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Launch Demand Implications of LEO Mega Constellations
A SCENARIO-BASED ANALYSIS OF DEPLOYMENT SCALE AND
ECONOMIC FOOTPRINT

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Abstract

The rapid expansion of low Earth orbit (LEO) satellite mega-constellations is driving an unprecedented increase in demand for orbital launch services, reshaping both the space transportation market and the broader space economy. This thesis analyzes the deployment dynamics of LEO mega-constellations with a primary focus on quantifying launch demand under different growth and technology scenarios.

The study first outlines the strategic and industrial landscape of major LEO constellation programs in the United States, Europe, and China, emphasizing the emergence of satellite systems that function as long-lived infrastructure rather than purely commercial telecommunications services. Building on this context, four deployment scenarios are developed to estimate the number of satellites deployed over time and the resulting mass-to-orbit requirements.

These scenarios are used to derive launch demand under three launcher capacity assumptions: current launch vehicle performance, partial adoption of next-generation high-capacity launch systems, and full adoption of future launch capabilities. The results highlight the strong sensitivity of launch demand to payload capacity, while showing that large-scale constellations remain the dominant drivers of launch activity across all scenarios. Even under optimistic assumptions regarding future launcher performance, the deployment of mega-constellations implies sustained and structurally high launch demand.

Finally, the thesis contextualizes launch demand within a broader economic framework by linking deployment requirements to satellite manufacturing and launch cost estimates, and by introducing revenue- and service-value proxies to illustrate the order of magnitude of the associated economic footprint. Overall, the analysis frames LEO mega-constellations as a central driver of future launch markets and provides a structured scenario-based approach to assess the implications of large-scale orbital infrastructure deployment.

*To family.
Sometimes it is shelter from the storm.
Sometimes it is the storm itself.*

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Acronyms

LEO Low Earth Orbit.

ITU International Telecommunication Union.

IRIS2 Infrastructure for Resilience, Interconnectivity and
Security by Satellite.

Chapter 1

Introduction

1.1 Context

The space sector is rapidly evolving. We are witnessing a shift in the forces driving this industry. Up until 50/60 years ago, this economy was primarily led by national governments that could afford the high costs associated with space activities. In recent years, especially with the entry of reusable rockets in the market, access to space has become significantly more affordable, and therefore, more accessible.(F.Nicoli, September 2024) It is within this changing landscape that this research takes place. Due to this new scenario, an increasing number of companies, agencies, and governments have begun designing and launching more objects into space, particularly satellites, which are the primary focus of this research project.

Satellites can be considered the flagship objects of the new space millennium. In particular, over the past decade, both private companies and space agencies have concentrated on developing Low Earth Orbit (LEO) satellite mega-constellations. These constellations aim to guarantee internet access for everyone, including people living in remote and rural areas. However, their purpose is not limited to connectivity alone. Today, these constellations are considered also as strategic assets from a sovereignty and security point of view. The key capabilities of these satellite mega-constellations are:

- Broadband internet access
- Secure government communications
- Redundancy and sovereignty

These capabilities have led the development of various new constellations, usually referred as *mega-constellations*, due to the fact that most of them have more than 1,000 satellites.(Kendzierskyj, Jahankhani, & Hussien, 2024) Needless to say, this expansion and increase of satellites in orbit has a cost whether environmental, logistical, or political.

1.2 Literature review

In recent years, the space sector has undergone a profound transformation, driven by rapid technological advancements and an increasing presence of private actors. One of the most clear manifestations of this progress is the rise of different satellite mega constellations, networks composed of hundreds or thousands of satellites in low Earth orbit (LEO), with the primary goal of providing global broadband connectivity. Projects like Starlink, OneWeb, Amazon LEO, and IRIS² are redefining global digital infrastructure, opening new frontiers while also introducing significant challenges.

This section aims to review the existing literature on the generic advantages and disadvantages of satellite mega-constellations, before examining the main constellations developed by key global actors. Finally, it will address the current literature on the total market value of internet focused mega-constellations.

1.2.1 General

Even though they seem like a recent trend, satellite mega-constellations are not a new concept. The idea was already proposed in the 1990s (Evans, 2000) but was then abandoned due to the technological and economic difficulties of the time. Backed by the significant reduction of launch costs and the new technological advancements, the idea of a satellite mega-constellation has now regained momentum.

As illustrated in the literature, these constellations offer several advantages, including increased data transfer speed, latency reduction, coverage of remote areas, and better network reliability (Bod, Sojoodi, & Mohammadi, 2023).

However, like any major innovation, mega-constellations can also determine the rise of a new set of challenges, like increased frequency interference, reduced sky visibility and negative impact on astronomy, the rise of space debris, and network security concerns (Bod, Sojoodi, & Mohammadi, 2023). Notably, the latter has emerged as a strategic driver for various countries that now plan to establish their own sovereign satellite networks.

Furthermore, the rapid growth in the number of satellites that will need to be deployed in the coming years raises another concern: the capacity of ground infrastructure to properly produce and manage such a large volume of satellites (Curzi, Modenini, & Tortora, 2020). For this reason, many companies like Leanspace, specializing in ground segment solutions are now heavily investing in the development and expansion of their infrastructure. (Leanspace, September 17, 2024) But it is not only the infrastructure that struggles to keep up with the rapid development of these constellations, also the regulatory frameworks. Organizations such as the ITU are facing increasing difficulties in managing the growing congestion of LEO orbital slots. (Bod, Sojoodi, & Mohammadi, 2023)

1.2.2 US Mega-constellations

The United States plays a leading role in the development and deployment of Low Earth Orbit (LEO) satellite mega constellations, with two flagship projects: SpaceX's Starlink and Amazon's Project Amazon LEO. These initiatives are not only reshaping broadband infrastructure but are also influencing regulatory norms, space sustainability debates, and the global balance of digital power.

As of today, mainly all the literature agrees that **Starlink** is the most advanced and extensive mega constellation in operation, with over 6,750 operational satellites currently in orbit. The project began on May 24, 2019, with the launch of an initial batch of 60 prototype satellites (McDowell, 2020). Since then, it has progressed rapidly, with founder Elon Musk aiming to eventually deploy a constellation of up to 42,000 satellites (Pultarova, Last update 28 March 2025).

All Starlink satellites currently in orbit have been launched by SpaceX, the aerospace company also founded by Elon Musk. As of now, nearly 247 dedicated missions¹ have been conducted, placing over 8,000 satellites into low Earth orbit. (Wikipedia contributors, 2025a)

As one might expect, many more launches will be required to reach the target of 42,000 satellites in low Earth orbit. (Pultarova, Last update 28 March 2025) However, current literature lacks detailed projections regarding the number of future missions needed to achieve this goal.

The second major American mega constellation, Project **Amazon LEO**, is following a different philosophy. While Starlink went for the development of an in-house launch system, Falcon 9, before deploying its constellation, Amazon has taken a diversified approach. Rather than waiting for its own New Glenn rocket, that is under development by Blue Origin², Amazon has already committed to launching Amazon LEO satellites using different external providers. This strategy is intended to avoid delays in constellation deployment that might arise from setbacks in the development of its proprietary launch system. According to recent data, Project Amazon LEO has committed to deploy their 3236 satellite constellation using 38 launches with United Launch Alliance's Vulcan Centaur rocket, along with 7 additional launches using the Atlas V. The company also plans to conduct 18 launches with Arianespace's upcoming Ariane 6, 27 with its own Blue Origin New Glenn rocket, and 3 using SpaceX's Falcon 9. (Ginsberg, 2025) To complete the full deployment of the constellation by July 2029, Amazon may require up to 27 New Glenn missions. (Rainbow, April 2, 2025) A third emerging initiative in the U.S. commercial satellite landscape is the **Meridian constellation**, developed by SpinLaunch. While SpinLaunch is pioneering an innovative kinetic launch technology aimed at reducing launch costs and environmental impact, the Meridian satellites themselves are planned to be launched via traditional rockets. (Berger, 2025) The Meridian constellation is expected to consist of up to 1,200 small satellites, primarily targeting low-latency data services and Internet-of-Things

¹Mainly using the Falcon 9

²Also in this case, the mega constellation company and the rocket one share the same owner, Jeff Bezos

(IoT) connectivity. Although still in a pre-deployment phase, Meridian has attracted attention due to its alignment with next-generation sustainable space access models. Phased launches are anticipated toward the late 2026, contingent on regulatory approvals and partnership arrangements for launch vehicles. If successful, Meridian could position SpinLaunch as a disruptive actor in the LEO broadband and sensor data markets.

1.2.3 EU Mega-constellations

In recent years, Europe has begun to assert itself more proactively in the satellite mega constellation landscape, seeking to balance the influence of private and non-European systems with strategic autonomy, secure connectivity, and technological competitiveness. The two leading European initiatives in this domain are the IRIS² programme, headed by the European Union, and the OneWeb constellation, now operated under the Eutelsat Group.

OneWeb-Eutelsat is Europe's first operational LEO mega constellation. To date, OneWeb has deployed 648 satellites in low Earth orbit, completing the first-generation constellation as originally planned. The company now plans to replenish the current network with an additional 100 LEO satellites, which have been commissioned to Airbus Defence and Space. (Rainbow, December 17, 2024) As of now, OneWeb launches have been conducted using the Soyuz rocket, SpaceX's Falcon 9, and the LVM3 launcher operated by the Indian Space Research Organization (ISRO). This second generation satellites have the possibility to be compatible with the other mega constellation that the European Union is developing, **IRIS²**, that stands for *Infrastructure for Resilience, Interconnectivity and Security by Satellite*. Europe has committed to developing this constellation in order to reduce its dependency on non-European actors for strategic, military, and governmental communications. Unlike purely commercial systems such as Starlink or Amazon LEO, IRIS² is conceived as a hybrid constellation serving both public and private needs. (Diris, March 11th, 2025) The system will consist of 264 satellites in low Earth orbit (LEO), positioned at an altitude of approximately 1,200 km, and an additional 18 satellites in medium Earth orbit (MEO), at around 8,000 km. The project is being developed by Europe's two leading aerospace manufacturers, Airbus Defence and Space and Thales Alenia Space, under the supervision of the European Space Agency (ESA). With a projected total cost of €10.6 billion, including contributions from private partners, IRIS² will be operated from a central command center located in Italy. The constellation is expected to improve the digital sovereignty of Europe, provide secure governmental communications while offering resilient broadband access in underserved areas across Europe and Africa. (Reuters, December 16, 2024) Europe plans to start deploying the constellation in 2029, using the only medium-heavy lift launcher available within the European Union, Ariane 6. The company estimates that between 10 and 15 Ariane 6 launches will be required to deploy the entire constellation. (Parsonson, January 13, 2025)

1.2.4 China Mega-constellations

Across this changing global scenario, China is determined to not remain dependent on Western powers, especially due to the strategic role of satellite connectivity. As a result, different satellite mega constellations are being developed by China. However, the available literature remains poor, particularly regarding the technical details of these constellations and, consequentially, also regarding the number of launches required to deploy the full satellite networks in low Earth orbit (LEO).

The first major initiative is **Guowang**, China's state-led mega constellation. The Guowang project was initially started in April 2021, and it's managed by China SatNet. It aims to deploy approximately 13,000 satellites in LEO. For now, China has begun deploying its initial satellites using Long March 5B and Long March 8A launchers. Based on publicly available data, it is estimated that the number of Guowang satellites launched is growing slowly. (Jones, February 11, 2025). The second significant Chinese project is **Qianfan**, also known as **Spacesail**. This constellation is led by Shanghai Spacecom Satellite Technology (SSST) and is expected to have more than 14,000 LEO satellites. Also for Qianfan, detailed public information remains limited. However, as of now, 62 satellites have been launched, utilizing various configurations of the Long March launch vehicle family. (Press, June 05, 2024)

1.2.5 Launchers

Details about the cumulative number of launches needed to deploy all the mega constellations satellites are not revealed in the current literature.

1.2.6 Total market value

Determining a more accurate demand for satellite launches, it is possible to estimate a more precise market value, or rather an *order of magnitude*, of the satellite internet mega constellation sector. The current literature offers a variety of predictions and estimation. that are often diverging significantly, especially regarding projected values and Compound Annual Growth Rates (CAGR).

For instance, *Fortune Business Insights* estimates the market was valued at \$6.88 billion in 2024, with projections reaching \$8.09 billion in 2025 and \$25.67 billion by 2032, obtaining a **CAGR of 17.9%** over the forecast period. (Insight, 2025) Instead, *Research and Markets* forecasts a more aggressive growth trajectory, projecting the sector to grow from \$5.6 billion in 2024 to \$23.6 billion by 2029, corresponding to a **CAGR of 27.7%**. (Research & Markets, 2025) Moreover, *Roots Analysis* estimates an increase from \$7.30 billion in 2024 to \$54.81 billion by 2035 representing a **CAGR of 20.11%**. (Analysis, 2025)

It is possible that all these estimates differed from each other because of the different methodologies and assumptions used by the research bodies. In most cases, it is not entirely transparent which parameters are included in the calculation of total market

value. For example, some forecasts may or may not incorporate key components such as:

- Revenue from subscription and service sales
- User hardware and terminal sales
- Satellite manufacturing costs
- Ground infrastructure investments
- Launch costs
- Research and development (R&D) and system integration expenses

Without a standardized valuation model, these discrepancies complicate direct comparisons between the estimates.

On the other hand, companies have not disclosed the total investment they anticipate for fully deploying their constellation. An important estimate came in 2018, when Gwynne Shotwell, Chief Operating Officer of SpaceX, stated that deploying the first phase of the Starlink constellation, approximately 12,000 satellites, would require around \$10 billion, covering both manufacturing and launch costs. (Kelly, 2018) However, even if the first round of 12,000 satellites is not yet complete, it is possible that SpaceX has already spent more than that. This is particularly plausible considering that, from 2023, the company began launching a new generation of Starlink satellites (V2 Mini), which are larger, heavier, and presumably more costly to produce and deploy.

1.3 Research question

In this general scenario, this thesis aims to contribute with insights about the development and deployment of satellite mega constellations. The growth of this sector has been largely driven by two key factors:

1. The declining cost of launching payloads into orbit, enabled by the rise of reusable launch systems.
2. The strategic need for national sovereignty, as satellite infrastructure becomes increasingly vital for both economic development and security.

Since mega constellations are expected to represent a significant share of the total mass launched into orbit, they can be considered as a useful indicator for estimating overall launch demand in the space economy.(Joseph N. Pelton, 2020) Therefore, the primary objective of this research is to analyze and forecast the number of satellite launches that will be required in the coming years to support the deployment of these constellations. However,it's possible that the projected expansion of mega constellations may be slower than initially anticipated due to several emerging challenges:

- In urban and densely populated areas, satellite broadband may remain less competitive compared to other terrestrial alternatives.
- High subscription costs still limit accessibility in key markets.
- Increasing operational and maintenance demands, particularly on ground infrastructure—may raise long-term costs.

These factors may introduce uncertainty into projections of constellation growth, underlining the need to consider the following analysis as a study of the lower and upper bounds.

Research question: *Given current technological, economic, and strategic conditions, how many satellite launches will be required to deploy major planned mega constellations, and do revised projections confirm or challenge previous forecasts for the sector's growth?*

1.3.0.1 Theoretical framework

The analysis developed in this thesis builds upon a simple analytical framework linking constellation deployment and launch demand. In general terms, the number of launches required to deploy a satellite constellation depends on three main variables: the number of satellites to be placed in orbit, the average mass of each satellite, and the payload capacity of the launch vehicles used. As a result, launch demand can be understood as a function of both constellation scale and launch system capabilities. Larger constellations increase the total mass that must be delivered to orbit, thereby increasing the number of required launches. Conversely, improvements in launcher payload capacity, particularly through the introduction of next-generation heavy-lift and reusable launch systems, reduce the number of missions required to deploy a given number of satellites. This interaction between deployment scale and launcher performance constitutes the central mechanism analyzed in this thesis.

Based on this framework, it is possible to derive a set of theoretical expectations regarding the relationship between constellation expansion and launch demand.

1.3.0.2 Hypothesis

First, if constellation deployment plans expand significantly, the number of required launches should increase accordingly. Second, improvements in launcher payload capacity should reduce the number of missions required to place a given amount of mass into orbit. Finally, even with substantial improvements in launch vehicle performance, the large scale of planned mega constellations suggests that launch demand will remain structurally significant over the coming years. These expectations lead to the following hypotheses:

- H1: Launch demand increases significantly across different constellation deployment scenarios.

- H2: The adoption of next-generation heavy-lift launch vehicles reduces the number of launches required for constellation deployment.
- H3: Despite improvements in launcher capacity, structural launch demand remains substantial due to the large scale of planned mega constellations.

The scenario-based analysis developed in the following chapters is designed to test these hypotheses by evaluating how different deployment trajectories and launcher capacity assumptions affect the number of required launch missions.

1.4 Division of the thesis

This thesis is organized into 11 chapters, each of them contributing to a comprehensive analysis of the satellite mega-constellation market. Following a general introduction to the topic and the literature review, the methodology chapter outlines the forecasting approach and the assumptions and limitations underlying the analysis. An overview of the current landscape and the key actors involved is provided in chapters 4 to 7. Chapter 4 introduces the large satellite constellation market, presenting its evolution and strategic relevance. Chapter 5 focuses on American initiatives, while Chapter 6 discusses the European efforts. Chapter 7 explores instead the Chinese satellite strategy.

The empirical analysis begins in Chapter 8, where the number of satellites expected under different deployment scenarios is forecasted. Chapter 9 addresses the aggregation of launch demand and provides estimates for the number of launches required in each scenario. Chapter 10 evaluates the economic scale of LEO Mega Constellations by aggregating satellite manufacturing, launch costs, and service revenue estimates. Finally, the conclusion in Chapter 11 summarizes the main findings, discusses their implications for the future of the space economy, and suggests areas for further research.

Chapter 2

Methodology

This chapter aims to highlight the methodology that will be used in this research thesis, in particular in chapters 8 (Number of satellites in the possible different scenarios), 9 (Demand Aggregation and Launches forecast) and 10 (Total market value).

2.1 Analyzing the different scenarios

In the first of these three empirical chapters, different scenarios of satellite deployment are constructed for the period 2025–2035. This chapter wants to provide a structured framework in order to explore alternative trajectories for the expansion of Low Earth Orbit (LEO) megaconstellations, which will later serve as inputs for the launch demand analysis developed in Chapter 9.

Rather than relying on arbitrary percentage increases, the division of the various scenarios follows a data-driven logic, grounded in historical and industrial trends. Four distinct trajectories are identified:

- **Scenario 1 – Baseline (2025 reference):** It represents the current real conditions, corresponding to the observed rate of satellite deployment by major LEO broadband operators. It provides the benchmark against which all other scenarios are compared.
- **Scenario 2 – Steady growth:** It assumes a stabilized number of satellite deployed per year. In particular, the number of satellites is calculated as the average of the total number of satellites deployed between the 2019 and the 2025. This scenario reflects a launch activity that continues at a consistent pace without significant acceleration or decline.
- **Scenario 3 – Trend projection:** It extrapolates the historical average increase in the annual satellite launches observed between the 2019 and 2025, without assuming any structural discontinuity.
- **Scenario 4 – Full deployment:** It models an accelerated trajectory in which all major constellations are deployed, achieving full operational deployment

within the 2025–2035 decade. This specific scenario captures the upper bound of plausible expansion, consistent with the commitments already announced by operators.

In Chapter 9, these satellite deployment scenarios are converted into estimates of the number of required launches under different assumptions of payload capacity and launcher technology adoption.

2.2 Method for Estimating the Number of Launches

To estimate the number of launches required to deploy the projected number of satellites in each scenario, a proportional and capacity-adjusted methodology was applied. The approach builds upon the 2025 baseline, that defines the reference payload-to-launch ratio.

For each scenario described in Chapter 7, the number of required launches was derived by scaling this baseline proportionally to the total number of satellites forecasted and then adjusting for the evolving payload capacity of future launch systems. In the **second** of these empirical chapters, the number of satellites for each scenario will be analyzed. Based on this, and using appropriate approximations, the number of launches required will be determined. To estimate the number of launches needed, the *payload capacity* of various launch systems will be taken into account. Starting from the permissible payload mass and considering the average weight of the satellites, the number of satellites per launch will be estimated accordingly.

2.2.1 General Formula

For each operator and scenario, the total number of launches L was obtained as:

$$L = \left\lceil \frac{N_{\text{sat}}}{n_{\text{sat/launch}}} \right\rceil$$

where:

- N_{sat} = number of satellites allocated to the operator (derived from scenario-specific shares);
- $n_{\text{sat/launch}}$ = number of satellites per launch, computed as the integer floor of the payload-to-mass ratio:

$$n_{\text{sat/launch}} = \left\lfloor \frac{M_{\text{payload}}}{m_{\text{sat}}} \right\rfloor$$

with M_{payload} being the launcher’s LEO payload capacity and m_{sat} the average mass of the satellite model.

The final number of launches per operator was computed using the ceiling function to ensure integer launch counts.

2.2.2 Adoption Levels of Next-Generation Launchers

Two launcher adoption levels were considered:

- **Partial adoption:** A mixed-fleet scenario representing a transitional phase where new high-capacity vehicles (e.g., Starship, New Glenn, LM-9) are partially introduced alongside existing medium-lift launchers (e.g., Falcon 9, Ariane 6, Long March 5). This configuration reflects near-term industrial and geopolitical constraints, where some operators (e.g., Guowang, Qianfan) have no access to certain Western systems.
- **Full adoption:** A technical lower bound in which all launches are conducted with next-generation heavy-lift systems, representing maximum payload efficiency and universal access to reusable super-heavy vehicles.

The “partial” and “full” adoption cases thus bracket the realistic range of future operational capacity.

2.2.3 Interpretative Framework

Finally, each scenario must be interpreted as an indicative, not deterministic, forecast. The “partial adoption” results approximate a plausible near-term transition path, while the “full adoption” results define the technical minimum number of launches achievable under optimal global adoption of high-capacity reusable launchers.

2.3 Method to estimate the Economic footprint of LEO Mega Constellations

The third empirical step of this thesis provides an order of magnitude estimate of the economic scale associated with LEO mega-constellation deployment. The analysis does not aim to compute a firm valuation or profitability. Instead, it combines (i) infrastructure cost estimates, used to quantify the investment scale required to deploy constellation capacity, and (ii) revenue-based proxies, used to approximate the potential market size enabled by the resulting service infrastructure. Accordingly, the economic scale is interpreted as an indicator and is structured around three components:

1. **Satellite manufacturing costs (CAPEX):** estimated on a per constellation basis. When a cost range is available, a lower- and upper-bound estimate is estimated to reflect learning curve and scale uncertainties.

2. **Launch costs (CAPEX)**: computed from the total mass-to-orbit implied by each deployment scenario and an assumed cost-per-kilogram trajectory. Two cases are used in Chapter 10: *Case A* (current-capacity baseline) is computed for Scenarios 1–4 to provide a conservative upper-bound envelope; *Case B* (future-capacity lower bound) is computed only for Scenario 4 as a sensitivity benchmark that captures the effect of increasing launcher payload capacity and improved launch economics.
3. **Service value proxies** (market-size indicator): for commercial constellations, annual revenues are estimated by scaling a reference case (Starlink) through a satellite-capacity proxy (“value per satellite”). The analysis does not assume that satellites directly generate revenue. Instead, the number of satellites is used as a proxy for system capacity. Larger constellations can serve more users and provide higher throughput, so satellite count acts as an approximate indicator of the scale of services that the system can deliver. For institutional constellations, for which market revenues are not an appropriate metric, an equivalent service value is used, reflecting the economic value of secure connectivity services delivered under public procurement and strategic autonomy objectives.

Because the cost components represent cumulative deployment expenditure whereas the service component represents the maximum value generation achievable with constellations of these size, results are reported as ranges and discussed as an order-of-magnitude estimate of the sector’s economic potential rather than as a break-even assessment.

Table 2.1: Launch CAPEX across deployment scenarios

Scenario	Satellites deployed	CAPEX: Launch
Scenario 1	N_1	C_1^ℓ
Scenario 2	N_2	C_2^ℓ
Scenario 3	N_3	C_3^ℓ
Scenario 4	N_4	$[C_{4,A}^\ell, C_{4,B}^\ell]$

2.4 Assumptions & Limitations

This analysis is based on a series of assumptions intended to establish a consistent and realistic framework for forecasting satellite deployment, launch demand, and market value. First, it is assumed that the current constellation deployment plans announced by major operators, such as Starlink, Amazon LEO, OneWeb, and Guowang, will proceed as intended unless otherwise specified. No major cancellations, suspensions, or radical redefinitions of these projects are anticipated within the forecast horizon. Second, the mass and technical specifications of satellites are assumed to remain stable over the studied period, based on existing publicly available data. Any significant changes in satellite design or mass will only be incorporated into the analysis if already announced by operators. Third, two different scenarios are considered to study the the evolution of launch capacity: a conservative one, in which launch costs decrease

moderately over time, and a bullish one, where the cost is lowered in a significant way due to technological breakthroughs (e.g., full reusability of launch systems like SpaceX's Starship). Another key assumption relates to the revenue estimates: to estimate the potential revenue generation of other satellite constellations, Starlink's revenue is used as an indicator, while it is a fact that different constellations may have different business models and customer bases, this method can provide a practical basis for estimation. It is also assumed that there will be no major regulatory or legal changes that will drastically modify the possibility to deploy and operate satellite constellations during the forecast period. While space traffic management and debris mitigation efforts are evolving, no particular restrictions are anticipated that could severely constrain launch activity.

Finally, it is presumed a relatively stable global economic and geopolitical environment. The analysis does not account for disruptive events such as large scale conflicts or global financial crises that could severely impact the space industry or broader market dynamics.

Although the methodology is based on current industry data and plausible growth scenarios, it is subject to different limitations. First, the actual deployment path followed by the mega constellations may differ from the plans announced, due to financial challenges or technical issues. Second, the launch cost trajectories are still uncertain and dependent on the commercial success of next generation launch vehicles. Additionally, the market dynamics may be oversimplified by the assumption of service revenues scaled directly with the number of satellites per constellation. Factors such as competition and regulatory barriers could significantly affect actual revenue generation. Moreover, the analysis does not take into consideration a potential market saturation, the geopolitical tensions affecting access to space, or any stricter environmental regulations regarding orbital debris mitigation, all of which could impact the deployment feasibility. These limitations should be considered when interpreting the results about the future evolution of the satellite mega-constellation market.

Chapter 3

Large Satellite constellations

3.1 Introduction and definition

The thousands of satellites operated and launched in LEO orbit over the past decade have led to a profound transformation of the satellite sector. Unlike more traditional constellations, which were typically composed of a few dozen satellites dedicated to specific functions such as navigation or weather monitoring, mega constellations are characterized by their unprecedented scale and frequent deployment schedules.

The concept of a mega constellation itself is not entirely new. Earlier attempts like Iridium and Globalstar in the late 1990s tried to establish global mobile telephony through LEO satellite networks.(Evans, 2000) However, the system struggled commercially due to high costs and immature market readiness. Today's situation is much different; advancements in technologies like reusable launchers and satellite miniaturization could guide the mega constellations sector. Another key paradigm shift is represented by the transition from programs led by the governments to commercially driven networks, although the strategic role of these constellations continues to maintain strong government interest. It's important to underline that this sector is not only reshaping satellite manufacturing and launch services, but also redefining how governments, businesses, and individuals access information and communicate across the planet.

In fact,the success of satellite mega constellations responds to a series of global, technological, and strategic needs. One of the primary drivers is the persistent digital disparity around the world: billions of people, particularly in rural and/or remote regions, still lack reliable internet access. It is considered that one-third of the global population does not have an internet connection. Terrestrial infrastructure,like fiber-optic cables, is often logistically unfeasible in such areas.(Yuchen, 2025) For this purpose,mega constellations in low Earth orbit (LEO) offer a scalable solution, capable of delivering broadband connectivity even in the most remote locations.The resilience of the communication infrastructure is also reinforced by satellite mega constellations. In fact, in scenarios where ground based networks are damaged, whether due to natural disasters or conflicts, satellite networks can maintain essential connectivity.

Moreover, there is a geopolitical dimension that is becoming more and more important in the last years. Concerns over data sovereignty and privacy are forcing governments to invest in their own space based infrastructure. By controlling their own satellite networks, they can reduce their reliance on foreign-owned terrestrial (or even space-based) systems and maintain greater oversight over the digital infrastructure. Finally, the mega constellation sector responds to the increasing demand for real-time connectivity required by different sectors such as autonomous vehicles and Internet of Things (IoT). These applications depend on uninterrupted, high speed communication, further reinforcing the role of satellite networks as critical infrastructure in the digital era.

3.2 Key characteristics

Large satellite mega constellations are becoming more and more requested by a set of technological features that distinguish them from traditional space infrastructures.

- *Low Earth Orbit (LEO) Operations:* Most mega constellations operate in LEO, typically between 300 and 1,200 kilometers in altitude. This orbital region allows significantly lower latency compared to geostationary satellites, making these constellations perfect for real-time applications.
- *High Throughput and Global Coverage:* By deploying satellites in coordinated orbital planes, mega constellations can offer uninterrupted, global broadband coverage. Their distributed architecture allows for increased redundancy, ensuring service continuity even if individual satellites fail.
- *High Frequency of Launch and Replacement:* Mega constellations follow a continuous deployment model. With short lifespans, usually between 5 and 7 years per satellite, operators rely on frequent launches and fast replacement cycles. The use of reusable rockets has dramatically reduced launch costs, making this aggressive resupply strategy possible.
- *Mass Production and Standardization:* Satellites in these constellations are typically smaller than MEO/GEO satellites, and are produced using standardized manufacturing processes. This industrial approach allows for economies of scale, reduced per-unit costs, learning economies and faster production timelines, bringing satellite manufacturing closer to the model of consumer electronics. (Jessica, 2016)
- *Advanced Networking Capabilities:* Many modern mega constellations are integrating inter-satellite links (ISLs) using optical (laser-based) communication systems. This allows satellites to share data across space directly, reducing the dependence on ground infrastructure and enabling a faster and more secure data transmission across long distances.

- *Autonomous Operations and Collision Avoidance:* Given the large number of satellites involved, constellation management relies especially on autonomous control systems, in particular for routing and collision avoidance. These systems are critical to maintaining orbital safety and avoiding cascading debris scenarios such as the Kessler Syndrome.

3.3 Market drivers and technological enablers

3.3.1 Market drivers

As already stated, one of the most powerful market drivers is the increasing demand for broadband connectivity, accelerated by the digitization of services, cloud computing, and remote work. Mega constellations promise to help both developed markets, where network congestion and rural gaps persist, and regions under a developing process, where terrestrial networks are sparse or non-existent yet. The growing dependence on data intensive applications is another driver, including high-definition video streaming and real-time navigation, which require reliable, high-bandwidth and low-latency infrastructure. Satellite networks in LEO offer a way to expand capacity without the need of laying physical cables, especially critical in maritime and remote industrial contexts. Again, there is also a strong geopolitical and strategic motivation. Nations are increasingly viewing digital infrastructure as a primary matter for national security. This has led to public investment in regional constellations such as the EU's IRIS² and China's Guowang, aiming to secure sovereign communication capabilities and reduce dependence on non-national networks. In parallel, the commercial identity of space has opened new market opportunities. The rise of "NewSpace" actors, venture capital investment and public-private partnerships, has accelerated the pace of innovation and introduced commercial competition into a sector once dominated by state agencies.

3.3.2 Technological enablers

On the technological side, several advances have made mega constellations viable at large scale. Again, the first major enabler is the dramatic reduction in launch costs, driven by the advent of reusable rockets like SpaceX's Falcon 9. (McKinsey, 2025) Launching hundreds or thousands of satellite has become economically feasible, especially with vertically integrated players controlling both satellite production and launch services. Second, the standardization of satellite components has allowed for mass production. Modern LEO satellites are built using modular platforms, reducing manufacturing time and making rapid deployment possible.

Collectively, these developments have shifted satellite constellations from speculative concepts to operational realities, leading the way for a new era in global communication infrastructure.

3.4 Challenges and concerns

Even though mega constellations have the potential to revolutionize the sector, they also raise a set of challenges that could undermine their benefits if not personally addressed. These issues mainly concern technical viability, regulatory complexity, environmental sustainability and socio-political implications. A list of major challenges that this new technology has to overcome is presented:

- *Space Debris and Orbital congestion:* The most imminent concern is the risk of space debris and orbital congestion. With tens of thousands of satellites projected to be in orbit over the next decade, the probability of collisions rises sharply. (Reim, 2024) Each collision can generate thousands of debris fragments, which may endanger other satellites and trigger a cascading effect known as the **Kessler Syndrome**. Although operators claim to incorporate autonomous collision avoidance and end-of-life deorbiting mechanisms, actual compliance and oversight remain limited. (nasaspacenews, 2025) For reference, check figure 3.2.
- *Regulatory Fragmentation and Spectrum Allocation:* Mega constellations operate globally, but space regulation is largely national. In order to have a global overview of the allocation in the spectrum, the ITU is involved any time mega constellation providers have "to book" a slot in the radio frequency spectrum. Moreover, the limited availability of radio frequencies, especially in the Ka and Ku bands has led to disputes between operators and nations. Lastly, international coordination through bodies like the International Telecommunication Union is slow and often lags behind the speed of commercial deployments. (Chang, 2024)
- *Environmental Impact:* The environmental implications of mega constellations are twofold: first, the carbon footprint of frequent launches, and second, the impact of satellite re-entry. Although reusable rockets help reduce emissions, increased launch frequency offsets much of the gain. Additionally, the re-entry phase of satellites into Earth's atmosphere can release potentially damaging particles, such as aluminum oxides, which could affect the upper atmosphere, an area still under researched. (Zisk, 2023)
- *Astronomical Interference:* Astronomers have raised concerns over the increased brightness and density of LEO satellites, which interfere with ground-based observations with increasing frequency. Long exposure images are often ruined by satellite trails, undermining scientific efforts to monitor distant celestial bodies or detect near Earth asteroids. Some mitigation measures such as "darker" coatings, paintings or low-reflectivity designs have been proposed, but with limited effectiveness for now. (Pultarova, Last update 28 March 2025)
- *Digital Sovereignty and Ethical Concerns:* The rise of privately owned, globally operating satellite networks raises ethical and political concerns around digital

sovereignty. Who controls global internet access? Can states regulate content delivered via foreign satellite networks? Furthermore, the concentration of control in a few corporations (e.g., SpaceX, Amazon) risks creating quasi monopolies over the global internet backbone replicating existing inequalities on a planetary scale.

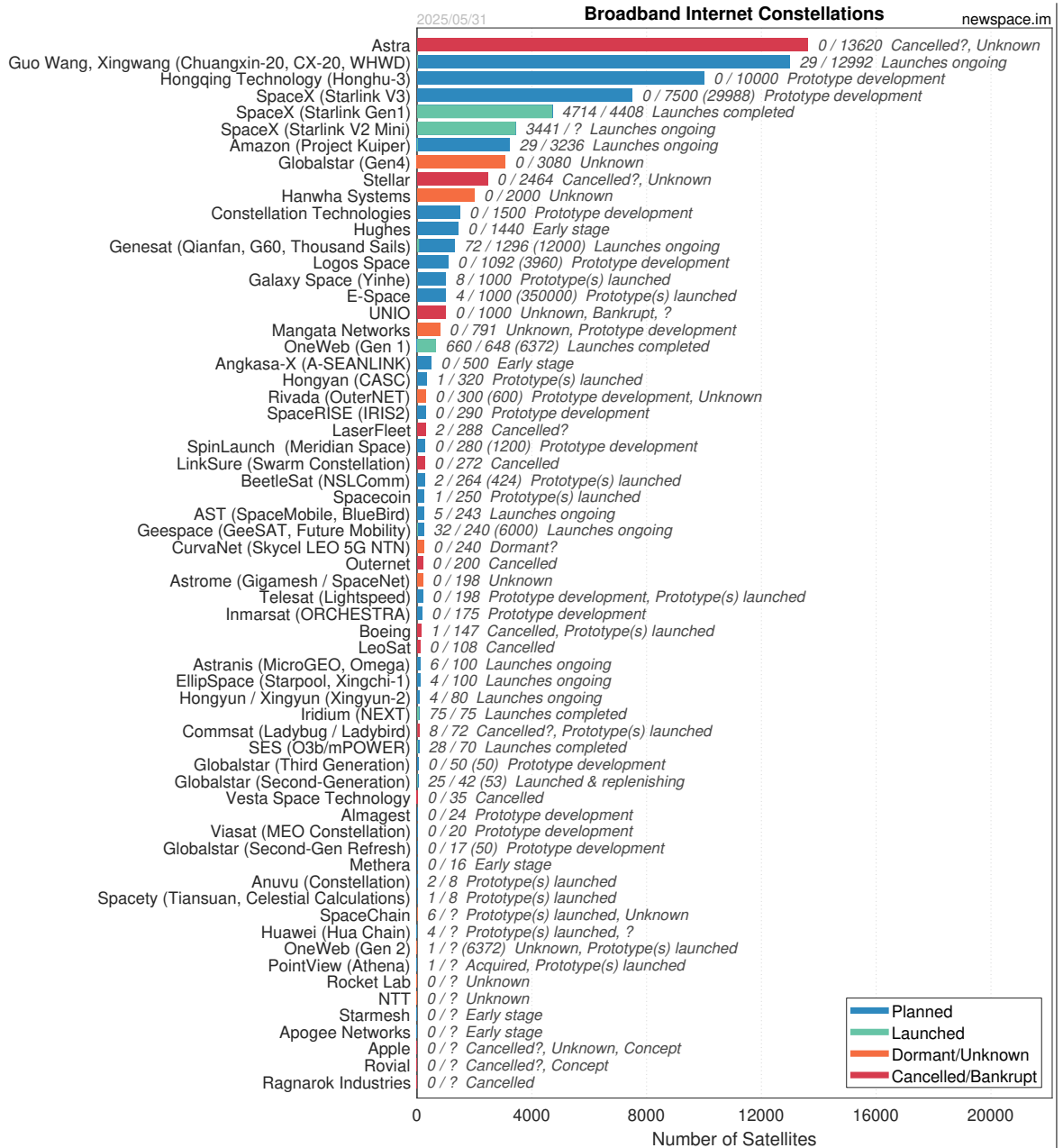


Figure 3.1: Broadband internet constellations. Credits: Newspace.im

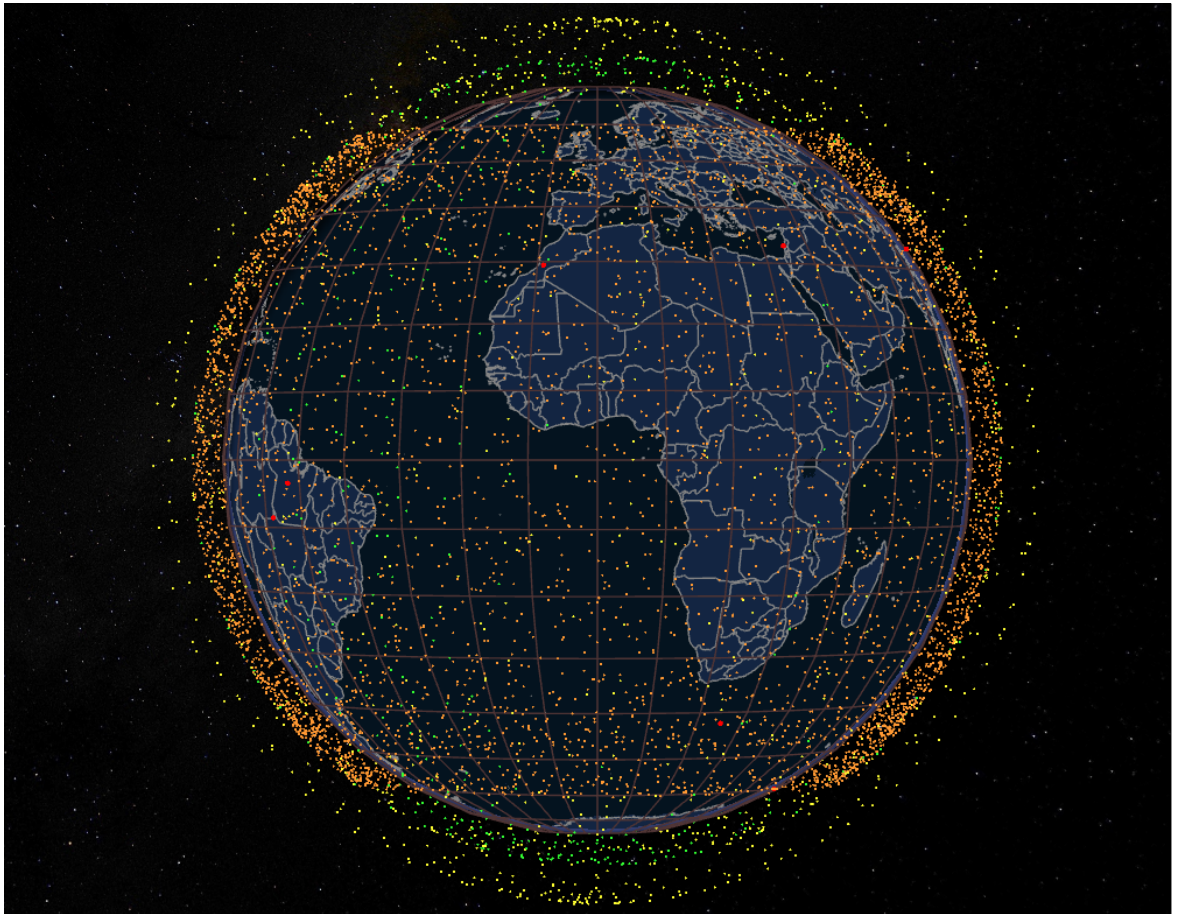


Figure 3.2: Rendering of LEO mega-constellation satellites orbiting the Earth

Chapter 4

The U.S. Commercial Approach

4.1 Starlink

Founded in 2002 by Elon Musk, SpaceX (Space Exploration Technologies Corp.) emerged with an important mission: make interplanetary travels possible, also by reducing the cost of access to space. In these years of activity, the company has reshaped the industry through the development of reusable launch systems like Falcon 9 and Falcon Heavy, and it continues to push the boundaries with its next generation launch vehicle, Starship.

Nevertheless, beyond its technical achievement, SpaceX faced a need to generate a stable recurring source of revenue that could support its long-term ambitions, in particular for the development of the Heavy launcher. Even if institutional and governmental contracts (especially with NASA) played an important role in SpaceX's early success, the company looked for a self-sustaining financial model.

This vision gave rise to Starlink, a satellite mega-constellation designed to provide high-speed, low-latency internet across the world, especially for under served and remote areas. (Manfredi, 2022) Starlink was announced in 2015, and it aimed to deploy tens of thousands of satellites in LEO in order to form a resilient communication network. The first operational batch of satellites was launched in May 2019 (O'Callaghan, 2019). By 2025, SpaceX has deployed more than 8,000 operational satellites, with approvals in place for up to 12,000, and additional applications filed to expand the constellation to more 40,000 units.

The constellation operates at altitudes of approximately 550 km, allowing for faster signal travel times compared to traditional geostationary systems, and it uses Ku- and Ka-band frequencies. More recent versions of Starlink satellites feature inter-satellite laser links, enabling data to be transferred directly between satellites without ground station intermediaries, an innovation that increases the coverage and latency performance, especially over oceans and polar regions.

Importantly, Starlink represents much more than just a commercial telecoms venture. In fact, for SpaceX, it serves as an internal economic engine: it is a product capable of generating substantial recurring revenue, in order to finance its space exploration goals. In recent years, Elon Musk has publicly emphasized that profits from Starlink

are intended to fund the Mars colonization program, reflecting an alignment between the near-term commercial opportunity with long-term existential ambition. (E. Gatti, 2025)

With the increasing global demand for broadband connectivity, especially in rural and developing regions, Starlink positions itself at the intersection between telecoms and space infrastructure creating a vertically integrated business model that supports both customer services and the company's internal strategic roadmap. Morgan Stanley have projected that Starlink could generate up to \$30 billion annually, even if for now the company seems to be behind this number. (Kan, 2025)

Beyond its commercial relevance, Starlink has emerged also as a critical strategic asset, especially where the terrestrial infrastructure is absent or under threat. By mid-2024, Starlink services were active in over 70 countries, spanning from advanced economies to conflict zones. One of the most notable examples is Starlink's role in the conflict in Ukraine, where the system was deployed shortly after the Russian invasion in 2022 to maintain secure communications for both civilians and military personnel. Provided initially through shipments coordinated by SpaceX and Western governments, Starlink terminals became vital for conflict operations and emergency response. However, this use raised questions about private control over military important infrastructure: Elon Musk and SpaceX intervened at times to restrict usage, such as limiting access near Crimea to avoid offensive strikes, leading to debates over who controls connectivity in conflict settings. (Talmazan, 2023)

In a broader geopolitical context, Starlink clearly represents a new form of infrastructure power: a specific power that is able to overcome national borders. This makes the constellation attractive for countries with fragile telecoms infrastructure or in need of redundant secure communication systems.

The dual-use nature of satellite megaconstellations, simultaneously commercial and strategic, is increasingly recognized by governments and defense agencies, shaping policy decisions on spectrum allocation, launch licensing, and industrial investment. As such, Starlink exemplifies how demand for launch capacity is no longer driven solely by commercial applications, but by strategic imperatives to secure orbital presence and digital autonomy.

4.2 Amazon LEO

Starlink idea was followed by Amazon's ambitious initiative to build a large scale satellite broadband network in LEO, in order to provide low-latency internet connectivity to under-served and remote regions across the globe. Announced publicly in 2019, the project depicts Amazon's official entry into the space sector, with the idea of complementing its existing cloud and infrastructure business.

The constellation aims to deploy up to 3,236 satellites, Amazon LEOSat-1 and Amazon LEOSat-2, successfully launched in October 2023 with the United Launch Alliance (ULA) Atlas V rocket. Full-scale deployment is expected to ramp up by 2026, with a service that will gradually expand as more orbital planes are popu-

lated.(Ginsberg, 2025)

Amazon LEO project has different motivations. On one hand, Amazon LEO is a natural extension of Amazon’s mission to reach customers everywhere; it represents a long-term infrastructure investment that aligns perfectly with the company’s core business, Amazon Web Services (AWS). Integrating global satellite connectivity with Amazon’s terrestrial cloud services could provide a harmonious backbone for IoT and edge computing in even the most isolated regions, improving the company’s global reach and capabilities.

As the rest of the mega constellations, Amazon LEO also serves a geopolitical function. By investing in an American-built, U.S.-licensed LEO network, Amazon is reinforcing the United States’ industrial and technological leadership in the orbital broadband sector, which has become increasingly strategic. Following the rapid rise of SpaceX’s Starlink and growing competition from international constellations, such as China’s Guowang, Amazon LEO represents an important effort to ensure that U.S. infrastructure remains dominant in orbit, not only in terms of quantity of satellites, but also in controlling key data pathways and setting standards for space governance. Amazon has committed over \$10 billion to the development of Amazon LEO, including building an advanced satellite production facility in Kirkland, Washington, and securing multiple launch contracts across different providers, including Blue Origin’s New Glenn and Arianespace’s Ariane 6. This diversified launch strategy reflects both logistical prudence and Amazon’s interest in shaping a resilient U.S. launch ecosystem, mitigating reliance on any single provider while bolstering American launch capacity.(AmazonStaff, 2024)

Overall, Project Amazon LEO is not just a commercial venture; it is a strategic instrument through which Amazon, and by extension, the United States, seeks to consolidate its presence in LEO, foster domestic aerospace innovation, and compete in a rapidly evolving global space race where satellite constellations are becoming critical infrastructure.

4.3 Meridian

In such competitive landscape, dominated by major initiatives already discussed, a third emerging player is emerging, SpinLaunch’s Meridian constellation, illustrating the growing diversity of use cases and business models in the LEO market.

Meridian is technically a mega constellation since it plans to deploy up to 1,200, but it is clearly mid-sized with respect to the competitors. As for the rest, the primary focus is low latency communications and Internet-of-Things (IoT) connectivity.(Kongsberg, 2025)

Unlike its competitors, Meridian is not designed to serve just consumer broadband directly. Instead, it targets industrial and governmental applications, such as logistics, smart infrastructure, remote sensing integration, and potentially defense and emergency communications. This narrower vertical focus could allow SpinLaunch to operate in lower competition segments, while leveraging partnerships in the fast-

growing IoT market.

Even if the constellation is being developed by SpinLaunch, mostly known for its experimental kinetic launch technology (in which payloads are accelerated via a ground-based centrifuge rather than a chemical rocket), Meridian satellites will not be launched initially via kinetic methods in their first deployment phases. Due to the current technical limitations of kinetic systems, especially payload constraints and velocity profiles unsuitable for orbital insertion, the Meridian constellation is expected to rely on traditional rocket launches in the short-to-medium term. (Berger, 2025)

SpinLaunch has attracted attention for its vision of sustainable, low-cost access to space, which will eventually benefit the expansion or replenishment phases of Meridian, once the technology matures and achieves orbital certification. In the meantime, the constellation will contribute to the growing demand for launch capacity, particularly for small- to medium-lift missions, adding pressure to an already crowded LEO environment.

Strategically, Meridian demonstrates two important dynamics:

- The fragmentation and specialization of the mega-constellation market beyond broadband
- The role of next-generation satellite operators in pushing the U.S. further ahead in orbital presence, including in segments adjacent to telecoms, such as data telemetry, smart cities, and edge networks

If successfully deployed, Meridian could establish a distinctive niche in the U.S. LEO ecosystem and act as a technological test for alternative launch methods.

Chapter 5

The European Institutional Response

While the USA and China are running ahead with thousands of satellites in orbit, Europe's response has been comparatively weak and late. With both IRIS² and Eutelsat-OneWeb, the European Union and the UK are trying to secure a strategic presence in LEO, for both connectivity and security.

5.1 Eutelsat–OneWeb

Among the European efforts to secure a presence in the LEO market, OneWeb represents an ambitious, but limited, attempt to compete with Starlink and the rest of the constellations.

Originally a U.S.-based startup launched in 2012, OneWeb aimed to deploy a global broadband constellation to connect remote areas worldwide. However, after filing for bankruptcy in early 2020, the company was rescued by the UK government, in joined forces with Bharti Global (India), through an intervention that acquired and restructured the company. (Amos, 2020) This move marked a significant strategic trigger, as the UK pursued to preserve sovereign capabilities in space after Brexit and to maintain a place in the fast-developing satellite communications sector.

Following its recovery, OneWeb restarted satellite deployment in collaboration with international partners. By 2023, it had launched over 600 satellites, nearing completion of its initial constellation of 648 LEO satellites. In a major consolidation move, OneWeb merged with Eutelsat, a French geostationary satellite operator, in a deal finalized in September 2023. (Wood, 2025) The newly formed entity, Eutelsat-OneWeb, is now headquartered in Paris, and it aims to combine GEO and LEO assets under one operational framework. This merger created the world's first major hybrid GEO–LEO satellite operator, designed to offer global connectivity with low latency, while leveraging existing GEO infrastructure for broadcasting applications. However, even if technologically advanced, the combined OneWeb-Eutelsat system remains modest in scale compared to the US and Chinese constellations, which are deploying thousands of satellites. Additionally, OneWeb satellites operate in polar orbits and

provide regional coverage rather than full global redundancy, limiting their role in high-demand defense or crisis response scenarios.(Intelligence, 2025)

From a strategic standpoint, the OneWeb case illustrates Europe’s slow reactive posture together with its growing awareness of the geopolitical importance of LEO constellations. The UK government maintains a “golden share” in the company, allowing it to veto decisions on national security ground, an indication of the project’s dual-use potential.(Nostro, 2020) Nevertheless, the constellation was not originally designed for secure government communications, in fact its capabilities in that domain are limited. Unlike Starlink, which has demonstrated its strategic value in conflict situations (e.g., Ukraine), OneWeb has not yet proven itself as an asset for defense resilience or sovereign digital autonomy.

In conclusion, Eutelsat–OneWeb represents a transitional model: a commercially driven platform now reoriented toward strategic relevance, but yet constrained by its initial design and scale. It serves as a stepping stone toward a more integrated European space policy, but it is not itself a sufficient answer to the proliferation of global mega-constellations.

5.2 IRIS²

In response to the growing strategic relevance of satellite constellations, the European Union launched the project IRIS² in 2022 as its first truly sovereign satellite initiative,with the explicit purpose to serve both civilian and governmental needs. Positioned as a cornerstone of Europe’s digital and geopolitical autonomy, IRIS² aims to provide secure and resilient satellite communication services, with a clear emphasis on space-based defense and crisis response capabilities. Supported by €2.4 billion in EU funding under the Multiannual Financial Framework 2021–2027, the project will therefore be developed through a public-private partnership model, complemented by private investments from key European aerospace players such as Airbus, Thales Alenia Space, Telespazion and OHB.(Commission, 2022b)

Unlike previous commercial projects such as OneWeb, IRIS² is designed with high military grade encryption and priority channels for government use, making it a critical component of the EU’s Secure Connectivity Programme. It also seeks to support the European Green Deal and digital inclusion goals by expanding broadband access in underserved regions, including remote rural areas and African partner countries. Operational deployment is planned to begin in 2027, with a multi-orbit architecture of 264 satellite, (LEO and GEO) similar to Eutelsat-OneWeb, likely to be implemented to optimize coverage and latency.(Commission, 2022a)

Despite its strategic ambitions, IRIS² faces significant challenges, including fragmented industrial coordination and tight timelines. While not designed to match the scales of Starlink or the Chinese constellations, IRIS²’s value lies in its strategic specificity: it is less about dominating the commercial broadband market and more about ensuring European digital sovereignty and operational autonomy in space, especially for conflict scenarios.

5.3 Limitations and Criticisms of the European Response

Despite recent efforts to enter the satellite constellation race, the European response seems to remain limited and delayed. European projects are in fact defined by a modest number of satellite and complex governance structures. (Intelligence, 2025)

The most visible limitation is the scale mismatch IRIS² is expected to deploy only a few hundred satellites by the end of the decade, while Eutelsat–OneWeb’s first generation constellation is capped at 648 satellites. In contrast, Starlink had over 8,000 satellites in orbit by mid-2025, with thousands more authorized for deployment. This difference is not only quantitative, but instead it has direct implications for network redundancy and capacity to support real-time military or crisis operations. In addition, Europe’s industrial and institutional fragmentation has delayed deployment timelines. While the IRIS² project was officially launched in 2022, actual satellite production and orbital operations are not expected to begin until 2027 or (more likely) later. Meanwhile, differing priorities between the European Commission, ESA, individual Member States, and private sector partners have raised concerns about inefficiency and diluted strategic focus. Unlike the U.S. model, where commercial giants like SpaceX act quickly under centralized regulatory frameworks, Europe must navigate multiple layers of public-private governance. (Lory, 2025)

Another major constraint is launch capability. With Ariane 6 still awaiting full operational ramp-up and Vega C still undergoing upgrades, Europe has become temporarily reliant on non-European launchers, including SpaceX’s Falcon 9, which has been used to deploy OneWeb satellites. This reliance undermines the EU’s ambition for strategic autonomy, especially in an increasingly polarized geopolitical environment where access to space may become a contested domain.

Lastly, while IRIS² and OneWeb aim to provide secure communications, only IRIS² is being designed explicitly with sovereignty and security in mind, including features such as segmented channels for military users.

In conclusion, the European response reflects a political and technological awakening, but not yet a transformation. The continent has made significant moves to reaffirm itself in the space domain, but without increased investment and faster implementation, it risks remaining dependent on foreign infrastructures in what is rapidly becoming a critical frontier of digital sovereignty.

Chapter 6

China's State-Led LEO Strategy

People's Republic of China has launched its own large scale initiative to secure orbital dominance and proof its global communication networks, as satellite mega-constellations become central instruments of digital power. The two most relevant projects among all are Guowang and Qianfan, which together express Beijing's dual pursuit of technological self reliance and strategic deterrence in space. While Guowang represents China's answer to Starlink in the broadband domain, Qianfan targets the Internet-of-Things (IoT) market through a high-density mesh of small and low-cost satellites. Both constellations reflect the Chinese state's ambition to reshape the orbital environment, aligning it with the national interest and industrial policy.

6.1 Guowang

China's flagship project for LEO satellite internet is the Guowang constellation, that literally means "National Network" In 2020, it was initially reported in the ITU filings, and was then backed by the State Council in 2021. Guowang aims to deploy over 13,000 LEO satellites, making it one of the largest satellite constellations ever proposed.

The program is coordinated by China SatNet, an enterprise owned by the state, created specifically to manage Guowang and the related space infrastructure, operating under the supervision of the *State-owned Assets Supervision and Administration Commission (SASAC)*. (Reuters, 2024) The Guowang constellation is conceived as a state-centric alternative to the commercial dominance of Starlink and Kuiper. It is designed not only to provide broadband access across mainland China, including underserved rural areas and border regions, but also to extend digital infrastructure to Belt and Road partner countries, thereby exporting Chinese standards and deepening Beijing's international influence. In this sense, Guowang serves as both a technological and a diplomatic asset.

Unlike Western constellations developed by private actors with commercial motivations, Guowang is centralized, government-directed, and tightly integrated into China's industrial and military planning. Several reports suggest it will rely on

dedicated launch services by CASC (China Aerospace Science and Technology Corporation), as well as secure payload architectures with potential dual-use capabilities. (Suess, 2023)

6.2 Qianfan

In addition to the Guowang broadband initiative, China is advancing another large-scale LEO constellation known as Qianfan, sometimes referred to in English sources as the “Thousand Sails” or Spacesail constellation. Officially initiated in 2024 and driven by Shanghai Spacecom Satellite Technology (SSST), a company backed by the Shanghai Municipal People’s Government and the Chinese Academy of Sciences, Qianfan aims to create a massive low-Earth orbit satellite network for internet connectivity and related services. The project plans for the constellation to eventually consist of more than 14,000 satellites, making it one of the largest planned LEO systems by any country. (Jones, 2024)

In August 2024, China launched the initial batch of Qianfan satellites, with subsequent launches in late 2024 and early 2025 contributing further spacecraft to the constellation. These deployments mark the beginning of operations for a system that analysts describe as China’s answer to non-Chinese LEO broadband projects such as Starlink and Amazon LEO. (Bela, 2026)

Although detailed technical and application-specific ambitions of Qianfan are not as widely documented in open sources as they are for some Western programs, state media and industry commentary frame the project as a strategic effort to broaden China’s presence in global satellite internet infrastructure. The scale of Qianfan’s planned deployment and its positioning within China’s broader space activities reflect the country’s goal of establishing a significant capability in next-generation satellite networks.

6.3 Implications

The coexistence of both Guowang and Qianfan, two constellations with more than 12,000 satellites each, signals a maturing sector and a Chinese approach at different levels, but with an unified long term goal. In fact, both constellations are deeply embedded in national policy: from the 14th Five-Year Plan to the Made in China 2025 initiative, satellite networks are increasingly portrayed as strategic infrastructure akin to ports, energy grids, and semiconductors. (Gatdula, 2025)

Importantly, this evolution marks an important change in the orbital landscape from commercial competition to geopolitical structuring. With Guowang and Qianfan, China seeks not only to ensure resilience and independence in space-based communications, but also to challenge Western digital dominance and offer alternative technological ecosystems to its partners abroad.

Despite limited public transparency and ongoing development hurdles, the enormous

scale, speed, and institutional backing of these initiatives indicate that China is positioning itself as a long-term contender in LEO, with significant implications for orbital traffic management and the militarization of space.

From Strategic Landscape to Empirical Scenarios

Chapter from 4 to 6 have detailed the industrial landscape of LEO mega-constellations, highlighting the different approaches adopted by the United States, Europe and China in terms of program objectives and funding mechanisms. While the qualitative context needed to understand this sector was provided in these chapters, they do not quantify by themselves how fast the orbital infrastructure may scale.

The remaining work of this thesis therefore shifts from a descriptive perspective to a scenario-based analysis. The objective is therefore to translate into quantitative deployment pathways, expressed as the number of satellites launched over time, the strategic dynamics discussed above. These deployment scenarios constitute the core input for the subsequent assessment of launch demand, industrial requirements, and the overall economic scale of the market.

Chapter 7

Deployment Scenarios

The forecast of satellite deployment between 2025 and 2035 is presented in this chapter, reflecting different assumptions about market dynamics and strategic execution. Each scenario explores a plausible trajectory based on current deployments, projected trends, and full scale ambitions of key actors in the satellite mega constellation domain.

The output of this chapter is a scenario-dependent estimate of the number of satellites deployed over time. The number of satellites analyzed are the ones to which the various constellations committed to until September 2025.

7.1 Scenario 1: Catastrophic scenario

In this first scenario, it is assumed that no additional satellites will be launched between 2026 and 2030. Only the satellites launched in 2025, or those already officially committed for launch within that year, are taken into account.¹

Considering this catastrophic scenario, and relying solely on official data, the estimated number of satellites launched in 2025 is approximately **1,751**.

The majority of these satellites belong to the Starlink megaconstellation, which plans to place around 1,400 satellites into orbit in 2025. This means that roughly 80% of all satellites launched in 2025 will be Starlink spacecraft. The remaining 20% is split between Amazon LEO and the Chinese Guowang and Qianfan constellations, since there are no official commitments for launches from other constellations such as IRIS², OneWeb, or Meridian. In this scenario, these 1,751 satellites represent the final deployed constellation, as no further launches are assumed to occur between 2026 and 2030.

Additional data can be found in Table 7.1.

¹All information regarding the number of satellites launched and the launch cadence was taken from *Nextspaceflight*, the *Wikipedia list of spaceflight launches in 2025*, and *Space.skyrocket*.

	Satellites for 2025	Percentage
Starlink	1401	80,01%
Amazon LEO	232	13,25%
IRIS ²	0	0
OneWeb	0	0
Guowang	46	2,63%
Qianfan	72	4,11%
Meridian	0	0
TOTAL	1751	100%

Table 7.1: Satellite Launch Data for 2025

7.2 Scenario 2: Current launch capacity projection

In this scenario, the number of satellites launched per year is assumed to remain approximately constant from 2025 to 2035. Based on historical data, **1800** satellites were launched in 2022, **2070**² in 2023, **2002**³ in 2024, and an estimated **1751**⁴ in 2025. Taking the average of these four years, we obtain an annual launch rate of approximately **1906 satellites**.

Assuming this trend continues consistently over the next decade, the total number of satellites launched from 2026 to 2035 would be approximately:

$$1,906 \times 10 = \mathbf{19,058 \text{ satellites}^5}$$

Although this is a significant number, it is still insufficient to fully meet the deployment goals of all planned mega constellations, highlighting the immense scale of these programs.

For this scenario, it possible to consider two different methodological approaches. The first possible approach is a trend-based projection, where the estimated 19,058 satellites launched between 2026 and 2035 are assumed to be deployed exclusively from operators already active in 2025, like Starlink, Amazon LEO, Guowang and Qianfan. This approach is strictly aligned with current market structure and avoid introducing additional assumptions about new actors, offering a consistent coherence with the launch patters observed in recent years. However, it excludes the likely emergence of new actors such as IRIS² and Eutelsat OneWeb, which already have funding commitments and development underway.

The second approach is a forward-looking projection, acknowledging that new constellations, particularly those backed by public institutions like the European Union, are expected to enter the market during this period. Under this view, 19,058 satellites

²Mainly Starlink and OneWeb

³Mainly Starlink

⁴This reduction is due to the suspension of OneWeb’s launch program and the slow market entry of other competitors

⁵Considering that no further firms will enter the market

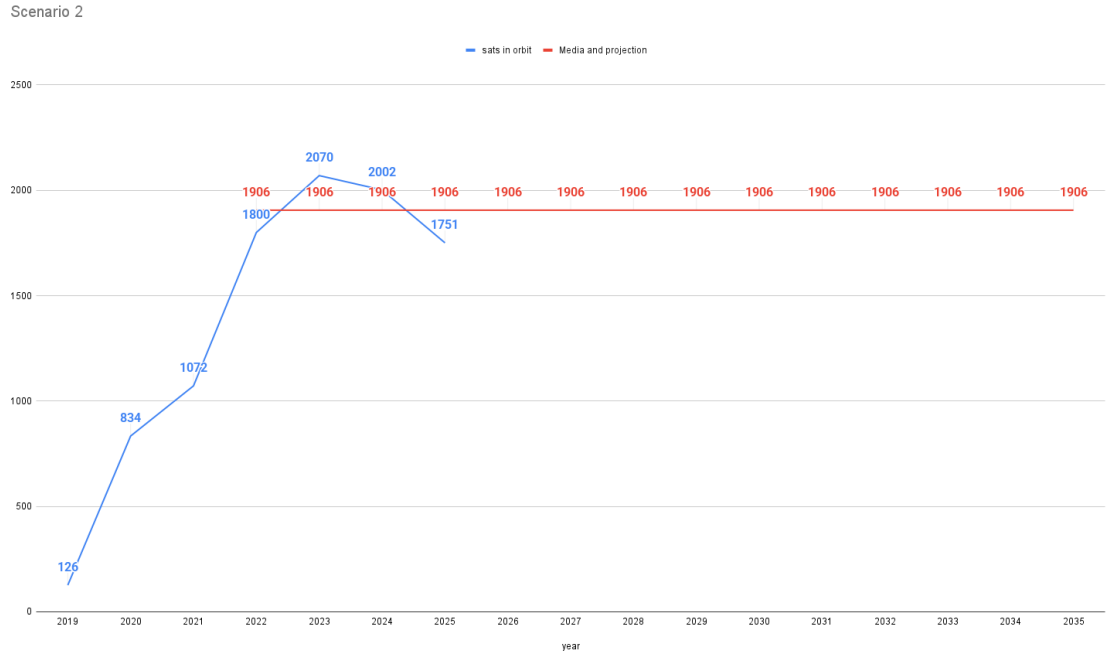


Figure 7.1: Satellites to be launched per year in scenario 2

likely underestimates actual future deployment as new entrants will add capacity beyond current growth averages. While this introduces more uncertainty, it reflects an evolving competitive and geopolitical landscape of satellite communications.

In this analysis, the first approach will be adopted for consistency, while the implications of the second will also be discussed where relevant.

Based on the historical launch dominance, it's assumed that a significant share, potentially over 75% of 19,058 satellites, will be deployed by the Starlink program, due to the established production and launch cadence. It can be assumed that the remaining satellites would be split between Amazon LEO and Chinese programs such as Guowang and Qianfan, with the marginal contribution divided between other minor operators. This distribution reflects current capabilities but may evolve depending on technological or regulatory changes.

Moreover, if the current annual launch rate is maintained like the current one, without significant acceleration in the deployment process, mainly all the planned constellations will face delays in achieving full operational capacity. This could also slow the commercial roll-out of satellite broadband services, limit redundancy and resilience for strategic communication networks, and especially reduce expected returns on public and private investments. Furthermore, this pace may not be sufficient to support rapid expansion in demand from emerging use cases, especially for governmental digital sovereignty initiatives, that can be fundamental in this chaotic geopolitical scenario.

7.3 Scenario 3: Current trend projection

In scenario 3, an increase in the number of satellites launched over the period between 2025 and 2035 is projected, based on the historical trend observed from 2019 to 2025. A linear projection was adopted, rather than just applying a multiplicative acceleration to the current launch rate. In particular, it was extrapolated from the average yearly growth in the number of satellites deployed into orbit over the past six years.

Between 2019 and 2025, an average of 271 more satellites were launched with respect to the previous year. By extending this growth trend to 2035, it is estimated that approximately **32,406 satellites** would be deployed during the period 2026–2035. The visual result of this projection can be seen in Figure 7.2 , adding 271 satellites annually to the 2025 baseline of 1,751 satellites launched.

This approach reflects a conservative, but data-driven, trajectory. This trend assumes that future satellite deployment will continue expanding, but without assuming exponential growth. It incorporates:

- The progressive expansion of current mega-constellations such as Starlink, Amazon LEO, and Guowang.
- The consistent institutional investment in public-private initiatives such as IRIS² and Guowang.
- A general increase in demand for LEO-based broadband services, especially in under-served regions.

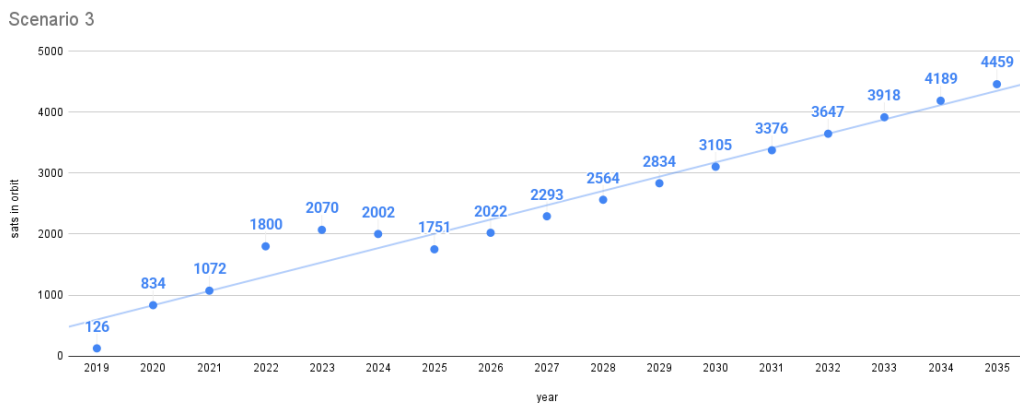


Figure 7.2: Satellites to be launched per year in scenario 3

Even if scenario 4 is presented later in this chapter, its satellite deployment projections are still used here as a benchmark in order to approximate a proportional number of satellites per operator under the moderate growth trajectory presented in scenario 3. Although scenario 3 presents a lower number of satellites launched with respect to scenario 4, it is in fact assumed that the launch responsibilities among companies remains coherent. In other words, major actors will maintain similar

strategic priorities and resource commitments even under a moderate expansion process.

	% launch share based on scenario 4	respective # of sats
STARLINK	51,34%	16,637
Amazon LEO	4,92%	1,596
IRIS ²	0,41%	131
ONEWEB	0,15%	50
GUOWANG	19,91%	6,451
QIANFAN	21,43%	6,944
MERIDIAN	1,84%	597

Table 7.2: Launch Share and Respective Number of Satellites

7.4 Scenario 4: Full deployment ambition

This last scenario assumes a maximum deployment trajectory, where all companies successfully launch the entire satellite constellation they have announced.

Such an outcome would require substantial scaling of satellite production and launch frequency. Table 7.3 below provides an overview of the number of satellites already in orbit, the total number planned, and the corresponding gap that would need to be covered between 2025 and 2035 to reach full deployment: This scenario reflects the

	# of today sats	# planned sats	# sats to be launched
STARLINK	8542	42,000	33,458
Amazon LEO	27	3236	3209
IRIS ²	0	264	264
ONEWEB	648	748	100
GUOWANG	18	12,992	12,974
QIANFAN	36	14,000	13,964
MERIDIAN	0	1200	1200
TOTAL	9271	74,440	65,196

Table 7.3: Satellite Deployment Overview

most optimistic outcome, where all planned satellite networks are completed on time and at scale. It also represents the upper bound of launch demand and space traffic implications across the forecast period. Based on the estimated 65,196 satellites still to be launched, the table 7.4 below provides the percentage share of satellites that each operator is expected to carry into orbit between 2025 and 2035:

As already stated, this breakdown highlights the dominant role of Starlink, which alone accounts for over half of the projected deployment activity. Instead, the Chinese programs Guowang and Qianfan represent together more than 40% of the total, emphasizing once again the central role that China plans to have in this sector.

	% sats carried to orbit
STARLINK	51.34%
Amazon LEO	4.92%
IRIS ²	0.41%
ONEWEB	0.15%
GUOWANG	19.91%
QIANFAN	21.43%
MERIDIAN	1,84%

Table 7.4: Percentage of Satellites Carried to Orbit

Emerging activities such as IRIS² and OneWeb, even if remaining relevant from a political point of view, play a smaller role in terms of final quantity of satellites deployed.

This full deployment scenario, which foresees the launch of approximately 65,196 satellites in 10 years, implies an unprecedented level of pressure on the global launch ecosystem. As of today, even under the more optimistic assumptions regarding increased payload capacity and reusability, this volume of launch cadence would require several hundred launches within a single decade. This complex topic will be developed in the next chapter.

A relevant note is that if deployment launches continue at the current pace, the objective of deploying the full number of satellites projected by the major constellations would only be achieved by 2041, as shown in figure 7.3. However, it is reasonable to expect that launch capacity will significantly increase in the coming years, especially due to the more frequent use of larger launch vehicles with higher payload capabilities and the emergence of new launch vehicles. As a result, this target could realistically be reached well before 2041.

7.5 Visual Comparison of Deployment Scenarios

In conclusion, the following figure provides a visual comparison of the total number of satellites expected to be launched under each of the scenarios analyzed. The difference in projected deployment volumes clearly illustrates the increasing intensity of satellite activity, ranging from a deployment shutdown in Scenario 1 to a full scale implementation of all planned constellations in Scenario 4.

This visual summary reinforces the core message: the trajectory of satellite deployment will largely depend on the extent to which launch capacity can be expanded and effectively utilized over the coming decade.

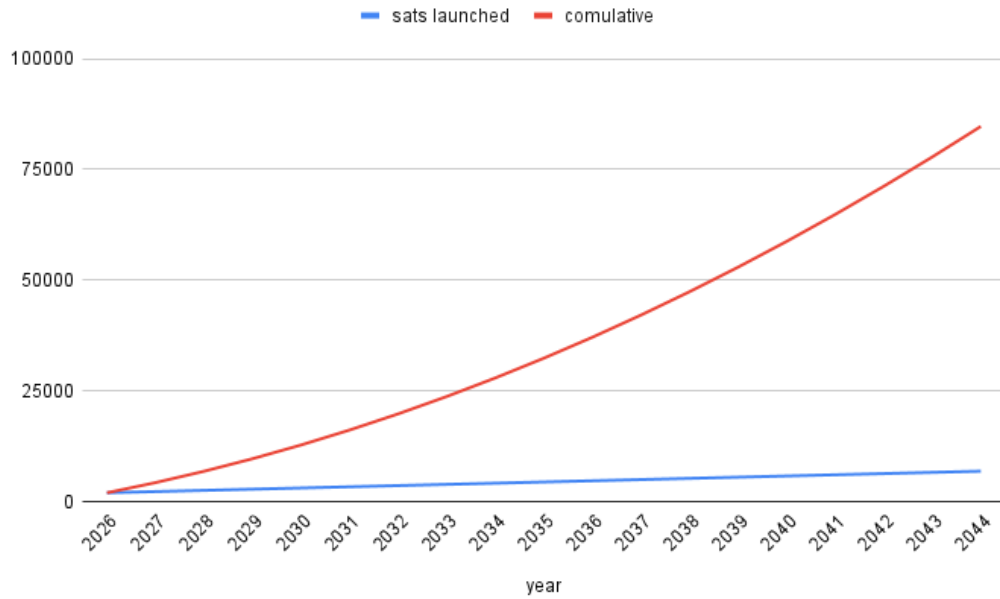


Figure 7.3: Annual and cumulative launches projected to reach target satellite deployment by 2041

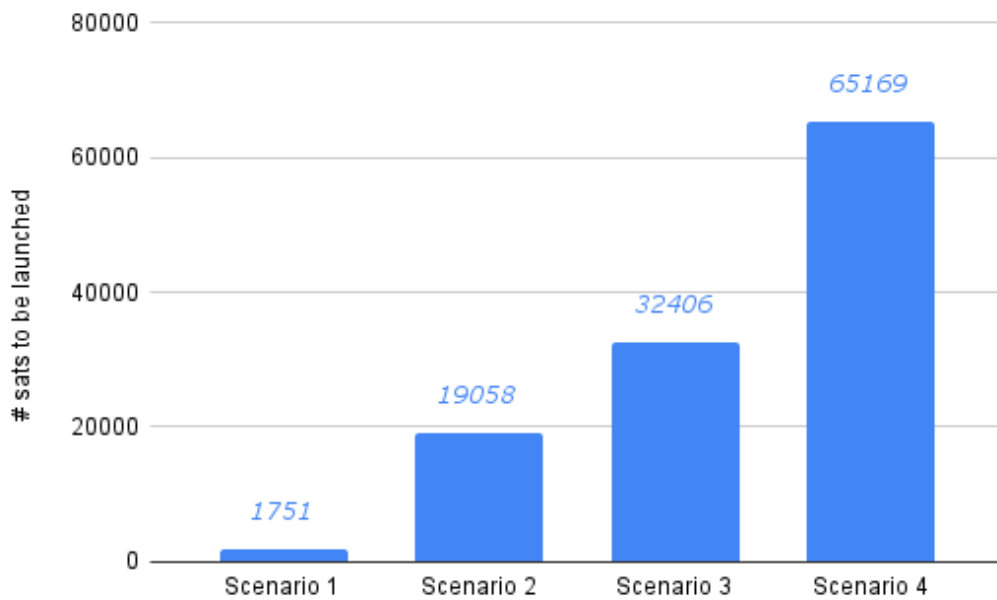


Figure 7.4: Comparison of satellites launched in each scenario

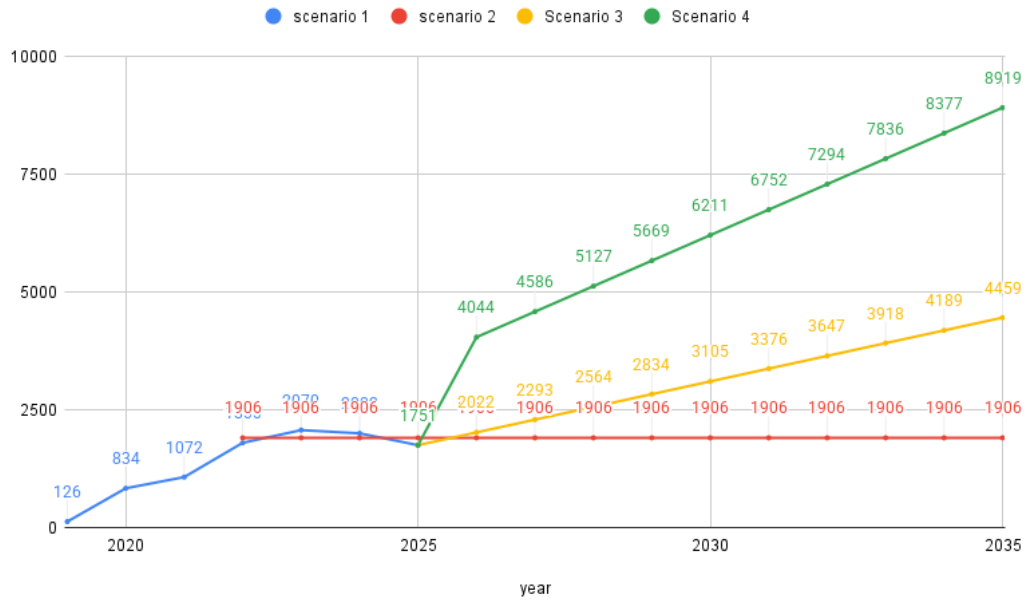


Figure 7.5: Comparison of satellites launched in each scenario, divided per year

Chapter 8

Introduction to Launchers

This chapter provides a comparative overview of the main orbital launch vehicles currently in service and those expected to enter operation in the coming years. The focus is on how their technical characteristics, particularly payload capacity, reusability, and launch cadence, affect the deployment of large satellite constellations. The primary reference is the Comparison of orbital launch systems table on Wikipedia, which classifies launchers as operational, in test, or planned, and provides essential data such as payload performance, propulsion type, reusability, and program status.(contributors, 2025)

8.1 Initial classification

Launch vehicles are generally classified according to their payload capacity to Low Earth Orbit (LEO):

- Small-lift launchers: typically delivering up to 2,000 kg to LEO.
- Medium-lift launchers: delivering between 2,000 kg and 20,000 kg to LEO.
- Heavy-lift launchers: capable of placing 20,000 kg to 50,000 kg into LEO.
- Super heavy-lift launchers: exceeding 50,000 kg to LEO.

The classification (Wikipedia contributors, 2025b) described is directly relevant to constellation design, since it directly impact the number of satellites that can be deployed per mission and the associated derived cost per kilogram.

Moreover,the different deployment strategies can play an important role in constellation deployment:

- Dedicated launches: In this type of launches, a single operator can use the full payload capacity of the vehicle to deploy its own satellites. In this way, the operator has complete control over the launch schedule and the orbital parameters, bearing the entire launch cost.
- Rideshare launches: In this deployment strategy, multiple customers share the available payload mass and fairing vole on a single mission. In this way,it's

possible to reduce the cost per satellite, but for less flexibility regarding orbital insertion.

- Piggyback payloads: smaller spacecrafts can be deployed as secondary payloads alongside a primary mission. The orbital flexibility of this type of mission is even more limited.

8.2 Operational launchers

The current market for LEO constellation launches relies on a few set of rockets with proven performance and flight legacy. Key systems include:

- United States:
 - SpaceX’s Falcon 9 Block 5 – partially reusable, payload 13–22.8 t to LEO, with over 130 launches in 2024.(Kurkowski, 2024) It has become the backbone of commercial constellation deployment, particularly Starlink, due to its high launch cadence and cost efficiency.
 - SpaceX’s Falcon Heavy – partially reusable, payload 30–63.8 t to LEO, with 11 launches completed by 2024. It is used for heavy cluster deployments or missions requiring higher energy orbits.
 - ULA’s Atlas V (551 and N22) – expendable, payload 13–18.9 t to LEO, with fewer than 20 launches remaining before retirement, serving high-value telecom and broadband missions.
- Europe:
 - Ariane 6 (A62 variant) – expendable, payload 10.9 t to LEO, with three launches as of 2025, gradually replacing Ariane 5 for medium- to heavy-lift missions.
- China
 - Long March 2C / 2D / 2F – expendable, payload 3.8–8.4 t to LEO, widely used for small satellite constellations, with up to 95 flights each.
 - Long March 3B/E – expendable, payload 11.5 t to LEO, 95 launches, supporting heavier telecom payloads.
 - Long March 5 / 5B – expendable, payload 23–25 t to LEO, <10 flights combined, intended as China’s main heavy-lift solution for LEO and GTO missions.
 - Long March 6A / 7 / 8A / 12 – expendable, payload 8–13.5 t to LEO, in low-rate early service, targeting commercial constellation deployments.
 - Gravity-1 (Orienspace) – expendable, payload 6 t to LEO, 1 launch to date, representing the emergence of small private launch vehicles.
- Russia:

- Soyuz 2.1a/2.1b – expendable, payload 7.8 t to LEO, with over 150 launches, making it a long-standing workhorse for telecom and Earth observation satellites.
- Angara A5 – expendable, payload 24.5 t to LEO, with three operational flights to date, designed as a modular replacement for Proton.

8.3 Launchers in development

Next-generation heavy and super-heavy launchers will redefine constellation deployment by enabling massive batch sizes and lower cost per kilogram. SpaceX’s Starship, a fully reusable system, targets capacities of up to 100–200 t (and even 400 t if expendable), introducing an unprecedented cost structure and launch cadence.

Blue Origin’s New Glenn and Rocket Lab’s Neutron plan to develop partially reusable solutions for the commercial constellation market, while China implements its own advanced systems, including the Long March 9, taht is projected to carry 150 t to LEO by 2033.

A set of additional vehicles, like the Ariane 6 A64 and several reusable Chinese designs, are expected to enter service in the next ten years, as summarized in table 8.2.

Collectively, these developments suggest a transition toward reusability, ultra-high payload capacity, and reduced costs, fundamentally changing deployment strategies for large scale constellations.

Rocket	Origin	Manufacturer	ton to LEO	Type	Orbital Launches	Latest flight
Falcon 9 - block 5	USA	SpaceX	13	Part. reusable	460	2025
Falcon 9 - block 5	USA	SpaceX	18.5	Part. reusable	460	2025
Falcon 9 - block 5	USA	SpaceX	22.8	Expendable	460	2025
Falcon Heavy	USA	SpaceX	30	Part. reusable	11	2024
Falcon Heavy	USA	SpaceX	63.8	Expendable	11	2024
Soyuz 2.1a- 2.1b	RUSSIA	RKTs Progress	7.78	Expendable	153	2025
Angara A5	RUSSIA	Khrunichev	24.5	Expendable	3	2025
Ariane 6 - A62	FRANCE	ArianeGroup	10.9	Expendable	3	2025
Atlas V - 551	USA	ULA	18.85	Expendable	16	2025
Atlas V - N22	USA	ULA	13	Expendable	3	2024
Gravity-1	CHINA	Orienspace	6	Expendable	1	2024
Long March 2C	CHINA	Calt	3.85	Expendable	74	2025
Long March 2D	CHINA	Calt	4	Expendable	95	2025
Long March 2F	CHINA	Calt	8.4	Expendable	25	2025
Long March 3A	CHINA	Calt	6	Expendable	27	2018
Long March 3B/E	CHINA	Calt	11.5	Expendable	95	2025
Long March 3C	CHINA	Calt	9.1	Expendable	19	2025
Long March 5	CHINA	Calt	25	Expendable	7	2024
Long March 5B	CHINA	Calt	23	Expendable	4	2022
Long March 6A	CHINA	Calt	8	Expendable	14	2025
Long March 7	CHINA	Calt	13.5	Expendable	9	2025
Long March 8A	CHINA	Calt	9.8	Expendable	2	2025
Long March 12	CHINA	Calt	10	Expendable	2	2025

Table 8.1: Current available rockets comparison

Upcoming rockets	Origin	Manufacturer	ton to LEO	Type	Planned flight
New Glenn	USA	Blue Origin	45	Part. reusable	2025
Starship Block 2	USA	SpaceX	100	Reusable	2025
Starship Block 3	USA	SpaceX	200	Reusable	TBD
Starship Block 3	USA	SpaceX	400	Expendable	TBD
SLS Block 1B	USA	NASA/Boeing	105	Expendable	2028
SLS Block 2	USA	NASA/Boeing	130	Expendable	2033
Neutron	USA/NEW ZELAND	Rocket Lab	13	Part. reusable	2025
Neutron	USA/NEW ZELAND	Rocket Lab	15	Expendable	2025
Terran R	USA	Relativity Space	23.5	Part. reusable	2026
Terran R	USA	Relativity Space	33.5	Expendable	2026
Vulcan Centaur VC0	USA	ULA	10.8	Expendable	TBD
Vulcan Centaur VC6	USA	ULA	27.2	Expendable	2025
Ariane 6 A64	FRANCE	ArianeGroup	21.9	Expendable	2025
Gravity 2	CHINA	OrienSpace	21.5	Part. Reusable	2025
Hyperbola 3	CHINA	i-Space	8.5	Part. Reusable	2025
Hyperbola 3	CHINA	i-Space	13	Expendable	2025
Long March 9	CHINA	Calt	150	Part. reusable	2033
Long March 10A	CHINA	Calt	14	Part. reusable	2026
Long March 10A	CHINA	Calt	18	Expendable	2026
Zhuque 3	CHINA	LandSpace	12.5	Part. reusable	2025
Zhuque 3	CHINA	LandSpace	18.3	Part. reusable	2025
Zhuque 3	CHINA	LandSpace	21	Expendable	2025

Table 8.2: New upcoming rockets

8.4 Conclusion

A structural change in the global launch ecosystem can be observed when the current and upcoming launchers ecosystem. Today’s operational rockets offer a constrained payload capacity, generally lower 20–25 tons to LEO, which limits the number of satellites that can be deployed per mission. In contrast, the next generation of vehicles, such as Starship and Long March 9, guarantee a substantial increase in capacity, exceeding 100 tons to orbit in some cases, combining this capacity with different levels of reusability.

This evolution implies that, while forecasts based on today’s launch systems suggest that a very high number of launches will be required to deploy planned mega-constellations, the actual demand for launches may be lower due to the higher average payload capacity of these new vehicles. In other words, fewer missions would be needed to place the same satellite mass into orbit, potentially reshaping the balance between launch frequency and cost efficiency.

Nevertheless, these projections remain conditional. The speed at which next-generation rockets will become operational, their reliability, and their effective cost structure are still uncertain. As a result, while the trend clearly points to an increase in average payload per launch, the impact on the aggregate number of required missions is not necessary straightforward. These aspects will be examined in detail in the following chapter, which focuses specifically on demand aggregation and launch forecasts under different deployment scenarios.

Chapter 9

Demand aggregation and launch forecast

This chapter aims to translate into the corresponding estimates of launch demand the satellite deployment scenarios outlined in Chapter 7. While the previous chapter focused primarily on the number of satellites expected under different possible growth trajectories, the next step is to determine how many launches will be required to deploy these satellites into orbit.

The number of launches depends not only on the total amount of satellites to be deployed, but also on the different payload capacity and availability of the launcher in the market. For this reason, this chapter will consider two parallel approaches. The first assumes that the current fleet of launchers, with its average payload capacity, remains the dominant option throughout the forecast horizon. The second accounts for the potential entry into service of next-generation vehicles, such as SpaceX's Starship, Blue Origin's New Glenn, or China's Long March 9, which promise significantly higher payload capacities and varying degrees of reusability. The methodology applied to derive these estimates follows the general framework introduced in Chapter 2, where the principles of proportional conversion from satellites to launches were presented. A further consideration concerns the economics of reusability. As highlighted in recent analyses, reusability is not equally viable at all scales. The fixed costs of developing and operating a reusable system are significantly higher than those of expendable rockets, which means that reusability only becomes economically sustainable when applied to very large vehicles. In other words, only launchers with very high payload capacities can amortize the additional costs of refurbishment and infrastructure over a sufficient mass to orbit, thus lowering the cost per kilogram. This explains why the current wave of next-generation rockets is not only larger but also designed from the outset with reusability in mind.

By comparing these two perspectives, constant capacity versus increased capacity with large reusable vehicles, this chapter seeks to highlight the extent to which

the evolution of the launcher ecosystem could alter the number of launches required under different deployment scenarios.

In practice, the analysis begins by establishing a baseline ratio between satellites launched and launches performed in 2025. This ratio is then used in each scenario to obtain the number of launches under the assumption of constant launcher capacity. In a second section, alternative estimates are provided in order to adjust this baseline in line with the increased capacity expected from new launchers.

The results will be presented separately for each deployment scenario, closing with a comparative analysis of the different results between the two capacity assumptions. Finally, the limitations of this approach will be considered.

9.1 Forecast under current payload capacity

Considering the first assumption, the global launcher fleet maintains its current average payload capacity throughout the forecast horizon. This means that the ratio between the number of satellites launched and the number of launches observed in 2025 can be applied directly to the scenarios outlined in Chapter 7. In other words, no improvement in payload performance is considered in this methodology, and no significant breakthrough in launcher technology.

The baseline ratio was calculated by comparing the number of satellites launched in 2025 with the corresponding number of launches related to mega constellations performed in the same year. This provides a conversion factor, satellites per launch, which is then used to estimate the total number of launches required to support each deployment scenario. Using this method, a conservative estimate of launch demand can be estimated highlighting the upper bound of the number of missions that would be needed if no technological improvement occurs.

Table 9.1 summarizes the results. Each scenario is reported with the number of satellites projected (as derived from Chapter 7) and the corresponding number of launches required under the assumption of current launcher capacity. The

Scenario	of satellites	Estimated launches
1	1,751	95
2	19,058	1034
3	32,406	1758
4	65,169	3517

Table 9.1: Results considering current payload capacity

results show a dramatic increase in the number of launches across all the different scenarios, reflecting the exponential growth in missions needed. This outcome depicts the structural challenge that the launch industry would need

if technological improvements are not realized. In particular, constellations such as Starlink or Guowang would require an unsustainable high number of launches, putting pressure especially on production capacity and ground infrastructure.

9.1.1 Scenario 1

As already stated, the first scenario is grounded in the deployment plan publicly available for 2025. In total, between the six constellations considered, 1,751 satellites are expected to be placed in orbit during the year. This deployment will be carried out through **95 launches**, as reported in the baseline dataset. Knowing the number of satellites and the respective number of launches, is it possible to derive the average number of satellites launched per mission. The ratio between satellites deployed and launches performed gives a value of approximately 18 satellites per launch.

An uneven distribution of launch demand is shown in the breakdown of launches by constellation. Starlink dominates with 1,401 satellites that will be deployed in 76 launches, corresponding to more than 80% of total missions. Amazon LEO follows with 232 satellites, deployed in 8 launches, while China's Guowang requires 9 launches for 46 satellites, reflecting a much lower satellites per launch ratio. Qianfan will deploy 72 satellites in 2 launches, representing a smaller contribution. Other actors remain negligible in this baseline year.

This baseline scenario demonstrates the limits of the current launcher fleet. Having an average of less than 20 satellite per mission, combined with the size of upcoming constellations, implies that the number of launches will escalate rapidly in the absence of higher-capacity vehicles.

Constellation	Satellites	Launches	Avg. sats per launch	Share of launches
Starlink	1,401	76	18	80%
Amazon LEO	232	8	29	8%
Guowang	46	9	5	9%
QianFan	72	2	36	2%
Other	-	-	-	-
Total	1,751	95	18	100%

Table 9.2: Launches needed for scenario 1 maintaining the current payload capacity

9.1.2 Scenario 2

The second scenario extends the baseline analysis by projecting the average constellation deployment observed in 2025 into the following decade. Based on the methodology introduced in Chapter 2 and applied in the previous section, the expected number of satellites to be launched annually between 2026 and 2035 amounts to approximately 1,906 units per year, for a cumulative total of

19,058 satellites over the period.

Applying the proportional conversion derived from 2025, where the observed ratio was around 18 satellites per launch, the forecast results in approximately 103 launches per year. Over the full decade, this corresponds to **1,034 launches**, to which the 95 launches of 2025 must be added, yielding a total of **1,129 launches** between 2025 and 2035.

The distribution of launches across constellations reflects the relative shares already established in 2025. Starlink continues to dominate, accounting for over 80% of the satellites to be deployed and therefore the majority of the launch demand, with more than 830 launches over the decade. Amazon LEO contributes with around 9 launches per year, while the Chinese constellation of Qianfan remain a smaller player, requiring 20 launches across the period.

This scenario confirms the strong growing trend in launch demand if current launcher capacity remains unchanged. Even under a this "current trend" assumption, where the number of satellites launched annually does not increase beyond the average of the previous years, the requirement for more than one hundred launches per year places pressure on global launch infrastructure. The dependence on medium capacity rockets translates into high launch frequencies that may strain manufacturing and ground logistics.

Constellation	Satellites (per year)	Launches (per year)	Launches (2026-2035)	Share of launches
Starlink	1,525	83	830	80%
Amazon LEO	253	9	90	8%
Guowang	50	10	100	9%
QinFan	78	2	20	2%
Other	-	-	-	-
Total	1,906	103	1,034	100%

Table 9.3: Launches needed for scenario 2 maintaining the current payload capacity

9.1.3 Scenario 3

In this scenario, the number of satellites to be launched between 2026 and 2035 is projected by extending the linear trend observed from 2019 to 2025. Over this six-year period, satellite deployment grew at an average rate of +271 satellites per year, starting from 126 satellites in 2019 and reaching 1,751 satellites in 2025. <if this growth is extended, the total number of satellites to be deployed until 2035 amounts to approximately 32,406.

Still considering an unchanged launcher capacity, the same proportional relationship derived from 2025 it's applied to this case. The result is that **1,758 launches** are estimated over the decade, before adding the 95 launches considered for 2025. The total number of launches required in the 2025–2035 period is therefore **1,853**.

Even under this moderate growth trajectory, the demand for launches more than doubles compared to the 2025 reference. The year-by-year distribution of launches presented in table 9.4, reflects the steady growth of the underlying

trend. Annual demand rises from 110 launches in 2026 to 242 launches in 2035, with an average of about 185 launches per year if the current capacity is maintained.

Year	Satellites	Launches
2025	1,751	95
2026	2,022	110
2027	2,293	124
2028	2,564	139
2029	2,834	154
2030	3,105	168
2031	3,376	183
2032	3,647	198
2033	3,918	213
2034	4,189	227
2035	4,459	242
Total	32,406	1,758

Table 9.4: Launches needed for scenario 3 maintaining the current payload capacity

9.1.4 Scenario 4

This last scenario assumes the complete deployment of all planned satellites, approximately 65,000 units, by 2035. Under current trends, with an incremental growth of 271 satellites per year, this target would not be achieved until 2041. In order to reach full deployment within the 2026–2035 timeframe, the number of satellites deployed each year must therefore be doubled compared with the trend projection of Scenario 3.

Applying the baseline conversion ratio derived from 2025 (18 satellites per launch), the total number of missions required to achieve full deployment by 2035 amounts to **3,517 launches** between 2026 and 2035. Including the 95 launches of 2025, the overall requirement for the period 2025–2035 rises to **3,612 launches**.

The resulting annual cadence is unprecedented. Launches would increase from nearly 219 missions in 2026 to 484 launches in 2035, considering several years surpassing 300/400 launches per year. This magnitude of activity represents more than a four times increase compared with scenario 1 and 2, and an order of magnitude higher than today’s global launch capacity dedicated to the mega constellation sector.

This scenario highlights the dramatic limitations of maintaining today’s launcher capacities when comes to the deployment of full constellations. Even under the assumption that the industry could scale up production and infrastructure to sustain nearly 500 launches per year, such a cadence would raise fundamental questions about logistical feasibility and orbital congestion. In conclusion, this

projection demonstrates that achieving full deployment by 2035 is incompatible with current launcher performance and underlines the strategic necessity of high-capacity reusable rockets.

Year	Satellites	Launches
2025	1,751	95
2026	4,044	219
2027	4,586	249
2028	5,127	278
2029	5,669	308
2030	6,211	337
2031	6,752	366
2032	7,294	396
2033	7,836	425
2034	8,377	455
2035	8,919	484
Total	65,169	3,612

Table 9.5: Launches needed for scenario 4 maintaining the current payload capacity

9.2 Forecast under future payload Capacity

The availability of new heavy-lift reusable launchers such as *Starship*, *New Glenn*, and *Long March 9* will significantly alter the relationship between satellite deployment and the number of launches required. To estimate the potential impact, the mass values of the satellites listed in Chapter 7 have been combined with launcher capacities derived from Table 8.2. The resulting forecasts compare the number of launches required under three cases: (i) current launcher capacity, (ii) a partial adoption mix in which operators gradually employ new vehicles alongside existing ones, and (iii) a full adoption case in which all satellites are assumed to fly on the highest-capacity launcher available to their operator. To illustrate sensitivity, two Starship capacities are considered: a conservative 100 t case and an optimistic 200 t case.

9.2.1 Inputs

The following satellite masses are assumed (values available online or conservative estimates where data are unavailable):

- Starlink V2mini: 730 kg
- Starlink V3: 1,900 kg (planned exclusively for Starship)
- Amazon LEO: 740 kg
- Qianfan: 300 kg
- Guowang: 800 kg (estimate - no official data)

- OneWeb: 150 kg
- IRIS²: 300 kg (estimate - no official data)
- Meridian: 70 kg

Operator launch shares are based on the distribution calculated in Chapter 7, specifically the one of the last scenario: Starlink (51.34%), Amazon LEO (4.92%), IRIS² (0.41%), OneWeb (0.15%), Guowang (19.91%), Qianfan (21.43%), Meridian (1.84%).

Scenario totals (number of satellites to be launched between 2026 and 2035) are also taken from Chapter 7: Scenario 2 (19,058), Scenario 3 (32,406), Scenario 4 (65,196). Scenario 1 corresponds to the 2025 baseline (1,751 satellites).

Launcher capacities are drawn from Table 8.2: Falcon 9 (22.8 t), New Glenn (45 t), Starship (100 t conservative, 200 t optimistic), Long March 5 (25 t), Long March 9 (150 t), Ariane 6 (21.9 t), Neutron (15 t), Terran R (23.5 t).

9.2.2 Specif Methodology

For each operator, the total satellites of a scenario were multiplied by its launch-share fraction to obtain satellites per operator. These were then mapped onto plausible launcher assignments:

- Starlink: split into 70% V2mini and 30% V3. In partial adoption, 50% of Starlink satellites fly on Starship and 50% on Falcon 9. In full adoption, all are on Starship.
- Amazon LEO: 40% on New Glenn, 60% on Falcon 9 in partial adoption ¹; 100% on New Glenn in full adoption.
- Guowang and Qianfan: 80% on Long March 5, 20% on Long March 9 in partial adoption; 100% on Long March 9 in full adoption.
- OneWeb: all on Falcon 9 in partial adoption; on Falcon 9 or large-capacity partner vehicles in full adoption.
- IRIS²: all on Ariane 6.
- Meridian: on Neutron or other small-medium vehicles.

Satellites per launch were computed as:

$$\text{satellites per launch} = \left\lfloor \frac{\text{launcher capacity [kg]}}{\text{satellite mass [kg]}} \right\rfloor,$$

and the number of launches as the ceiling of satellites divided by satellites per launch. This ceiling treatment reflects indivisibility of satellites and unused payload margin.

¹Percentuals taken from initial Amazon LEO distribution of Launches

9.2.2.1 Worked Example

Consider Starlink in Scenario 3 (16,637 satellites). Splitting into V2 (11,646) and V3 (4,991), with 50% assigned to Starship and 50% to Falcon 9:

- Starship (100 t) with V3: $\lfloor 100,000/1,900 \rfloor = 52$ satellites per flight. For 4,991 satellites, 96 launches are required.
- Starship (100 t) with V2: $\lfloor 100,000/730 \rfloor = 136$ satellites per flight.
- Falcon 9 (22.8 t) with V2: $\lfloor 22,800/730 \rfloor = 31$ satellites per flight.

The resulting launch counts are then summed to give the Starlink total in partial adoption. Equivalent calculations were performed for all operators and can be found in the appendix A.

9.2.2.2 Results

Tables 9.6 and 9.7 summarise the outcomes for both the conservative Starship (100 t) and optimistic Starship (200 t) assumptions.

Scenario	Total Satellites (2026–2035)	Current Capacity	Partial Adoption	Full Adoption
Scenario 1 (2025 baseline)	1,751	95	44	19
Scenario 2 (steady growth)	19,058	1,034	406	159
Scenario 3 (trend projection)	32,406	1,758	683	264
Scenario 4 (full deployment)	65,196	3,517	1,372	530

Table 9.6: Launch forecasts under current capacity, partial adoption, and full adoption with conservative Starship capacity (100 t).

Scenario	Total Satellites (2026–2035)	Partial Adoption (200 t)	Full Adoption (200 t)
Scenario 1 (2025 baseline)	1,751	40	14
Scenario 2 (steady growth)	19,058	370	105
Scenario 3 (trend projection)	32,406	623	173
Scenario 4 (full deployment)	65,196	1,249	345

Table 9.7: Launch forecasts under partial and full adoption with optimistic Starship capacity (200 t).

9.2.3 Discussion

The results confirm that new heavy-lift reusable vehicles dramatically reduce the number of launches required for constellation deployment. Even with conservative assumptions, the partial adoption case reduces launch demand by a factor of two to three compared to current capacity; the full adoption technical lower bound suggests reductions of up to fivefold. However, these estimates must be critically qualified:

1. **Cadence limits.** High per-flight capacity does not guarantee sufficient annual flight rates. A handful of Starship launches cannot substitute hundreds of Falcon 9 missions without massive production and infrastructure scaling.

2. **Orbital plane and dispenser constraints.** Large payload mass does not translate linearly into deployable satellites. Volume, dispenser mechanics, and the need to populate multiple orbital planes constrain realised satellites per flight.
3. **Political fragmentation.** Operators are unlikely to pool across national launchers (e.g., Chinese constellations will not use Starship).
4. **Risk concentration.** Very large launches increase the impact of single launch failures, discouraging operators from extreme consolidation.
5. **Market effects.** Even if launcher capacity increases, market structures and pricing strategies may limit the diffusion of cost benefits.

Therefore, the “full adoption” case should be interpreted as a *technical lower bound* rather than a realistic forecast. The partial adoption figures represent a more plausible medium-term trajectory, capturing both the benefits of new high-capacity vehicles and the constraints that prevent their universal uptake.

Tables 9.8,9.9 and 9.10 summarize the estimated number of orbital launches required under the four deployment scenarios, distinguishing between current launch vehicle payload capacity, partial or full adoption of next generation launch systems. The comparison highlights the strong sensitivity of launch demand to payload capacity assumptions.

Under current capacity constraints, so considering ~18 satellites per launch, the total number of launches reaches more than 3 600 launches in Scenario 4. This case is an upper bound estimate of launches demand. As payload capacity increases, the total number of launches decreases substantially. Partial adoption reduces aggregate launch demand by approximately 60% across scenarios, while full adoption yields an overall reduction of nearly an order of magnitude compared to the current capacity case.

Table 9.8: Number of launches considering current capacity

Current Capacity	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Starlink	76	827	924	1859
Amazon LEO	8	87	89	178
Guowang	9	98	358	721
Qianfan	2	22	386	776
IRIS ²	0	0	7	15
OneWeb	0	0	3	6
Meridian	0	0	33	67
TOTAL	95	1034	~ 1800	~ 3622

Table 9.9: Number of launches considering partial adoption of future payload capacity

Partial Adoption	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Starlink	29	357	390	785
Amazon LEO	7	68	43	87
Guowang	3	14	174	349
Qianfan	2	9	70	141
IRIS ²	0	0	2	4
OneWeb	0	0	1	1
Meridian	0	0	3	6
TOTAL	41	448	683	1373

Table 9.10: Number of launches considering full adoption of future payload capacity

Full Adoption	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Starlink	11	167	182	367
Amazon LEO	4	43	27	54
Guowang	1	3	35	70
Qianfan	1	2	14	28
IRIS ²	0	0	2	2
OneWeb	0	1	0	2
Meridian	0	0	3	3
TOTAL	17	215	264	526

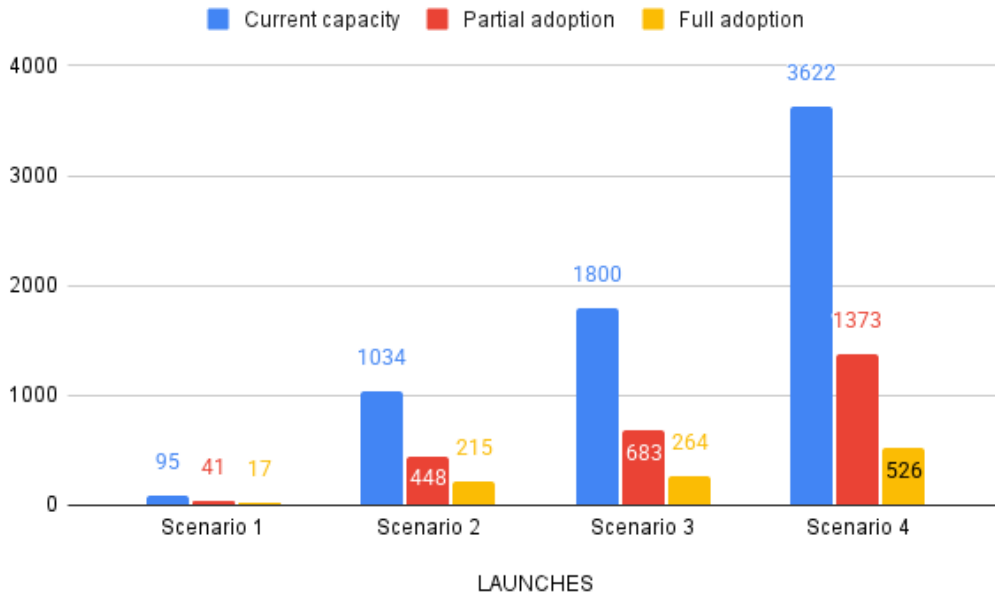


Figure 9.1: Comparison of launches needed in each capacity scenario considered

The results presented in this chapter provide support for the hypotheses introduced in the research framework. First, the analysis confirms H1, according to which launch demand increases significantly across different constellation deployment scenarios. The scenario-based projections show that the number of required launches grows sharply as the scale of constellation deployment expands.

Second, the results support H2, indicating that the adoption of next-generation heavy-lift launch vehicles can substantially reduce the number of missions required to deploy a given constellation. In particular, the comparison between current launch capacity and scenarios including high-capacity vehicles highlights the strong sensitivity of launch demand to payload capability.

Finally, the findings also support H3. Even under optimistic assumptions regarding the widespread adoption of high-capacity launch systems, the large scale of planned constellations implies that launch activity remains structurally significant. This suggests that improvements in launcher performance can reduce the number of missions required, but cannot eliminate the underlying demand generated by large-scale constellation deployment.

Chapter 10

Investment Scale and Revenue Potential of LEO Mega-Constellations

10.1 Deployment cost and Economic Potential of LEO Satellite Constellations

This chapter aims to provide an order of magnitude estimate of the economic potential of Low Earth Orbit satellite constellations by combining revenue based market sizing with an assessment of the investment scale required to deploy such systems. It does not aim to assess the profitability of LEO mega-constellations. A proper profitability assessment would require annualized capital costs, operating expenditures, replacement cycles, financing conditions, and discounted cash-flow considerations, all of which lie beyond the scope of this chapter. Since the available financial data across satellite operators is very limited, the analysis will adopt a simplified valuation framework.

The total revenues are primary used to estimate the market size of the relative sector, since it represents the standard metric used to quantify the economic dimension of a market. In parallel satellite manufacturing and launch costs are estimated to depict the magnitude of the capital investments required to place constellations into orbit. In particular, launch costs per kilogram are derived from the estimates provided in (Terzi & Nicoli, 2024), a working paper that provides detailed cost assessments for launch services. These costs are not included in the market size itself, but are used to estimate the overall economic scale of the sector.

To estimate the revenues, Starlink is used as a benchmark case, due to its advanced deployment status, constellation size and well documented pricing and subscriber base. The method choose to extrapolate the revenues based on the number of satellites and the number of clients, an hybrid scaling method is

adopted. In order to link these two quantities, a constant average revenue per user (ARPU) and a constant customer-to-satellite are considered and derived from Starlink.

The result of this analysis should not be interpreted as a forecast of the future market outcome, but as a theoretical upper bound of the economic potential of the LEO satellite constellation sector. In order to do so, a set of assumptions have to be taken into consideration, since they enable an appropriate analysis for this market valuation.

10.2 Key assumptions

10.2.1 Operational Efficiency Assumption

The first assumption considers that all satellite constellations will achieve operational, manufacturing and launch efficiency, comparable to the one of the Starlink system. Starlink is considered as the benchmark since it is widely regarded as the most cost-efficient LEO satellite operator, especially benefiting from vertical integration and reusable launch rockets.

Under this assumption:

- manufacturing unit costs per satellite are minimized
- launch costs per satellite are reduced
- High capacity utilization characterizes service provision

This assumption allows the analysis to focus on the economic potential of LEO constellations and to isolate firm level inefficiencies.

10.2.2 Absence of Market saturation and crowding-out effects

Secondly, the analysis does not assume any market saturation or crowding-out effects. Instead, total market revenues are assumed to scale linearly with the number of satellites deployed. As a result, an increase in constellation size brings to a proportional increase in the number of possible customers served, without inducing price reductions.

Formally, this implies that:

- the customer-to-satellite ratio remains constant overtime
- service prices (and ARPU) remain unchanged as capacity increases
- the additional supply is absorbed by the expansion of the demand

This assumption overestimate the revenues for very large constellation, but it enables a direct scaling of revenues and it is useful to provide an upper bound estimate of the market size.

10.2.3 Absence of competitive interactions

This assumption assumes no commercial competition among satellite operators. In this way, each constellation is potentially able to capture its own demand without facing pricing pressure from the competitors.

This assumption eliminates the need to model:

- price competition
- market segmentation
- or strategic interactions among operators

Although unrealistic in practice, this simplification is commonly adopted in first-order market assessments and allows the focus to remain on the aggregate economic potential rather than on competitive dynamics.

10.2.4 Revenue Scaling Assumption

Under this assumption, revenues are scaled using a hybrid methodology that links constellation capacity to economic output through the demand. In particular, it is assumed that:

- a fixed average capacity is provided for each satellite
- each satellite can serve a constant number of customers
- the average revenue per user (ARPU) is obtained from Starlink data

Total revenues are expressed as follows, considering the previous assumptions:

$$R = N_{\text{sat}} \times \left(\frac{N_{\text{customers}}}{N_{\text{sat}}} \right)_{\text{Starlink}} \times \text{ARPU}_{\text{Starlink}} \quad (10.1)$$

10.3 Cost Estimation

10.3.1 Satellite Manufacturing costs

One of the most significant expenses in the deployment of LEO constellations is the cost of satellite manufacturing. Since the available public financial data is very limited, manufacturing costs are estimated as a combination of industry benchmark and available technical papers.

For large-scale production programs, satellite unit costs are assumed to decrease over time as a result of economies of scale, learning effects, and production line standardization. Consequently, when appropriate, manufacturing costs are expressed as a range, where the upper bound represents early production units characterized by lower efficiency and higher non-recurring engineering costs, while the lower bound reflects mature, steady-state production conditions.

10.3.1.1 Cost Assumptions by Constellation

Satellite manufacturing cost estimates are derived primarily from publicly available industry analyses produced by specialized space-sector research organizations, notably *Quilty Space*, which provides comparative cost assessments for commercial LEO constellations, and from disclosed manufacturing contracts where available.

Starlink satellites are assumed to represent a best-in-class efficiency benchmark due to SpaceX's vertically integrated and highly standardized production process. Other constellations are assumed to achieve comparable efficiency levels over time, in line with the assumptions outlined before.

For Amazon LEO, Qianfan, and GuoWang, manufacturing cost ranges are derived from comparative megaconstellation cost models reported by Quilty Space and other strategic space-economics studies. The use of cost ranges explicitly accounts for the transition from early production batches to mature mass production enabled by learning effects and industrial scaling.

Manufacturing cost estimates for the Meridian constellation are based on a publicly disclosed production contract awarded to NanoAvionics, covering the serial production of several hundred satellites.

For IRIS², a sovereign and institutionally funded constellation, no official per-satellite manufacturing cost has been publicly disclosed. Unlike early proxy estimates based on total program budgets, this analysis assumes that IRIS² satellite manufacturing costs remain comparable to those of commercial LEO communication satellites and do not exceed 2 M£ per unit. This assumption reflects the adoption of standardized satellite platforms and avoids merging manufacturing costs with ground segment, research and development, or operational expenditures.

10.3.1.2 Estimated Manufacturing Costs

Table 10.1 summarizes the estimated unit manufacturing costs and total manufacturing expenditures for each constellation. All values refer exclusively to satellite manufacturing and exclude launch services, ground segment infrastructure, and operational costs.

10.3.1.3 Aggregate Manufacturing Cost

By aggregating the estimated manufacturing costs across all considered constellations, the total capital investment required for satellite production alone can be approximated as:

- a **lower-bound estimate** of approximately 56–57 B£,
- an **upper-bound estimate** of approximately 71–73 B£.

Table 10.1: Estimated satellite manufacturing costs by constellation

Constellation	Number of satellites	Unit cost (M€)	Total cost (M€)
Starlink v2	23,421	0.8	18,737
Starlink v3	10,037	1.2	12,044
Amazon LEO	3,236	1.5 – 2.0	4,854 – 6,472
Qianfan	14,000	0.5 – 1.0	7,000 – 14,000
GuoWang	12,992	1.0 – 1.5	12,992 – 19,488
OneWeb	100	1.0	100
IRIS ²	264	≤ 2.0	≤ 528
Meridian	1,200	0.4 – 0.5	480 – 600

The wide range reflects both uncertainty in cost data and the strong influence of production scale and learning effects. Nevertheless, even the lower-bound estimate highlights the unprecedented industrial scale associated with current and planned LEO megaconstellation deployments.

The results indicate that satellite manufacturing constitutes a highly capital-intensive component of LEO constellation deployment. Although unit costs have been dramatically reduced compared to traditional satellite programs, the large number of satellites required results in total manufacturing investments on the order of tens of billions of euros.

These results explain why only a limited number of actors, usually supported by strong institutional backing, can enter and sustain operations in this market.

10.3.2 Launch costs

10.3.2.1 Case Definition: Current-Capacity Baseline and Future-Capacity Lower Bound

In order to avoid an overly large set of scenarios, and keep the analysis easy to follow, launch costs are estimated under two different cases.

- **Case A:** Current launcher capacity (baseline)

This case is estimated for all four deployment scenarios developed in the previous chapters. Only the current launcher capacity is taken into consideration for the deployment of the constellations, considering the near term cost per kilogram trajectory. The main set of results will be provided for all scenarios, from 1 to 4.

- **Case B:** Future launcher capacity

Case B is computed only for scenario 4, which is the most sensitive scenario in term on launch deployment pathway. In this scenario, the future capacity cost per kilogram trajectory is considered, therefore providing a lower bound estimate of launch costs, capturing the potential impact of significantly improved launch economics. In order to keep the analysis compact, Case B is not repeated for Scenarios 1–3.

Under this structure, the launch cost envelope for Scenario 4 can be interpreted as:

- **Upper bound:** Scenario 4 under Case A (current capacity);
- **Lower bound:** Scenario 4 under Case B (future capacity).

Table 10.2: Launch cost estimation under current launcher capacity (Case A)-Scenario 1

Year	Total satellites	Total mass to orbit (kg)	Avg. cost (€/kg)	Total launch cost (M€)
2025	1751	1.255.130,00	3741	4.695.441.330,00

Table 10.3: Launch cost estimation under current launcher capacity (Case A)-Scenario 2

Year	Total satellites	Total mass to orbit (kg)	Avg. cost (€/kg)	Total launch cost (M€)
2025	1751	1.255.130,00	3741	4.695.441.330,00
2026	1906	1.365.650,00	3230	4.411.049.500,00
2027	1906	1.365.650,00	2785	3.812.894.800,00
2028	1906	1.365.650,00	2399	3.276.194.350,00
2029	1906	1.365.650,00	2064	2.818.701.600,00
2030	1906	1.365.650,00	1774	2.430.857.000,00
2031	1906	1.365.650,00	1523	2.081.250.600,00
2032	1906	1.365.650,00	1307	1.802.658.000,00
2033	1906	1.365.650,00	1121	1.541.818.850,00
2034	1906	1.365.650,00	961	1.345.165.250,00
2035	1906	1.365.650,00	823	1.178.555.950,00
TOT				29.394.587.230,00

Table 10.4: Launch cost estimation under current launcher capacity (Case A)-Scenario 3

Year	Total satellites	Total mass to orbit (kg)	Avg. cost (€/kg)	Total launch cost (M€)
2025	1751	1.255.130,00	3741	4.695.441.330,00
2026	2022	1.289.919,56	3239	4.166.440.170,73
2027	2293	1.462.709,87	2785	4.083.885.957,04
2028	2564	1.635.500,18	2399	3.923.564.937,82
2029	2834	1.808.290,50	2064	3.732.311.581,68
2030	3105	1.981.080,81	1774	3.526.323.837,35
2031	3376	2.153.871,12	1523	3.282.499.586,88
2032	3647	2.326.661,43	1307	3.071.193.090,90
2033	3918	2.499.451,75	1121	2.821.881.020,11
2034	4189	2.672.242,06	961	2.632.158.426,64
2035	4459	2.845.032,37	823	2.455.262.935,31
TOT				38.390.962.874,45

It should be noted that the lower-bound estimate is conditional on the realization of the assumed future cost-per-kilogram trajectory; therefore it should be interpreted as a sensitivity benchmark rather than a baseline forecast.

The comparison between Table 10.5 and Table 10.6 provides an interpretable launch-cost envelope for the most demanding deployment pathway (Scenario 4), where Case A represents a conservative upper bound and Case B represents a technology-enabled lower bound.

A non-monotonic trend emerges in the annual launch cost profiles for Scenarios 3 and 4. While the total mass delivered to orbit increases steadily over time, the rapid decline in the cost per kilogram eventually dominates the effect of rising deployment mass, leading to a reduction in total annual launch costs in

Table 10.5: Launch cost estimation under current launcher capacity (Case A)-Scenario 4

Year	Total satellites	Total mass to orbit (kg)	Avg. cost (€/kg)	Total launch cost (M€)
2025	1751	1.255.130,00	3741	4.695.441.330,00
2026	4044	2.580.063,81	3239	8.333.606.102,64
2027	4586	2.925.646,05	2785	8.168.403.757,79
2028	5127	3.271.228,28	2399	7.847.676.646,69
2029	5669	3.616.810,52	2064	7.465.096.907,96
2030	6211	3.962.392,75	1774	7.053.059.101,43
2031	6752	4.307.974,99	1523	6.565.353.884,45
2032	7294	4.653.557,23	1307	6.142.695.538,30
2033	7836	4.999.139,46	1121	5.644.028.452,79
2034	8377	5.344.721,70	961	5.264.550.872,88
2035	8919	5.690.303,93	823	4.910.732.295,51
TOT				72.090.644.890,42

Table 10.6: Lower-bound launch cost for Scenario 4 under future launcher capacity (Case B)

Year	Total satellites	Total mass to orbit (kg)	Avg. cost (€/kg)	Total launch cost (M€)
2025	1751	1.255.130,00	3344	4.567.684.092,40
2026	4044	2.580.063,81	2831	7.305.961.527,44
2027	4586	2.925.646,05	2393	7.001.422.063,34
2028	5127	3.271.228,28	2019	6.605.820.254,28
2029	5669	3.616.810,52	1701	6.154.708.373,45
2030	6211	3.962.392,75	1432	5.675.263.817,93
2031	6752	4.307.974,99	1204	5.187.805.645,89
2032	7294	4.653.557,23	1011	4.707.189.473,01
2033	7836	4.999.139,46	848	4.243.915.964,22
2034	8377	5.344.721,70	711	3.805.005.719,94
2035	8919	5.690.303,93	596	3.394.872.883,35
TOT				58.649.649.815,24

the later years of the analysis.

This behavior indicates the presence of a turning point beyond which improvements in launch economics outweigh the impact of increasing constellation scale. Beyond this point, additional satellite deployment becomes progressively less expensive in absolute terms, despite higher mass-to-orbit requirements.

Under the current-capacity baseline (Case A), Scenario 4 represents a conservative upper-bound estimate of cumulative launch costs over the full deployment horizon. Although annual launch costs decrease in later years due to declining cost-per-kilogram assumptions, the large mass deployed in the early and mid phases results in the highest total cumulative expenditure among all scenarios. The lower-bound estimate reported for Scenario 4 under Case B further amplifies this effect, as accelerated reductions in cost per kilogram shift the turning point earlier in the deployment timeline, leading to substantially lower cumulative launch expenditures despite identical mass-to-orbit requirements.

Overall, these results demonstrate that in high growth scenarios, the efficiency of launch economic can even outweigh the cost impact of increasing mass to orbit, not only mitigate it. These findings suggest that, with sustained reductions in launch cost per kilogram, constellation scale will no longer be a primary cost driver, but instead becomes a lever for economic efficiency.

10.4 Revenue Estimation

10.4.1 Starlink as a reference case

Starlink is taken as the reference case for revenue estimation because of its position as the LEO broadband constellation currently closer to near global scale. Unlike other systems, Starlink also provides publicly observable data on constellation size, number of subscribers, and pricing, enabling the extrapolation of a capacity-to-revenue relationship grounded into real data.

As of late 2025, Starlink operates approximately 9,400 active satellites and serves around 9 million subscribers worldwide. These current quantities yield an average ratio of approximately 1,000 users per satellite. (SkyLinker, 2026) This ratio is interpreted as an empirical estimation for the demand that can be supported by a single LEO broadband satellite under efficient operating conditions.

For revenue estimation, a normalized global Average Revenue Per User (ARPU) of 1,200 USD per year is adopted. (Smith, 2024) This value is representative of a mature LEO constellation market and avoids overestimating revenues based on regional price disparities and/or non recurring revenue components.

The reference annual revenue per satellite implied by the Starlink benchmark can therefore be expressed as:

$$R_{\text{sat}}^{\text{ref}} = \left(\frac{N_{\text{users}}}{N_{\text{sat}}} \right)_{\text{Starlink}} \times \text{ARPU}_{\text{Starlink}} \approx 1,000 \times 1,200 = 1.2 \text{ MUSD/year.} \quad (10.2)$$

This value will be used as the baseline scaling factor, in order to estimate revenues for other commercial LEO constellations.

10.4.2 Revenue Estimation for Commercial Constellations

Revenue estimation for commercial LEO constellations is performed by scaling the Starlink reference case according to the final planned constellation size of each system. For each constellation, revenues are assumed to scale linearly with the number of satellites deployed, consistent with the assumptions of no market saturation, no crowding-out effects, and comparable operational efficiency across operators.

The final planned constellation size is adopted rather than intermediate deployment states, as this analysis aims to estimate market size under steady-state conditions in which the full technical capacity of each system is deployed and utilized.

For a generic commercial constellation i , annual revenues are estimated as:

$$R_i = N_{\text{sat},i} \times R_{\text{sat}}^{\text{ref}}, \quad (10.3)$$

where $N_{\text{sat},i}$ is the final number of satellites in constellation i , and $R_{\text{sat}}^{\text{ref}}$ is the reference revenue per satellite derived from the Starlink benchmark.

Table 10.7 summarizes the resulting revenue estimates for the commercial constellations considered in this study.

Table 10.7: Estimated annual revenues for commercial LEO constellations

Constellation	Final satellites	Revenue per satellite (MUSD/year)	Final annual revenue (BUSD/year)
Starlink	42,000	1.2	50.4
Amazon LEO	3,236	1.2	3.88
OneWeb	748	1.2	0.90
Qianfan	14,000	1.2	16.80
Meridian	1,200	1.2	1.44

These estimates represent order-of-magnitude approximations of annual market revenues under idealized steady-state conditions, so it's suggested to consider them as an indicative measures of market size rather than forecasts of realized revenues for individual operators.

10.4.3 Equivalent Service Value for Institutional Constellations

Institutional constellations such as *IRIS²* and *Guo Wang* are not designed to compete in the consumer market as commercial LEO broadband constellations, so they do not generate revenues through user subscriptions. Instead, these systems are primarily developed through public budgets and institutional contracts, with the objective of providing secure and sovereign communication services.

For this reason, revenues for institutional constellations cannot be interpreted as market transactions. Instead, in this analysis the concept of *equivalent service value* will be adopted, defined as the respective monetary value of the services provided.

Under this interpretation, the economic value of institutional constellations is taken from the corresponding worth of the communication capacity they provide, rather than by observable cash flows. To maintain methodological consistency with the commercial revenue estimation, the equivalent service value is also assumed to scale linearly with the number of satellites deployed.

Accordingly, the annual equivalent service value for an institutional constellation j is expressed as:

$$V_j = N_{\text{sat},j} \times R_{\text{sat}}^{\text{ref}}, \quad (10.4)$$

where $N_{\text{sat},j}$ is the final number of satellites in constellation j , and $R_{\text{sat}}^{\text{ref}}$ is the reference per satellite value derived from the Starlink benchmark, as before.

This approach provides a consistent order of magnitude estimate of economic value, while not considering a commercial revenue comparable to private operators.

Table 10.8 summarizes the resulting equivalent service value estimates.

Table 10.8: Estimated annual equivalent service value for institutional LEO constellations

Constellation	Final satellites	Value per satellite (MUSD/year)	Equivalent value (BUSD/year)
IRIS ²	264	1.2	0.317
GuoWang	12992	1.2	15.59

10.5 Discussion of the results

This chapter aimed to provide an order-of-magnitude of the economic potential of large LEO satellite constellations by jointly considering satellite manufacturing costs, launch costs, and the value of services delivered. The analysis was designed to quantify the scale of investments and economic activity associated with mega-constellation deployment under an internally consistent set of assumptions.

10.5.0.1 Cost structure and investment scale

The cost estimation results show the important capital intensity of LEO mega-constellations. Across the constellations considered, total satellite manufacturing costs are estimated to lie in the range of approximately **50–70 BUSD**, reflecting the combined effect of large constellation sizes and mass-production unit costs below traditional satellite program levels.

Launch costs represent a similarly significant component of total investment. Under the current capacity baseline (Case A), cumulative launch expenditures for the most intensive deployment pathway (Scenario 4) are estimated to reach the order of **72 BUSD**, defining a conservative upper bound for deployment costs. Under future capacity launchers assumptions (Case B), the same deployment pathway yields cumulative launch costs closer to **58 BUSD**, establishing a technology enabled lower bound.

Taken together, satellite manufacturing and launch costs imply that the upfront investment required to deploy global LEO mega-constellations plausibly lies in the range of **100–140 BUSD**, depending especially on launcher availability and cost-per-kilogram trajectories.

Importantly, the analysis shows that launch costs do not scale monotonically with deployment intensity. In high-growth scenarios, declining cost-per-kilogram trajectories eventually dominate increasing mass-to-orbit requirements, resulting in a non monotonic annual cost trajectory. This dynamic underscores the central role of launch economics in shaping long-term deployment feasibility.

10.5.0.2 Revenue and service value interpretation

On the value side, annual revenues for commercial constellations were estimated by scaling a reference revenue-per-satellite derived from Starlink, while institu-

tional systems were evaluated using an equivalent service value metric. Under steady-state conditions, the maximum aggregate annual revenues generated by commercial LEO constellations are estimated to be on the order of **70–75 BUSD per year**, with the largest contribution arising from high-capacity broadband systems.

Institutional constellations such as IRIS² and GuoWang, while not generating market revenues, contribute a comparable order of economic value through the provision of secure and resilient communication services.

When interpreted as equivalent service value, these systems add several additional billions of USD per year to the overall economic scale of the LEO ecosystem.

Table 10.9 presents a cost and revenue breakdown for the LEO mega-constellation ecosystem under the modeling assumptions introduced in this chapter. Manufacturing and launch costs are reported as ranges to reflect uncertainty in production learning effects and in the evolution of launch vehicle capacity and pricing. In particular, the lower bound launch cost assumes the gradual adoption of next generation high-capacity launchers, while the higher bound case reflects a conservative trajectory based on current launch system performance. Across both bounds, the results highlight the capital intensive nature of large constellations deployment. Manufacturing and launch costs are of comparable magnitude, accounting together for more than two-thirds of the total economic value. It is important to note that manufacturing and launch costs represents one-time expenditures, while the revenues reported here are annual. Specifically, they correspond to the year in which the constellation is fully deployed. Overall, the results show that LEO mega-constellations require very large upfront infrastructure investments, but they also point to substantial annual service value once full deployment is achieved. The chapter therefore highlights the scale of the economic system involved, rather than demonstrating whether individual constellations are already profitable.

Table 10.9: Economic footprint breakdown

	Billion \$	
	Lower bound	Higher bound
Manufacturing cost	57	73
Launch cost	59 ^a	72 ^b
Annual estimated Revenues	72	90

^a Considering launchers with increasing capacity – next gen launch price trajectory

^b Considering no increasing capacity – current launch cost trajectory

Chapter 11

Conclusions

This thesis has investigated the development of satellite mega constellations with a specific focus on launch demand and strategic implications. While the rapid increase in the number of planned satellites is often presented as the main feature of this phenomenon, the analysis conducted in this work suggests that the most decisive factor shaping the future of mega constellations is not their overall scale, but the availability and capacity of launch systems.

A central outcome of the scenario-based analysis is the strong sensitivity of launch demand to launcher payload capacity and adoption of next-generation vehicles. For a given constellation architecture, the number of required launch missions varies by orders of magnitude depending on whether current launch capabilities or high capacity next-generation launchers are employed. This result shifts the usual interpretation of mega constellations: rather than being driven solely by downstream demand for broadband connectivity, their feasibility and pace of deployment are fundamentally constrained by upstream industrial capabilities. In this sense, mega constellations emerge as a derivative of the launch sector's industrial trajectory rather than as an independent market development.

From an economic perspective, the thesis highlights a counterintuitive dynamic. Beyond a certain threshold, increasing scale does not necessarily lead to higher total system costs. Instead, improvements in reusability launcher performance and cost per kilogram can offset, and in some cases outweigh, the increase in total mass deployed to orbit. This suggests the existence of an industrial turning point, after which scale becomes a source of efficiency rather than a burden. Such behavior aligns the mega constellation ecosystem with experience-curve dynamics observed in other capital intensive industries, where early movers able to sustain high upfront investments benefit disproportionately from long-term cost reductions.

The analysis of manufacturing and launch costs further reveals a structural

asymmetry between upfront capital expenditure and revenue generation. Mega constellations require investments on the order of tens to hundreds of billions of dollars, while revenues, where commercial in nature, are realized gradually and remain subject to regulatory, and competitive uncertainty. This mismatch represents a fundamental barrier to entry and explains the increasing concentration of the sector around a limited number of actors capable of sustaining long periods of financial exposure. As a result, competition in this domain is less about marginal cost efficiency and more about access to capital and industrial scale commitment.

Beyond purely economic considerations, the thesis demonstrates that mega constellations are increasingly acquiring the characteristics of critical infrastructure. Their relevance extends beyond commercial telecommunications to include national security and technological sovereignty. Consequently, competition between constellation operators cannot be fully understood as a contest between commercial offerings alone, but rather as a competition between different models of industrial organization and political power. In this context, the size of a constellation is not necessarily the most appropriate indicator of success; instead, its strategic function, whether oriented toward market dominance or autonomy, becomes equally important.

This perspective is particularly relevant when interpreting regional differences. While some actors pursue large scale deployments, others prioritize institutional objectives such as sovereignty and security, accepting smaller constellation sizes in exchange for greater control and independence. These divergent strategies highlight that mega constellations serve different functions depending on the policy and industrial context in which they are embedded.

At the system level, the expansion of mega constellations exposes a growing gap between technological capability and institutional governance. Issues such as orbital congestion, spectrum allocation, space debris mitigation, and dependence on privately controlled infrastructures are no longer marginal concerns but structural challenges. As mega constellations evolve into essential components of global connectivity, the absence of a robust and widely accepted governance framework becomes a limiting factor for sustainable growth. The long-term viability of these systems will therefore depend not only on technological innovation, but also on the ability of regulatory and institutional mechanisms to adapt to a rapidly changing orbital environment.

In conclusion, this thesis confirms the transformative potential of satellite mega constellations while simultaneously challenging simplified narratives of linear growth driven by market demand alone. The findings show that the future of mega constellations is shaped by a complex interaction between

launch capacity, industrial scalability, financial asymmetries, and geopolitical considerations. Ultimately, understanding mega constellations requires moving beyond questions of technical feasibility toward a broader reflection on how global infrastructure is built and governed in the long term.

11.1 Future research

Several directions for future research emerge from this analysis. First, future studies could incorporate dynamic deployment models that explicitly account for satellite replacement cycles and partial deployment phases, allowing a more realistic representation of constellation evolution over time.

Second, further research could examine competitive interactions among different constellation operators. The present analysis assumes independent deployment strategies, while in practice deployment decisions may be influenced by strategic competition, spectrum allocation, and regulatory constraints.

Third, future work could integrate considerations related to orbital congestion, space traffic management, and debris mitigation policies. As the number of satellites in low Earth orbit increases, these factors may become critical constraints shaping the long-term sustainability of mega-constellation deployment.

Finally, further research could refine the economic dimension of the analysis by incorporating operational expenditures, financing structures, and market demand in order to assess the long-term economic sustainability of large-scale satellite constellations.

Appendix A

Appendix A

Detailed Launch Calculations for Scenarios 1–4

This annex provides explicit, step-by-step calculations of the number of launches required to deploy satellites in Scenarios 1–4, under the assumption of increase future payload capacity. For each scenario we compute:

- Current-capacity launches (baseline at ~ 18 satellites per launch);
- Partial-adoption launches (mixed use of existing and new high-capacity launchers);
- Full-adoption launches (technical lower bound: all satellites on the most capable launcher available).

Satellite masses and launcher capacities are taken from Chapter 7 and Chapter 8 respectively.

$$\text{sats_per_launch} = \left\lfloor \frac{\text{launcher capacity (kg)}}{\text{satellite mass (kg)}} \right\rfloor, \quad \text{launches} = \left\lceil \frac{\text{assigned satellites}}{\text{sats_per_launch}} \right\rceil$$

All floors/ceilings and intermediate arithmetic are shown explicitly.

A.1 Scenario 1: 2025 baseline (1,751 satellites)

A.1.1 Inputs

- Total satellites: 1 751
- Operator shares: (assumed for scenario 1 and 2): presented in Table A.1

A.1.2 Current Capacity

From the baseline presented in Chapter 9, right now to launch 1 751 satellites, 95 launches are needed.

(Average ~ 18 sats/launch).

Operator	Share
Starlink	80.01 %
Amazon LEO	13.25%
Guowang	2.63%
Qianfan	4.11%
IRIS ²	0%
OneWeb	0%
Meridian	0%

Table A.1: Operators' share for Scenario 1 and 2

A.1.3 Partial adoption

1. Allocate satellites per operator:

$$\text{Starlink: } 1\,751 \times 80.01\% = 1400.9751 \Rightarrow \mathbf{1401}$$

$$\text{Amazon LEO: } 1\,751 \times 13.25\% = 231.9975 \Rightarrow \mathbf{232}$$

$$\text{Guowang: } 1\,751 \times 02.63\% = 46.0513 \Rightarrow \mathbf{46}$$

$$\text{Qianfan: } 1\,751 \times 04.11\% = 71.9661 \Rightarrow \mathbf{72}$$

2. Launcher assignments:

Starlink: split between 50% Falcon-9 and 50% Starship

Amazon LEO: mix (40% New Glenn, 60% Falcon-9)

Guowang: 80% Long March-5, 20% Long March-9

Qianfan: same as Guowang

3. Compute launches operator by operator:

- Starlink (1,401 sats) & Assume all V2mini (730 kg) in 2025.

$$\text{Falcon-9 sats/launch} = \left\lfloor \frac{22\,800}{730} \right\rfloor = 31.$$

$$\text{Half sats on F9} = 700$$

$$\text{Launches} = \lceil 700/31 \rceil = 23.$$

$$\text{Starship sats/launch} = \lfloor 100\,000/730 \rfloor = 136$$

$$\text{Half sats on Starship (100t)} = 701$$

$$\text{Launches} = \lceil 701/136 \rceil = 6.$$

$$\text{Total Starlink partial} = 29.$$

– Amazon LEO (232 sats, 740 kg).

40% of sats on New Glenn = 93

NG sats/launch = $\lfloor 45\,000/740 \rfloor = 60$

Launches = $\lceil 93/60 \rceil = 2$.

60% of sats on Falcon 9 = 139

F9 sats/launch = $\lfloor 22\,800/740 \rfloor = 30$

Luanches $\lceil 139/30 \rceil = 5$.

Total Amazon LEO partial = 7.

– Guowang (46 sats, 800 kg).

80% of sats on LM-5 = 37

LM-5 sats/launch $\lfloor 25\,000/800 \rfloor = 31$

Launches = $\lceil 37/31 \rceil = 2$.

20% of sats on LM-9 = 9

LM-9 sats/launch $\lfloor 150\,000/800 \rfloor = 187$

Launches = $\lceil 9/187 \rceil = 1$.

Total Guowang partial = 3.

– Qianfan (72 sats, 300 kg).

80% of sats on LM-5 = 58

LM-5 sats/launch $\lfloor 25\,000/300 \rfloor = 83$

Launches = $\lceil 58/83 \rceil = 1$.

20% of sats on LM-9 = 14

LM-9 sats/launch $\lfloor 150\,000/300 \rfloor = 500$

Launches = $\lceil 14/500 \rceil = 1$.

Total Qianfan partial = 2.

4. **Scenario 1 partial adoption total = 29 + 7 + 3 + 2 = 41 launches.**

A.1.4 Full adoption.

- Starlink all on Starship

Number of sats = 1401

Starship sats/launch = $\lfloor 100\,000/730 \rfloor = 136$

Launches = $\lceil 1401/136 \rceil = 11$

- Amazon LEO all on New Glenn;

Number of sats = 232

NG sats/launch = $\lfloor 45\,000/740 \rfloor = 60$

Launches = $\lceil 232/60 \rceil = 4$

- Guowang all on LM-9

Number of sats = 46

LM-9 sats/launch $\lfloor 150\,000/800 \rfloor = 187$

Launches = $\lceil 46/187 \rceil = 1$

- Qianfan all on LM-9

Number of sats = 72

LM-9 sats/launch $\lfloor 150\,000/300 \rfloor = 500$

Launches = $\lceil 72/500 \rceil = 1$

Scenario 1 full adoption total = 11 + 4 + 1 + 1 = 17 launches

A.1.5 Summary Scenario 1

- Current number of launches = 95
- Partial adoption number of launches = 41
- Full adoption number of launches = 17

A.2 Scenario 2: steady growth (19,058 satellites)

A.2.1 Inputs

- Total satellites: 19 058
- Shares: same as the ones presented in Table A.1

A.2.2 Operator allocations

$$\text{Starlink: } 19\,058 \times 80.01\% = 15\,247$$

$$\text{Amazon LEO: } 19\,058 \times 13.25\% = 2\,525$$

$$\text{Guowang: } 19\,058 \times 2.63\% = 501$$

$$\text{Qianfan: } 19\,058 \times 4.11\% = 784$$

A.2.3 Current capacity

19 058 satellites will need **1 034** launches as presented in chapter 9.

A.2.4 Partial adoption

1. Compute launches operator by operator:

– Starlink(15 247 sats)

$$\text{V2 sats} = 70\% \text{ of starlink sats} = 10\,673$$

$$\text{V3 sats} = 30\% \text{ of starkink sats} = 4\,574$$

$$\text{Half of sats launched on Starship} = 7\,624$$

$$\text{Half of sats launched on Falcon 9} = 7\,623$$

Assign all V3 (4 574) to Starship, other 3 050 V2 launched with Starship.

$$\text{V3/launch for Starship} = \lfloor (100000/1900) \rfloor = 52;$$

$$\text{Starship Launches needed for V3 sats} = \lceil (4574/52) \rceil = 88$$

$$\text{V2/launch for Starship} = \lfloor (100000/730) \rfloor = 136$$

$$\text{Starship launches needed for V2 sats} = \lceil (3050/136) \rceil = 23$$

$$\text{V2/launch for Falcon 9} = \lfloor (22800/730) \rfloor = 31$$

$$\text{F9 launches needed for V2 sats} = \lceil (7623/31) \rceil = 246$$

$$\text{Total Starlink partial} = 357$$

– Amazon LEO (2 525 sats)

40% of sats to be launched with New Glenn = 1 010

60% of sats to be launched with Falcon 9 = 1 515.

NG sats/launch = $\lfloor (45000/740) \rfloor = 60$

NG Launches = $\lceil (1010/60) \rceil = 17$

F9 sats/launch = $\lfloor (22800/740) \rfloor = 30$

F9 Launches = $\lceil (1515/30) \rceil = 51$

Total Amazon LEO partial = 68

– Guowang (501 sats)

80% of sats to be launched with LM-5 = 401

20% of sats to be launched with LM-9 = 100

LM-5 sats/launch = $\lfloor (25000/800) \rfloor = 31$

LM-5 launches = $\lceil (401/31) \rceil = 13.$

LM-9 sats/launch = $\lfloor (150000/800) \rfloor = 187$

LM-9 launches = $\lceil (100/187) \rceil = 1.$

Total Guowang partial = 14.

– Qianfan (784 sats)

80% of sats to be launched with LM-5 = 627

20% of sats to be launched with LM-9 = 157

LM-5 sats/launch = $\lfloor (25000/300) \rfloor = 83$

LM-5 Launches = $\lceil (627/83) \rceil = 8$

LM-9 sats/launch = $\lfloor (150000/300) \rfloor = 500$

LM-9 launches = $\lceil (157/500) \rceil = 1.$

Total Qianfan partial = 9.

Scenario 2 partial adoption total = 357+68+14+9=448 launches.

A.2.5 Full adoption.

- Starlink all on Starship;

$$\text{V2 sats} = 10673$$

$$\text{V3 sats} = 4574$$

$$\text{Starship launches for V2} = \lceil (10673/136) \rceil = 79$$

$$\text{Starship launches for V3} = \lceil (4574/52) \rceil = 88$$

$$\text{Total starlink launches} = 79 + 88 = 167$$

- Amazon LEO all on New Glenn;

$$\text{Number of sats} = 2525$$

$$\text{Sats per launch} = 60$$

$$\text{Launches} = \lceil (2525/60) \rceil = 43$$

- Guowang all on LM-9;

$$\text{Number of sats} = 501$$

$$\text{Sats per launch} = 187$$

$$\text{Launches} = \lceil (501/187) \rceil = 3$$

- Qianfan all on LM-9;

$$\text{Number of sats} = 784$$

$$\text{Sats per launch} = 500$$

$$\text{Launches} = \lceil (784/500) \rceil = 2$$

- **Scenario 2 full adoption total = 167 + 43 + 3 + 2 = 215 launches.**

A.2.6 Summary Scenario 2

- Current capacity = 1,034 launches
- Partial adoption = 448 launches
- Full adoption = 215 launches

A.3 Scenario 3: trend projection (32,406 satellites)

A.3.1 Inputs

- Total satellites: 32 406
- Operator shares: (assumed for scenario 3 and 4): presented in Table A.3

Operator	Share
Starlink	51.34 %
Amazon LEO	4.92%
Guowang	19.91%
Qianfan	21.43%
IRIS ²	0.41%
OneWeb	0.15%
Meridian	1.84%

Table A.2: Operators' share for Scenario 3 and 4

A.3.2 Operator allocations

$$\text{Starlink: } 32\,406 \times 51.34\% = 16\,637$$

$$\text{Amazon LEO: } 32\,406 \times 4.92\% = 1\,594$$

$$\text{IRIS}^2 : 32\,406 \times 0.41\% = 133$$

$$\text{OneWeb: } 32\,406 \times 0.15\% = 49$$

$$\text{Guowang: } 32\,406 \times 19.91\% = 6\,452$$

$$\text{Qianfan: } 32\,406 \times 21.43\% = 6\,945$$

$$\text{Meridian: } 32\,406 \times 1.84\% = 596$$

A.3.3 Current capacity

32 406 satellites need **1 758** launches (baseline ratio from 2025: 1 751 sats / 95 launches 18.43 sats/launch).

A.3.4 Partial adoption

- Starlink (16 637 satellites);

$$70\% \text{ of sats are V2} = 0.70 \times 16\,637 = 11\,645.9 \Rightarrow 11\,646$$

$$30\% \text{ of sats are V3} = 0.30 \times 16\,637 = 4\,991.1 \Rightarrow 4\,991$$

$$\text{Half of sats launched on Starship} = \lceil 0.5 \times 16\,637 \rceil = 8\,319$$

$$\text{Half of sats launched on Falcon 9} = 16\,637 - 8\,319 = 8\,318$$

Assign all V3 (4 991) to Starship; remaining Starship capacity for V2 = 3 328

$$\text{Starship sats/launch (V3)} = \left\lfloor \frac{100\,000}{1\,900} \right\rfloor = 52$$

$$\text{Starship launches needed for V3 sats} = \left\lceil \frac{4\,991}{52} \right\rceil = 96$$

$$\text{Starship sats/launch (V2)} = \left\lfloor \frac{100\,000}{730} \right\rfloor = 136$$

$$\text{Starship launches needed for V2 sats} = \left\lceil \frac{3\,328}{136} \right\rceil = 25$$

$$\text{Falcon 9 sats/launch (V2)} = \left\lfloor \frac{22\,800}{730} \right\rfloor = 31$$

$$\text{Falcon 9 launches needed for V2 sats} = \left\lceil \frac{8\,318}{31} \right\rceil = 269$$

$$\text{Total Starlink partial} = 96 + 25 + 269 = \mathbf{390}$$

- Amazon LEO (1 594);

$$40\% \text{ of sats to be launched with New Glenn} = \text{round}(0.40 \times 1\,594) = 638$$

$$60\% \text{ of sats to be launched with Falcon 9} = 1\,594 - 638 = 956$$

$$\text{New Glenn sats/launch} = \left\lfloor \frac{45\,000}{740} \right\rfloor = 60$$

$$\text{New Glenn launches} = \left\lceil \frac{638}{60} \right\rceil = 11$$

$$\text{Falcon 9 sats/launch} = \left\lfloor \frac{22\,800}{740} \right\rfloor = 30$$

$$\text{Falcon 9 launches} = \left\lceil \frac{956}{30} \right\rceil = 32$$

$$\text{Total Amazon LEO partial} = 11 + 32 = \mathbf{43}$$

– Guowang (6 452);

$$80\% \text{ of sats to be launched with LM-5} = \text{round}(0.80 \times 6\,452) = 5\,162$$

$$20\% \text{ of sats to be launched with LM-9} = 6\,452 - 5\,162 = 1\,290$$

$$\text{LM-5 sats/launch} = \left\lfloor \frac{25\,000}{800} \right\rfloor = 31$$

$$\text{LM-5 launches} = \left\lceil \frac{5\,162}{31} \right\rceil = 167$$

$$\text{LM-9 sats/launch} = \left\lfloor \frac{150\,000}{800} \right\rfloor = 187$$

$$\text{LM-9 launches} = \left\lceil \frac{1\,290}{187} \right\rceil = 7$$

$$\textbf{Total Guowang partial} = 167 + 7 = \textbf{174}$$

– Qianfan (6 945);

$$80\% \text{ of sats to be launched with LM-5} = \text{round}(0.80 \times 6\,945) = 5\,556$$

$$20\% \text{ of sats to be launched with LM-9} = 6\,945 - 5\,556 = 1\,389$$

$$\text{LM-5 sats/launch} = \left\lfloor \frac{25\,000}{300} \right\rfloor = 83$$

$$\text{LM-5 launches} = \left\lceil \frac{5\,556}{83} \right\rceil = 67$$

$$\text{LM-9 sats/launch} = \left\lfloor \frac{150\,000}{300} \right\rfloor = 500$$

$$\text{LM-9 launches} = \left\lceil \frac{1\,389}{500} \right\rceil = 3$$

$$\textbf{Total Qianfan partial} = 67 + 3 = \textbf{70}$$

– OneWeb (49);

$$\text{Falcon 9 sats/launch} = \left\lfloor \frac{22\,800}{150} \right\rfloor = 152$$

$$\text{Launches} = \left\lceil \frac{49}{152} \right\rceil = 1$$

$$\textbf{Total OneWeb partial} = \textbf{1}$$

– IRIS² (133; placeholder mass 300 kg);

$$\text{Ariane-6 sats/launch} = \left\lfloor \frac{21\,900}{300} \right\rfloor = 73$$

$$\text{Launches} = \left\lceil \frac{133}{73} \right\rceil = 2$$

$$\textbf{Total IRIS}^2 \textbf{ partial} = \textbf{2}$$

- Meridian (596);

$$\text{Neutron sats/launch} = \left\lfloor \frac{15\,000}{70} \right\rfloor = 214$$

$$\text{Launches} = \left\lceil \frac{596}{214} \right\rceil = 3$$

Total Meridian partial = 3

- **Scenario 3 partial adoption total = 390 + 43 + 174 + 70 + 1 + 2 + 3 = 683 launches.**

A.3.5 Full adoption.

- Starlink all on Starship;

$$\text{V2 sats} = 11\,646$$

$$\text{V3 sats} = 4\,991$$

$$\text{Starship sats/launch (V2)} = \left\lfloor \frac{100\,000}{730} \right\rfloor = 136$$

$$\text{Starship launches for V2} = \left\lceil \frac{11\,646}{136} \right\rceil = 86$$

$$\text{Starship sats/launch (V3)} = \left\lfloor \frac{100\,000}{1\,900} \right\rfloor = 52$$

$$\text{Starship launches for V3} = \left\lceil \frac{4\,991}{52} \right\rceil = 96$$

Total Starlink full = 86 + 96 = 182

- Amazon LEO all on New Glenn;

$$\text{Number of sats} = 1\,594$$

$$\text{New Glenn sats/launch} = \left\lfloor \frac{45\,000}{740} \right\rfloor = 60$$

$$\text{Launches} = \left\lceil \frac{1\,594}{60} \right\rceil = 27$$

- Guowang all on LM-9;

$$\text{Number of sats} = 6\,452$$

$$\text{LM-9 sats/launch} = \left\lfloor \frac{150\,000}{800} \right\rfloor = 187$$

$$\text{Launches} = \left\lceil \frac{6\,452}{187} \right\rceil = 35$$

- Qianfan all on LM-9;

Number of sats = 6 945

$$\text{LM-9 sats/launch} = \left\lfloor \frac{150\,000}{300} \right\rfloor = 500$$

$$\mathbf{Launches} = \left\lceil \frac{6\,945}{500} \right\rceil = \mathbf{14}$$

- OneWeb all on Starship;

Number of sats = 49

$$\text{Starship sats/launch} = \left\lfloor \frac{100\,000}{150} \right\rfloor = 666$$

$$\mathbf{Launches} = \left\lceil \frac{49}{666} \right\rceil = \mathbf{1}$$

- IRIS² all on Ariane-6: same as partial \Rightarrow **2** launches.

- Meridian all on Neutron: same as partial \Rightarrow **3** launches.

- **Scenario 3 full adoption total** = 182 + 27 + 35 + 14 + 1 + 2 + 3 = **264 launches.**

A.4 Scenario 4: full deployment (65,196 satellites)

A.4.1 Inputs

- Total satellites: 65 196
- Operator shares: (assumed for scenario 3 and 4): presented in Table A.3

Operator	Share
Starlink	51.34 %
Amazon LEO	4.92%
Guowang	19.91%
Qianfan	21.43%
IRIS ²	0.41%
OneWeb	0.15%
Meridian	1.84%

Table A.3: Operators' share for Scenario 3 and 4

A.4.2 Operator allocations

$$\text{Starlink: } 65196 \times 51.34\% = 33\,516$$

$$\text{Amazon LEO: } 65196 \times 4.92\% = 3\,208$$

$$\text{IRIS}^2 : 65196 \times 0.41\% = 267$$

$$\text{OneWeb: } 65196 \times 0.15\% = 98$$

$$\text{Guowang: } 65196 \times 19.91\% = 12\,987$$

$$\text{Qianfan: } 65196 \times 21.43\% = 13\,976$$

$$\text{Meridian: } 65196 \times 1.84\% = 1\,199$$

A.4.3 Current capacity

65 196 satellites need **3 517** launches.

A.4.4 Partial adoption

– Starlink (33 516) satellites;

$$70\% \text{ of sats are V2 } = 23\,461$$

$$30\% \text{ of sats are V3 } = 10\,055$$

$$\text{Half of sats launched on Starship } = 16\,758$$

$$\text{Half of sats launched on Falcon 9 } = 16\,758$$

Assign all V3 (10 055) to Starship, other 6 703 V2 can also be launched with Starship.

$$\text{Starship V3 } = \lfloor (100000/1900) \rfloor = 52;$$

$$\text{Starship Launches needed for V3 sats } = \lceil (10055/52) \rceil = 194$$

$$\text{Starship V2 } = \lfloor (100000/730) \rfloor = 136$$

$$\text{Starship launches needed for V2 sats } = \lceil (6703/136) \rceil = 50$$

$$\text{Falcon 9 -V2 } = \lfloor (22800/730) \rfloor = 31$$

$$\text{F9 launches needed for V2 sats } = \lceil (16758/31) \rceil = 541$$

$$\text{Total Starlink partial } = 785$$

- Amazon LEO (3 208);

40% of sats to be launched with New Glenn = 1 283

60% of sats to be launched with Falcon 9 = 1 925.

NG sats/launch = $\lfloor (45000/740) \rfloor = 60$

Launches = $\lceil (1283/60) \rceil = 22$

F9 sats/launch = $\lfloor (22800/740) \rfloor = 30$

Launches = $\lceil (1925/30) \rceil = 65$

Total Amazon LEO partial = 87

- IRIS² (267);

Ariane 6 sats/launch = $\lfloor (21900/300) \rfloor = 73$

Launches = 267/73 = 4

- OneWeb (98);

F-9 sats/launch = $\lfloor (22800/150) \rfloor = 152$

Launches = 98/152 = 1

- Guowang (12 987);

80% of sats to be launched with LM-5 = 10390

20% of sats to be launched with LM-9 = 2597

LM-5 sats/launch = $\lfloor (25000/800) \rfloor = 31$

LM-5 launches = $\lceil (10390/31) \rceil = 335$

LM-9 sats/launch = $\lfloor (150000/800) \rfloor = 187$

LM-9 launches = $\lceil (2597/187) \rceil = 14$

Total Guowang partial = 349

- Qianfan (13 976);

80% of sats to be launched with LM-5 = 11181

20% of sats to be launched with LM-9 = 2795

LM-5 sats/launch = $\lfloor (25000/300) \rfloor = 83$

LM-5 Launches = $\lceil (11181/83) \rceil = 135$

LM-9 sats/launch = $\lfloor (150000/300) \rfloor = 500$

LM-9 launches = $\lceil (2795/500) \rceil = 6$

Total Qianfan partial = 141

- Meridian (1 199);

Neutron sats/launch = $\lfloor (10055/70) \rfloor = 214$

Launches = 1199/152 = 6

- **Scenario 4 partial adoption total = 785+87+4+1+349+141+6 = 1 373 launches**

A.4.5 Full adoption.

- Starlink all on Starship;

V2 sats = 23461

V3 sats = 10055

Starship launches for V2 = $\lceil (23461/136) \rceil = 173$

Starship launches for V3 = $\lceil (10055/52) \rceil = 194$

Total starlink launches = 173 + 194 = 367

- Amazon LEO all on New Glenn;

Number of sats = 3208

Sats per launch = 60

Launches = $\lceil (3208/60) \rceil = 54$

- IRIS² all on Ariane-6: Same as before
- OneWeb all on Starship: Same as before

- Guowang all on LM-9;

Number of sats = 12987

Sats per launch = 187

Launches = $\lceil (12987/187) \rceil = 70$

- Qianfan all on LM-9;

Number of sats = 13976

Sats per launch = 500

Launches = $\lceil (13976/500) \rceil = 28$

- Meridian all on Neutron: Same as before

- **Scenario 4 full total = 526 launches**

Final Comparison (Scenarios 1–4)

Scenario	Current capacity	Partial adoption	Full adoption
1 (2025 baseline, 1 751 sats)	95	41	17
2 (steady growth, 19 058 sats)	1 034	448	215
3 (trend projection, 32 406 sats)	1 758	683	264
4 (full deployment, 65 196 sats)	3 517	1 373	530

Critical caveats. These calculations provide *technical* mappings from satellites to launches based on payload masses and capacities. They do not model cadence.

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