professionals in the operation) could actually be saved and the mission lifetime could be longer. Moreover, the satellite might arrive on a less useful orbit after manoeuvring.
- The second problem is that performing the rendezvous with a debris to enable its removal is quite hard without knowing its exact position and trajectory, because the space craft requires a high level of autonomy during close proximity operations while moving at high speed in orbit.
- Third, nowadays it is very hard for insurers, lawyers and operators themselves to assess responsibilities and liabilities about activities in space and the generation of debris, as happened with the loose rocket that crashed on the Moon surface on the 3rd of March 2022. (35)

Fortunately, this situation is going to change soon.



Artistic installation by Roosegaarde Studio in Almere (the Netherlands). The green lasers point at the actual debris passing over the sky.

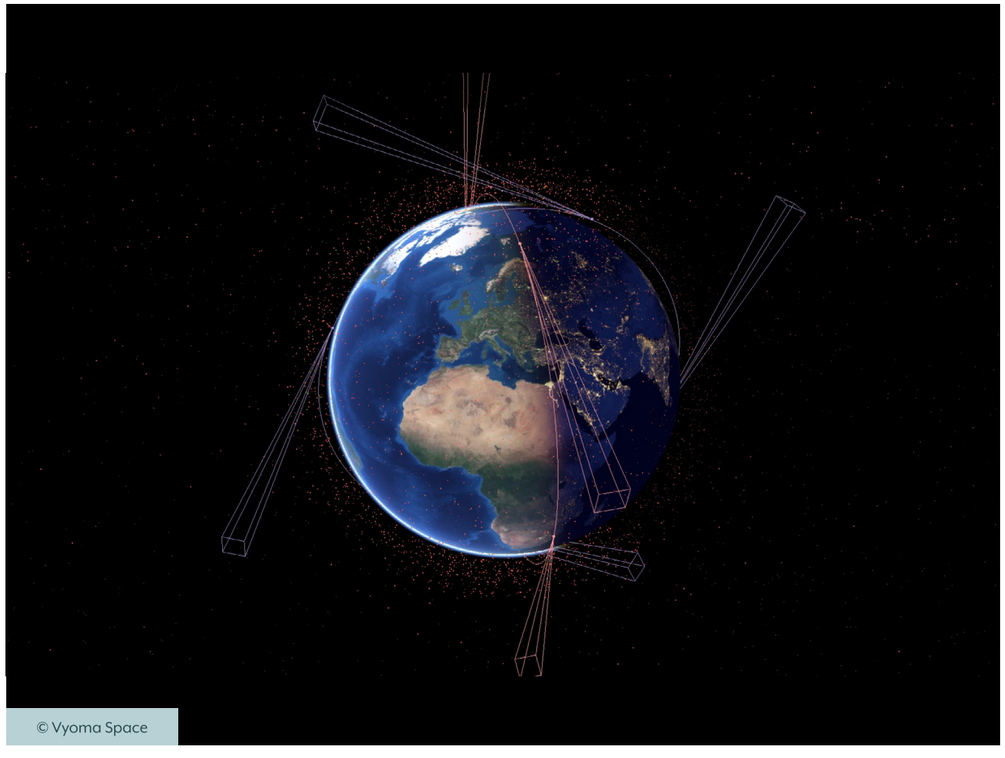
34. ESA: "Automating collision avoidance" www.esa.int
35. Haiye, P. (2022): "A rocket crashed into the moon. The accidental experiment will shed light on impact physics in space", www.space.com

Vyoma is a German startup launched in 2020 with the goal to reduce this approximation and provide higher confidence to operators, by generating accurate data about space objects position and trajectory and improved collision assessments. In order to do it, Vyoma will be among the first missions to bring space observation systems directly into orbit, by building a small constellation of telescopes.

With this innovative system and with the development of advanced machine learning algorithms they expect to save operators 95% of unnecessary collision avoidance manoeuvres. Moreover, they will be able to track smaller debris down to 1 cm size and to reduce the damage they cause to satellites which cannot see them yet. Finally, the better data generated will be extremely valuable for legislators and insurance companies, since it will become easier to assess risks, liability and responsibilities of in-space activities.

Companies like Vyoma are game changers and will contribute to start a new era of space missions, since advancing SSA capabilities represents an essential step towards the creation of space traffic management systems, the full automation of space navigation and the enhancement of active debris removal missions.

Besides this, I have involved Vyoma as partner of this graduation project because I believe that their technology can increase the space situational awareness not only for professionals working in the space sector but for the whole civilian society, which corresponds to one of the goals of my initial project brief. The other goal is to enable individual civilians to give a collective contribution to make the space ecosystem more resilient.



© Vyoma Space

Redesigning the New Space economy with the blockchain

After extensive research around space technologies, I have decided to focus on the blockchain because it might unlock interesting opportunities for the space economy, like it is already doing with many other sectors. As explained by PhD Jérémie Decouchant in a conversation we had at the TU Delft Blockchain Lab, the use of blockchain technology is still a niche in the space industry but it can bring important advantages, especially in terms of cybersecurity (36) (37) . Companies like Vyoma can benefit from it to share and mutually validate their data with other SSA companies, building even more accurate databases and algorithms (38) . ESA has experimented with several applications since 2016 (39) but has never integrated them systematically, probably due to the technology's premature usability, whereas the US Center For Space and Policy Strategy foresees a "gradual adoption trend over the next few decades" (40) . For the aim of this project, the most relevant feature of blockchain is the possibility to link the value of physical assets to correspondent virtual instances that cannot be replicated as normal digital contents, defined as ***cryptocurrencies***.

This feature has the potential to trigger significant financial implications within an ecosystem, by proposing alternative ways to manage resources, and very recently some companies have started to apply this paradigm in space too. One of the first ones, SpaceChain, was founded in 2017 to build the first decentralised infrastructure in space with satellites. Another, Copernic Space, started in 2021, is transforming space assets into NFTs in order to crowdfund missions and "to build a new financial system for space that benefits everyone on earth". Notably, this statement resonates with article I of the Outer Space Treaty and it seems to take seriously the requirement to overcome the concepts of national sovereignty and private ownership in space.

In fact, it enables a more cosmopolitan approach to fund missions, alternative to the widespread VC methods. Meanwhile, Doge-1 (a mission by Geometric Energy Corporation, in collaboration with SpaceX) is expected to become the first mission funded with cryptocurrencies by June 2022 and some space mining companies are planning to adopt the same strategy.

Besides disrupting traditional financial systems, the decentralising power of blockchain can also empower communities to design new models of governance, based on new ways to manage a pool of resources. Following this thought, many experts agree that a globally shared space traffic management system should be built on a decentralised platform like blockchain (41) , in order to convince stakeholders and nations to coordinate the flow of objects in orbit automatically, without the need to agree every time with the decisions of a single centralised authority. Nevertheless, what is still missing is a vision to counterbalance the space economy towards a positive environmental impact and to involve the most important stakeholder mentioned in the Outer Space Treaty: humankind as a whole.

In recent years some groups of technologists and economists have started to cooperate in the creation of the so-called **cryptocommons**: blockchain-based systems designed to empower communities to self-manage their shared resources, without the direct control of governments and mitigating the issue of free riders, on the basis of Ostrom's theories (42) . In practice they try to re-balance micro-economies by putting into circulation tokens, accurately engineered to encourage members to perform sustainable actions and whose value is linked to the actual benefits that the common resources can bring. An example is the Vienna Kultur token: a reward that tourists can receive every time they use eco-friendly means of transport in the city, that is worth free access to cultural services, like museum tickets. It is a way to redistribute real value throughout the ecosystem, in several forms, by design. I have interviewed a PhD at the Scuola Normale Superiore di Pisa and founder of the CryptoCommons Hub in Vienna, a non-profit association collaborating with the Research Institute for Cryptocurrencies of the Vienna University of Economics and Business. He said that a case study on the space ecosystem has not been explored yet but it might be a valuable experiment.

36. *Graczyk, R., Völp, M., Esteves-Verissimo, P. (2021):"EphemeriShield - Defence Against Cyber-Antisatellite Weapons"*
37. *Graczyk, R., Mendonça, J., Völp, M. (2021): "Consent to shoot – rethinking the anti-satellite weapon versus space debris dilemma", 8th annual Space Traffic Management conference – STM 2022 02-03 March, 2022, Austin, TX, USA*
38. *Capez, G.M., Buinhas, L., Caceres, M.A., Setty, S. (2021): "Distributed Space Traffic Management Solutions with Emerging New Space Industry", 16th International Conference on Space Operations, Cape Town, South Africa – 3 - 5 May 2021.*
39. *ESA (2017): " Distributed Ledger Technology Leveraging Blockchain for ESA's Success"*
40. *Johnes, K.L. (2020): "Blockchain in the space sector", Center for Space Policy and Strategy*
41. *Surdi, S.A. (2020): "Space Situational Awareness through Blockchain technology", Journal of Space Safety Engineering, volume 7, pp 295–301*
42. *Rozas, D. , Tenorio-Fornés, A., Díaz-Molina, S., Hassan, S.(2021):"When Ostrom Meets Blockchain:Exploring the Potentials of Blockchain for Commons Governance", SAGE Open*

How do cryptocurrencies work ?

Cryptocurrencies *(or simply "tokens") are unique digital assets. They can be exchanged through encrypted smart contracts and registered on an open decentralised ledger (the "blockchain"). In fact, each token is represented by a unique serial number and is linked to an anonymous owner (o, better, a virtual "wallet").*

Tokens can be exchanged by the members of the decentralised network safely, because all transactions are encrypted through advanced algorithms and validated by other anonymous members by means of sophisticated protocols. Once validated, the transactions are registered as "blocks" on a shared ledger, which is transparently accessible for anyone with an internet connection. The blocks on the ledger are immutable, they can be neither edited nor removed; it is only possible to add new blocks or use them to overwrite previous permanent information.

There can be fungible tokens (or simply "coins"), exchangeable with other tokens of the same value, like equal banknotes with different serial numbers; or non-fungible tokens ("NFTs"), which are unique like the Apollo 8 spacecraft.

RESEARCH

DESIGN

04

Envisioning a resilient future for space

Chapter 2 pointed out the main findings of my research in the New Space context, provided insights on why a cosmopolitan approach is required to face the space debris issue and analysed potential alternative ways to do business in space.

In this chapter a vision is presented of what could happen if the three niche trends analysed became mainstream, integral part of the landscape level. For each of them I have elaborated hypothetical future scenarios, considering both probable and impractical possibilities, both positive and negative aspects, starting from *"What if ... ?"* questions. These three assumptions are also coherent with my initial project brief, which is to make people aware not only of their co-ownership of space resources but also of their co-responsibility for space issues, in line with Elinor Ostrom's theories.

Niche trends		Hypothetical scenarios
Space tourism	⇝	*What if anyone could experience the overview effect?*
In-orbit observation	⇝	*What if advanced SSA provided a service for civilians?*
Cryptocommons	⇝	*What if cryptocommons were applied to space?*

In order to diversify the outcomes of this speculative process, several methods have been applied and several stakeholders from my network have been involved in co-design activities. Each scenario focuses on the three main objectives of a good strategic design project: desirability, feasibility, viability.

The insights generated have drawn the guidelines for the subsequent design phase, whose outcome consists in a business intervention aimed at priming a new transition process in the space ecosystem, in order to achieve a more desirable and resilient future.

What if anyone could experience the overview effect?

To test this assumption I have organised an “immersive” workshop with 6 design students, inside a dark room where a big screen projected the real time streaming of the overview effect seen from the ISS. The workshop lasted 90 minutes, like the time the ISS takes to orbit around Earth.

I have asked the participants to reflect about their value perception about space activities, to freely imagine how their daily life would be if they could inhabit space environments, to consider limitations but also opportunities and what kind of relationship they would still have with Earth, their previous home.

The team of space citizens who joined the immersive workshop

Space was seen by the participants as “our home’s home”, a place from which it is possible to see the world in a different way and to learn many things that can help solve many problems that affect our planet. Indeed, besides all the physical limitations, the main value of space was found in the opportunity to switch perspectives, that would feed the need to “stay curious and constantly surprised”. For someone, this would lead to developing “a huge diversity” with other humans on Earth. Nevertheless, the link with their original home would remain, since happiness would still depend on “being with loved ones” and taking care of oneself, for example by keeping fit and “jogging with amazing views”.

After this first explorative part, I put them in front of the threat of space debris by showing them a short but comprehensive video. A new awareness completely changed the consideration about space for all the participants, in particular about the Earth orbit: “I used to feel space as something infinite I know little about, while the orbit is something we could feel as an extension of our planet”; “This workshop has caused me to consider space as a closer dimension, it’s not far away but it appears to be more approachable and tangible”. The issue of space debris also triggered negative emotions: “I never expected it could be so crowded, which now disturbs me”; “It saddens me that we humans are not only polluting our planet but also beyond”. Finally, the issue led them towards a political focus: “What is the real impact of space debris on my life on Earth and for future generations? What is being done right now? Is it on the political agenda?”; “What can ordinary people do to help solve it?”.

The conclusion is that getting people to take a perspective of Earth from space and making them aware of the real time situation in orbit motivates them to commit to the mitigation of issues like space debris, like it already happens with environmental issues on Earth, which would provide a higher degree of resilience for the space ecosystem.

If providing a real immersive experience of the overview effect through space tourism will not be feasible for at least a decade, the recent progress of immersive digital technologies can represent a valid alternative to make this experience accessible for a wide audience. An exemplary cultural project of this kind is “The Infinite”, the world's largest interactive immersive experience about space exploration. Statistics show that the number of VR/AR devices shipped worldwide is expected to increase to 68.6 million units in 2023 (1) . Furthermore, AR and VR features are being integrated more and more in smartphones and smart wearables and the cost of visors is expected to drop.

What is driving the market is the revived narrative of the so-called “metaverse”, meant as an immersive persistent dimension expanding the physical world and enhancing social interactions. An example of metaverse can be experienced in some contemporary videogames like Fortnite, but this paradigm is going to revolutionise many other industries such as education, healthcare and tourism. Experts like Louis Rosenberg believe that AR in particular will disrupt the way we interact with the real world, improving the interaction with people, services and environments that we usually perform through smartphone 2d screens (2) .

For a sector like space, whose activities cannot be experienced in place by many people for obvious physical reasons, the metaverse can represent an interesting business opportunity. For instance, in the present early development stage a space tourism company could offer a real experience in orbit only for the few wealthy customers who can afford it, while also a virtual and augmented experience can become accessible to a wider audience for a very cheap price. It would help the company to expand its market, become profitable earlier and anticipate farther horizons, like opening an orbital hotel for hundreds of guests by 2027. Finally, this innovative way to interact with users could bring relevant insights to the designers of the mission, so that aspects like the spacecraft, its environments and the services can be virtually co-designed with the final users before they become physically available.

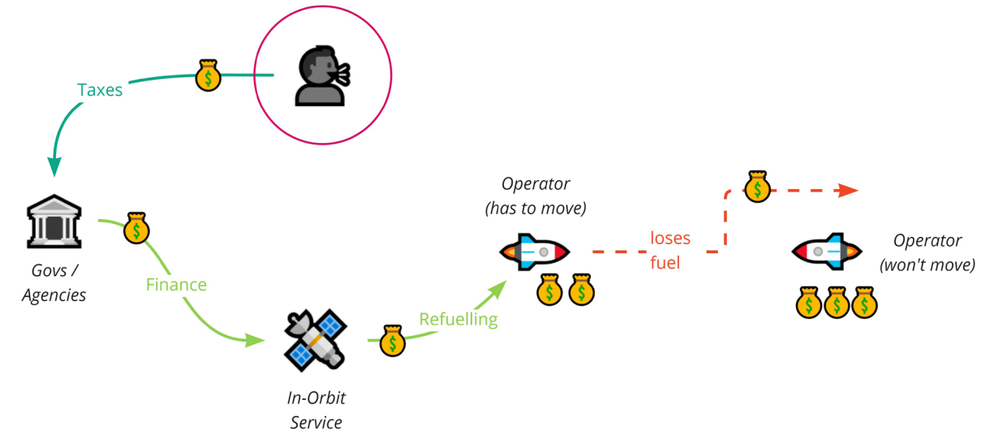
© Orbital Assembly: A rendering of the orbital hotel

1. www.statista.com
2. Rosemberg, L. (2021): "Why AR, not VR, will be the heart of the metaverse", www.venturebeat.com

What if advanced SSA provided a service for civilians?

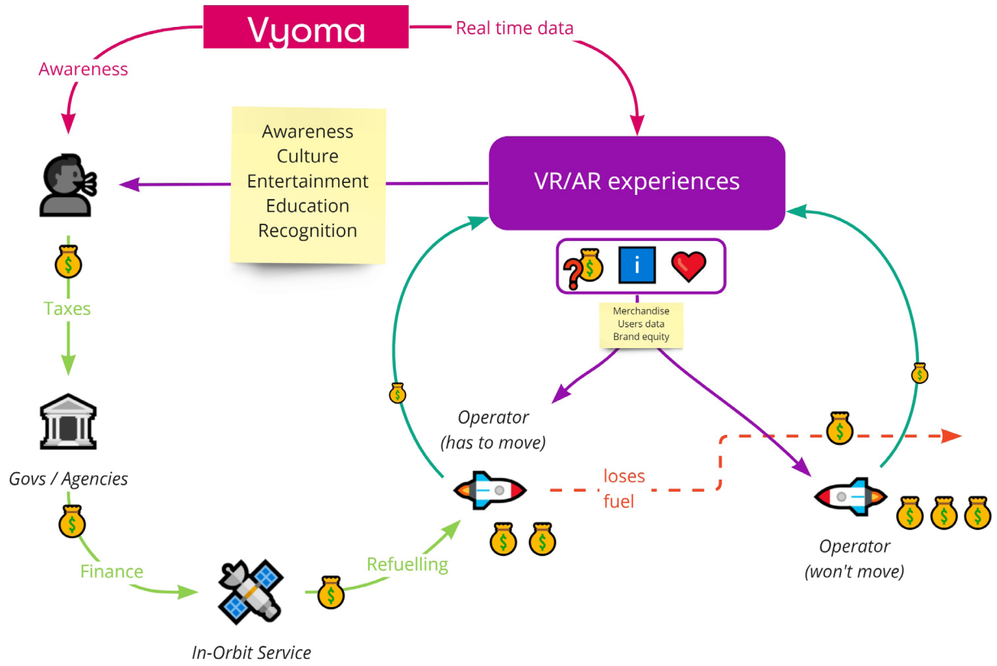
I have collaborated with the team of Vyoma Space for several months, having frequent insightful conversations with my mentor Stefan Frey. He helped me to understand why advancing SSA capabilities is essential to mitigate the space debris risks and what is the potential of Vyoma technologies in the short and medium term.

We have analysed the main stakeholders involved in the space sector, their relationships, their value exchange and their impact on the environment. Finally we have investigated the system gaps, especially concerning the space debris issue.



We have realised that at the moment the most penalised stakeholder is the civilian society: Citizens of space faring countries are paying taxes to fund missions they know little about and on which they have no decisional power. Arguably, this might be the cause of a common misperception of space activities benefits, expressed through the emblematic question “Why are you busy with experiments up there, while we have so many problems to solve here on Earth?”. Moreover, citizens might pay even more in the future to remediate an environmental problem that they have not created, since only governments are willing to fund ADR missions so far, which also confirms the assumption elaborated in the initial project brief: It is necessary to raise awareness about the situation in space among the civilian population. So I made a probing scheme of the space stakeholders, but placing Vyoma services in the middle (between the operators, the policy makers and the civilians).

On the one hand, this might decrease the confidence in space missions even more, since citizens might be annoyed to assess a tragedy of the commons caused by public and private actors. On the other hand, as the previous “immersive” workshop demonstrated, people’s awareness about the real time space situation can arouse an attachment feeling for the orbital environment and motivate their political commitment, so to ask for better regulations, to nudge operators for more responsible behaviours or even to contribute themselves to the cause, for instance through a signed petition or a crowdfunding campaign to clean orbits. Moreover, the marketing of such a service would give more ethical sense to the taxes that citizens already pay to fund space missions, since their impact would be communicated in a more transparent way. Besides the civic/cultural purpose, it might satisfy other people’s needs as well, such as entertainment, creativity and education, also enhanced by social interactions.



As far as feasibility is regarded, there would be no difficulty in developing it as a digital product (be it a website, an app or an immersive experience), since these technologies are already becoming commodities. Connecting Vyoma real time data through API might also unlock unique features, like for example playing with the position of actual satellites and space debris. Stretching this concept, it would even be possible to make users interact with a digital twin of the space environment, so that space professionals can use their input to co-design mission requirements, to train their algorithms or to simulate hypothetical scenarios in which non-rational human behaviours can have a critical repercussion. Similar applications are already widespread in the military industry, although their feasibility is way more complicated.

As far as viability is concerned, such a kind of service is usually non for profit. The reason is because it is harder to monetize a civic/cultural service. In case it is publicly funded, some governments may be willing to pay but some others may not, making it not as cosmopolitan as it is aimed to be. If it is privately funded it can be monetised through advertisement from partner brands, but this often implies privacy issues like in the case of social media. Finally, people might be willing to pay a fee to access the service, or an abonnement, but this would make it less accessible to less wealthy users; hence, not universally accessible as the project aims to be. Some interesting monetisation opportunities might arrive instead from blockchain applications.

What if cryptocommons were applied to space?

As discovered in the previous chapter, blockchain technologies have the potential to generate alternative financial systems and new models of governance for communities, capable of going "beyond markets and states", quoting the renowned book by Elinor Ostrom (3) . Actually, they can make even more sense in the space context, where international treaties ban private ownership and national sovereignty.

Maintaining that tokenizing economies is a sophisticated art of engineering, that requires extensive research and community engagement, I have tried to figure out a suitable token model for this project, together with the CryptoCommons Hub. The conclusion is that there might be two solutions: the first one involves the circulation of a fungible token in the network (a "coin"), that sustains the system viability through the taxation of every transaction; the second is just as simple as effective, and consists in linking the space debris and their real time position to virtual assets by transforming them into non-fungible tokens (NFTs). There is also a hybrid way, which consists in releasing a limited collection of space debris NFTs for the early buyers and, afterwards, minting a coin to give to each NFT owner access to premium services. It remains an option to apply a fee every time the tokens are resold. This system would enable keeping the platform free to anyone for cultural purposes, while also stimulating a community of premium users willing to contribute through their exchanges to the maintenance and resilience of the space environment. An initiative that involves a long lasting commitment by the community and that would go beyond a short term marketing campaign.

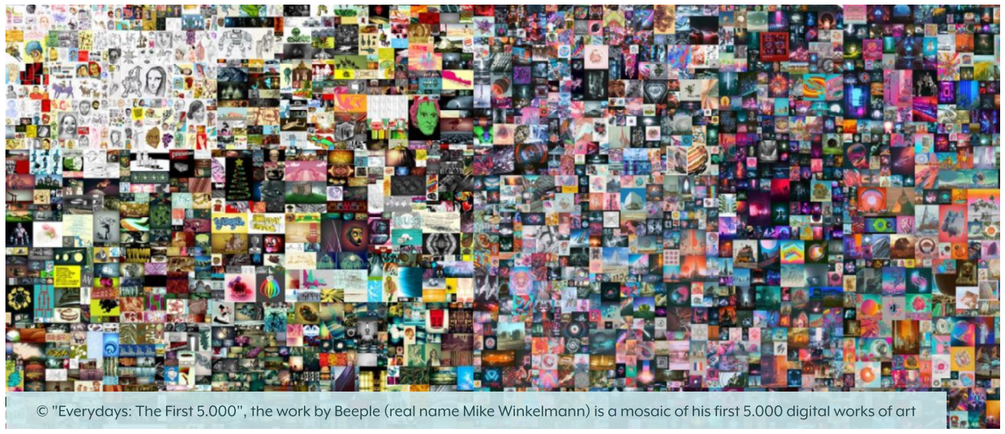
The Bored Apes Yacht Club (BAYC), one of the most successful NFT projects so far, launched in April 2021, applied this business model. They have released a limited collection of 10.000 NFTs connected to an equal number of funny illustrations of bored apes, which went sold out in less than one year including many VIPs. At the time of writing, one piece of the BAYC collection costs at least $ 350.000 and the ApeCoin has already generated a market capitalization of more than $ 2,5 billion through its exchange. Considering that the first ClearSpace mission will cost overall about € 100 million, and even assuming that the Bored Apes project will lose its traction soon, such an opportunity has the potential to transform a lengthy and expensive ecological activity (like active debris removal) into a profitable business.

© Bored Ape bought by the basket player Stephen Curry for $ 180.000

3. Ostrom, E. (2010): "Beyond Markets and States: Polycentric Governance of Complex Economic Systems", The American Economic Review, volume 100, n. 3, pages 641-672

But what is the exact reason that would induce people to buy a space debris NFT?

A buyer might simply decide to spend a lot of money to keep it as a work of art, like it happened to the buyer of the NFT linked to the digital artwork "The First 5000 Days" by Beeple, sold for $ 69 million at Christie's.



© "Everydays: The First 5.000", the work by Beeple (real name Mike Winkelmann) is a mosaic of his first 5.000 digital works of art

But there is the suspicion that labelling every NFT as "art" will not confer them a real value in the long run. For example, a person paid $ 48 million for the "Jack Dorsey's First Tweet" NFT but now he is desperate because he cannot resell it anymore (4) .

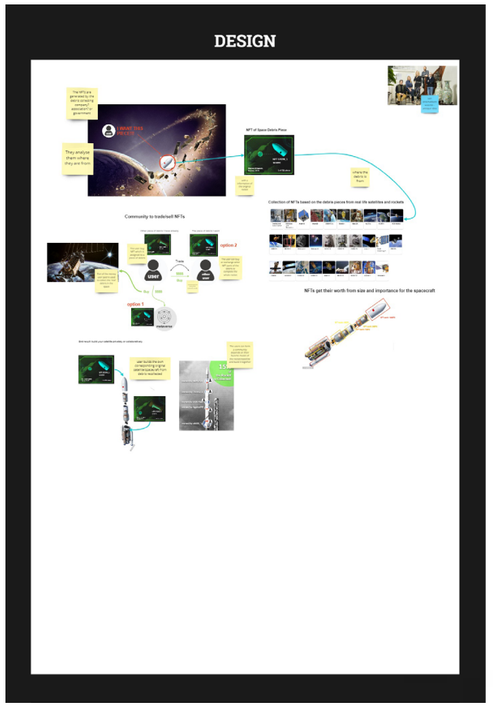
The first tweet by Jack Dorsey in 2006, sold as an NFT in 2021

4. Reuters (2022): "Man who paid $2.9m for NFT of Jack Dorsey's first tweet set to lose almost $2.9m", www.theguardian.com

In addition to this, now it seems that also Yuga Labs (the company behind BAYC) is trying its best to keep its Bored Apes entertained, since it plans to release a metaverse called Otherside for its community of NFT owners. These case studies made me understand that delivering value through NFTs by design is not as easy as it seems. I tried to look for agencies specialised in NFT projects but actually very few professionals can say they are experts of NFT design, because the trend is still very young and the successful projects are probably less than 1%, while the vast majority seems to be scam or short term marketing of poor quality, often sold as art.

For this reason I have decided with my graduation mentor Erik Tempelman to organise a one-day workshop with 40 design students of TU Delft. The plan was to introduce them to the topic of metaverses and NFTs during the morning, to start an open debate with the expert Aurore Geraud (Senior Researcher at L'Atelier BNP, connected in streaming from Paris) and, in the afternoon, to assign students the task to design a NFT value proposition linked to space debris.

The ideas generated by the students have been extremely inspiring to design my final solution, but even more inspiring has been the target users they have decided to address and the needs they have tried to satisfy through their product/service concepts.



At the end of the day I have asked them to write recommendations for designers on how to deliver value through NFTs. The most interesting insight has been an analogy with the DotCom bubble: In the 1990s some people were willing to pay an insane amount of money just to buy a domain on the internet, probably because the real value of the internet could only be guessed but not really understood at that time. Nowadays everyone is well aware that without a website on that domain, without an easy interface and a compelling experience and - most importantly - without a valuable service provided for every second the users spend in it, that project is bound to fail quickly. In the same way, although the idea of space debris might be fascinating for some people, linking them to NFTs will not generate a long lasting and resilient business by default. Adopting this historical perspective has been essential to design a NFT-related service to increase the resilience of the space ecosystem.

05

DESIGNING FOR "SPACE 5.0"

After a forecasting process with many divergent ideas about the future of space, elaborated on the base of *"What if ...?"* assumptions, it is time converge towards the specific future vision that I wish to propose for the space industry to move towards a more resilient state. Now the question is *"How?"*.

This chapter presents such a vision and illustrates the process that guided me towards the elaboration of my final design concept: A business intervention aimed at priming a new transition in the space ecosystem, through a cosmopolitan approach.

A new era of space missions

A vision proposed by the European Space Agency presents the history of space missions as the sequence of 4 consequential transitions (1) :

- ***Space 1.0*** consisted in the very early study of astronomy.
- ***Space 2.0*** was the era of the first space missions that led to the Apollo moon landings
- ***Space 3.0*** was marked by the International Space Station, a commendable demonstration that humans could understand the civilisational value of space as the next frontier for cooperation among nations.
- ***Space 4.0*** is the era we are living, "a time when space is evolving from being the preserve of the governments of a few spacefaring nations to a situation in which there is the increased number of diverse space actors around the world, including the emergence of private companies, participation with academia, industry and citizens, digitalisation and global interaction".

Unfortunately, the second part of this statement is yet far to be accomplished. As analysed in chapter 2, the latest 4.0 era is showing all its limitations due to a lack of active involvement of the citizens under the political and market point of view, a structural issue that might undermine the ecosystem resilience. As a matter of fact, the current war in Ukraine is having harsh consequences for the entire space sector and the peaceful dream of the ISS to bring nations together is slowly falling apart, since the mission will be over before the end of this decade and no one of the members involved seems interested in renewing it. The risk is to regress to the Space 2.0 era even before the Space 4.0 comes to full maturity.

Many experts in the field advocate for a next, more regulated, "sustainable" era (2) , for a "responsible" era (3) or for the "ethics" era (4) . With this graduation project I argue that, if a "Space 5.0" era has ever to come, it will have to prove a good deal of resilience and develop independently from the "good sense" of individuals. As history and the recent military initiatives by Russia are showing, no regulation in the world is actually able to stop the irresponsible and unethical behaviour of a single actor willing to alter an ecosystem balance. In order for a next space era to exist at all, the new socio-technical regime should be designed in a way not only to avoid a possible Kessler scenario, but also to be ready to face its eventuality.

I envision Space 5.0 as a time when space is evolving from being dependent on the initiative of a few private and public actors, to a situation in which all the resources are managed on the basis of co-creation, co-ownership and co-responsibility with the whole civilian society, which encompassess disaster response and recovery too.

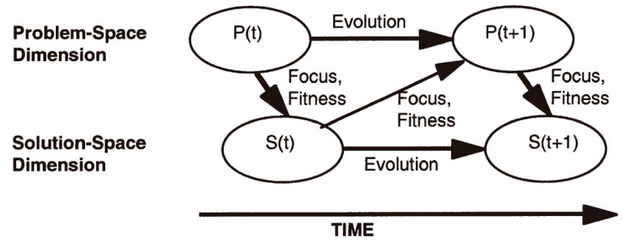
1. *ESA: "What is space 4.0?", www.esa.int*
2. *Bhutada, G. (2021): " Space Sustainability: Preserving the Usability of Outer Space", www.visualcapitalist.com*
3. *McClintock, B., Feistel, K., Ligor, D.C., O'Connor, K. (2020): "Responsible Space Behavior for the New Space Era: Preserving the Province of Humanity", Santa Monica, USA*
4. *Daemen, T. (2021): " The ethics of the new space age"*

In order to pursue this vision I have outlined some key characteristics that the future space services can assume. The following list is meant to be exemplary and not comprehensive:

- *Services based on a trust-less decentralised ledger that tracks all the space-related assets (natural and artificial) and links the resources to all the actors dealing with them; this can apply to a trans-national space traffic management but also to moon mining.*
- *Based on fully automated and coordinated navigation systems, with transparent real time communication to all the stakeholders, including civilians.*
- *Diversifying funding methods including crowdfunding, for the whole mission or only for eventual in-orbit services, like refuelling.*
- *Providing free cultural experiences to explain the humanitarian value of the missions.*
- *Providing immersive experiences to give access to the exploration of space environments.*
- *Providing experiences to co-design the features of future services.*
- *Simulating hypothetical scenarios through interactive digital twins, receiving strategic insights that can also inform legislators to anticipate needs.*
- *Going beyond the traditional operativity in space to provide brand experiences, involving for instance entertainment and merchandising.*
- *Advertising space assets within digital experiences.*
- *Providing NFT-related services to reward users who support sustainability operations.*
- *Enable civilian communities to vote on some crucial mission-related decisions that might have an impact on the environment, through decentralised trans-national systems.*
- *Participating in the co-design of disaster response strategies and allocating globally shared resources for defence R&D.*
- *Involving civilian communities to co-envision the future space ecosystem.*

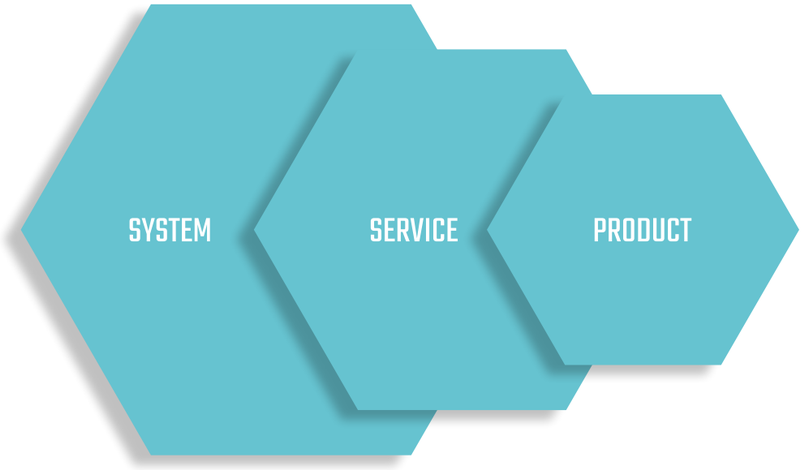
My design process

After making sense of the research insights and elaborating a coherent future vision, I have designed a business intervention to prime a transition within the space ecosystem towards a more resilient state. In reality, since design is not a linear process and **the research question co-evolves in parallel with the solution elaboration** (5) , these two moments of research and design have not been consecutive but simultaneous.



The design process as described by Dorst & Cross (2001)

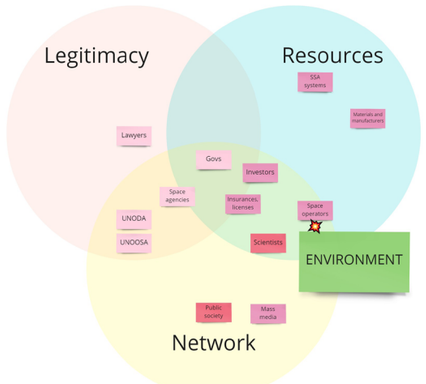
As a Strategic Designer, I set up my process starting from the **systemic level**. Afterwards I scaled down my scope to figure out consistent features for my concept at a **service and product level** (meant as the concrete manifestation of the service). Empirical studies demonstrate that this top-down approach has already become effective to advance industries through design (6) .



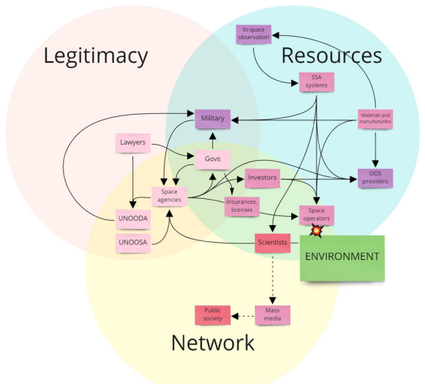
5. Dorst, K. & Cross, N. (2001): "Creativity in the design process: co-evolution of problem–solution", Design Studies, volume 22, n. 5, pp. 425-437
6. Price, R.A, De Lille, C., Bergema, K. (2019): "Advancing Industry through Design: A Longitudinal Case Study of the Aviation Industry", She Ji: The Journal of Design, Economics, and Innovation, volume 5, n. 4, pages 304-326

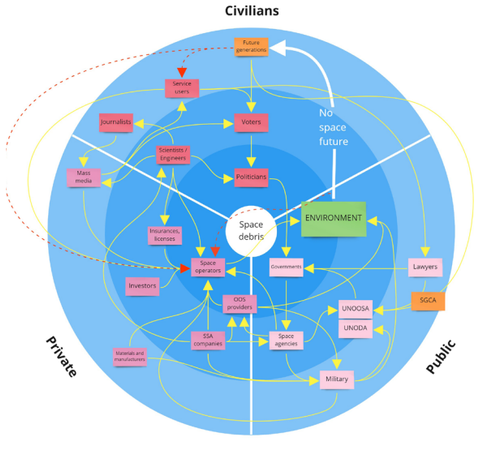
More in detail, at the systemic level I have tried to identify the **values** flowing in the space industry, by analysing the level of power of the stakeholders, their mutual relations, their exchange of resources and, most importantly, the gaps in the system caused by the space debris issue. Inspired by the theories of Mark Starik (7) , in my analysis I have always included the environment as a dynamic force capable of enhancing its resource power. Numerous interviews with experts have been carried out in order to validate my assumptions in this phase.

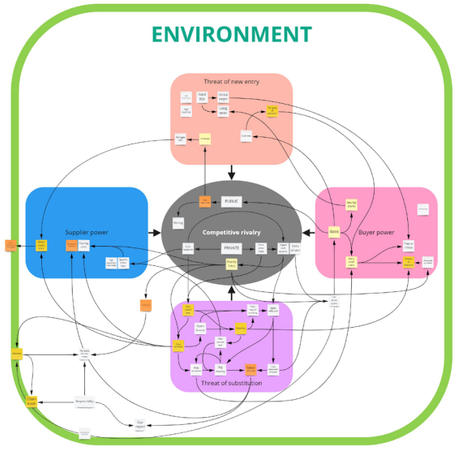
How it is



How it is evolving

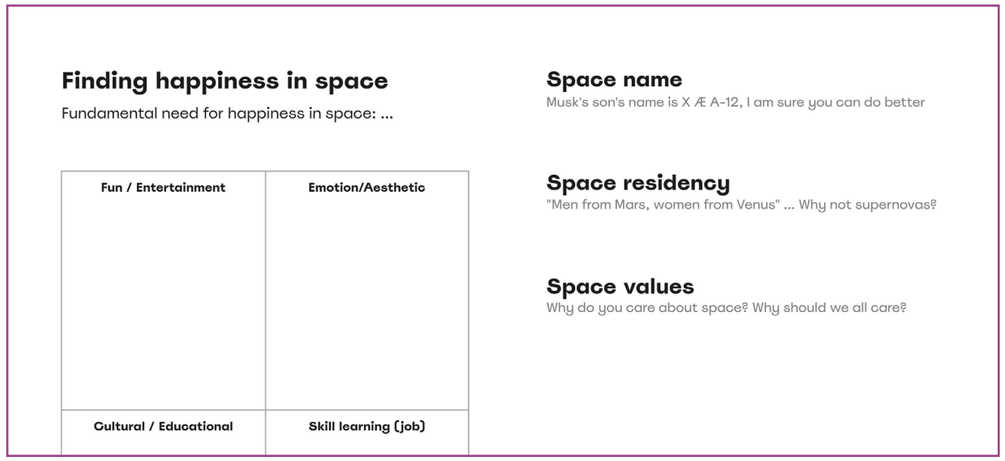




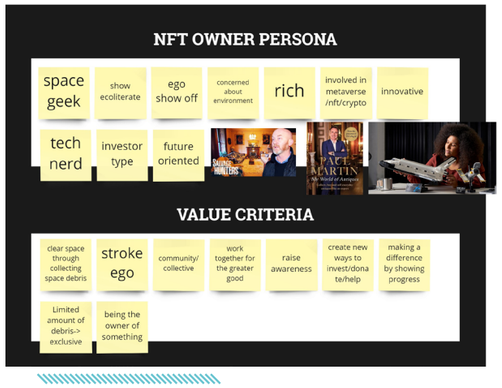


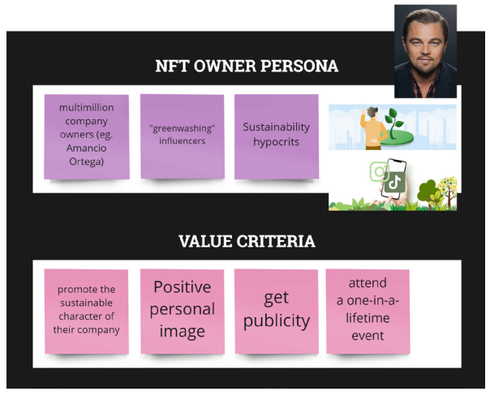
7. Starik, M. (2004): " Stakeholders, the Environment and Society", Edward Elgar Pub

At the service level I have focussed on understanding the **needs** of civilian people in relation to the space industry, through the immersive workshop I organised with the "space citizens". During this activity I have connected the framework of the 13 fundamental psychological needs (8) with the 4 main categories of experiences proposed by Pine and Gilmore (9) (educational, esthetic, escapist, and entertainment), in order to understand not only *why* and *what* people require but also *how* they wish to experience it.



In order to generate a variety of ideas of how concretely the service could manifestate at the product level, I have organised a one-day workshop with 38 design students. With the aim to make them focus on people's **emotions**, I have asked them to start by creating the persona of a target user who would be interested in such a service.





8. Desmet, P. & Fokkinga, S. (2020): "Beyond Maslow's Pyramid: Introducing a Typology of Thirteen Fundamental Needs for Human-Centered Design", Multimodal Technologies and Interaction, volume 4, n. 3, page 38
9. Pine, B. J & Gilmore, J.H. (1999): "The Experience Economy", Harvard Business Review Press

Finally, I have discussed with my mentors and other experts to **iterate** on the most critical points of the ultimate concept designed.

The overall outcome of this design process is illustrated in the following graphic:

- ***Democracy in space (it is not a global common yet)***
- ***Civilians pay taxes unawarely for space missions, (more money will be used for debris remediation)***
- ***Digital platform to make them aware and take "collective ownership" of space***

- ***Commitment, impact, mission, curiosity***
- ***Space Situational Awareness as a civilian service***
- ***Culture and education in change of entertainment and recognition***

- ***Feeling something wide and far like space as limited and close; sense of belong***
- ***A metaverse of space, experiences based on real-time data***
- ***Use of immersive technologies***

- ***Focus more on political values***
- ***Adjust user value proposition***
- ***Avoid transforming it into a trading platform***

Design guidelines

During the workshop organised with the 38 design students at TU Delft, a very fruitful debate about the metaverse and NFTs has originated. Since these topics have been the base of my design direction, I have synthetised the insights obtained from the debate and elaborated a set of **6 principles to design good services related to NFTs and the metaverse**. The principles have been discussed and refined through an interview with an analyst working at Newzoo, a company specialised in market research for in the gaming industry, and they have been useful not only for my decision making but also for the assessment from my graduation mentors.

MAKE IT PERSONAL

Make every individual of the community feel represented by his/her own NFT. Involve artists in the collection design, key on nostalgic emotions and exclusivity value.

MAKE IT FUN

Set a clear quantifiable goal that the community has to pursue collectively. Use gamification to make it fun and entertaining. Use token-base systems to reward positive behaviours.

EDUCATE YOUR AUDIENCE

Inform the users about the project mission and the actual value of NFTs, quantifiable through the impact on environment and society. Inspire your audience to commit, by using compelling and honest storytelling.

DESIGN FOR A LIFETIME

NFT are meant to stay and someone might decide to keep them forever. Make sure to deliver value for the longest term. Target younger users but design for adulthood, so that the value can be passed on through generations.

THE COMMUNITY OWNS, THE COMMUNITY LEADS

Let the community co-create the real value of the project, by giving them freedom to experiment.
Organise physical and virtual social events to make them all feel an active part of a common mission.

COMPETITION FOR GOOD = COOPERATION

Competing for good contributes to the sustainability mission. Encourage other similar projects to join the cause in order to achieve a higher impact, but always differentiate the services.
Involve a wide network of partners.

06
ONE League for the planet

Be the pioneer of a brave new world, join ONE, The League for the planet

A cultural metaverse, to experience and learn about outer space like never before.
A network of custodians, moved by the mission to safeguard the province of all mankind.

«O wonder!
How many goodly creatures are there here!
How beauteous mankind is! O brave new world,
That has such people in't.»

— William Shakespeare, The Tempest, Act V, Scene I, ll. 203–206

The service

The challenge of keeping the space environment safe and sustainable, with particular concern of the space debris issue, cannot be addressed by governments through taxes paid by unaware citizens.

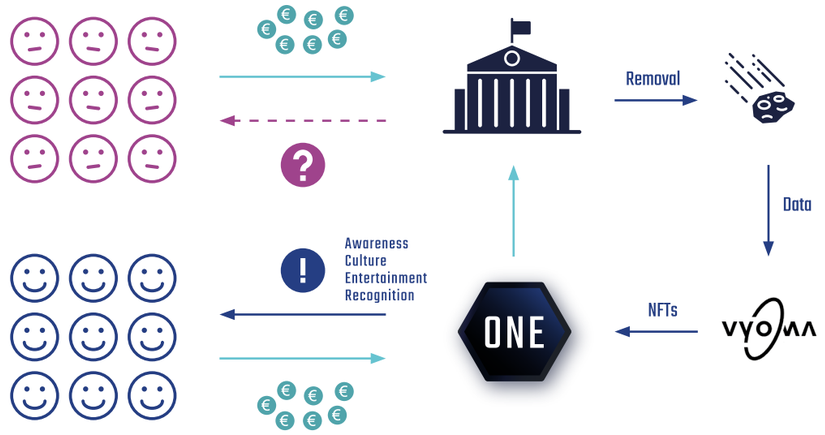
Civilians shall know how their money is expended for space activities, how these can generate critical problems and how they can determine the way to solve them. This is not only good to make the ecosystem more democratic, but also to make it more financially effective and, ultimately, resilient in the face of massive disruptive events. As required by the Outer Space Treaty, it is time to move the governance of the "province of all mankind" (1) from the hands of few public and private subjects to mankind as a whole. With this mission, I have designed:

ONE, The League for the Planet

A project to turn the space situational awareness into a public civilian service. A social digital platform to educate the next generations of space citizens, to make them custodians of the "province of all mankind" and to engage them in the co-creation of a more resilient space ecosystem.

© ESA

1. UNOOSA (1967): "Outer Space Treaty", article I



By enhancing the innovative tracking technologies developed by Vyoma Space, project **ONE transforms space debris into unique virtual assets**, that parents can purchase for their children under the form of non-fungible tokens (NFTs). The NFTs are released in a limited number, corresponding to the actual number of debris listed in the database provided by Vyoma. By owning one of them, the kid becomes the guardian of that space asset and can monitor its position, its daily risk of collision against other objects and its probability to be removed, an event that would benefit anyone involved in the space economy. The token also serves as an identity card to get in exchange the possibility to enter **a universe of cultural and educational services**. The money generated through the project is spent to **fund initiatives aimed at enhancing the resilience of the space ecosystem**.

© SpaceRobotics.EU - Nubalo Studios S.L. Space Division

Making space truly accessible, for anyone

In fact, the platform can be defined as a **metaverse of the universe**: A digital world that replicates the real outer space environment, with real-time data from spacecrafts, debris and other objects, to be experienced through immersive technologies like virtual or augmented reality (VR/AR).

The service is designed to **encourage parents to invest in their children's culture about space**, with a target users from 8 year old, but this doesn't exclude that adults can enjoy the platform too.

By joining ONE, The League for the Planet, users can:

- Customise the owned debris NFT
- Attend courses to learn about the history of the universe and human missions
- Explore space environments like The moon, Mars or other celestial bodies
- Experience the overview effect while having fun at a virtual concert, held in orbit around Earth
- Walk through an art gallery based on the rings of Saturn
- Play videogames based not only on simulations but also on real-time data from space, for example to experience how hard it is for operators to avoid collisions with debris every week
- Help companies to co-design (not so) futuristic services, for instance by visiting a preview of an orbital hotel and giving feedback

If users wish to leave the League, they can simply resell their space debris NFT so to give other people the opportunity to access the services offered by ONE, by also recovering the amount of money initially invested.

© Cloud Imperium, a space game

The members of the League

ONE offers **unprecedented opportunities for businesses** too. Space companies and from other sectors can purchase the biggest pieces of debris and transform them into **virtual exhibition rooms for cultural marketing purposes**. They are the ones who make the ONE metaverse livable and fun for the private users, by offering **memorable premium experiences and merchandising**. All these branded services are designed in collaboration with the platform developers with the aim to provide the highest cultural value for the members of the League. The service options depend on the typology of NFT purchased, which determines the user typology.

PRIVATE USERS	GUARDIANS	PATHFINDERS
NFT typology	Space debris (size between 1 and 10 cm)	Space debris (size bigger than 10 cm)
Availability	+1 million	About 40.000
Customisation	Flag (a 2d element, like a static image or a gif)	Gem (any digital file, lincluding 3d and audio)
Educational services	Unlimited access Completion of courses is rewared in DEBRIS coins, the ONE internal currency	Unlimited access Completion of courses is rewared in DEBRIS coins, the ONE internal currency
Premium branded services	Can be paid with DEBRIS coins	Unlimited access

The main difference for private users is that *Pathfinders* can have unlimited access to all the services provided in the ONE metaverse, whereas *Guardians* can benefit from branded services by paying with **DEBRIS, the fungible tokens (or "coins") of the ONE platform**, that they can earn through the completion of learning activities.

BUSINESS USERS	DEFENDERS	Leaders
NFT typology	Space debris (derelict satellites, massive and most dangerous) (2)	Active satellites (given only to the company demonstrating the actual ownership of the object in orbit)
Availability	More than 3.000	More than 4.000
Customisation	Mausoleum (a virtual space in which branded experiences and merchandising can be provided to private users)	Shuttles (like Mausoleums, but customisable with real-time data from the actual satellite)
Conditions	A transaction fee for every premium service purchased by users	The earnings can be used only to pay in-orbit services for their missions

For business users, the main difference is that *Defenders* can profit from premium experiences by paying a fee on transactions, whereas *Leaders* can use the money earned exclusively for **in-orbit services** during their missions. These services will be essential to increase the durability of space missions and the sustainability of the orbital environment.

2. *McKnight, D., Letizia, F., Witner, R., Lemmens, S. (2021): "Identifying the 50 statistically-most-concerning derelict objects in LEO", Acta Astronautica, volume 181, pages 2-3*

Enhancing social interactions

All these services can be enjoyed through desktop applications or VR visor. In 2025 **AR glasses** will probably become mainstream, then people will have a lot more interaction opportunities.

Furthermore, the services are enhanced through the **ONE application for smartphones**. *Guardians* and *Pathfinders* users can open the app at any time to check which objects are passing over their head and see what is actually going on in orbit, by using **AR technology**. The ONE app is also a gateway to **unlock other social features**, since the smartphone receives a notification every time its linked piece of debris risks colliding against another object:

- In case of an encounter with another *Guardian* or *Pathfinder*, the user can get to know its owner, visualise its *flag* or *gem*, and socialise with other members of the League for the Planet
- In case of an encounter with a *Defender* or *Leader*, the user can jump on board of its *mausoleum* or *shuttle* to get access to cultural branded experiences and merchandising (including buying unique branded NFTs)

The Museum of Space Resilience

What happens when space debris actually disappear from orbit?

If the actual debris crash against active satellites or one of the biggest pieces is destroyed, they risk generating a cloud of many new pieces and endangering other satellites in the environment. In this case, the NFTs linked to the lost debris are "burnt" [3] , which means that the owner has to buy a new one in order to access again to the services by the ONE platform. On the one hand such a circumstance is unfortunate, but it is nothing compared to the actual monetary damage caused to space operators in orbit. On the other hand, this policy **allows new users to join the League for the Planet** by purchasing one of the new debris generated through the accident, and providing in this way new financial resources to **fund the remediation within the space ecosystem**.

If instead the debris decay in the atmosphere or are actively removed through missions designed on purpose, all the stakeholders in the space sector draw benefits since a dangerous element is permanently removed from the environment, causing operators to save ingent resources currently expended to avoid collisions with those debris.

Visualisation of Russia anti-satellite test (15/11/2021), by Hugh Lewis, engineering professor at the University of Southampton (UK)

3. A technical term to say that the token is eliminated from the blockchain, and not spendable anymore

Such an event is celebrated by the whole League for the Planet, through a ceremony inside the **Museum of Space Resilience**: A virtual space within the ONE metaverse where all the NFTs linked to removed or decayed debris are showcased. Depending on which kind of objects they represent, the NFTs will display the *flags* drawn by the *Guardians*, the *gems* created by the *Pathfinders*, the *mausoleums* designed by the *Defenders* or the *shuttles* curated by the *Leaders*. Together with the NFTs customisations, the museum will also pay homage to the authors of the missions that made the removal possible (companies like Astroscale or ClearSpace) and to the Governments that allowed them, in line with international legislations. If a *Leader* user concretely ends the mission of its satellite by actively moving it out of orbit, its *shuttle* will have its place in a dedicated room of the museum too.

© Adobe Stock

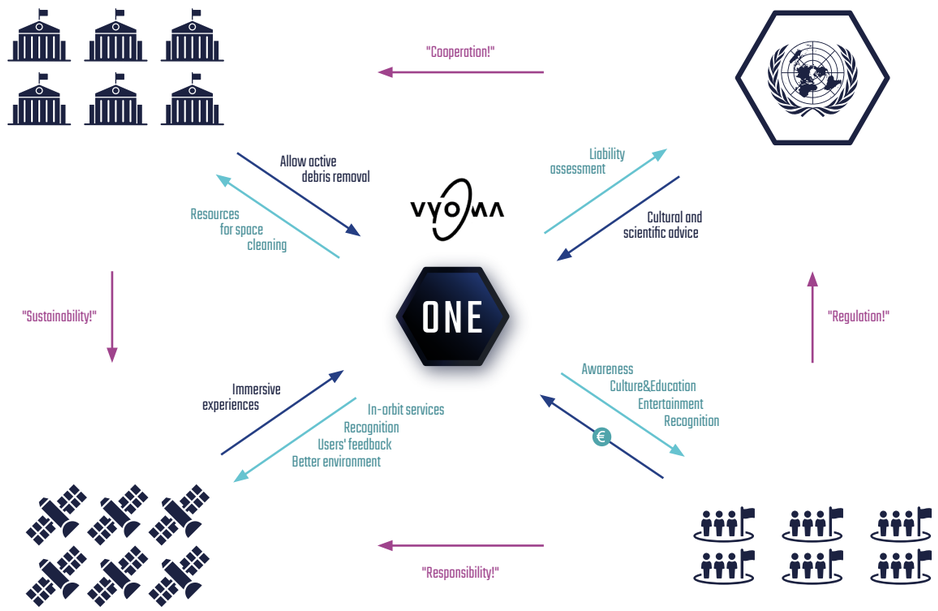
This represents the additional value offered by ONE to people and companies of the world: Purchasing a NFT connected to a space debris does not mean only entering the ONE metaverse and enjoying its services, but also having the opportunity to customise the owned NFT and transforming it into a work of art worth showcasing, **a sort of message to the rest of humanity to express how much members of the League for the Planet really care to safeguard the orbital environment for the future generations of space citizens**. The important aspect of this is that anyone in the League can have this opportunity, since both the biggest pieces can be removed by sophisticated missions (like the ones designed by ClearSpace and Astroscale) and the smallest pieces can be zapped through laser technologies from ground stations. For this reason all the users have the same possibility to display their message inside the *Museum of Space Resilience* as custodians of space, the province of all mankind.

The governance

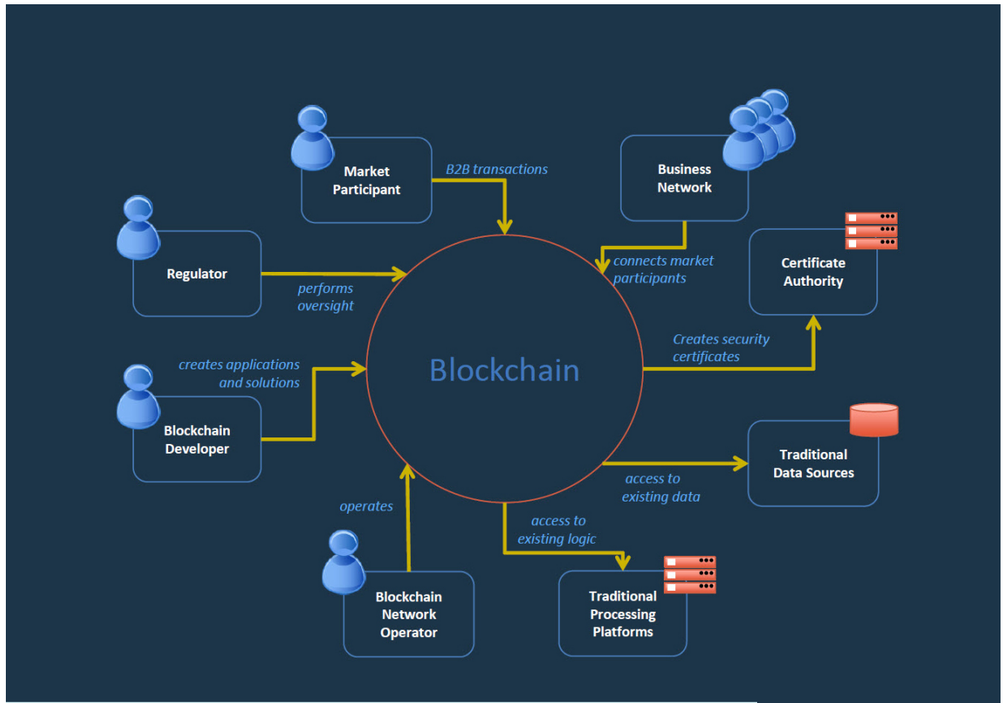
The ONE project is conceived as **non for profit**. Its financial inflow is expended to enhance the digital platform and to **fund initiatives aimed at increasing the resilience of the space ecosystem**, such as research projects, missions for active debris removal and other in-orbit services. The ideal governance would be a private non profit organisation, with expertise in the information technology and cultural media (essential to develop such a platform).

Due to its **cultural and political connotations**, the project is expected to be supported by governmental and intergovernmental institutions, like national space agencies and UNOOSA (the United Nations Office for Outer Space Affairs). Since they are the organs that most should care about democracy in the space ecosystem, they would have the interest to initiate and promote the ONE project among international fora.

Governments would be concretely incentivised to partner with such an initiative because it is designed to generate resources aimed at rebalancing the space economy and to set the foundations for a more peaceful use of outer space in the future, by educating the next generations of space citizens to cooperate. **UNOOSA** instead can become part of the scientific committee, by employing a minimum number of experts to **oversee the cultural value offered through the branded experiences** and to **advice about the resource allocation for the R&D initiatives**, in the position of an institutional, intergovernmental and neutral partner in the network. In exchange, UNOOSA and policy makers would get thousands (hopefully more than one million) civilian users to watch over the orbital environment and to nudge operators towards responsible behaviours.



Besides this private organisation and the institutional support, **the economy of the community is governed as a cryptocommon**: All the NFTs purchased and the circulation of DEBRIS coins among the members are engineered to benefit the network as a whole and to regenerate the space environment. They are enabled by a blockchain decentralised system, hence no individual private user or organisation can interfere on the system in disrespect of the rules, since these are encoded within automated smart contracts that make every transaction transparent, unchangeable and validated by the network as a whole. This means **managing the platform as a true common pool of resources "beyond markets and states"**, in line with the principles proposed by Elinor Ostrom.



© IBM Blockchain Team. Example of how a blockchain can work in a complex system of stakeholders

The technology

The boost registered by AI and immersive digital technologies in the last few years is making them cheaper and easier to use. With their current state of the art, a sufficient initial investment and a strategic management of resources, a launch version of **such a digital platform can be developed in one year**. A reasonable comparison can be made with the NFT project of Bored Apes Yacht Club: After only 12 months from the NFT collection release, without offering any other service in the meantime, they have launched their own metaverse called Otherside. Nevertheless, the initiative had some technical problems due to the underlying blockchain system (necessary to deploy the NFT provision), from which it is important to learn in order to avoid initial hindrances. Furthermore, it is also important to design a **blockchain system with a relatively low carbon footprint** on the environment, for example by employing a proof-of-stake protocol for the validation of blocks.

Each NFT available on the ONE platform can be generated on the basis of the actual position of space debris in orbit around Earth, called in technical terms "ephemeris". This can be possible by **connecting the catalogue of space objects developed by Vyoma Space**, based on accurate real time data, to the system through APIs (Application Programming Interfaces). Through the partnership with other scientific organisations (for example space agencies like NASA and ESA) other features can be conceived in order to offer users the possibility to interact with virtual space elements and processes, on the basis of realistic physical simulations. Running complex algorithms to simulate physical phenomena can make the digital infrastructure heavy and slower, but this can be overcome by providing a low fidelity photorealism in the platform, at least in an initial development stage. Projects like The Sandbox demonstrate that it is not photorealism to determine the success of a metaverse project, rather the **value of the social interactions and creativity options offered to users**.

As speculated in chapter 4 (*"What if advanced SSA provided a service for civilians?"*), extending the potential of such a scientific application, in the future the platform could enable academia to **conduct research with digital twins in an immersive environment**. This would not only mean observing scientific simulations like never before but also integrating non-rational factors through the **interaction with the actual behaviours of the platform users**.

© ESA

The impact

The viability of the project is highly dependent on how many users can be drawn in the platform in the very beginning, through the purchase of NFTs linked to actual space objects. The composition of the NFT catalogue depends on the actual number of space objects present in orbit at the moment (the may grow in the years due to the expected raise of orbital traffic), which can be devided in 4 categories:

a) Debris between 1 and 10 cm size: More than 1 million NFTs (*Flags*, for *Guardians*)
b) Debris bigger than 10 cm size: About 40.000 NFTs (*Gems*, for *Pathfinders*)
c) Derelict massive and most dangerous satellites: More than 3.000 NFTs (*Mausoleums*, for *Defenders*)
d) Active satellites: More than 4.000 NFTs (*Shuttles*, for *Leaders*)

Considering unrealistic that millions of people decide to purchase a NFT in the initial phase, it is recommended to release the NFTs in rounds and to start with a limited collection. For example, by **making available only NFTs of category b) at the launch event**. If 40.000 pieces are sold through an auction on a NFT platform like OpenSea, with an initial price of 0,5 ETH (4) (about € 826, slightly less than the average price in the general NFT market) (5) , it would already generate a minimum earning of € 33 million. For the buyers this means joining the League for the Planet as an elite group of early adopters as *Pathfinder* users, getting unlimited access to the cultual services provided by the platform including the premium branded contents, forever. The engagement of such a restricted group of users in the initial stage can also represent a good strategy to test the beta version before opening the project to a larger audience, which might overload the system in the beginning. Moreover, this would help create traction in the project to draw investments and partnerships. If the target user for the project is children between 8 and 18 year old, it would be sensible to **address only teenagers for the launch campaign** (older than 14), since they are the most active in the gaming industry (6) . With the release of a second NFT collection it will be possible to **expand the community to more than a million users**, including younger children too.

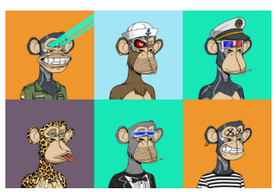
As far as production is concerned, **it is still hard to assess the production cost of such a complex metaverse platform**, (with APIs for real-time data from space, VR experiences, blockchain system and AR application for smartphone). The biggest companies like Meta (the financial group owning Facebook) are investing billions, others hundreds of millions, while some brands are launching beta metaverse projects on third-party platforms like Decentraland for way less. Considering that standard projects can vary between about € 10.000 and € 300.000 (7) it is possible to assume that € 1 million can be enough to develop at least the first launch version. As demonstrated in the previous paragraph, the sole sale of the initial NFT collection to 40.000 users can bring a sufficient return.

Total NFT market

(source: NonFungible, 06/06/2022)

17.400 daily primary sales
Average individual price: $ 916

Total market cap 2021: $ 17.6 billion
Total unique buyers 2021: 2.5 millions



Bored Apes Yacht Club

(source: Coingecko, 06/06/2022)

10.000 pieces sold
Initial price (Apr 2021):
0.08 ETH ($ 190)
Min. individual price now:
87 ETH (about $ 166.000)

4. *ETH is the cryptocurrency based on the Ethereum blockchain technology, the second most used in the world after Bitcoin*
5. *Kharif, O. (2022): "NFT Mania Show Signs of Cooling as Average Price and Sales Decline", www.bloomberg.com*
6. *McAloon (2018): "Survey: Teens spend an average of $184 on video games a year", www.gamedeveloper.com*
7. *Seyer, J. (2022): "It can cost up to $300,000 per project to create metaverse real estate" www.metaversenews.com*

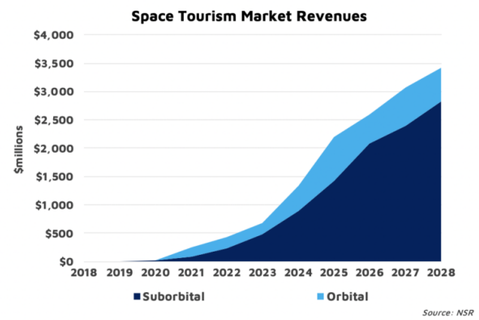
In order to **generate a constant cash inflow after the launch**, a transaction fee on the branded premium experiences and merchandising can be applyed. As a consequence, the long term viability of the project will depend on the **ability of the managers to involve business users** and to encourage them to offer numerous premium services on the ONE platform. For this reason, it will be important to co-design the platform together with the commercial users, in order to provide them with the most meaningful interaction options to engage the users in the virtual space environment.

Stated the non profit purpose of the project, besides the yearly structural costs, it is anyway necessary to maximise the continuous extra income of money to **fund initiatives for the resilience of the space ecosystem, as expressed in the mission**. Considering that an important mission like ClearSpace-1 to remove a massive debris would cost overall € 100 million (8) and assuming that the ONE project wishes to fund at least a relevant part of a similar mission every year to be considered impactful, € 50 million would be a sufficient extra income to generate yearly. This can be possible by **expanding the community up to 1 million users in 8 years, 125.000 new every year**. The NFT platform OpenSea managed to do it in 4 years, as a pioneer in an early niche market. (9)

In fact, after selling the first NFT collection and engaging an initial group of early adopters as *Pathfinder* users, the platform can open its gates to the *Guardian* users too, by **selling 1 million additional NFTs of the category a)**. Assuming a yearly release of 125.000 new NFTs for a starting auctionable price of 0,25 Ethereum (equivalent to about € 413, the half of the price paid by Pathfinders and of the average NFT market), the ONE project can generate more than € 50 million every year for 8 fiscal periods. In order to target a young group of children, it will be decisive to **make the platform more and more attractive for the parents who actually pay for the service**, for example by offering a growing quality of learning experiences. **Renowned education institutions might be willing to join the platform and release their official certifications,** intrigued by the opportunity to offer courses in an innovative way, through immersive technologies and real-time data from actual space objects currently in orbit.

If the ONE platform succeeds in attracting more than 1 million users and to convince business partners to offer a good variety of virtual experiences, the project would be able to reach financial resilience also for the years to come thanks to the earnings from the transactions made by *Guardian* users for premium branded services. This would also mean giving continuity to the funding of R&D initiatives for the resilience of space.

Finally, if the ultimate scientific application assumed in the previous chapter proves to be valuable, the ONE platform could enter the new market of digital twins, by offering a powerful tool for young reserchers and their universities. The unique value proposition would be to **include human behaviours in the simulations thanks to the numerous users' interaction**. This can be useful to test for example space missions with humans on board and to assess astronauts' psychological reactions. (10) This can result a strategic move since the human space traffic is expected to become mature by 2028. (11)



8. *Jewett, R. (2022): "ESA Contracts Clearspace for Mission to Remove Space Debris", www.satellitetoday.com*
9. *Ischei, A. (2022): "OpenSea Surpasses One Million Active User Wallets", www.cryptopotato.com*
10. *Miskinis, C (2018): "What is the real value of digital twin simulations for operations in space", www.challenge.org*
11. *Northern Sky Research (2020): "Space tourism: Humanity leaving the cradle?", nsr.com*

STRATEGIC

Metaverse of outer space for cultural entertainment

Teenagers (>14 yo),
gamers, NFT collectors

40.000 users
More than € 30 million
(for the whole 2-year phase)

H1 | 2024
The launch

Immersive learning platform for certified space education

Children (>8 yo)
and their parents

125.00 new users /year
More than € 50 million /year

H2 | 2026
The expansion

Human-driven digital twin of space for advanced research

Young researchers (>18 yo)
and universities

+1 million total users
New market proposition for
scientific applications

H3 | 2030
The resilience

ROADMAP

Network

Vyoma, UNOOSA, Governments
Space agencies (like ESA, NASA, JAAXA, ...)
In-Orbit Service companies (like ClearSpace)
Other space companies
Brands from other sectors

More governments
More commercial companies
Educational institutions
Policy makers

Universities
Public and private research centres
Space tourism companies

Technology

- Launch version of the metaverse on a third-party platform
- Connected to Vyoma catalogue through APIs
- Experiences available in desktop version
- Some experiences available in VR visors
- Smartphone app with AR technology
- NFT collection released on an existing platform (like OpenSea)

- Unlocking interactions for AR smart glasses
- Using more sophisticated kind of data (premium) in collaboration with space operators
- Collaborating with schools to offer more courses (hybrid learning systems)
- Collaborating with space agencies for scientific applications

- Developing advanced capabilities in data analysis and AI algorithms training
- Running complex simulations, merging rational factors and human factors (by making users interact with scenarios in the digital twin)

Context

- Increase of satellites in orbit
- Vyoma technologies and constellation will be ready to provide data about space objects with highest accuracy
- Satellites will be more automated

- In orbit services become feasible and viable
- ClearSpace-1 mission is succesful
- Space tourism reaches a wider audience and starts to drop ticket prices
- Blockchain protocols become more regulated and more resilient

- Satellites in space are almost 50.000, but the traffic is manageble thanks with the new international STM system
- Space tourism becomes mainstream
- AI helps developing new knowledge in space, in a much easier way
- Mining in space has started, and resources are handled through cryptocurrencies

ONE last mission

«人类命运共同体» are the only words that Zhi Li can pronounce, while watching the morning news from his dimmed living room in Beijing. "A community with a shared future" has been a dream resonating in his mind for almost 20 years. What his eyes are witnessing now is its most truthful manifestation.

The windows are closed in the apartment at 161 West Fourth Street, New York. It's a lazy late afternoon, a hard rain is falling and Rob is trying to cover its sound with an old melancholic song played on Spotify. The music suddenly stops and "People have the power" starts playing. A Patty Smith's classic. Rob's girlfriend, Lucy, is laughing on the couch. «Stop changing my playlist. People haven't got any power to change anything. And your song won't change my mood», says Rob hoarsely. «We'll see», she replies, keeping her smile.

The streets in Amsterdam, like in many other European cities at this moment, are full of people with their nose to the sky. Their smart glasses are showing in augmented reality long clouds of space debris running at high speed far above the Earth, like a hundred highways of diamonds crossing on desolated orbits. They know that the live streaming from outer space might end at any moment, due to the numerous internet satellites damaged. Meanwhile, a few kilometres away, Gianmarco and Erik are having lunch in the headquarters of ONE, The League for the Planet.

«Well, here we are in the end», says Erik, «The project you started years ago is now proving to be crucial for the future of space». «So it seems. And there is actually nothing positive in this,» adds Gianmarco. «Oh, come on,» Erik replies with a smile, «did you really believe that history could go in a different way? In 2022, with the start of that war in Ukraine, we all had the ultimate confirmation that there will always be someone with interests in provoking a global disaster. And this is why you decided to launch ONE. Then the internet infrastructure was quickly moving to space, by building mega constellations of satellites, and we were aware that someone would have tried to shoot it down, one day. Now that day has come and the internet constellations are shattering like a clockwork of glass. The dream of a hyper connected world risks falling and the people are experiencing the Kessler syndrome for real, acknowledging that it looks even worse than the immersive experiences simulated on the ONE platform. Still, your project has helped them not only to get prepared for such a view but also to face it. So, tell me, how is the Arete mission going?»

Gianmarco is staring at the ground, he needs some seconds before finding the words to say «I hope it goes well». He pauses again. «The Arete spacecraft was launched yesterday and everything is going according to plan. Stefan says it might take one year to burn 50% of the debris generated by the five-day attack. But it is the first mission of this kind and - despite all the simulations run with the scientific partners in our digital twin - it is hard to assess the mission's success rate. Anything could go wrong.»

«I heard the attack has ended, is the author known?» Asks Erik. «Good news is that the president of Rwanda has been arrested this morning and the so-called "Cinnamon operation" has been blocked. The original plan was to shoot more than 300.000 missiles from multiple hidden bases, most of them from Low Earth Orbit. Fortunately only a hundred satellites were destroyed. The bad news is that - as we all know - Rwanda was just the executor of this wicked plan, it could not develop such a military force alone, but the mandator is still unknown. Cyber spies are investigating, we have a few suspects.»

«Sure, I don't think we need cyber spies to find it out.» replies Erik sarcastic.

«Anyway,» he continues, «this is not the point. The merit of project ONE has been to give people the power to self-determine their future in space. In 10 years, The League for the Planet has funded 16 missions for active debris removal, while working on the Arete mission from the very first day. This was possible thanks to millions of users learning and having fun on a platform aimed at funding initiatives for the resilience of space. Maybe the effort to educate the new generations of space citizens has not been enough to avoid a disaster, but it is proving enough to face it. Don't you think?»

«As I said, I don't know whether Arete will be successful or not. Maybe most of the debris generated by the attack will be removed and the damaged infrastructure will be totally regenerated in a few months. Or, maybe, the Arete spacecraft will stop working after a few days. And what if another attack happens next year? The mission of the League, to protect the space environment through the cultural empowerment of civilians, has revealed to be a utopia. We'd better deal with it.»

Now Erik is staring at the ground. «Listen,» he finds the courage to say, calmly, after some seconds, «I think this event is proving your nerves more than you could expect. I was there when you started this project and I know that your initial mission was a bit different than what you are saying now. You didn't aim to protect space from attacks. This is bullshit from superhero comics, you will never be able to avoid such disasters. I remember well: Your goal has always been to create a wide network of space citizens, experts and civilians together, empowered with the resources to protect the province of mankind by themselves against the threat of free riders. Because this is the true meaning of "resilience". And this is the only way to make people share a common future, by letting them co-create it every day.»

It is getting late and the day is full of meetings. Gianmarco's summit with UNOOSA partners starts in few minutes. «Thanks for your words, Erik.»

«I had a chat with Giulia and Chris yesterday. We believe you shouldn't end project ONE.» Erik says, firmly. «This is not the day a utopia is unmasked, but the day an awareness is strengthened.»

«I will think about it» Gianmarco answers with a smile, before waving and turning his shoulders.

«And remember: Unlucky are those who need for heroes.»

07
Validation

After iterating on the concept presented, I have conducted a risk analysis considering all the strategic aspects of the project. In the following pages I present a list of 8 points on which further research and development is required. It is the result of four interviews conducted with field experts working in some of the most relevant organisations, who could actually be collaborators of ONE - The League for the Planet. Their analysis adds to the feedback received also from my academic mentors and from Vyoma Space, my partner company for this project.

- Chief Commercial Officer, **ClearSpace**
  The first company to remove a piece of debris through controlled reentry
- Business Developer, **Astroscale**
  The only world company solely dedicated to in-orbit servicing across all orbits, including active debris removal and end-of-life operations
- Policy Advisor Outer Space and Culture, **European Parliament**
  Focusing on culture and space affairs in the interest of new generations of European citizens
- Innovation Director, **Media.Monks**
  One of the biggest and most awarded media companies in the world

Risks assessment

Value proposition

"At Astroscale we are also doing research about the value of removing debris for the public, but I have to admit I've never been so far into looking at this problem like you did."

According to the experts the research touches a real problem, going to the roots of the human values in relation to space activities and does it in a way that is novel to the system. Nevertheless, the value proposition of the service presented requires further research to understand whether this solution would actually be desirable by a significant audience. Especially in relation to the price to pay.

It would be nice to offer a demo preview before the launch, to test the users' interest. A good strategy might be to involve artists in the NFT release so as to increase the individual value of each.

Entry price

"The project looks really cool and fashionable, but I wonder whether the price proposed is a bit too high"

Although the price is in line with the average of the general NFT market (analysed in a moment of recession) and although the launch strategy is dedicated to a limited community of about 40.000 users, the initial price of € 826 might be too much. Further research in the market of gaming and NFT is required ("How much do teenagers spend in gaming?").

An idea could be to enable users to share the value of an NFT, and hence the rights to access the services provided. This could unlock interesting features, like cooperative customisation of the contents (an example is the "family playlist" on Spotify, through which users of the same Family account can co-create a shared playlist). Moreover, if schools are involved with the aim to provide advanced tools for education they might be interested in paying the subscription for tier students. This could also be a strategy to expand the community of users in a quicker way, with a lower accessibility barrier.

Competition

"There are some similar projects to raise awareness about space debri through gaming and immersive technologies, although they are not as advanced as the concept you are proposing. But how would you bear the competition?"

Although the project is developed with a strategic partner like Vyoma Space, who will be able to create one of the most accurate catalogues of space objects, other competitors might have the same idea. Especially if in a few years part of these advanced catalogues will become open source. As mentioned in chapter 5, "competition for good = cooperation". So, to overcome this crucial point, a good strategy could be to create a wide network of international cooperators starting from important political institutions (like UNOOSA or The World Economic Forum).

Cooperation would be fruitful also for a network of companies like Vyoma, since they could build on each other's algorithms and develop together a unique catalogue with essential open source data, as a side business to the "premium" data that they can provide as part of their individual intellectual property.

Stakeholders management

"I find the project amazing, it has potential if made with the right people and the right visibility. I am impressed by the complexity of your stakeholder system, but this can also be a critical point"

Even though the project can bring concrete benefits for all the stakeholders mentioned, in fact, bringing together such a diversified network of organisations (commercial, political, cultural, technological, ...) is not easy at all. It is positive that the project is conceived to be non for profit, this would increase the confidence of policy makers and maybe even of other commercial partners. This assumption needs to be validated, together with the assumption that such a project could nudge governments to improve their national space licensing policies through stricter sustainability requirements.

Transparency

"If in this digital platform the sustainability rating of each satellite is displayed and showed to a wide audience of civilians, I think that operators would be nudged to do better for the sustainability of the space environment"

Encouraging space operators to share data about their mission would be hard, but it might be possible if those data are used to provide unique immersive experiences as a premium service for the users (hence increasing profits through transparency). It will be important to co-design the premium experiences with the platform developers, the data providers and the brands/space operators.

Blockchain technology

"Applying the decentralisation power of blockchain to increase the consensus systems in a particular field like space is definitely a good idea, many researchers are studying this to build an international STM system. Nevertheless, many policy makers are still sceptical".

As the markets have demonstrated during the month of May 2022, although blockchain systems are becoming more and more resilient, it is still very hard to trust this technology, especially projects based on cryptocurrencies. This is also bringing a strong volatility in their actual value, causing the users involved to risk halving their actual asset value. Moreover, policy makers still struggle to get confidence with smart contracts due to usability issues.

Finally, as far as crypto-commons are concerned, they are still facing challenges with scalability. In order to avoid bugs in the system, it is necessary to develop the blockchain infrastructure for such a project in collaboration with expert economists and engineers.

Metaverse paradigm

"Metaverse is still a broad and vague concept, but it is definitely the future of how people will interact with the internet. But this also comes with many open questions"

One of the issues of conceiving a platform like ONE is the big variability in the development resources, but for sure the cost of technology will drop in the following years.

The open questions concern what one wishes to achieve with the resources available: Developing an own private platform or rely on environments provided by third parties? How pervasive is the use of blockchain? How are different categories of stakeholders authenticated? And how is the value earned technically distributed among the users?

Strategic goals

"Regulations won't be an issue for projects of this kind, indeed there is the need to incentivise active debris removal. The only issue I see is whether it will be really possible to raise enough money to fund R&D initiatives, to have a concrete impact I mean."

The goal of reaching € 50 million of extra income every year to invest in R&D missions seems a bit too high, but it would definitely be enough to be impactful.

The roadmap is realistic, setting the horizons between 2025 and 2030 is good because everything is going to happen in space in that period, both on a political and on a commercial level. It would still be interesting to consider partnerships with insurance companies.

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