



Business roadmap for the European Union in the NewSpace ecosystem: a case study for access to space

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Abstract

A business roadmap is a high-level strategic management tool that maps the actions to develop new industries. It serves as a guide to plan and forecast technological, market and product developments in a more operational way. Precisely, the business roadmap of this article highlights the main actions to be taken by the European Union (EU) space ecosystem with regards to Low Earth Orbit (LEO)—orbits from 450 to 2000 km—and Very Low Earth Orbit (VLEO)—orbits from 150 to 450 km. On the one hand, it is necessary to (1) develop industrial and technological space capabilities, (2) continue investing public funds in European Programs to develop new vehicle concepts of access to space, (3) improve testing, demonstration and exploration for faster the Technology Readiness Level (TRL) development, (4) promote an entrepreneurial and risk-taking culture, and (5) leverage the private investment to boost the development of advanced access to space technologies, attract talent, promote collaboration between public and private companies, and finance NewSpace Small–Medium sized Enterprises (SMEs). On the other hand, it should also strengthen its relationship with the European Space Agency (ESA) to foster its space capabilities and become a competitive player in the access to space market in the medium term (5–10 years). The implementation of these actions will help the EU to improve its international positioning, and adapt the technology to the needs and requirements of NewSpace demand, mobilizing around €40,500 million euros for the EU economy during the first 10–15 years of operations with an average Leverage Factor (LF) of 4.

Keywords Business roadmap · European Union · Access to space · Very low earth orbit · NewSpace

1 Introduction

According to Bryson [1], the current industrial environments in which companies and organisations operate have become not only highly uncertain in recent years but also more tightly interconnected.

Specifically, the traditional business models of the space sector are being disrupted due to great technological changes, such as digitization, miniaturisation, artificial intelligence or reusable launchers, reducing the cost of accessing and using space [2]. This transformation combined with the growing uncertainty in the environment creates new challenges that increase the complexity of strategic management.

In fact, Schwenker and Wulf [3] outline that traditional planning tools are not able to meet the current market and industry’s uncertainty. Consequently, traditional approaches to strategic planning have attracted considerable criticism [4–7], which resulted in many companies starting to use new frameworks to understand any business model according to Amit and Zott [8] and business roadmaps for reflecting how their business will be developed and implemented, in addition to innovative methods that seek to optimise the management and production processes of companies, reducing the use of resources and making processes more efficient [9]. According to Twiss [10], innovation “implies newness [...] It manifests itself in new products, new production processes or new managerial systems, frequently utilizing new technology. These developments can be associated with new markets, new business diversification, or new organisational structures”.

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When analysing the European space market, a recent European Parliament report [11] shows that in recent decades the European Union (EU) has lagged behind the US, China, Russia, and other players in terms not only because of low investment in institutional launch technology but also due to the lack of industrial capability¹ that allow the development of reusable space access vehicles. This has had a direct impact on the European launcher industry.

Although it seems that the development of the EU and the response times to the reality of the space sector is a disadvantage for its competitiveness at present to meet the low-cost demands of NewSpace smallsats [13], Europe has achieved many successes in space with cutting-edge technologies such as Copernicus or Galileo; exploration missions such as Rosetta or BepiColombo, as well as unique Earth observation and meteorology capabilities, such as Meteosat, and world-leading commercial launch and telecommunication systems with the Ariane and Vega launcher family [14].

Additionally, Europe's story on launcher development would not have taken off without the failure of the first Ariane 5 launch in December 2002 [15] nor without investments by space SMEs and startups in technology and supply chain [16]. To become a competitive actor in the access to space market, on the one hand, the EU is learning from its past mistakes as it is already developing a fully recoverable first-stage reusable vehicle, Themis, with the goal of being ready to fly by 2025 [17]. Even so, this is not enough to make the EU competitive in the space market. First, because its launch costs are much higher than those of its competitors [2, 18] and second, because it has missed developing a reusable space access vehicle design capability.

On the other hand, companies such as United Launch Alliance (ULA) with the Vulcan rocket family, Arianespace with the Ariane rocket family, the Indian Space Research Organization (ISRO) with the PSLV, and China as an emerging market are trying to beat the SpaceX's Falcon family launchers by developing strong capabilities in vertical landing and reusable rockets to be competitive and reduce the cost of access to space [19]. Still, this is not enough. Therefore, promising new reusable launch vehicles are being developed for future space transportation roles.

Three typical examples of this type of space transportation are (1) SpaceX with the BFR (Big Falcon Rocket) concept with vertical take-off landing characteristics [20], (2) the German Aerospace Center with DLR's SpaceLiner concept with horizontal take-off landing characteristics [20], and (3) the European project H2020, STRATOFly, led by the Italian University Politecnico di Torino. This

last concept represents the first step towards future reusable launchers enabling high-speed civil transportation at stratospheric altitudes [21, 22]. These three concepts aim to: (1) transport satellites and/or passengers, and (2) offer a drastic reduction in launch costs thanks to the reuse and mass production of hardware [20, 22].

New technological trends of reusability, propulsion systems, aerodynamic structures, and miniaturisation are changing the space industry [2, 22]. These trends motivate the appearance of new companies such as PLD Space with Arion 2 (Spain), SpaceX with Falcon 9 FT and Falcon Heavy (US), CASIC with Fein Tian 1 (China), RocketLab with Electron (New Zealand), JAXA with SS-520-4 (Japan), among others micro-launchers that provide a solution to the growing demand of the NewSpace to launch as main payload small satellites to LEO (Low Earth Orbit) and VLEO (Very Low Earth Orbit) offering competitive launch prices [23] and/or relevant and fostering technologies.

In addition, these new technological trends also open the market to new startups that supply competitive technologies to micro-launchers, such as reusable propulsion systems such as the PANGEA aerospike engine or zero-emission fuels such as hydrogen and oxygen liquid, etc. All these supplies make the micro-launchers more efficient and cheaper, which allows them to offer more competitive prices in the market.

The key to the success of these NewSpace startups lies not in the technology, but in a well thought out and efficient business model, which enables the company to offer not only the technical capabilities to launch payloads to a variety of LEOs and VLEOs on demand, but also to compete with an industrial capability that ensures a competitive advantage. For instance, SpaceX is known for not having invented the Falcon 9, but for engineering the DC-X (Experimental Delta Clipper) idea and demonstration into an operational system by avoiding any new-costly-risky technology. That was its primary 'secret sauce' to advance fast and outperform the competition.

To help companies (1) prioritize technical and industrial capabilities, market uncertainty, and new product development, (2) set up objectives, (3) reduce uncertainties, and (4) link those goals with priorities to justify investments and coordinate activities, it is necessary to draw up a roadmap.

Consequently, the development of a roadmap can not only serve as a guideline for the European Commission (EC) and the EU companies, but also improve Europe's technical and industrial capabilities to be competitive in the access to space market preserving its competitiveness.

Therefore, this article presents a business roadmap that defines an EU strategic management plan focused on boosting the creation and development of access to space capabilities and adapting technologies to the needs and requirements of NewSpace companies. Translating the insight goals of the

¹ Industrial capability is defined as the "skills, facilities, processes or technology needed to design, develop, produce, repair or maintain products" [12].

EU's space industry into effective strategies, according to the current market and industry's challenges.

The article begins by reviewing the literature on roadmapping and the different strategic management planning tools applied in business roadmapping. Subsequently, the growth and forecast of the global access to space industry is presented. Finally, the article presents a business roadmap that supports the development of the different actions required for the implementation of the EU strategic plan to respond to its current weaknesses and threats and recover its competitiveness in the access to space market.

2 Literature review

2.1 Introduction to roadmaps

The roadmap has been around for at least two decades, becoming popular after its application by Motorola [24]. A wide variety of roadmapping approaches and tools exist, even though most approaches to the roadmap focus on technology development. According to Vishnevskiy et al. [25], technological roadmaps are applied in the setting of the development of a new product or service that may include new emerging technologies, while according to Garcia and Bray [26] business roadmaps are used as an analysis tool to map the development and implementation of new industries.

Both roadmaps take into account how products, technologies, and markets change over time. It helps establish the relative priority between technologies, markets and products, establish objectives and link them to justify investments and coordinate activities [27].

Furthermore, the roadmap is typically used as an ad-hoc tool for project management and strategic planning rather than an integral part of strategy development and business model design [28].

In fact, Phaal et al. [29] explain that business roadmapping is seen as a key step used to capture and communicate the implementation of the results obtained in the strategic planning process. Nevertheless, in the same reference, the authors also outlined that nowadays roadmaps present the whole strategic planning process of a business, causing that both terms have merged in one.

Therefore, the roadmap presented in this article is intended to help the EU to plan and forecast technological, market and product developments in a more operational way.

2.2 Strategic management planning tools

Strategic planning is the process of designing the desired future and identifying ways to carry it out [30]. Consequently, the strategic management plans implement different tools that enable analysis of the current position of the

business and provide enough information to identify which key metrics must be tracked and pursued to achieve the desired future position.

To comply with current strategic management standards, the case study developed in this article includes the following strategic management planning tools:

- *PESTEL analysis*: a strategic analysis tool that studies trends and external drivers in the political, economic, social, technological, environmental, and legal fields that influence how businesses compete in the market [29].
- *SWOT analysis*: a strategic planning tool used to understand what businesses do or do not do well compared with the competition and where companies can grow or be vulnerable and lose their competitive advantage [29].
- *Balanced scorecard model*: a strategic planning tool and management system that is used to (1) align business activities to the vision and strategy of the organization, (2) improve internal and external communications and (3) monitor organization performance against strategic goals. It views the organization from four perspectives: customer or stakeholders, internal business processes or operations, financial, and Learning and growth [31].
- *Stakeholders analysis*: a project management tool as well as an organisational planning tool that identifies and understands the needs and expectations of major interests inside and outside the organisation environment to ensure that their needs will be met [32].

3 Growth of the access to space business and forecast

The EU Parliament stresses that the space sector is an indispensable part of the EU economy [11]. Although the space sector creates 10% of the EU's GDP and provides more than 230,000 jobs [33], there is a strategic loss of not yet having a robust and time-to-market European reusable transportation vehicles, which increases the risk of European operators of small satellites looking for foreign launchers [34].

According to a SpaceWorks forecast [35], a large increase in launches of small satellites (from 1 to 100 kg) was estimated from 2019 onwards. Figure 1 shows the growth of small satellites launched into space according to different countries between 2011 and 2021. Specifically, Bryce Tech [36] states that between 2011 and 2020, 2,013 small commercial satellites were launched. Figure 1 shows that this trend continues in 2021. It is worth mentioning that the data shown only takes into account the first nine months of 2021 (until September 2021). This means that small commercial satellites are receiving a lot of attention from the private market, especially in the communications market during 2021 [37].

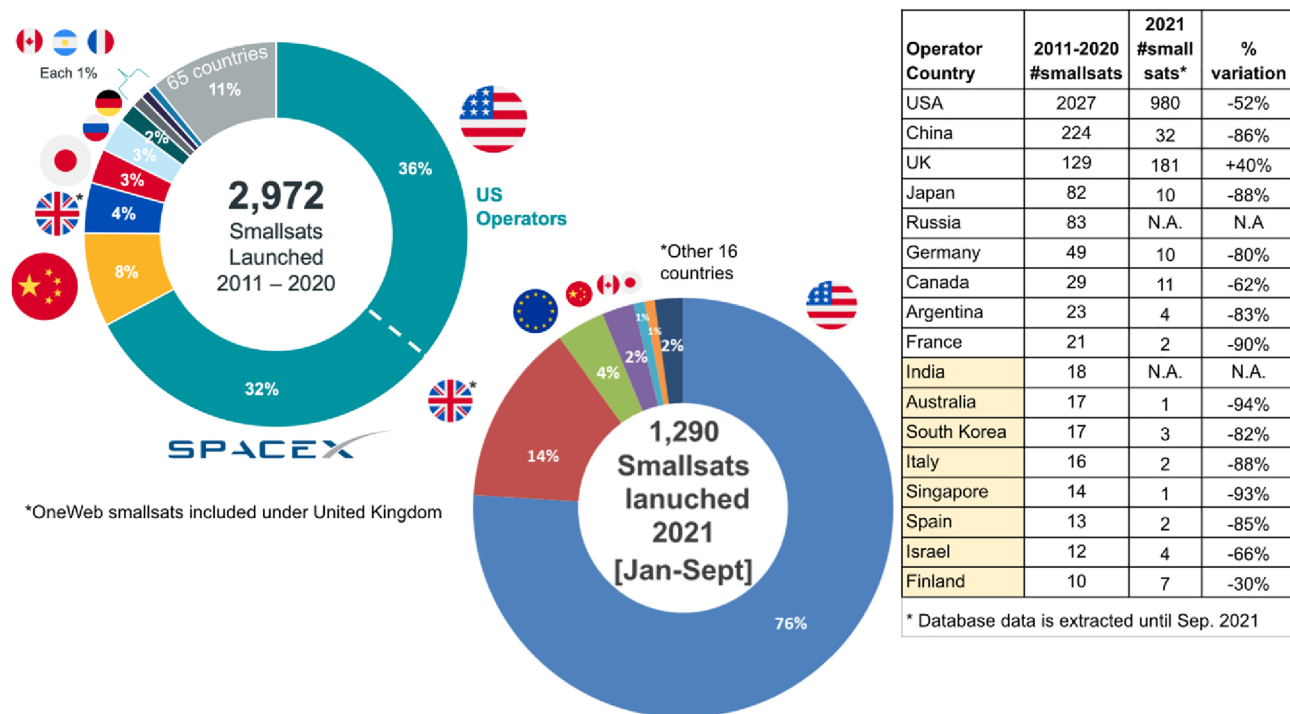


Fig. 1 Evolution of small satellites launched into space according to different countries from 2011 to 2021. Extracted from [36, 38]

Both the US and the EU space agencies, NASA and ESA, are well aware of the future space exploration and how private companies will take a key role in the future of space economic exploitation. That is why both agencies actively support start-ups [39] and companies within their zone of influence.

The launch of the first consignment of satellites in the Starlink constellation by SpaceX's Falcon 9 rocket in 2020 marked a particular shift in the space industry regarding the use of reusable rockets. The Falcon 9 and Falcon Heavy rank SpaceX as the only launch provider in the world capable of accomplishing the reusability of the first stage and boosters [18, 40], putting great pressure on competitors like ULA, Airbus, Adeline, ISRO, and Arianespace.

To beat the competition, Europe is developing the next generation of access to space capabilities by launching Vega-E in 2022 and Themis in 2025. On the one hand, Vega-E will improve flexibility in terms of payload mass and volume and reduce the cost of launch service and globally the launch cost per kilo offered in the market in relation to Vega-C [11, 41]. On the other hand, Themis will advance key technologies and demonstrate reusability capabilities in Europe. According to Daniel Neuenschwander, ESA Director of Space Transportation, "Themis will create additional options for lowering the cost of access to space and increase Europe's flexibility to offer a variety of launch services" [17].

According to the DISCOVERER project [42], the next generation of European land-based launchers as well as fierce international competition will drastically reduce the costs of access to space by driving the development of constellations of small satellites in LEO and even VLEO by the private sector like SpaceX with Starlink, Amazon with Kuiper, or OneWeb satellites, or Telesat satellites among others.

However, for the EU to be competitive in the access to space market, only with the development of reusable space launch will not be enough. The EU should focus its efforts also on other types of products to access space such as the initiatives like aircraft-based EU H2020 ALTAIR Project [43] or the balloons of Zero2Infinity [44]. Other worthy concepts include the oceanic launch system of Ripple Aerospace [45].

These initiatives will enhance the EU's industrial and technological capabilities by allowing great flexibility in launch positions and reducing launch costs, still, they will not make them competitive enough price-wise. For that reason, the EU should go beyond the SpaceX vehicle line and focus its industrial capability also on other types of access to space products such as DLR SpaceLiner and STRATOFly projects.

Both projects, DLR SpaceLiner and STRATOFly project, will provide the EU capabilities to go a step forward on the reusability and re-entry space transportation

systems. DLR SpaceLiner is a multi-mission reusable launch vehicle that shares several characteristics with the BFR SpaceX concept. The main difference is focused on their design solutions, such as propellant choice, higher structural indices due to the low density hydrogen and its robust design philosophy with an emergency rescue system for the passengers, less tons of payload, more realistic flight trajectories, and dedicated passenger rescue capsule in case of emergency [20]. While STRATOFLY, a commercial civil high-speed transportation flight would try to achieve lightweight structures, optimize the performance and efficiency of the propulsion systems by means of ABEP (Air-Breath Electric Propulsion) systems, reduce the noise level due to high-speed jets, enhance the efficiency of the tank, use of Liquid hydrogen as a propellant, and improve the thermal protection system [21].

According to Martin Sippel, "SpaceLiner reveals a considerably more ambitious approach of the US-concept in the fields of propulsion, structure, weight and aerothermodynamics. The SpaceLiner, somehow less demanding, could still become a challenging endeavour for Europe" [20].

In addition, the SpaceLiner concept also provides a drastic reduction in launch cost thanks to the reusability and the serial production of hardware. According to Martin Sippel [20], "an attractive specific launch cost of less than €2000/kg in GTO and less than €1000/kg in LEO can be achieved for the SpaceLiner" based on the evaluation of the production cost of passenger transport.

On the other hand, the STRATOFLY MR3 concept highlights the level of maturity of the enabling technologies for future hypersonic vehicles, which can operate both as high-speed civil passenger transport aircraft and as a first stage of reusable access to space vehicles [21]. To do this, it takes advantage of the legacy of European projects such as LAPCAT I and II, ATLAS I and II, HEXAFLY, and FAST 20XX exploiting various technological as well as industrial capabilities such as: (1) double or multiple bubble structure to achieve lighter structures with multifunctional roles to harmoniously integrate all vehicle subsystems, reduce noise and optimize aerodynamics, (2) exploitation of liquid hydrogen as fuel to drastically improve performance, (3) the inclusion of thermal protection systems and Energy Management Subsystem (TEMS) conceived in the LAPCAT-II project [46] based on ceramic matrix compounds (CMC) and heat pipes to cool the leading edges of the vehicle, (4) the reduction of noise produced by high-speed jets through strategies based on the integration of the nozzle-fuselage, and (5) the development of Air-Breathing Electric Propulsion (ABEP) technologies.

According to Nicole Viola, Principle Investigator of STRATOFLY H2020 project, "STRATOFLY MR3 has the ambitious goal of satisfying the need that urges Europe to shorten the time of flights for long-haul routes and at the

same time to move toward a more sustainable aviation from the environmental point of view: zero CO₂ emissions are guaranteed thanks to the exploitation of liquid hydrogen and NO_x emissions as well as noise shall be mitigated" [21] and lower operational costs thanks to proportionality on lost weight.

4 Importance of roadmaps for boosting the EU's access to space sector

According to ESA [34], developments in the global space sector and the geopolitical context, in general, are putting European leadership at risk. To remain competitive in the access to space industry and reaffirm its international role, Europe must act decisively in a timely manner to speed its technology development, strengthen its space technology and industrial capabilities, invest in technology testing and demonstration, create an entrepreneurial and risk-taking culture to attract the best and brightest talent, and reap the benefits of space for its countries and people.

According to the European Investment Bank (EIB) [2], for Europe to once again lead the access to space market, it must have:

- Financing available to overcome high upfront costs for testing and demonstration of the new technology,
- Friendly regulations,
- The availability of a market demand, which may require a key player in the technological or financial part to guarantee the success of the result.

Regarding financing, public, and institutional investments are going to be vital for any future in space [47]. Due to the lack of private investment and the conservative culture in Europe, European space firms are on the lookout for American investors who have a greater appetite for risk and failure acceptance. To solve this, according to the EIB [2], Europe should combine existing financial tools and mechanisms to support the EU's technological advance in space such as the Fund of Funds (FoF) model, or establish co-investment programs with the corporate branches of European aerospace companies or the use of the EU Structural Funds of the Member States to speed time-to-market technological development. Currently, there are more than 15 small launcher system projects in Europe, most of which are privately funded. Considering the narrow market accessible to Europe, commercially sustainable operations can only be realistically viewed by a couple of little European pitchers.

Regarding space regulations, the European scene is heterogeneous, as only a few countries have national space laws. Remarkably, Luxembourg and Finland have produced regulations to enhance the attractiveness of the country

for corporations and SMEs addressing NewSpace operations and activities [48], while countries like Spain, Sweden or Norway don't have national space regulations even though they hold and support space activities on the national ground, mainly related to small launcher initiatives.

Even if many countries are rushing, it has been proven that regulations are to play an important role in EU competitiveness in access to space as they will enable the necessary conditions for space business operations. In fact, to be effective, a common EU policy should be developed, but this is far to be accomplished given the present scenario. In fact, it has been proved that legislation on its own is not enough, even if it is necessary, to increase the attractiveness of NewSpace operations on the national ground. Given that the market for small launchers is far from being established and that many countries are rushing into this type of activity, infrastructure, and technology testing and demonstration. These are the main needs to be covered by public authorities so an operator selects the country to operate, thus minimising recurring costs for the operator. Portugal and the UK are on their way to developing both launching sites and regulations on NewSpace activities.

Currently, there is a growing demand for small launch services in Europe [50, 51] prompting the EU to initiate partnerships between European countries to address global market challenges and provide significantly cheaper and optimized launch services and support development of the small satellites market due to launch limitations in high-performance satellites.

Given that EU needs to put a lot of public and private financial resources, it is necessary to design a roadmap that allows the EU to establish priorities between its industrial capabilities, its novel technologies, the market and products in the access to space market, as well as setting up the objectives and link them with the priorities to help Europe become an international competitive player again.

5 Case study: roadmap for the EU's access to space field

Before starting with the case study, it should be noted that the roadmap presented in this article has been developed to ensure the sustainability of the EU's access to space market. Consequently, the business roadmap serves as a guide to foster the entrepreneurship and risk-taking culture that drives the entry of new European SMEs into the access to space sector and establish Europe as a competitive player again.

5.1 Business statement

Therefore, the first stage of the business roadmap consists on a brief explanation of the high-level objectives of the European access to space market (Table 1).

5.2 Industry scenario

With the main objectives of the European access to space market presented in Table 1, the next step on the roadmap is to analyze the launcher industry and its competitiveness, to explore opportunities and threats.

The tool that will be used to identify the opportunities and threats that affect the market for launchers for access to space is PESTEL. This tool will help us to analyze the positive and negative shifts that the market is currently experiencing. The results of the external analysis of the market are presented in Table 2, where the most important points of the external factors of the access to space market are considered.

The most important points observed in Table 2 are highlighted below. In the political factor, we highlight (1) the emergence of new policies and actors to re-evaluate long-term European strategic approaches [34], (2) trade agreements between public and private institutions to beat the US competition [2, 34], and (3) the dependence of Arianespace launchers' supply chain on the EU external countries and resources (e.g.: Ukraine and Antonov cargo aircraft) [53].

Regarding the economic factor, we highlight (1) the lack of private funding sources in Europe, which makes the United States more interesting for space entrepreneurs and new companies [2, 55], (2) although there are numerous Union programs and initiatives to accompany the early stages of start-ups [2] it is difficult to find all the information in one place [56], and (3) the lack of further financing slows down the pace of advancement of the TRL (Technology Readiness Level) of new technologies development, which makes them reduce its competitiveness.

Regarding the social factor, it should be noted that Europe is an immature market with a great need for a partnership between public and private capital [2]. However, the large number of stakeholders involved in both public and private funding institutions and companies, as well as of the EU low-risk culture and economic benefits approach, results inconvenient to ensure the competitiveness of the EU's access to space market.

As regards the technological factor, access to the space market is in rapid and unpredictable technological change [11, 19–22, 48, 50, 59] that Europe must be time-to-market ready to accelerate its technological development.

Regarding the environmental scenario, the trends are (1) transition towards new and/or green propellants (e.g. LCH₄ or LH₂) that have more potential in terms of reusability and

Table 1 Main goals of the European access to space market

Main goal EU space market	
Market	Position the EU within the international space market by improving industrial and technological capabilities ^a , financing novel projects and technology inflight demonstrations, and establishing collaborations with other countries to address the global challenges of the space market
Economical	Development of new financial tools and mechanisms to support the technological advances in the EU and promote investments for SMEs and start-ups with public and private funds
Technological	Development of new technologies that provide new (reusable) vehicle concepts, serial production that reduce launch and operational costs bringing a more competitive price to launch small satellites in (V)LEO
Environmental	Reduce CO ₂ emissions from launches and implement satellite deorbit systems, in accordance with the United Nations (UN) sustainable development goals presented in [50]
Regulation	Establish common legislation covering EU states for space activities, in order to provide a solid basis for regulating NewSpace operations together with funding for space activities and infrastructures, while converging towards a policy to serve as the EU's declaration of competitiveness with regard to access to space [11]

^aTechnological capability is defined as the ability that enables organizations to identify, acquire, and apply new external knowledge to develop operational competencies that can lead to superior performance [49]

environmental constraints for small launchers, (2) use of air-breathing propulsion system that translates in a drastic reduction of oxidizer propellant amount, and (3) enforceable regulations on self-deorbit capabilities for space objects.

And finally, to guarantee the competitiveness of the EU in accessing the space market, it is necessary to create a legal framework that regulates (1) NewSpace operations (such as small launchers) and its safety [50], and (2) the cooperation between space agencies [2].

5.3 Business scenario

The next step in the business roadmap is to describe the most promising needs and functional requirements to be met by European small launcher projects targeted towards LEO and VLEO missions, taking into account the EU strategy.

On the one hand, as it is noted that there is a growing market demand that asks for the development of a satellite launch solution that (1) reduces the launching and operational costs [20, 21, 57], (2) enables launcher in-orbit operations such as multi-orbit injection, and (3) provides sufficient flexibility [13, 23, 37, 50]. The development of these industrial capabilities by the EU will meet the low-cost demand of the NewSpace companies [13]. One of the promising initiatives is the ESA Space Rider, an uncrewed robotic laboratory launched on Vega-C that will stay in low orbit for about two months and then return to Earth with its payloads [60]. Furthermore, according to ESA [61], the development of new propulsion systems by the EU using liquid oxygen and methane as propellants like Vega rocket [36] and SpaceLiner DLR or air-breathing like STRATOFly hypersonic vehicle, would lead to a reduction in CO₂ emissions and a significant gains, such as a simpler and lighter launcher design, reusable engines and storage, and easier handling [20].

On the other hand, the EC seeks to strengthen ESA-EU relations by using ESA as Europe's gateway to the world

to promote space activities and allow the development of key partnerships between space agencies [2]. None of this would be possible without strong public investment to mobilize funds for R&D, e.g. the Horizon 2020 Program and the European Fund for Strategic Investments (EFSI), as well as private investment to support the development of the EU's industrial and technological capabilities, especially in launchers intended to operate in LEO at competitive prices, to attract the attention of private companies and enhance their position as a key player in the space access market [2].

In addition, the EU must provide not only economic but also legal advantages to attract the entry of new private companies into the small launchers market with new industrial and technological capabilities that will improve the EU's position at the international level in the market for access to space through establishing partnerships with European countries to address global challenges. For example, involving assets such as launch infrastructures (e.g. Norway, Sweden) or launch pads (e.g. UK and Portugal), as well as a recurring launch demand [50].

After fully analysing the business scenario, it is important to highlight the main points that will position the EU as a key player in the global access to space market:

- Incentivise technology and novel concepts (Stratofly, SpaceLiner DLR) testing and demonstration, in order to accelerate and move forward their TRL development fastly.
- Development of advanced industrial capabilities for the manufacture of reusable launchers, hypersonic engines, space riders, vertical landing systems, and 3D printing.
- Development of technological capabilities related to novel technologies like ABEP, aerospike nozzles made by additive manufacturing underdevelopment by PAN-GEA Space, combustion technologies, heat transfer technologies for shell materials and wing's leading edge

Table 2 PESTEL analysis of the access to space sector. Based on the information obtained from: [2, 11, 19–22, 48, 50, 52–59]

Political [2, 11, 29, 52–54]	<p>New policies and actors have emerged, increasingly pressing institutions across the whole of Europe to reassess their long-term strategic approach. [29]</p> <p>The EU lacks an overarching concept for space, security and defence. [11]</p> <p>International cooperation and coordination between the various space agencies. [2]</p> <p>The Russia-Ukraine war has put a full stop to ESA-Roscosmos collaborations. [52]</p> <p>The Russia-Ukraine war has evidenced the dependence of Arianespace launchers' supply chain on the EU external countries and resources (e.g.: Ukraine and Antonov cargo aircraft). [53]</p> <p>European space sector increased the private industry participation in launcher development with companies like PLD Space, Deimos and Orbex, Avio, MT Aerospace, and ArianeGroup. [54]</p>
Economical [2, 55–57]	<p>European space entrepreneurs feel a lack of private financing sources and keep an eye on the US. [2]</p> <p>US and Chinese companies have attracted the majority of capital. Private funding in the US reached €5 billion compared with €188 million in Europe (for start-ups only). [55]</p> <p>Numerous Union programmes and initiatives accompany the early stages or scaling up of start-ups, notably through the Union's Investment Plan and its European Fund for Strategic Investments (EFSI) or the Union Framework Programme for Research and Innovation. [2]</p> <p>There is no official (one-stop-shop) web site granting access to all European public funding programs and few digital tools to facilitate access and provide guidance are available. [56]</p> <p>Public European Funding for new developments is largely done through Framework Programs (e.g.: H2020). [57]</p>
Social [2, 58]	<p>Global competition increases with new entrants bringing new ambitions into space. [2]</p> <p>Space activities are becoming increasingly commercial with greater private sector involvement. [2]</p> <p>Immature markets with questionable demand, technology risks and high capital needs are the key risks from the perspective of space investors. [2]</p> <p>Compared to the US entrepreneurial and risk-taking culture, the EU institutions and private companies usually involve many stakeholders that prime no risk-taking projects and look out for benefits in every inversion. [58]</p>
Technological [19–22, 48, 50, 59]	<p>Miniaturization and advanced manufacturing techniques. [19]</p> <p>Reusable launch and civil transportation vehicle technology. [19–20, 21]</p> <p>Technological-advanced air-breathing propulsion systems -ABEP- (hypersonic engines). [22]</p> <p>Development of Aerospike engines for small launchers. [59]</p> <p>Enhanced automation. [50]</p> <p>Cost reduction from €10,000 to €2000 per kilo or even €1000 per kilo. [20]</p> <p>New uses for space transportation (human and cargo). [20]</p> <p>Airplane-like operations. [21]</p> <p>Space launchers are targeted towards Low-Earth-Orbit (LEO) and Very-Low-Earth-Orbit (VLEO) missions. 3D printing technology allows the use of the "Design-Produce-Test-Fail-Redesign" method. [48]</p> <p>Double or multiple bubble structures to achieve lighter structures with multifunctional roles to harmoniously integrate all vehicle subsystems, reduce noise and optimize aerodynamics. [21]</p> <p>Exploitation of liquid hydrogen as fuel drastically improves performance. [21]</p> <p>Inclusion of thermal protection systems and Energy Management Subsystem (TEMS) based on Ceramic Matrix Compounds (CMC) and heat pipes to cool the leading edges of the vehicle. [21]</p>
Environmental [20, 21, 50]	<p>Transition towards new propellants (LOx/LCH₄) for small launchers with the best potential for evolution, especially regarding reuse and environmental constraints. [20]</p> <p>Green Hydrogen development as a fuel. [20, 21]</p> <p>In order to comply with the applicable space debris mitigation rules, all the components for new launchers must have their own deorbit capability (international guidelines from IADC, ISO, UN-COPUOS, for instance, and national laws like the French space operations law). [50]</p> <p>Reduction of noise produced by high-speed jets through strategies based on the integration of the nozzle-fuselage. [21]</p>
Legal [50]	<p>Regulatory change is essential to facilitate improvements in economic efficiency. [50]</p> <p>Europe, Germany, Sweden, Norway, and Spain are supporting small launcher projects but have not yet put in place a legal framework. [50]</p> <p>The United Kingdom has recently adopted the first regulation on small launcher projects. [50]</p> <p>Law of Space Operations (LOS), a legal requirement defined in France, certifies that the launch objects and launchers meet customer expectations in proven reliability. [50]</p>

- | | |
|--|---|
| <ul style="list-style-type: none"> refrigeration at STRATOFly MR3 and SpaceLiner DLR. • Provide competitive launch prices. • Reduce the launch cost and increase the flight rate. | <ul style="list-style-type: none"> • Reduce launching and operational costs of access to space platforms (airplane-like). • Turn Small satellites into main payloads instead of piggy bags. |
|--|---|

- Increase in low-cost demand by NewSpace companies operating in low earth orbit (LEO) and very low earth orbit (VLEO).
- Assume higher risks and failure acceptance.
- Give more space competences to EU institutions.
- Develop an entrepreneurial culture.
- Attract the entry of new private companies with higher public and private fundings.
- Create a regular space financing forum to quickly identify specific financing needs, new business models, and possible financing solutions for the European space sector.
- Create an official space website that grants access to all European funding programs.
- Establish collaborations with other countries and between space agencies to address the global challenges of the space market.
- Reduce the space carbon footprint by reducing not only CO₂ emissions during launch but also space debris in low and medium orbits.

5.4 SWOT analysis and actions definition

Analysing various roadmaps from the Phaal bibliography [62], it was observed that most of the companies that use business roadmaps do not present an analysis of the situation, are not able to understand where the current situation of their business is or do not even correctly define its strategic position. To analyse the business situation, the SWOT strategic management tool will be used. This will identify the main strengths, weaknesses, opportunities, and threats of the access to space market in the EU, more precisely launchers for small satellites in LEO and VLEO. It should be mentioned that the strengths and weaknesses correspond to internal factors of the European market and the opportunities and threats correspond to external factors of the global market of access to space.

The first objective of this analysis is to identify the main favourable and unfavourable factors of the SWOT analysis. Each item has been classified into three main categories adapted from the Balanced ScoreCard (BSC) strategic management tool [31]: value network (refers to the customer

category of the BSC), Market (refers to the financial category of the BSC) and technology (refers to the knowledge and operational efficiency category of the BSC).

The second objective of this analysis is to identify the actions that must be carried out to achieve the main objectives of the business roadmap (Table 1) in order to position the EU internationally in the market for access to space. From each element of the SWOT analysis, three specific actions will be generated according to the three categories mentioned above (see Tables 3, 4, 5, and 6).

The actions presented in Table 3 are detailed hereunder:

- *AS1*: to beat the competition and develop relevant technologies, the EU cooperated with Russia. Due to the Russia–Ukraine war and its consequences, the EU should focus on developing their variety of current efforts on space launcher disruptive technologies by improving funding and accepting failures and risks to develop faster the potential of those projects and their TRL. Also the EU should gain more sovereignty by filling the lack of some EU suppliers with European SME enterprises.
- *AS2*: the EU is one of the main public institutions financing the space sector. However, to remain competitive, the EU will need to combine existing financial tools and mechanisms to support the EU's technological advancement in space.
- *AS3*: even though the EU has a large public investment that supports the development of the EU's industrial and technological capabilities, accessing this information is not easy. Therefore, it will be necessary to concentrate all the European public financing programs, mechanisms, and tools for the space market on a single website.

The actions presented in Table 4 are detailed hereunder:

- *AW1*: there is a growing technology gap between Europe and other nations navigating the space access market. To resolve this situation, the EU must continue to work on the development of advanced industrial and technological

Table 3 Strengths of the European market and their specific actions

Category	Strengths	
	SWOT analysis	Action
Technology	S1: Multiple EU-funded technology projects with high disruptive potential	AS1: Improve financing and testing capabilities (assume risks) of EU Framework Programmes projects for faster TRL advancement
Value Network	S2: EU is one of the major public institutions financing the space sector	AS2: Blend existing financial tools and mechanisms to support the technological advancement of the EU in space
Market	S3: High public investment to support the development of the EU's industrial and technological capabilities	AS3: Concentrate all the European public funding programs on one single website

Table 4 Weaknesses of the European market and their specific actions

Category	Weaknesses	
	SWOT analysis	Action
Technology	W1: growing technology gap between Europe and other space-faring nations	AW1: work on the development of advanced industrial capabilities and a range of launch services
Value network	W2: lack of European private financing sources that leads to a flight of talent and companies to the US	AW2: encourage private financing sources to improve competitiveness
Market	W3: low level of institutional demand with a non-competitive price	AW3: reinforce its space capabilities, talents, and country collaboration to be cost-competitive

capabilities as well as a range of launch services through new concepts like Stratofly MR3 or SpaceLiner DLR.

- *AW2*: a lack of sources of private European financing has been detected that causes a flight of talent and companies to the US. To solve this situation, the EU must promote private sources of financing to improve competitiveness with new investment funds such as the European Fund for Strategic Investments (EFSI) or the Union Framework Program for Research and Innovation.
- *AW3*: there is a low level of institutional demand with an uncompetitive price. To solve this situation, the EU must not only strengthen its spatial capabilities, talents, and collaboration with the country to be profitable, but also develop a more entrepreneurial and risk-taking culture.

The actions presented in Table 5 are detailed hereunder:

- *AO1*: the global access to space market has seen an improvement in launcher operations in orbit (multi-orbital injection) using space riders to deploy constellations of small satellites more efficiently. To seize this opportunity, the EU will need to continue investing in new access to space vehicle concepts, airplane-like operations as well as inflight demonstration and testing to be time-to-market with new space vehicles and technologies.
- *AO2*: it has been seen in the global market of access to space that space activities are becoming increasingly

commercial with increased participation from the private sector. To seize this opportunity, the EU will need to continue promoting collaboration and coordination between public and private actors.

- *AO3*: the global market of access to space is in full expansion of small commercial LEO/VLEO satellites. To take advantage of this opportunity, the EU will have to continue not only adapting technologies to the needs and requirements of NewSpace's demand -reusable launch systems and weight reduction that bring down costs and production times- but also establishing a legal framework that certifies that launch objects and launchers meet customer expectations in terms of proven reliability.

The actions presented in Table 6 are detailed hereunder:

AT1: the global market of access to space is in rapid and unpredictable technological change. To adapt to this pace and become competitive, the EU should promote the creation of national regulations that share a commonality, so they provide a solid ground to develop and integrate new technologies and competitive vehicle concepts that ensures noise reduction and optimal trajectories.

AT2: EU lacks an overarching concept for space, security and defence becoming dependant on EU external countries on supply chain activities. For instance, the current Russian-Ukraine war has evidenced this dependence (e.g.: key components of Arianspace launchers—

Table 5 Opportunities of the global access to space market and their specific actions

Category	Opportunities	
	SWOT analysis	Action
Technology	O1: enhancement of launcher in-orbit operations (multi-orbit injection) to deploy constellations of smallsats in a more efficient way	AO1: invest in European Programme for new concepts for access to space
Value Network	O2: space activities are becoming increasingly commercial with greater private sector involvement	AO2: promote collaboration and coordination between public and private actors
Market	O3: expansion of commercial small satellites in LEO/VLEO	AO3: adapt technologies to the needs and requirements of the NewSpace demand

Table 6 Threats of the global access to space market and their specific actions

Category	Threats	
	SWOT analysis	Action
Technology	T1: rapid and unpredictable technological shift	AT1: promote common regulations and national legal frameworks
Value Network	T2: EU lacks an overarching concept for space, security and defense becoming dependant on EU external countries on supply chain activities	AT2: keep strengthening EU space ecosystem and ESA relationship to increase the resources devoted in EU to space-related activities, research, technology, and efficiency in managing resources
Market	T3: global competition is increasing with new reusable space vehicles bringing new ambitions in space	AT3: increase its budget in technology testing and demonstration; to aggregate demand and increase the bargaining power of national launch providers to remain competitive; and promote an entrepreneurial and risk-taking culture

Vega's upper-stage rocket- were produced by a Ukrainian company [53]). To mitigate this threat, the EU should continue to strengthen the EU space ecosystem and ESA relationship to increase the resources dedicated to demonstration and testing in the EU.

AT3: global competition is increasing. The emergence of new space vehicles concepts, such as Falcon 9 Heavy or Big Falcon Rocket (Startship), brings new ambitions and trends into the space market. To mitigate this threat, the EU should (1) increase its budget for the demonstration and testing of new technologies such as STRATOFLY or SpaceLiner, (2) continue to negotiate and finance access to space for European smallsat companies to aggregate cargo and passenger demand and increase the bargaining power of national launch providers, and (3) promote an entrepreneurial and risk-taking culture that helps SMEs face the risks associated with the constant evolution.

Finally, the actions have been classified into different groups to make the analysis more visual. Actions that are in the same group mean that they have similar characteristics. Therefore, the actions have been classified into five different categories (collaboration, public investment, private investment, research and development, and strategic planning) taking into account the main objective of each action, as shown in Table 7.

5.5 Stakeholders

According to Smith [32], a stakeholder is defined as a member or an organization that has a certain influence on a project or company, supporting or blocking it. Consequently, it is necessary to identify the key stakeholders in the access to space industry, since without their support it will not be possible to improve the EU's position in the market. To graph the stakeholder analysis the Mendelow matrix is used (Fig. 2).

Table 7 Categories of the actions

Category of the action	Action
Collaboration (Collab)	AO2
Public investment (Pub Funds)	AS2, AO1
Private investment (Priv Funds)	AW2
Research and development (R+D)	AW1, AO3
Strategic planning (SP)	AS1, AS1, AS3, AW3, AT1, AT2, AT3

Figure 2 shows the key stakeholders of the global space access industry, some groups such as research centres, universities, and private investors have been represented in a general way and not by specific companies. However, due to its remarkable importance, key players in the industry have been profiled such as the European Commission (EC), the European Space Agency (ESA), the market triopoly (SpaceX, ULA, and Ariane Group), in addition to other key competitors such as Airbus, JAXA, CASC, among others.

As can be seen in Fig. 2, the EC (public financing) and private financial entities will be directly related to the distribution of the economic resources necessary to develop and grow the market for access to space. It is worth mentioning that both the EC and private investors focus mainly on promoting the market [11], so their power is high but their interest is medium.

On the other hand, as shown in Fig. 2, the EU, space agencies (NASA, ESA, JAXA, CNES, ISRO, and CASC), large companies that dominate the aerospace market (SpaceX, ULA, Ariane Group and Airbus), SMEs (PLD Space, MT Aerospace and Avio), as well as technical universities and technological research centres are entities with a great interest in the development and global growth of the access to space sector. However, the last three entities due to their

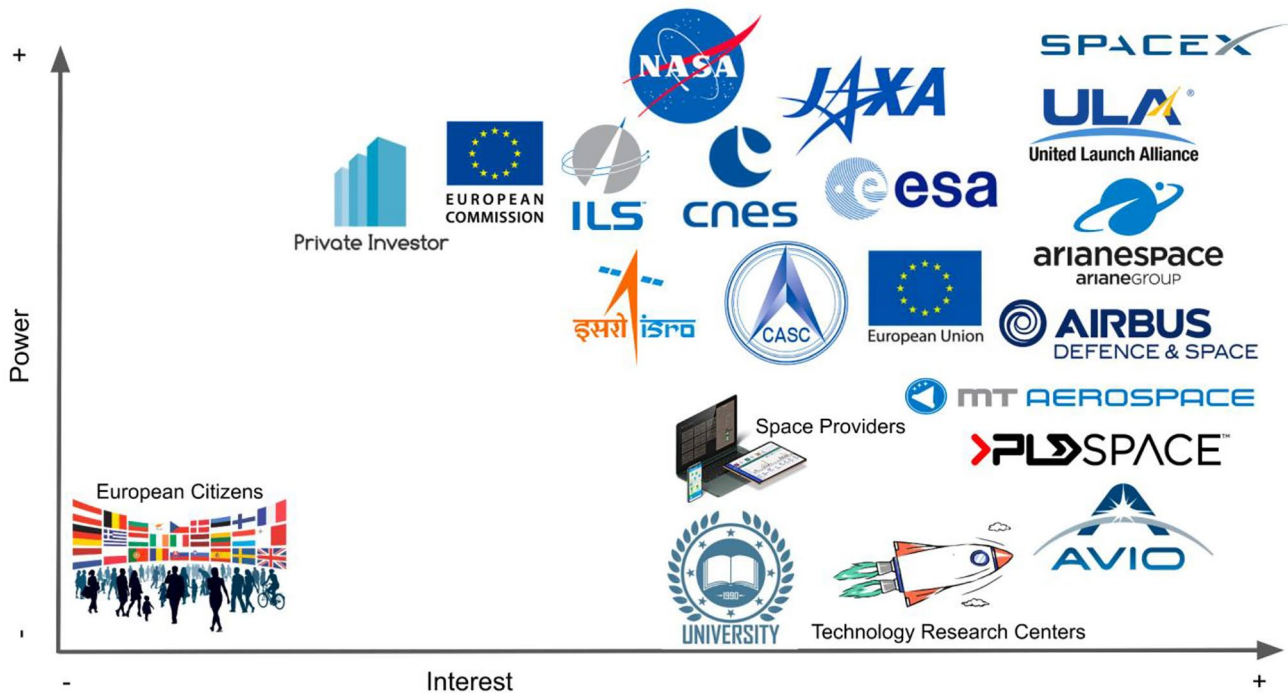


Fig. 2 Stakeholders matrix of the access to space sector

size, their power in the growth of the space market will be less than space agencies or large aerospace companies.

It is worth mentioning that the French space agency, CNES, and India (ISRO) have enjoyed close cooperation in space for decades, particularly in launch vehicle technologies. Currently, they are investigating reusable launch technologies [63]. This cooperation will help both countries to remain competitive in the international launch market in both LEO and geostationary orbits.

In addition, ESA is the most important space actor in Europe currently, as it executes almost 60% of the total European budget dedicated to space and can therefore take advantage of its recognized heritage to be the door to the world of Europe to not only provide the necessary new impetus to the European space sector, but also promote space activities and infrastructures [34].

5.6 Definition of the budget

At this stage of the business roadmap, the budget required to develop each specific action is estimated. The final budget for each action depends on the Leverage Factor (LF) as well as the required resources. The LF is defined as the amount of private funds that a project or technology could raise for each public euro invested, that is, the ratio between private and public investment [64].

In addition, it should be noted that the LF of a specific action is associated with the level of technological maturity

used at the time the action is carried out, obtaining this through the Technology Readiness Level (TRL). TRL defines the operational capability of technology and its maturity [66]. The LF of a specific action can be estimated regarding the TRL of the corresponding technology along the process (Fig. 3). Nevertheless, the TRL can change during the action. Making that some actions will have a specific LF at the beginning and a different one at the end of the business roadmap.

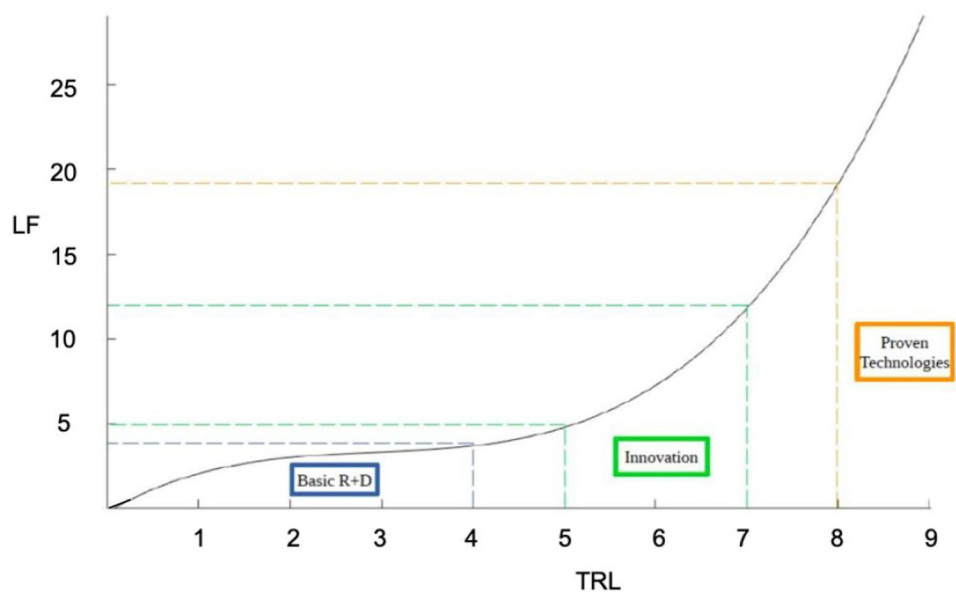
What Fig. 3 shows is that private investment increases simultaneously with the advancement of technology, since its development provides more security to investors.

5.7 Risk analysis

To ensure a correct implementation of the business roadmap, it is important not only to determine the probability that the risk arises but also to forecast and design a contingency plan in the event that the risk occurs [68]. According to Twiss [10], the objective of designing a risk forecast is to reduce them, giving an indication of the level of performance that must be achieved in the technology, market or even value network. However, some uncertainties will remain, it would be necessary to analyze the risks of each action.

The risk is evaluated through three elements: the organisational readiness of the technology (technology), the readiness of the market (market), and the maturity of the stakeholders relationship (value network). These elements are

Fig. 3 Relationship between the LF of an action and the TRL of a technology. The information used to generate the plot was extracted from [64–66], and Sect. 1.9 of reference [67]



used to measure the inherent risk of each action using a scale from 1 to 3 (1 being the minimum risk and 3 the maximum).

Technology maturity: aims to analyse the risks linked to the stage of the technology maturity (basic R&D; Innovation; and Proven technologies) at the moment that the action is done. Table 8 classifies the TRL level of each action in the technological maturity stages, connecting what is done in [69] with the divisions presented in Fig. 3.

Market maturity: aims to analyse the risks linked to the market development stage at the moment that the action will be done. In this case, we will adapt the “Market life cycle phases” [70] that is a macro-level methodology that aims to “measure” the market maturity of the existing technical system regarding the market development stage (introduction phase; growth phase; or maturity phase) (see Table 9).

Value network maturity: aims to analyse the risks linked to the stakeholders’ commitment in a specific action. In this case, we will consider the “Stakeholder commitment curve” [71] that estimates the status of the stakeholders involved in each action and evaluates the way that they interact along with the evolution of the business roadmap. Besides, the value network maturity depends on how advanced is the overall business development stage (prepare, accept, or committed) (see Table 10).

Once the risks have been defined according to the maturity in the three areas (technology, market and value network), the next step is to multiply the three obtained values in each area, getting as a figure between 1 and 27, that serves as a measure of the inherent risk of each action. Depending on the result, the overall risk will be ranked as low, medium, or high, according to Table 11.

5.8 Timeline

The business roadmap ends with a calendar that shows not only the path to be followed to develop the actions, but also the connection between the actions as well as their duration. For this article, it is considered that the best way to present the schedule of the roadmap is by dividing the general schedule into three different stages (short-term, medium-term, and long-term), as shown in Table 12. Adaptation of the format presented by [72].

On the one hand, the business roadmap presented in this article attempts to identify new technological opportunities that allow the EU to become a key player in the market for access to space.

On the other hand, taking into account the results obtained in the work carried out by Abele and Schimpf [73] (who analyzed roadmaps of more than 2000 companies) and given the amount of R&D and the enormous investment required to carry out technological progress in the sector of space, it is observed that TRL advances tend to be slower than in other industries. Except for SpaceX, which is probably one of the fastest as it was created in 2002, launched its first small launcher in 2008 and its first GEO satellite in

Table 8 Risk evaluation of the technology maturity

Stage	TRL	Technological risk
Basic R+D	1–4	3
Innovation	5–7	2
Proven technologies	8–9	1

Table 9 Risk evaluation of the market

Stage	Market risk
Introduction	3
Growth	2
Maturity	1

Table 10 Risk evaluation of the value network

Stage	Value network risk
Prepare	3
Accept	2
Commit	1

Table 11 Risk category according to the final score of the action

Final risk	Score
Low	1–9
Medium	10–18
High	19–27

Table 12 Main periods of the access to space timeline

Stage	Period (years)
Short-term	0–5
Medium-term	5–10
Long-term	10–15

2013. With this, it can be estimated that the duration of the business roadmap in the space sector can be between 10 and 15 years. Considering the 15-year limit for the schedule of this case study, see Table 12 and Fig. 4.

Next, Fig. 4 presents the timelines of the business roadmap for access to space carried out in this case study:

The main aspects that should be highlighted from Fig. 4 are:

- In the short term, the EU should continue to invest public funds in European Programs (AO1) to (1) enhance the development of advanced space technologies (AW1) to improve being a competitive player in the sector, (2) attract talent (AW3), (3) promote collaboration between public and private companies (AO2), (4) improve financing and testing capabilities for faster TRL advancement (AS1), and (5) finance access to space for SMEs and promote entrepreneurial and risk-taking culture (AT3).
- Another short-term action is to encourage private financing (AW2). This would make Europe an interesting country for companies. In addition to contributing to the development of advanced space technologies (AW1), attracting talent (AW3), speeding the TRL development

(AS1) and financing European SMEs and failure acceptance (AT3).

- The EU space ecosystem should further enhance its relationship with ESA (AT2) in the short and medium-term to (1) promote collaboration between public and private companies (AO2), (2) further progress in the development of advanced space technologies (AW1), and (3) strengthen its space capabilities (AW3) and become a key player in the space market in the medium term.
- Another short-term action is the combination of existing financial tools and mechanisms (AS2) to support the EU space technology development (AW1), inflight demonstration activities (AS1), and concentrate all European public funds in one place (AS3).

All these actions in the short- and medium-term will help the EU to (1) improve European cooperation between institutions (AO2) and (2) adapt the technology to the needs and requirements of NewSpace demand (AO3).

The summary of the access roadmap to the space is presented in Table 13.

From Table 13 and Fig. 5 it can be extracted that private investment in the access to space industry will increase at the same time that the risk of the business decreases, due to greater confidence in the technology. It is worth mentioning that some of the budgets assigned in the business roadmap are global for the space sector, such as the regulatory framework, closer relations between the EU space ecosystem and ESA, combining tools and financing mechanisms, concentrating European public financing in a single place or negotiating and financing the EU SMEs. Obtaining, in the end, the quantity of €40,500 million with only €8000 million of public investment (Table 14).

Furthermore, Fig. 5 clearly reflects the three-stage periods considered in the business roadmap timeline. Obtaining the following results:

In the first place, it is observed that in the short term the public investment (€2300 million) is similar to the private financing (€3200 million) since the actions included in this stage are focused on promoting (1) research, (2) private funds, (3) blending existing financing mechanisms and tools, (4) strength relationship between EU space ecosystem and ESA, and (5) create a legal framework.

Subsequently, once the technology is at higher TRLs, private investment heavily increases (€23,000 million) and public investment as well (€7,000 million), making a total budget in the mid-term of €300,000 million. Private investment will finance the development of advanced technological and industrial capabilities; and the reinforcement of the EU's spatial capacities, talent, and collaboration between companies in the sector, while private investment will finance collaboration between public–private institutions; the entry and financing of SMEs to the business of access to

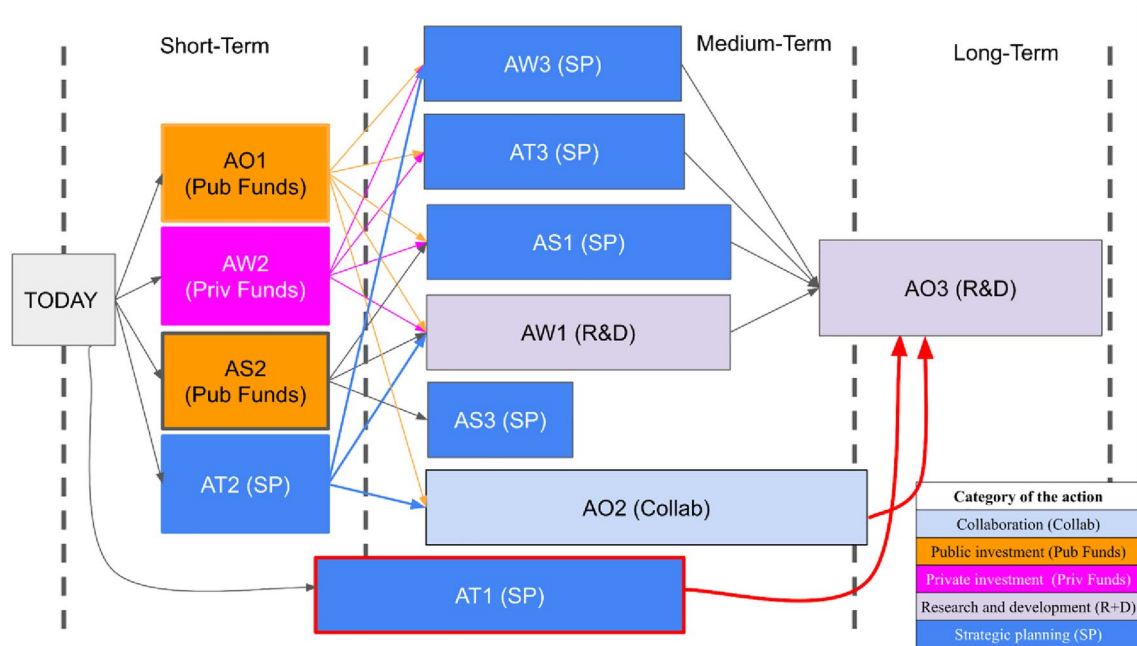


Fig. 4 Timeline of the access to space business. In parenthesis is included the category of each action, according to the information provided in Table 7.

Table 13 Summary of the access to space roadmap

ID	Term	Actions	Budget (M€) ^a	Risk ^b	Stakeholders ^c
AO1	Short	Invest in European Programme for new concepts for access to space	225	High	EC—EU—PFE—ABC—SME—TRG—Univ
AW2	Short	Attract the private investors	1900	Medium	EC—PFE—PI—EU
AS2	Short	Blend existing tools and mechanisms of finance to support technology development	700	Low	EC—EU
AT2	Short	Keep strengthening the relation between EU space ecosystem and ESA	1900	Low	EC—EU—NSA
AT1	Short—Medium	Regulation and national legal framework	2000	Low	EC—EU—NG—NSA—ISA
AS1	Medium	Improve financing and testing capabilities for faster TRL advancement	5100	High	All stakeholders (excluding ISA)
AW3	Medium	Reinforce space capabilities, talent, and collaboration	4100	Low	All stakeholders
AT3	Medium	Negotiate and finance EU small companies and promote an entrepreneurial and risk-taking culture	2500	Low	EC—EU—PFE—PI—NSA—SME
AW1	Medium	Work on the development of advanced technology capabilities	9000	Medium	All Stakeholders
AS3	Medium	European public funding system integration	225	Low	EC—EU—NG—NSA
AO2	Medium—Long	Promote collaboration between private and public institutions	3700	Low	EU—NG—PFE—PI—NSA—ISA—ABC—SME
AO3	Long	Adapt technology to need and requirements of NewSpace demand	9000	Low	EU—PFE—PI—NSA—ISA—ABC—SME—TRG—Univ

^aBudget calculated using references [33, 74–76] and Fig. 3

^bRisk calculated using the methodology presented in Tables 8, 9, 10 and 11

^cAcronyms of the stakeholders presented in Table 14

Fig. 5 Evolution of the budget required to implement the access to space roadmap [33, 74–76]

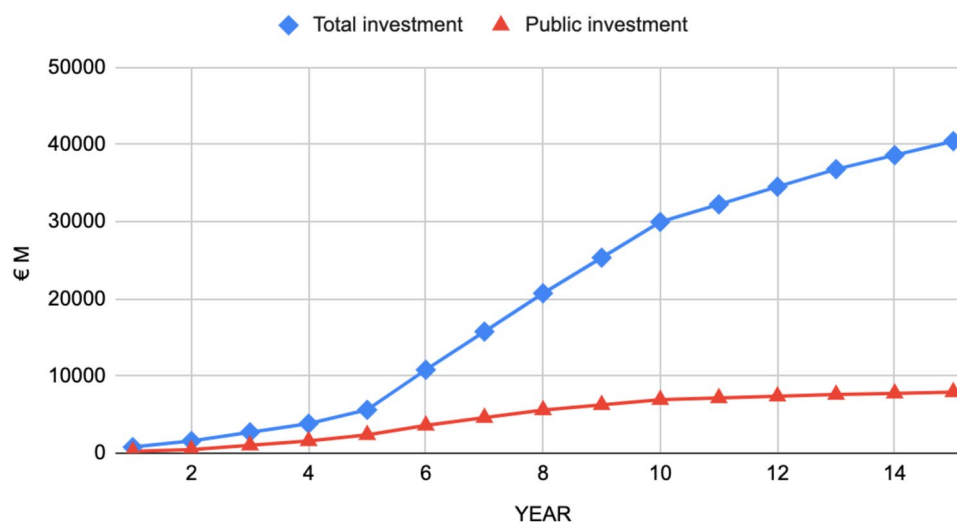


Table 14 Acronym used for each stakeholder

Stakeholder	Acronym
European Commission	EC
European Union	EU
National Governments	NG
Public Financing entities	PFE
Private Investors	PI
National Space Agencies (ESA, CNES and others)	NSA
International Space Agencies (NASA—JAXA—CASC—ISRO—ILS)	ISA
Aerospace big companies (SpaceX—ULA—Arianespace—Airbus)	ABC
Small and Medium sized Enterprises (MT—PLD—Avio—Space Providers)	SME
Technology research groups	TRG
Universities and academic institutions	Univ

space; technology demonstration and testing; and common regulation within the European legal framework.

In the long term, the total investment, on the one hand, falls up to €10,500 million and on the other hand, the private investment still increases around €9500 million and the public investment just increases €1000 million. Public investment mainly will be used to enhance European cooperation and most of the private investment will be used to adapt the technology to the needs and demands of NewSpace companies.

In summary, the implementation of the actions defined in the business roadmap of this article is expected to generate around €40,500 million for the EU economy, during the first 10–15 years of operations. In the first 5 years, the LF moves around 1, in the medium term, it is observed in Fig. 5 that public investment triples and private investment soars (tripling public investment), at the end of the business roadmap the LF is around 10, getting an average LF of the roadmap of 4.

6 Conclusion

The European space market has lagged behind the US, China, Russia, and India. Although it is the second-largest public budget entity for space in the world, it is not competitive in the access to space market for its lack of (1) risk-taking and failure acceptance culture that addresses the challenges of the global market in a fast way, (2) development of industrial and technological capabilities, (3) autonomous decision due to the number of stakeholders involved in decision making, (4) attraction of private investors and talent, (5) investment in testing and demonstration to accelerate the development of time-to-market technologies, and (6) having a common EU policy to regulate NewSpace activities.

In addition, the new technological trends of reusability, propulsion systems, aerodynamic structures, and miniaturization are changing the space industry, motivating (1) the development of new vehicle concepts to access space

such as the SpaceLiner DLR and STRATOFly MR3, (2) the appearance of new startups (e.g. PANGEA, KREIOS, Sateliot, ...), and (3) the growth of private demand to launch commercial small satellites in LEO and VLEO. This points out that European private companies will play a key role in the future of NewSpace economy through the development, demonstration, and exploration of new technologies that will make the EU internationally competitive again. Consequently, new frameworks are needed to understand space business models and to develop business roadmaps.

This article presents a business roadmap focused on driving and ensuring the creation and sustainable development of the EU access to space by developing industrial and technological space capabilities, increasing private investment, changing the European conservative culture, being time-to-market with the development of the new concepts, and adapting advanced space technologies to the needs and requirements of NewSpace companies. Therefore, it will serve as a guide to not only boost the entry of European SMEs, but also reestablish Europe as a competitive player in the global access to space market by:

- Investing public funds in European programs for new concepts of access to space and improving the EU financial systems
- Improving the relationship between the EU space ecosystem and ESA
- Combining existing financial tools and mechanisms
- Developing advanced industrial and technological capabilities
- Improving the testing, demonstration and exploration capabilities for faster the TRL development
- Providing competitive launch prices by reducing launch and operational costs and increasing launch time
- Promoting an entrepreneurial and risk-taking culture to awake the interest of talent and investors
- Establishing national and international collaborations between EU companies and between space agencies to develop advanced technologies
- Financing the entrance of SMEs in the NewSpace market
- Adapting the technology to the needs and requirements of NewSpace demand
- Establishing common legislation that covers EU states for space activities and fundings for space activities and infrastructures

The implementation of these actions is expected to generate around €40,500 million euros for the EU economy, during the first 10–15 years of operations. In the short term, public investment is similar to private, around €2500 million with an LF around 1, in the medium term, once the technology is at higher TRLs, public investment triples (€7000

million) and private investment soars (tripling public investment, €23,000 million) with a LF around 6–8. In the long term, public and private investment continues to increase in a more relaxed way, obtaining a total investment of €10,500 million with a LF of 10, getting an average LF of the roadmap of 4.

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