# Evaluating the Strategic Intent and Competitive Dynamics of China's Satellite Communications Constellations

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**ABSTRACT**

This thesis examines the strategic, technical, and economic feasibility of China's two flagship low Earth orbit (LEO) satellite megaconstellation programs, Guowang and Qianfan, in the context of the rapidly evolving global satellite communication (Satcom) market. Against the backdrop of SpaceX's Starlink dominance and intensifying geopolitical competition, China's efforts represent not only a telecommunications infrastructure push but also a broader assertion of technological sovereignty and global influence. This study uses a scenario-based analysis that integrates system throughput analysis and financial forecasting. Three deployment scenarios (base, optimistic, and pessimistic) are analyzed, accounting for satellite production rates, launch capabilities, and regional adoption patterns, particularly across Belt and Road Initiative (BRI) markets. The study also evaluates "system-of-systems" integration with China's military objectives, and spectrum coordination challenges. Key findings reveal that Guowang becomes marginally viable only in the optimistic scenario, assuming deployment of at least 9,000 satellites, reduced satellite unit costs (targeting ~$300,000 per satellite), expanded gateway infrastructure, and realization of these targets by 2035, while remaining unviable in base and pessimistic cases. Qianfan faces greater commercial risk, achieving viability only with early adoption in BRI countries and government dual-use contracts, incurring a pessimistic-case NPV loss exceeding $76B. Resource allocation problem (RAP) modeling suggests that projected throughput may saturate early without major gateway expansion. Both constellations require China to scale reusable rockets and sustain a combined annual launch rate exceeding 1,000 satellites by the early 2030s. Neither constellation system meets China's 2030 rural broadband targets under base-case conditions, over 40% of the 336M unconnected citizens remain underserved without terminal subsidies. Ultimately, China's LEO Satcom strategy depends not on satellite count alone but on coordinated progress in launch economics, affordability, dual-use policy, and international partnerships.

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# Acronyms, Terms, and Definitions

| | |
|---|---|
| **CDF** | Cumulative distribution function |
| **DRA** | Direct radiating array |
| **DRM** | Dynamic resource management |
| **EIRP** | Effective isotropic radiated power |
| **FCC** | Federal Communications Commission |
| **FoR** | Field of regard |
| **FSPL** | Free Space Path Losses |
| **GEO** | Geostationary Orbit |
| **GSO** | Geostationary satellite orbits |
| **ISL** | Inter-satellite link |
| **ISP** | Internet Satellite Provider |
| **ITU** | International Telecommunications Union |
| **LEO** | LEO Low Earth orbit |
| **LHCP** | Left-handed circular polarization |
| **LoS** | Line of sight |
| **MEGCON** | Megaconstellation |
| **MEO** | Medium Earth Orbit |
| **MODCOD** | Modulation and coding scheme |
| **NGSO** | Non-Geostationary satellite orbits |
| **NSGA-II** | Non-dominated sorted genetic algorithm II |
| **OISL** | Optical Inter-satellite links |
| **RAP** | Resource Allocation Problem Framework |
| **RHCP** | Right-handed circular polarization |
| **SatCom** | Satellite Communications |
| **TBD** | To be defined |
| **TT&C** | Telemetry, Tracking and Command |
| **CDF** | Cumulative distribution function |
| **DRA** | Direct radiating array |

# Chapter 1 : Introduction

The Satellite Communication (Satcom) industry is undergoing rapid transformation due to technological advancements, geopolitical shifts, and increasing commercial competition. China's growing presence in the global space sector may challenge established players like SpaceX's Starlink and OneWeb [1-16]. Through projects like GuoWang and Qianfan (Thousand Sails, the English translation of its official name and sometimes referred to as the G60 Constellation), China seeks to leverage megaconstellations to expand both domestically and internationally [17–19], with early international activity already underway through SpaceSail's partnerships in Brazil, Malaysia, Thailand, and a subsidiary in Kazakhstan. While the domestic use case remains important, particularly in underserved rural regions, the relatively strong terrestrial network coverage in China means that the most substantial market potential lies abroad. These satellite plans are being developed concurrently across both domains, alongside the advancement of reusable launch technologies. These plans will likely have joint military and commercial objectives [1-8]. This thesis examines China's strategic ambitions in the Satcom sector, evaluates its competitive positioning against global players, and analyzes the implications for market dynamics and China's space policy. While the focus remains on China's internal strategy and its global market positioning, the analysis also considers the competitive landscape, including the strategies of major players such as SpaceX, OneWeb, and Amazon Kuiper. However, detailed assessments of U.S. and EU policy responses fall outside the primary scope of this study.

## 1.1. Motivation and Background

China's expansion into Satcom has far-reaching implications for global communications and space infrastructure. With large-scale satellite constellations, including the GuoWang project (targeting 13,000 satellites), and the Qianfan constellation (Thousand Sails), China is positioning itself to strengthen domestic broadband capabilities, and expand into global markets.

This strategy reflects patterns seen in other technology sectors, notably in telecommunications. For instance, while companies like Nokia and Cisco led the 2G and 3G eras, Chinese firms such as Huawei and ZTE became dominant in 4G and 5G by rapidly building out China's terrestrial infrastructure while aggressively entering global markets. Similarly, in other sectors like rail and automotive, China has used its domestic scale as a launchpad for global competitiveness. In aviation, China's Commercial Aircraft Corporation (COMAC) aims to challenge Airbus and Boeing with its C919 aircraft, further signaling broader ambitions to disrupt Western-dominated industries. These cases suggest that China's Satcom trajectory may follow a familiar model: leverage state-backed domestic development to challenge incumbents on the global stage [20–25].

To support these ambitions, China has invested in commercial launch providers like China Rocket Co., which plays a critical role in scaling these constellations through enhanced launch cadence and capacity. This integration of launch infrastructure strengthens China's ability to maintain and expand its satellite networks [1–8].

However, the financial sustainability of these megaconstellations remains uncertain. The international market is becoming increasingly saturated, posing profitability risks for all operators, including China [14–16]. In addition to commercial challenges, China's growing presence in the Satcom sector raises geopolitical concerns, particularly regarding security risks and strategic influence. While China's megaconstellations aim to enhance global connectivity, the deployment of these systems may introduce vulnerabilities for international communications infrastructure. A central concern stems from China's emphasis on dual-use technologies, those serving both civilian and military objectives, which are integral to its military-civil fusion strategy [2,3].

This strategy, embedding military functionality into commercial platforms, has drawn parallels to controversies surrounding Chinese telecom firms like Huawei, where Western governments raised concerns about potential surveillance via network backdoors. Although there is no public evidence of backdoors in Chinese Satcom systems, Western analysts remain wary of strategic advantages China may gain through space-based infrastructure for intelligence gathering or secure communications.

Further concerns relate to China's global network of ground stations, which underpin satellite connectivity and data routing. Studies [2–5] highlight how investments in strategically located stations across Asia, Africa, and South America enhance China's capacity to support Belt and Road Initiative (BRI) partners while potentially enabling secure communication channels and space-based reconnaissance capabilities.

A final emerging dimension involves the use of inter-satellite links (ISLs). While SpaceX's Starlink constellation uses laser-based ISLs to route traffic without relying on local ground stations, thereby raising regulatory concerns about bypassing landing rights, Chinese constellation developers are exploring more hybrid architectures. By limiting or excluding ISLs in early versions of their systems, they may alleviate foreign governments' concerns and better align with host country regulations.

These developments highlight the complex intersection of technological advancement, commercial ambition, and geopolitical influence. As China's Satcom capabilities expand, international stakeholders may increasingly focus on regulatory frameworks, data sovereignty, and market safeguards to mitigate strategic risks.

Consequently, analyzing China's influence on the Western-dominated market, including its dual-use technologies and military-civil fusion strategy [2,3], helps to identify potential shifts in global competition, regulatory dynamics, and space security. This makes China's Satcom rise not only a technical development but a strategic one with far-reaching global implications.

## 1.2. Research Objectives and Aims

China's Satcom strategy, encompassing Megaconstellation (MEGACON) development, strategic funding mechanisms, and reusable launch vehicles, positions it as a formidable player in the global space race. This strategy includes state-backed investments in emerging commercial Satcom companies as well as pre-purchasing satellite capacity to secure demand and mitigate financial risks for these ventures. This dual approach, combining equity support with demand-assurance strategies, has accelerated the growth of China's space sector.

This thesis aims to provide an analysis of China's role in the Satcom market, with attention to the financial risks of market oversaturation, the challenges of providing affordable connectivity to developing nations, and revenue opportunities in niche markets. By examining these dynamics, this research should offer further insights into China's potential to redefine satellite telecommunication markets [14-18].

### 1.2.1. Research Questions

The thesis focuses on the following research questions:

i. **Current Status of China's Satcom Industry**

a) How does China's existing Satcom infrastructure compare to global competitors in terms of capabilities and market position, regardless of provider (e.g. Starlink, OneWeb) [26-27]?

b) What is the current distribution of Satcom users in China and China-friendly locations (e.g., Russia, Africa) [26-27]?

ii. **China's Ambitious Roadmap for Satcom**

a) What are the technical and strategic goals of China's planned megaconstellation projects (e.g., GuoWang, G60 Starlink, Honghu-3), and how do these align with China's international outreach and Belt and Road Initiative [2,14-17,28-29]?

b) To what extent can these megaconstellations deliver anticipated throughput performance compared to competing systems?

c) What technological advancements in commercial launch capabilities and reusable rockets is China pursuing, and how do they compare to global competitors?

iii. **Domestic Expansion Strategy**

a) To what extent could Satcom improve connectivity in rural regions in addition to existing ground infrastructure in China?

b) To what extent are commercial and military objectives integrated in China's Satcom strategy [30-31]?

iv. **International Expansion Potential**

- How does China's competitive positioning compare to global players in the Satcom market?
- What are the potential markets and use cases for China's international Satcom expansion, particularly in developing nations?

## 1.3. Overview of Thesis Structure

This thesis is organized into ten chapters, each contributing to a comprehensive exploration of China’s Satcom strategies, technical feasibility, economic viability, and global implications: Chapter 2 Literature Review examines the global Satcom landscape, China's space ambitions, and prior research on related strategies. It also outlines regulatory challenges, spectrum policies, and market segmentation, forming the foundation for the study. Chapter 3: China’s Current Satcom Status analyzes existing infrastructure, market presence, and strategic objectives shaping the GuoWang and Qianfan constellations. Chapter 4: Methodology and Model Description describes the analytical framework, based on System Architecture and Resource Allocation models, used to assess throughput capacity, financial viability, and global deployment dynamics. Chapter 5: China’s Satcom Roadmap outlines phased deployment plans for both constellations, with detailed financial forecasts, scenario analysis (base, optimistic, pessimistic), and model-derived insights into deployment feasibility. Chapter 6: Domestic Expansion Strategy focuses on China’s efforts to connect rural populations, integrating commercial, military, and civil broadband objectives with supporting cost and affordability analysis. Chapter 7: International Expansion Potential explores geopolitical expansion via Belt and Road Initiative (BRI) markets, analyzing demand, adoption constraints, and China’s potential role in a bifurcated Satcom landscape. Chapter 8: Geopolitical and Military Dimensions evaluates the implications of China's Satcom strategies on global security and competitive positioning, including civil-military integration, spectrum strategy, and system-of-systems resilience. Chapter 9: Strategic Recommendations and Policy Implications expands the analysis by incorporating stakeholders, risk propagation (technical, geopolitical, and market-based), and system-of-systems considerations to assess program success drivers and vulnerabilities. Chapter 10: Conclusion and Future Implications summarizes key findings across scenarios, discusses strategic and operational implications, and proposes directions for future research in Satcom governance, public-private partnerships, and systems architecture. References provide a comprehensive list of all cited works, while Appendices include supporting datasets, scenario assumptions, model parameters, and extended technical detail. This structure ensures a logical progression from conceptual foundation to technical modeling and strategic synthesis, offering a holistic view of China’s Satcom programs and their global relevance.

# Chapter 2 : Literature Review

## 2.1. Global Satcom Landscape

The global satellite communications (Satcom) market is a rapidly evolving sector, segmented across multiple dimensions: by Satellite Mass (<10 kg, 10-100 kg, 100-500 kg, 500-1,000 kg, >1,000 kg), Orbit Class (Geostationary Orbit [GEO], Low Earth Orbit [LEO], Medium Earth Orbit [MEO]), End Users (Commercial, Military & Government), and Region (North America, Europe, Asia-Pacific, Rest of the World) [26-35]. The market was valued $171 billion in 2021 and is projected to reach $200 billion by 2025 and $318.9 billion by 2030 [36-40, 45-53]. This corresponds to a compound annual growth rate (CAGR) of 9.76% from 2025-2030, through past growth rates which provide a more factual basis for future projections [53-56].

Global investments in LEO constellations and megaconstellations have accelerated significantly in recent years, driven by increased demand for broadband connectivity and further amplified by the COVID-19 pandemic, which highlighted the need for robust communications infrastructure, particularly in remote and rural areas [26-32, 53-56]. However, while industry increasingly formed partnerships and acquisitions, this trend has been driven largely by competitive pricing pressures, particularly from Starlink's cost structure and capabilities rather than purely as a sign of market expansion. Market players attempted to strengthen their positions in sectors such as maritime, defense, and aviation. Furthermore, the integration of Satcom with 5G networks, Artificial Intelligence (AI), and the Internet of Things (IoT) is enabling advanced connectivity and data solutions [53-56]. This has driven a shift towards a multi-orbit architectures, combining LEO and GEO satellite systems. MEO satellites provide a balance between LEO's low latency and broad coverage, making them suitable for high-bandwidth applications like enterprise networking and government services. Meanwhile, GEO satellites remain essential for wide-area broadcasting and high-throughput applications, particularly in regions with limited terrestrial infrastructure. This complementary approach allows operators to optimize service delivery across different market segments [50-55].

Countries historically resistant to LEO investments, such as Japan, are now developing national LEO constellations to provide low-latency broadband to underserved rural areas and enhance disaster management capabilities [26-32, 53-56]. These systems could significantly improve emergency responses to natural disasters, such as earthquakes and tsunamis, where terrestrial networks are vulnerable to disruption.

The concept of LEO constellations for broadband communications dates back to the early 1990s, but early initiatives faced major setbacks due to technical feasibility of ground-terminal connectivity, high satellite replacement costs, and unexpected capital expenditure growth [26-32, 53-56]. Companies like Iridium declared bankruptcy, Globalstar scaled down its plans, and Teledesic ultimately canceled its project and returned investor capital. These failures raised skepticism about the economic viability of LEO megaconstellations [26-32, 53-61].

Traditionally, GEO satellites dominated the Satcom market due to their broad coverage area and stationary position relative to Earth, minimizing the need for complex tracking systems. GEO platforms remain widely used for broadcasting, government services, and weather monitoring. However, recent advancements in phased array antennas, digital beamforming, and satellite miniaturization have enhanced LEO constellation efficiency, allowing for scalable, high-throughput broadband services with low latency [50-55]. Additionally, decreasing launch costs, driven by reusable rocket technology, have further improved the economic viability of LEO megaconstellations [50-55]. Table 2-1 summarizes different Satcom architectural features, excluding power requirements and ground stations, as the power depends on the distance for a signal to travel and its frequency. Higher data throughput is achieved with higher frequencies but needs more power to travel the same distance. Regarding the ground stations, inter-satellite links are changing the architectural concepts, enabling the transmission of the signal across a constellation, resulting in reduced numbers of required ground stations for LEO MEGACON.

Table 2-1 - Example of different features for Satcom Architecture s [ref[48]]

| | **GEO** | **MEO** | **LEO** |
|---|---|---|---|
| Altitude (km) | 35, 786 | 5,000-20,000 | 500-1,200 |
| Latency (ms) | 500-700 | ~250 | 20-50 |
| Earth coverage | 1/2 | 1/4 | 1/16-1/64 |
| # Satellites Required | 3 | ~6 | O(100-)-O(1,000) |
| Antenna Speed | Stationary | Slow Tracking | Fast Tracking |
| Satellite Relative Size | School Bus | Car | Urban Scooter |

Figure 2.1 shows Earth coverage from a given orbital plane (LEO, MEO and GEO).

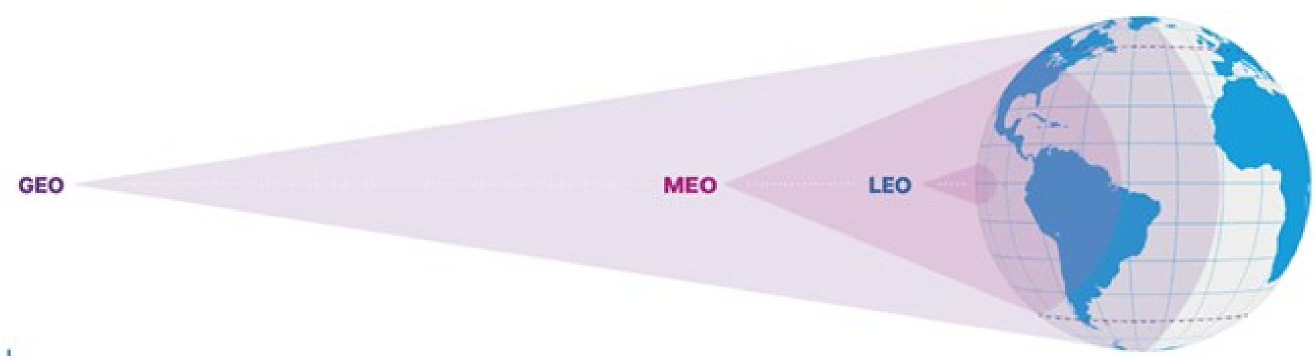



Figure 2.1 - Relative orbital altitude and Earth coverage for GEO, MEO, and LEO (source [48, 64])

Table 2.2 summarizes a generic comparison of orbits, covering main characteristics with their advantages and disadvantages.

Table 2-2 - Comparison of Orbital Characteristics with Pros and Cons [ref48,64]

| Characteristic | GEO (36, 000 km) | MEO (5,000-20,000km) | LEO (500-1,200 km) |
|---|---|---|---|
| Signal Latency | High | Moderate | Very low |
| Coverage Area | Extensive | Wide | Limited |
| Number of Satellites Required | Minimal (3) | Moderate (6) | Numerous (hundreds) |
| Data Gateway Infrastructure | Fixed, minimal | Regionally distributed, adaptable | Locally dispersed, high density |
| Antenna Movement | Stationary | Gradual tracking (~1 hour) | Rapid tracking (~10 min) |
| **Pros and Cons of Different Orbits** | | | |
| | **GEO (36, 000 km)** | **MEO (5,000-20,000km)** | **LEO (500-1,200 km)** |
| Advantages | Large coverage footprint enables broadcasting to millions of users (e.g., satellite TV). Stationary user terminals reduce ground equipment cost. GEO satellites offer continuous regional coverage, particularly suited for fixed-location services. | Low latency comparable to terrestrial networks, offers fiber-equivalent performance | Support for high-frequency trading, virtual gaming, and high-performance computing applications |
| | Fewer satellites over very large fixed geographical areas | Simple equatorial orbit covers 96% of global population | Smaller, lower power satellites batch-launched, less expensive than GEO |
| Disadvantages | High altitude and distant ground networking impacts latency-sensitive applications | Dual tracking antennas required to maintain continuous connectivity | Very complex tracking and ground network, plus complete constellation must be in place before service begins |
| | Signal power losses require larger satellites and antennas | Inclined plane orbits needed to cover high latitudes | Not fully proven business model, risky technology, and space debris risk |

**Note:** While High Throughput (HTS) can be used in GEO, it is not exclusive to GEO, MEO and LEO also employ HTS technologies.

The success of SpaceX's Starlink has played a pivotal role in validating LEO magaconstellations as a commercially viable model. Vertical integration, reusable rockets, and mass satellite production have enabled Starlink to significantly reduce per-satellite costs, forcing competitors to reassess their strategies. As a result, market dynamics have shifted, with increasing LEO constellation proposals from both commercial and national entities, reinforcing the transition from GEO-dominated to LEO-dominated architectures [50-61] .

Between 2017 and 2019, GEO satellites accounted for the majority of Satcom launches. However, by 2020, LEO constellations gained momentum, with projections Indicating that LEO satellites will represent 79.5% of all deployed Satcom satellites by 2029, while GEO's market share will decline to 18% [53-56] . These statistics refer to annual launch volumes, not the cumulative number of operational satellites in orbit. While GEO satellites will persist, most new constellations will be In LEO due to Its cost-effectiveness and scalability.

During the period 2017-2022, approximately:

- 8 MEO communication satellites were launched.
- 105 GEO communication satellites were launched.
- 4,131 LEO satellites were deployed globally, with approximately 2,796 of these intended for communications purposes.

This trend is illustrated in Figure 2.1, which depicts the growing dominance of LEO constellations through 2030.

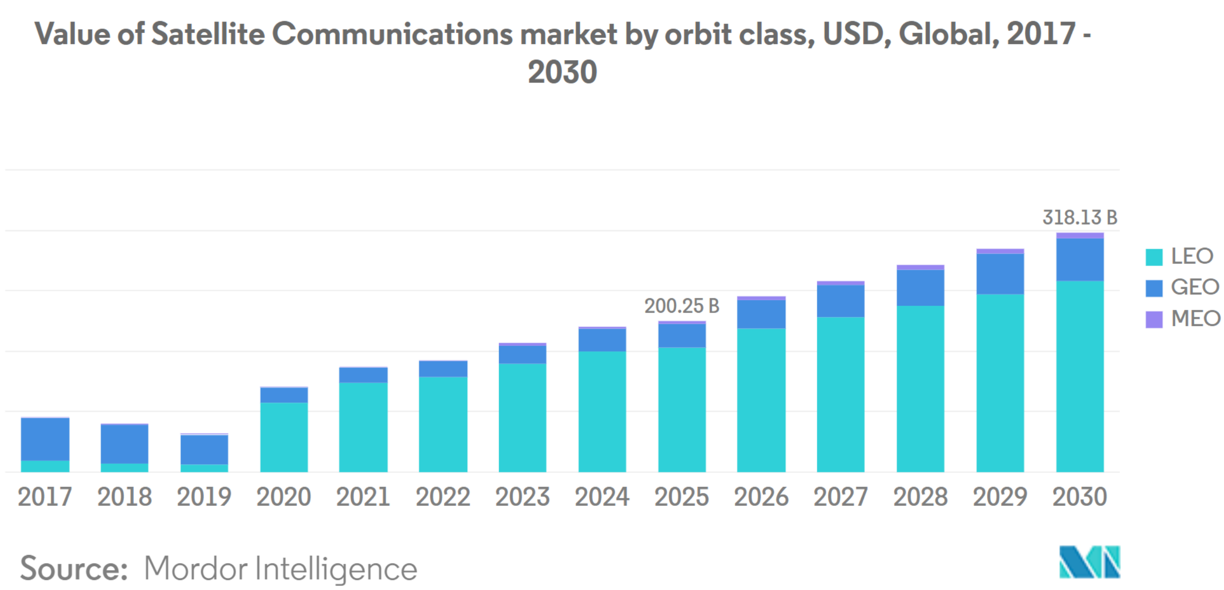



Figure 2.2 - Market Growth and Projected Deployment of LEO Satellites (source [50-55])

**Note:** In this context, "value" refers to recurring annual contract revenue, not capital expenditure or one-time equipment sales, and it serves as a primary financial performance indicator for Satcom operators.

In evaluating the competitiveness and sustainability of Satcom megaconstellations, annual contract revenue serves as a practical measure of financial "value", that is, the operator's recurring income from broadband subscriptions, enterprise services, or institutional contracts. This value dimension is important when analyzing long-term viability in a competitive market. For example, Starlink's estimated revenue is projected to reach $11.8 billion by 2025, largely driven by a blend of consumer subscriptions and military contracts (re [50-61]). In contrast, Chinese constellations such as GuoWang and Qianfan, while heavily state-backed, will require monetization strategies to generate sustainable operating income beyond capex-heavy deployment phases.

The Satcom market focusing on operator services can also be segmented by end-users, primarily divided into:

A. Commercial Applications: Accounting for 72.2% of global market revenue in 2024 (~$16.7 billion). These include services to consumers, enterprise, maritime, and aviation sectors.
B. Government and Military Applications: Encompassing defense communications, intelligence, and national security applications (27.8%, ~$5.5 billion), primarily where governments contract with private operators (e.g., Starlink contracts with DoD).

However, these figures do not account for Satcom systems that are entirely government-owned and operated, such as the U.S. Wideband Global SATCOM (WGS), Russian Raduga, or China's GuoWang constellations. These systems operate outside the commercial operator market and instead represent strategic infrastructure investments. Thus, the $5.5B estimate refers specifically to government procurement of commercial Satcom capacity, which is only a subset of total governmental Satcom activity.

North American satcom operators holds the largest share of the LEO megaconstellation market, driven by robust technological development, high satellite launch frequency (primarily from the United States), and a well-funded defense sector, including the U.S. Space Force. Commercial players such as SpaceX, HughesNet, Telesat, and MDA have further contributed to the region's leadership by deploying large fleets of broadband and broadcasting satellites [50-61].

Europe is also a significant player, although trailing North America. The region's strength lies in its aerospace manufacturing sector, with companies such as Airbus Defence and Space and Thales Alenia Space leading satellite production. Additionally, the commercial Satcom market in Europe is driven by operators like SES and Eutelsat, both of which manage extensive satellite fleets [50-55]. Asia-Pacific is emerging as the fastest-growing region in Satcom, underpinned by rising demand for high-speed data transmission, increased investments in satellite technology, and geopolitical considerations driving a desire for self-reliance in communications infrastructure. China and India are the primary regional players, both heavily investing in space programs to support national security, economic development, and digital transformation [50-61].

China’s Satcom market size is projected to grow from $16 billion in 2024 to over $25 billion by 2030, while India's Satcom sector is also expanding, with public-private partnerships (e.g., ISRO collaborating with Bharti-backed OneWeb) fueling domestic market growth [50-61].

The LEO megaconstellation segment is led by several influential players outside China:

- SpaceX (Starlink): Deploying large LEO broadband fleets.
- Amazon Inc. (Project Kuiper): Planning to launch 3,236 satellites, with partnerships involving Arianespace, Blue Origin, and United Launch Alliance (ULA).
- OneWeb: Expanding to provide coverage across India and other global regions.
- Telesat (Lightspeed): Backed by the Canadian government and operated by a mature GEO satellite provider, Telesat is developing a global LEO network focused on enterprise and government clients.
- Rivada Space Networks: Developing a 600-satellite constellation for secure government and enterprise communications, focusing on low-latency, high-speed services.
- Airbus, Thales, Leonardo: Announcing a potential joint venture to challenge SpaceX’s Starlink.
- IRIS² : A planned European Union megaconstellation (~170 satellites) backed by Airbus, SES, Eutelsat, Hispasat, and Thales. It aims to deliver secure, multi-orbit broadband services for both commercial and governmental applications, enhancing European sovereignty in space-based communications.

Table 2-3 summarizes the major LEO satellites MEGACON (status July 2024, GouWang Feb. 2025).

Table 2-3 - LEO Satellites MEGACON

| Company | MEGACON | First Launch | Total # Satellites Deployed | Operational | Total Plan |
|---|---|---|---|---|---|
| SpaceX | Starlink | 2019 | 6,805 | 6,206 | 42,000 |
| OneWeb (EutelSat) | OneWeb | 2019 | 640 | 632 | Complete |
| Iridium | Next | 2017 | 80 | 66 (14 spares) | Complete |
| Lynk | Lynk | 2018 | 10 | 5 | 10, plans to expand to 5,000 |
| Galaxy Space (China) | Yinhe | 2020 | 8 | 7 | 144 |
| Amazon | Kuiper | 2023 | 2 | 2 | 3,236 |
| AST SpaceMobile | SpaceMobile (BlueBird) | 2019 | 2 | 1 | 168 |
| Telesat | Lightspeed | 2023 | 1 | - | 198-300, plans to expand to 1,600 |
| China Satellite Network Group | GuoWang | 2024 | 19* | 19* | 13,000 |

| | | | | | |
|---|---|---|---|---|---|
| Limited | | | | | |
| Hongqing Technology (China) | Honghu-3 | 2023 | - | - | 10,000 |
| Shanghai Spacecom Satellite Technology (China) | Qianfan | 2024 | 90 (in 5 batches) | 90 | 1,296, plans to expand to 12,000 |
| Rivada | OuterNET | - | 0 | 0 | 576 |

*Estimate: the first launch carried out 10 satellites, while the second one in Feb. 2025, according to the Space Force space situation awareness, suggests nine satellites (i.e., payloads in 862 by 870-kilometer, inclination 50.0 degrees, as well as upper rocket stage Orbiting for disposal burn) [50-61].

A detailed overview of emerging space-based communication services is provided in Appendices B and C, which illustrate the landscape of orbital data relay and broadband internet constellations, respectively. These categories highlight both established platforms and cutting-edge developments that are reshaping space network architectures [50-61, 71-74].

As illustrated, multiple constellations are now focusing on providing in-orbit data relay services via inter-satellite links (ISLs), with an increasing emphasis on optical (laser-based) communication. These systems facilitate data transfer between satellites and to ground stations, improving latency and global coverage. Laser communication has become a core enabler for many of these systems, as covered extensively in the 2022 survey by Li et al [75].

China's commercial sector has made notable strides, with a high-speed laser communication demonstration to Earth successfully completed in 2023. In parallel, Capez et al. [76] explored the broader applicability of megaconstellation services in orbit, and Urban [50-61, 71-74] provided a state-of-the-market analysis for optical communications. Among the leading commercial systems, Addvalue's Inter-Satellite Data Relay System (IDRS), operating via Viasat/Inmarsat satellites, currently offers one of the most advanced real-time ISL capabilities. Additionally, legacy systems like Globalstar and Iridium remain operational for orbital relays.

New entrants such as Kepler Communications have begun testing optical ISLs, with their first microsatellites launched in late 2023 and plans to deploy 10 additional spacecraft by 2025. The company has also joined NASA's in-orbit demonstration program, which includes at least six laser relay missions scheduled for 2025–2026. Notably, SpaceX also demonstrated its proprietary Plug and Plaser laser terminal on Starlink during the Polaris Dawn mission. Meanwhile, firms like Analytical Space (renamed Hedron) initially attracted significant funding (USD 17.8 million in 2021) but later ceased operations, highlighting both the promise and volatility in this segment.

The broadband internet constellations encompass the most ambitious satellite deployments to date in terms of volume and service coverage. Starlink, the clear industry leader, had launched over 7,000 spacecraft by late 2024, including V2 Mini and V2-Mini DTC variants. The system achieved cash-flow positivity in late 2023 and, according to Quilty Space [50-61, 71-74], is expected to generate $6.6 billion in revenue in 2024. As of September 2024, Starlink had reached over 4 million global subscribers [50-61, 71-74].

OneWeb, now operated by Eutelsat, has completed its initial deployment phase but faces delays in global service rollout due to ground infrastructure limitations. Its next-generation platform is expected to feature spacecraft in the 500 kg range, with a likely fleet size below 1,000 satellites. A prototype of this class, JoeySat, was launched in 2023. China's Qianfan constellation, part of the G60 initiative, began its broadband internet deployment with the launch of its first 18 satellites in 2024. Although still in early stages, the program illustrates China's broader ambitions to establish a competitive global broadband footprint via state-supported and regional collaborative frameworks.

## 2.2. China's Space Programs and Satcom Initiatives

China is accelerating the launch of Low Earth Orbit (LEO) communication satellites to compete with Western-led megaconstellations such as Starlink. While Starlink provides global satellite broadband services, it is not legally available in China, as the government restricts access to foreign-controlled internet providers to maintain digital sovereignty and national security. However, beyond commercial competition, China views the expansion of its Satcom sector as a key strategic priority, aligning with broader objectives in space, defense, and technology [25-35].

In 2025, China Aerospace Science and Technology Corporation (CASC), the country's state-owned military and space contractor, reaffirmed its goal of making China the world's leading space power by 2045. This vision is embedded in a series of national space development roadmaps, which include major milestones such as sending Chinese astronauts to the Moon by 2030, constructing a permanent lunar base, and developing nuclear-powered spacecraft for interplanetary travel [25-35]. These efforts underscore China's broader strategy of integrating space technology into its economic development, defense capabilities, and global infrastructure projects.

China's space program has evolved into a central pillar of national technological and strategic ambitions, directly incorporated into economic planning documents such as the Made in China 2025 initiative and successive Five-Year Plans [37-39, 62]. The 2021 White Paper on China's Space Program reaffirmed this commitment, providing an official overview of China's progress in satellite deployment, deep space exploration, and international cooperation [37-39, 62]. The paper highlights the increasing role of satellite communications (Satcom) as both a domestic development tool and a strategic international asset.

A core focus of China's space efforts has been the development of a sophisticated satellite communication (Satcom) network, aimed at improving domestic connectivity and expanding international coverage [37-39, 62]. According to the 2021 White Paper [37-39, 62], China has constructed multiple satellite constellations to provide broadband communications, broadcasting, and navigation services, although certain claims require independent verification. One of the most notable achievements within China's space sector is the BeiDou Navigation

Satellite System (BDS), which reached full global operational status in 2020 with a constellation of 35 satellites. This system serves as China's alternative to the U.S. Global Positioning System (GPS), reducing dependence on foreign-controlled navigation services and enhancing national security. While Chinese sources claim that BeiDou offers greater signal reliability than GPS within Asia, independent evaluations suggest that performance remains less consistent in high-latitude regions, warranting further assessment of its global accuracy and operational efficiency [37-39, 62].

Alongside navigation and remote sensing systems, China's high-throughput satellite (HTS) communications capabilities have expanded in recent years. The ChinaSat series, operated by China Satellite Communications Co., Ltd., includes satellites with HTS capacity, though current technological capabilities remain limited and commercial performance has been modest. The majority of China Satcom's revenues still derive from traditional services such as broadcasting national and provincial TV channels and supporting government or military networks, rather than commercial broadband offerings. Nonetheless, these systems are positioned to support broader national goals, particularly in extending access to rural and underserved regions. These efforts align with China's stated objective of bridging the digital divide and promoting "information equality" across its territory. However, this raises the question of whether China's strategy is fundamentally unique or part of a broader global trend, as multiple countries have pursued integrated Satcom-terrestrial connectivity solutions to address similar infrastructure challenges [37-39, 62].

China's ambition in Satcom is not limited to domestic connectivity. The literature and White Paper [37-39, 62] emphasizes China's vision of enhancing international cooperation and expanding satellite services globally. This includes strengthening partnerships with countries involved in the Belt and Road Initiative (BRI), thereby positioning China as a provider of satellite-based solutions in emerging markets. The development of megaconstellations, including projects like Guo Wang and Qianfan, aligns with this outward-looking approach, reflecting a strategy to compete with Western-led systems such as SpaceX's Starlink and OneWeb [37-39, 62].

The White Paper also underscores China's goal of developing reusable launch technologies and enhancing the resilience and autonomy of its space infrastructure. This dual-use approach, integrating civilian and military applications, serves as a fundamental pillar of China's space development. By securing independent Satcom networks, China aims to ensure secure military communications, enhance real-time intelligence capabilities, and reduce vulnerabilities associated with reliance on foreign-controlled infrastructure [50-62]. Unlike previous broad statements, these dual-use capabilities are evident in specific technological advancements. For example, China's Tianlian relay satellites, originally deployed for civilian data transmission, have also been used to enhance military satellite communications and real-time battlefield awareness [64-65]. Similarly, the Hongyan and Hongyun projects, initially promoted as commercial broadband constellations, include encryption and anti-jamming features that align with defense priorities. This pattern mirrors similar developments in the U.S. and European space industries, where commercial advancements have directly contributed to national defense applications [64-65].

China's Satcom technology has progressed significantly over the past decade, narrowing, but not yet closing the gap with leading Western competitors. In 2015, Chinese-built communication satellites were roughly equivalent to Western systems from the late 1990s or early 2000s. By 2020, however, advancements in phased-array antennas, satellite miniaturization, and inter-satellite optical links began to elevate China's capabilities. These developments have enabled the deployment of high-throughput broadband satellites with performance levels gradually approaching mid-tier Western designs [37–39, 62–65]. Nevertheless, there remains a considerable gap in flexibility and throughput. For example, China's largest operational HTS system currently offers around 100 Gbps capacity with limited in-orbit adaptability, while European manufacturers such as Thales Alenia Space and Airbus have fielded satellites with fivefold capacity (500+ Gbps) and more advanced, software-defined payload flexibility. By most industry assessments, China remains 5+ years behind the technological frontier established by Airbus, Boeing, and Thales in high-throughput communications satellite design[37–39, 62–65].

At the same time, China has shown a strong focus on network optimization and architectural upgrades. The integration of AI-driven network management and adaptive beamforming technologies in its recent Satcom constellation planning suggests a push for greater operational efficiency and network resilience. The Shijian-20 satellite exemplifies this shift, showcasing high-throughput Ka-band communications, onboard digital signal processing, and optical inter-satellite links, marking a milestone in Chinese HTS system capability [37–39, 62–65].

In contrast to HTS, China has made more substantial progress in the field of Earth observation. The development of the Gaofen satellite series, focused on high-resolution imaging, has placed China closer to global leaders in civilian and military remote sensing. While EO innovation is challenging, it is arguably less software-intensive than the design of advanced, flexible Satcom payloads. These gains in EO capability underscore China's strategic investments in space infrastructure aimed at improving both self-sufficiency and global competitiveness.

## 2.3. Previous Studies on China's Space and Satcom Strategies

A growing body of literature has explored China's evolving space and satellite communications (Satcom) strategies, reflecting the country's increasing influence in the global space sector [1-5]. These studies often focus on China's dual-use space capabilities, geopolitical ambitions, technological advancements, and commercial satellite initiatives [27-36]. However, while existing research provides a strong foundation, critical gaps remain in understanding the specific performance metrics, regulatory challenges, and strategic military applications of China's Satcom programs.

### 2.3.1. Academic and Policy Oriented-Research

Several studies and policy reports have examined the strategic trajectory of China's space sector [27-50]. These studies highlight how China pursues self-reliance in space technology and seeks to reduce dependence on Western Satcom infrastructure. Johnson-Freese (2016) [2] argues that China's strategy aligns with its broader goal of technological sovereignty, while Moltz (2019) [63] emphasizes China's view of space as a domain of strategic competition. Specifically, he suggests that China's development of GuoWang represents a direct counter to the dominance of U.S.-led systems like Starlink.

Studies from institutions such as the Center for Strategic and International Studies (CSIS) and the U.S.-China Economic and Security Review Commission (USCC) analyze China's space sector within broader geopolitical and security frameworks [25-36]. Their reports emphasize:

1. China's Space Infrastructure as a National Security Asset
    - The People's Liberation Army (PLA) directly oversees key Satcom programs, ensuring that civilian and military applications remain integrated.
    - CSIS (2023) identifies China's focus on military-grade encryption, anti-jamming technology, and secure broadband for military command and control.

2. Belt and Road Initiative (BRI) and Satcom Expansion
    - China has established over 20 ground stations in BRI-affiliated countries, including Argentina, Namibia, Pakistan, and Ethiopia, to extend its Satcom reach beyond national borders. While some of these stations were initially constructed for China's non-LEO missions (e.g., lunar tracking, BeiDou navigation), recent reports suggest they are being upgraded or integrated to support broadband Satcom constellations, particularly GuoWang and Qianfan, as their deployments mature (CSIS, 2023, ref. [58-63]).
    - CSIS (2023) notes that these facilities provide broadband services but may also facilitate geopolitical influence and intelligence-gathering.

3. China's State Subsidization Model and Market Implications
    - Unlike the market-driven Western model, China funds its Satcom projects through direct government investment and soft loans from state-owned banks. This financing structure applies not only to the GuoWang constellation, which is state-led and directly managed by the China Satellite Network Group, but also to Qianfan and Honghu-3, which, despite commercial branding are backed by municipal governments, academic institutions (e.g., Chinese Academy of Sciences (CAS)), and military-industrial conglomerates. While Qianfan is often labeled as "commercial," its development trajectory is tightly interwoven with the Shanghai government's innovation policy and national-level space targets [58–63]. This subsidized approach, when paired with low-cost satellite internet offerings, could undercut private-sector providers, particularly in developing countries. By offering low-cost broadband to underserved regions, China may generate long-term technological dependencies, especially in countries lacking domestic Satcom capacity or strong regulatory oversight. This could not only shift market dynamics but also introduce sovereignty and surveillance risks in recipient nations.

    - USCC (2023) warns that China's low-cost satellite broadband offerings could undercut Western providers, creating long-term dependencies in emerging markets.

Consequently, these studies emphasize the People's Liberation Army's (PLA) role in shaping China's Satcom programs and dual-use systems, as well as the integration of Satcom infrastructure into the Belt and Road Initiative (BRI) to expand influence in Africa, Southeast Asia, and Latin America (USCC, 2023; CSIS, 2023) [58-63]. Ground stations help keep track of the tens of thousands of satellites and other objects in orbit, thereby providing the so-called situational awareness (SSA). Literature [63-65] suggests that China is aggressively pursuing the export of its space capabilities to governments (summary of overall satcoms delivered between 1984-2020 can be found in Appendix A, where nine of thirty-eight satellites launched from 2000 have dual-use case, thereby serving the military function). To ensure that China's customers do not have export related problems because of US sanctions, they contracted with several developing counters to provide alternatives for in-orbit delivery, where China also supplies the ground stations for operations. This covers training where countries can operate the satellites using their own operators. In-orbit delivery of satellites has occurred for example with Nigeria (two satellites In 2007 and 2011), Venezuela (2008), Pakistan (2011), Bolivia (2013), Laos (2015), Belarus (2016), Algeria (2017), and Indonesia (2020). These were priced at about $240-$250 million each, including launch, TT&C support, and operations training, thus becoming an attractive value proposition for developing countries. Inside China urban areas have high broadband penetration, as shown in Figure 2.3 there exist many ground operational centers for Telemetry, Tracking, and Command (TT&C), remote sensing or meteorological data reception that are adjusted or expanded to provide further capabilities. Therefore, China operates a dense network of domestic ground stations to support its expanding space activities, ranging from commercial Satcom operations to deep space missions. While, the density of China's ground network offers resilience and capacity for managing a growing constellation of LEO satellites, the distribution of these stations is concentrated along the eastern and southern coastal regions. This spatial distribution implies potential challenges in achieving uniform satellite coverage and communication latency reduction, particularly for orbital planes with high Right Ascension of the Ascending Node (RAAN) that are less visible from coastal sites. Additionally, while China's domestic infrastructure is not likely to be downlink-limited in the short term, even assuming moderate Inter-Satellite Link (ISL) usage, the ability to scale Satcom backhaul through this infrastructure depends on network redundancy and expanded use of Ka- and Q/V-band gateways [64–66].

China's ground stations provide the following services:

- TT&C functions for managing both LEO and GEO constellations.
- Data relay support, including for the Tianlian relay satellite system, akin to the U.S. TDRSS (Tracking and Data Relay Satellite System).
- Ground segment operations for the BeiDou Navigation Satellite System, supporting its global positioning services.

Key Domestic Ground Stations include:

- Xi'an Satellite Control Center (XSCC): The largest and most critical ground station in China, responsible for satellite command and tracking operations.
- Kashgar Ground Station: Located in western China, this facility plays a key role in tracking satellites over the Middle East and Central Asia.

- Sanya Ground Station (Hainan Island): Strategically positioned to support ocean monitoring, maritime intelligence, and space tracking in the South China Sea.
- Ngari Ground Station (Tibet): High-altitude station optimized for deep space communications and geostationary satellite operations, thus excluding LEO so far.
- Changchun Ground Station: Used primarily for Earth observation, remote sensing, and military reconnaissance.


Figure 2.3 - Market Growth and Projected Deployment of LEO Satellites (source [60-65])

China is also further upgrading its ground infrastructure to support inter-satellite laser communications, AI-driven data processing, and high-frequency S, X, and Ka-band transmissions, increasingly mirroring Western ground station capabilities. While public details remain limited, industry analyses and reports from the China Aerospace Science and Technology Corporation (CASC) and China Electronics Technology Group Corporation (CETC) suggest the integration of laser communication terminals and AI-enhanced data relay functions at newly constructed ground facilities [63–66]. These efforts are intended to reduce China's reliance on U.S. and European ground networks and strengthen its capacity for independent satellite operation and secure communications.

The deployment of higher-frequency bands (such as Ka and Q/V-band) and advanced optical ground stations positions China to keep pace with developments in the U.S., EU, and private-sector actors like SpaceX and OneWeb. This technological leap allows for greater data throughput, lower latency, and enhanced cybersecurity in Satcom operations.

**CONTROL FACILITIES**

- Base 26 - Xian Satellite Monitor and Control Center
- Beijing Aerospace Command and Control Center

**TRACKING STATIONS**

- Changchun
- Guiyang
- Khashi Tianshan Station
- Minxi
- Nanning Guijiang Station
- Weinan Station / Wei South station
- Xiamen
- Yilan
- Dongfeng Station
- Hetian / WADA Station
- Jiamusi / Jia linhai Station
- Lushan station
- Nanhai Station / Bureau of Nankai
- Qingdao Station
- Tianshan station
- Zhanyi Station

While China is heavily investing in domestic ground stations, it has also expanded its international presence across South America, Africa, and Southeast Asia. Overseas ground stations extend China's access windows for satellite telemetry and control, especially for non-geostationary (LEO and MEO) constellations that require frequent handovers due to shorter orbital periods. However, the extent to which these foreign stations enable "uninterrupted satellite control" depends significantly on satellite orbital parameters, station placement, and time zone coordination. For polar or sun-synchronous orbits, for instance, facilities in South America or Africa offer optimal contact windows that complement China's eastern coastal stations [63–66].

These overseas facilities are particularly sensitive in geopolitical discourse. Table 2.4 lists known Chinese ground stations located abroad, which have raised concerns among Western analysts and governments. The proximity of some of these facilities, such as the Espacio Lejano station in Argentina, located approximately 350 miles from the Santiago Satellite Station operated by Sweden's SSC has prompted fears of dual-use intentions. These concerns include the potential for these ground stations to intercept data, monitor Western satellite operations, or support

Chinese intelligence-gathering efforts. This suspicion is exacerbated by China's military-civil fusion strategy, under which ostensibly civilian infrastructure may support military objectives. As reported by CSIS and the USCC (2023) [61–65], the People's Liberation Army (PLA) is believed to be actively involved in the operation of many of these facilities, which increases Western apprehension over their role in global space competition and security dynamics.

Table 2-4 - China's LEO Megaconstellations compared to Starlink, OneWeb and Amazon Kuiper

| **Location** | **Country** | **Primary Function** | **Strategic Significance** |
|---|---|---|---|
| Espacio Lejano | Argentina | Deep space tracking data relay | PLA involvement raises concerns about dual-use functions |
| Swakompmund | Nambia | Satellite tracking, communications | Provides China with access to southern hemisphere satellite passes |
| Karachi Ground Station | Pakistan | BeiDou system integration | Strengthens China-Pakistan Military and intelligence cooperation |
| Lahore Ground Station | Pakistan | Satcom relay and data transmission | Expands Chinese digital infrastructure in South Asia |
| São Tomé Ground Station | São Tomé and Príncipe | Satcom relay, maritime intelligence | Expands China's coverage over the Atlantic and West Africa |
| Dongara (Leased from Sweden) | Australia | Scientific missions, telemetry | Potential intelligence-gathering capabilities |
| Kiruna Ground Station | Sweden | Arctic and deep space tracking | Enhances China's situational awareness in high latitudes |
| Malindi Station | Kenya | Remote sensing, Earth observation | Supports China's growing influence in Africa's space sector |
| South Tarawa Station | Kiribati | Satellite communications, tracking | Expands China's Pacific monitoring capabilities |
| El Sombrero Satellite Ground Station Guárico | Venezuela | Contract between Venezuela and China Great Wall Industry Corporation (CGWIC) | To develop Venezuela's first satellite (Venesat-1). It is located within the confines of the Capitán Manuel Rios Air Base |
| Luepa Satellite Control Ground Station | Venezuela | Back-up Facility | Secondary station to El Sombrero Satellite |
| Tucano Ground | Brazil | Joint Venture - unknown | Established between |

| | | | |
|---|---|---|---|
| Station<br>(Exact location unknown) | | | Brazilian start-up company Ayla Nanosatellites and Chinese aerospace company Beijing Tianlian Space Technology. |
| Amachuma Ground Station<br>La Paz | Bolivia | Communication | One of the ground stations that communicates with the TKSAT-1. It was developed and launched by China Great Wall Industry Corporation (CGWIC). |
| La Guardia Ground Station<br>Santa Cruz | Bolivia | Communication | One of the ground stations that communicates with the TKSAT-1. It was developed and launched by China Great Wall Industry Corporation (CGWIC). |
| China-Chile Astronomical Data Center for the Atacama Large Millimeter Array (ALMA) at Paranal Observatory<br>(Exact location unknown) | Chile | Data Center and Analysis | Developed by the Chinese Academy of Sciences (CAS) and Huawei. |
| San Juan Satellite Laser Ranging (SLR) Project, Felix Aguilar Astronomical Observatory | Argentina | Observation and Mapping | A joint venture between the National University of San Jose (UNSJ) and National Astronomical Observatories of China (NAOC) at the Felix Aguilar Astronomical Observatory. Designed and developed by the Chinese Academy of Surveying and Mapping (CASM). |

| | | | |
|---|---|---|---|
| China-Argentina Radio Telescope (CART) Project, Felix Aguilar Astronomical Observatory<br>San Juan | Argentina | Operation, Ratio Telescope | A joint venture between the National University of San Jose (UNSJ) and National Astronomical Observatories of China (NAOC), Felix Aguilar Astronomical Observatory. |
| Santiago Satellite Station | Chile | Satellite Launch Tracking and Control | Operated by the Swedish Space Corporation (SSC). Decades-long affiliation to China Satellite Launch and Tracking Control (CLTC). |
| Río Gallegos Ground Station (Unofficial) (Exact location unknown) | Argentina | Unknown | A joint venture between Argentinian company Ascentio and Chinese start-up Emposat. |
| Neuquén Station | Argentina | Satellite Launch and Tracking Control Center | Deep Space Station |

According to the literature and publicly available information [62–65], China's overseas ground stations utilize high-frequency S, X, and Ka bands, which are also commonly used by Western military and commercial operations. This overlap has raised concerns among Western governments and analysts due to potential implications for signal interception, interference, and broader space security.

a) Potential interception of satellite communications. This refers to the theoretical possibility that Chinese ground stations, particularly those located close to Western-operated facilities or in overlapping coverage zones, could intercept transmissions from U.S. or European satellites operating in the same frequency bands. While most contemporary satellite traffic is encrypted, legacy systems and older platforms may still be susceptible to interception or unintended data exposure. Furthermore, for satellites supplied by China to developing nations (e.g., Venezuela, Pakistan, Nigeria), concerns persist that pre-installed technical backdoors could allow continued remote access or data siphoning by Chinese entities.

b) Signal spoofing and interference capabilities. China's growing investment in advanced electronic warfare techniques has prompted fears that its ground station network could enable signal spoofing or targeted interference. Such capabilities could hypothetically disrupt Western Satcom operations, especially in conflict-prone regions. This concern is compounded by China's parallel development of kinetic and non-kinetic counter-space capabilities, including co-orbital and directed-energy systems.

c) Cybersecurity vulnerabilities. Ground stations, especially those with internet-connected systems, can serve as access points for cyber intrusions. China's cyber doctrine explicitly integrates electronic warfare, cyber operations, and space-based tools under unified military commands such as the PLA Strategic Support Force. Western cybersecurity agencies have warned that ground station infrastructure could be exploited to infiltrate Satcom networks, introduce malware, or disrupt operations through denial-of-service attacks.

Additionally, several reports, including Western Analysts [61–65] suggest that some Chinese overseas stations may be capable of communicating with foreign satellites, raising the specter of unauthorized signal hijacking under specific orbital and spectrum conditions. Given the opacity of China's military-civil fusion model, such concerns are taken seriously by Western space security players. The dual-use nature of this infrastructure, while nominally serving civilian or commercial roles may conceal latent military functions or facilitate covert intelligence-gathering operations. Consequently, scrutiny continues to intensify over China's expanding ground infrastructure footprint, both domestically and abroad. Given China's military-civil fusion strategy model, these concerns are not unfounded, particularly as China continues to develop counter-space capabilities.

### 2.3.2. Technical and Comparative Analysis

China's Satcom megaconstellations, particularly GuoWang, Qianfan, and Honghu-3, represent a significant shift in the country's approach to global satellite broadband. While technical evaluations of Western LEO constellations, such as SpaceX's Starlink, OneWeb, and Amazon Kuiper, are well-documented in both academic literature and industry reports, China's megaconstellations remain comparatively understudied in independent research. This section aims to assess existing technical analyses of China's Satcom proposals and identify research gaps that need to be addressed.

From a technical perspective, comparative analyses by Pachler, Crawley, and Cameron (2022 and 2024) [12-18] have assessed the performance of Chinese Satcom megaconstellations relative to Western LEO systems. Their work highlights key trade-offs in coverage, throughput, and frequency use among GuoWang, Starlink, and OneWeb, emphasizing that China's megaconstellation efforts are rapidly narrowing the technological gap. Their study emphasizes that China's investment in LEO broadband is closing the technological gap with Western counterparts, though critical performance aspects such as latency and spectrum efficiency require further validation.

Further research by Portillo et al. (2019) [17] explores the global potential for LEO constellations to bridge the digital divide, indirectly positioning China's rural broadband ambitions as part of a broader international movement. These analyses are instrumental in evaluating China's international connectivity goals and its potential to export Satcom solutions to developing nations. However, their study does not provide an assessment of Qianfan, or Honghu-3. The 2022 Analysis Mason report on LEO capabilities and limitations [66] offers another perspective on China's Satcom ambitions. Using the Non-GEO Constellation Analysis Toolkit

(NCAT2), this report models LEO network coverage, exclusion angles, and supply-demand heatmaps for broadband access. While NCAT2 includes technical parameters for GuoWang based on ITU filings, the report does not evaluate Qianfan or Honghu-3 and lacks comparative performance analysis against other Satcom systems. NCAT2 was used to analyze Starlink's effectiveness in Ukraine, highlighting how LEO Satcom can function in contested environments, but similar analyses have not been performed for China's constellations. The literature and these findings suggest that while technical modeling has been initiated for GuoWang, comprehensive independent assessments remain incomplete.

### 2.3.3. Research Gaps

While these previous studies provide valuable insights into China's space ambitions, gaps remain. There is limited analysis on China's specific throughput capacity, coverage efficiency, and market positioning compared to Western competitors. Additionally, the intersection of China's Satcom expansion with military doctrine and cyber capabilities remains underexplored in public literature. This thesis seeks to bridge these gaps, also considering China's current MEGACON plans with a total of 38, 000 satellites (Guo Wang, Qianfan, and Honghu - 3).

## 2.4. Overview of Regulatory Challenges

As China accelerates its Satcom ambitions, its development path is closely intertwined with international regulatory frameworks, spectrum allocation policies, and growing concerns over orbital congestion and space debris. These regulatory challenges play a role in shaping China's competitive positioning and its ability to expand Satcom services globally. China's increasing presence in the Satcom sector is evident through its ambitious megaconstellation projects, which aim to provide comprehensive broadband coverage both domestically and internationally. The deployment of these systems underscores China's strategic intent to become among top players in the global Satcom market .

### 2.4.1. Frequency Rights and Spectrum Allocation

The International Telecommunication Union (ITU) [5] governs global spectrum allocation and satellite orbital slot coordination, ensuring fair access to radio frequencies. China's GuoWang constellation has sparked concerns among competitors over spectrum congestion, as LEO systems operate within limited frequency bands. Initial reports suggested China has sought to preemptively secure spectrum filings under ITU's "first-come, first-served" principle, a tactic also employed by Western players like SpaceX (ITU, 2023 ref. [5]).

The strategic race for spectrum poses regulatory friction, as the failure to reserve spectrum for future users could limit the capacity of new market entrants. This issue is not specific to China but affects all players in the Satcom sector. Literature such as Maral & Bousquet (2020) [6, 57] highlights the competitive implications of spectrum scarcity, warning that the proliferation of megaconstellations (MEGACON) in general may strain existing regulatory frameworks. The concern is that if current players secure large portions of available spectrum, it could hinder the entry of new competitors, regardless of their country of origin.

In addition to these technical filings, China's broader approach to spectrum governance reflects its long-term strategic ambitions. According to a 2024 report by The Economist [60-65,80], China has actively placed delegates in international standards bodies, including ITU and other telecommunications forums to shape the evolution of technology norms and standards. This "stacking" of committees is seen as an effort to influence global rule-making in a direction favorable to Chinese commercial and political interests [60-65,80].

The spectrum race poses challenges to regulatory equity and innovation. If dominant players, regardless of nationality, lock in substantial spectral capacity through speculative filings, newer entrants may find themselves effectively excluded. This has raised concerns among policymakers and scholars [6, 57] emphasizing that the proliferation of megaconstellations (MEGACON) risks overwhelming existing regulatory mechanisms, potentially leading to long-term spectrum congestion and inefficient utilization. In response, the ITU has moved toward milestone-based enforcement for large LEO constellations. Under current guidelines, operators must demonstrate deployment of at least 10% of their filed satellites within two years of regulatory approval and 50% within six years. This policy aims to curtail speculative filings and enforce accountability in spectrum usage, though its effectiveness remains subject to further empirical assessment (ITU, 2023).

Overall, while China's aggressive spectrum acquisition strategy is not unique, its integration with broader geopolitical goals, including technological standard-setting and Satcom diplomacy raises distinct regulatory implications. Understanding the implications of China's ITU engagements is important for assessing the future competitive balance in global satellite communications.

### 2.4.2. Space Debris and Orbital Congestion

The proliferation of LEO MEGACON has escalated concerns over orbital congestion and space debris management. China's planned deployment of thousands of satellites under several programs raise questions about collision risks and debris proliferation, especially given China's anti-satellite (ASAT) tests, which generated large debris fields (Chen, 2021 ref. [39]).

International agreements on debris mitigation, such as the United Nations Outer Space Treaty (1967) and the Space Debris Mitigation Guidelines (2007), lack binding enforcement mechanisms. Researchers like Weeden (2022) [58] argue that China's expanding space activities amplify the need for stricter enforcement and data-sharing mechanisms on satellite tracking and collision avoidance.

### 2.4.3. Political and Security Dimensions

Beyond technical regulations, geopolitical tensions have further complicated regulatory cooperation. Western governments have expressed concerns over China's military-civil fusion in Satcom, suspecting that commercial satellite networks may serve dual-use purposes for intelligence and surveillance operations (Liu & Zhao, 2024 [30, 56]). One of the primary concerns raised by Western policymakers is China's "Military-Civil Fusion" (MCF) strategy, which integrates civilian technology developments with military applications.

Until recently, the People's Liberation Army (PLA) Strategic Support Force (SSF) was responsible for many of China's space-based assets, including Satcom infrastructure. However, in 2024, the PLA SSF was disbanded as part of the most significant military reorganization in China since 2015. Its responsibilities were redistributed across three new entities: the PLA Cyberspace Force, the PLA Aerospace Force, and the PLA Information Support Force [30, 56].

This restructuring does not diminish concerns about the dual-use potential of Satcom systems. Rather, it reflects a deepening integration of cyber, space, and information warfare capabilities within China's military doctrine. The continuation of MCF under this new structure suggests that commercial satellite assets may remain strategically relevant for defense communications, surveillance, and strategic deterrence. As a result, international scrutiny of China's Satcom initiatives is likely to persist, particularly in the context of market access, technology partnerships, and regulatory reciprocity.

China's emphasis on dual-use technologies, which serve both civilian and military objectives, is closely tied to its military-civil fusion strategy. This approach, a cornerstone of China's broader technological development policy, actively integrates military goals with civilian industrial advancements [60-65]. By embedding potential military functions within commercial Satcom systems, China's Satcom infrastructure may inadvertently or deliberately pose risks to foreign networks. For instance, China's development of advanced satellite-based surveillance capabilities, such as those associated with its BeiDou navigation system, has raised alarms about potential military applications.

Specific dual-use concerns in China's Satcom sector include ([60-65] and [30, 56]):

a) Intelligence and Surveillance Capabilities

- China's state-backed Satcom networks may provide the PLA with secure military communications, real-time intelligence transmission, and global reconnaissance.
- Analysts have pointed to China's extensive use of space-based synthetic aperture radar (SAR) and hyperspectral imaging, suggesting that commercial satellite networks could be leveraged for military reconnaissance under the guise of civilian applications (Liu & Zhao, 2024 [30, 56]).
- Ground stations operated by Chinese state-owned entities (sub-chapter 2.3.1), particularly in South America and Africa, have raised concerns that China may be using commercial satellite infrastructure to intercept foreign communications and track Western military movements.

While such capabilities may be comparable to those used by U.S.-based operators under commercial contracts with the Department of Defense (e.g., Intelsat or Viasat), the central concern lies in the opaque nature of China’s military oversight and control mechanisms, especially given the limited civilian oversight in the Chinese political system.

b) Cybersecurity and Network Integrity Risks

- The integration of China’s commercial Satcom with PLA infrastructure has raised concerns about cyber vulnerabilities, backdoor access, and the potential for espionage.
- Western governments fear that Chinese Satcom terminals, once deployed in international markets, could be used to intercept or disrupt communications. Analysts have warned that Chinese satellite terminals deployed abroad, especially under the Belt and Road Initiative, could serve as access points for espionage or be exploited for jamming or denial-of-service (DoS) attacks [60-65].
- Past incidents, such as the 2018 alleged PLA hacking campaign targeting U.S. satellite networks, have reinforced Western skepticism regarding China’s space-based infrastructure (U.S.-China Economic and Security Review Commission, 2023 [58]).

U.S. and European space policies have increasingly emphasized space security and resilience, with growing scrutiny toward potential collaborations involving Chinese Satcom entities. While specific collaborations might not be widely documented, the general trend involves heightened vigilance over any partnerships that could compromise Western security interests. For example, the U.S. has been cautious about allowing Chinese companies to participate in sensitive space-related projects, reflecting broader concerns about intellectual property theft and technology transfer [56-63]. This politicization of space regulation could significantly influence China’s access to foreign markets, especially in regions closely aligned with Western security interests. The scrutiny over potential collaborations and the emphasis on security and resilience may limit China's ability to expand its Satcom services globally, particularly in sensitive sectors like defense and government communications.

Therefore, China’s ambitions to expand its Satcom market globally have faced growing regulatory pushback, particularly in the United States, Europe, and Indo-Pacific countries closely aligned with Western security policies. Western regulatory frameworks have increasingly emphasized space security and resilience, leading to new restrictions on Chinese satellite communications providers, as follows:

- The United States Federal Communications Commission (FCC) has restricted licensing for Chinese Satcom operators, citing national security risks (FCC, 2022 [61]).
- In 2021, the European Commission announced stricter foreign investment screening for critical space infrastructure, effectively limiting China’s ability to acquire stakes in European satellite companies (European Commission, 2021 [59]).
- The UK has prohibited Chinese Satcom providers from participating in OneWeb expansion projects, due to security concerns over network vulnerabilities (UK Space Agency, 2023 [60]).

These policies highlight the increasing securitization of satellite communications, where market access is no longer dictated solely by commercial competitiveness but also by national security considerations [56-63]. As indicated, as a result China has encountered challenges in establishing Satcom footprint in regions aligned with Western security interests, particularly within:

- Five Eyes countries (U.S., UK, Canada, Australia, New Zealand)
- NATO-affiliated European nations
- Strategic Indo-Pacific allies (Japan, India, South Korea, Australia, Taiwan, Philippines)

Western governments have actively discouraged partnerships with Chinese Satcom firms to prevent:

- Potential infiltration or surveillance via Chinese-manufactured terminals
- Unintended transfer of sensitive technologies such as anti-jamming, encryption, or phased-array beam steering capabilities
- Dependence on broadband services which may be compromised during geopolitical conflict

Thus, while China's commercial Satcom capabilities may be expanding technically, their market reach is increasingly constrained by geopolitical dynamics and security-driven market segmentation.

### 2.4.4. Implications for China's Satcom Strategy

The current regulatory landscape presents both constraints and strategic opportunities for China’s Satcom expansion:

- Spectrum Constraints may limit Chinese MEGACON capacity or delay global deployment timelines. This concern is plausible when considering China's allocated spectrum filings and the proposed scale of its constellations. GuoWang alone targets 13,000 satellites operating in the Ku and Ka bands, spectrum that is already congested due to filings by Starlink, OneWeb, and others. According to ITU filings and recent analyses (e.g., Pachler et al., 2024), China’s orbital filings remain within the ITU’s deadlines, but effective coordination with other countries is needed to avoid harmful interference, especially in equatorial and densely populated regions. If such coordination fails, deployment delays and downlink limitations may occur, especially in contested areas like Sub-Saharan Africa or Latin America.
- Orbital Safety Concerns could subject China’s launches to heightened international scrutiny, particularly as debris and collision risks intensify due to the growing number of MEGACON satellites in Low Earth Orbit (LEO). While these risks are acknowledged internationally, current mechanisms such as the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) and national space traffic management (STM) efforts have limited enforcement power. Therefore, while concerns are valid, few expect meaningful international intervention unless an incident escalates geopolitical tensions [63].
- Security-Driven Export Restrictions could impede partnerships with countries under U.S. influence, while opening doors in non-aligned regions through Belt and Road cooperation.

China has signed space infrastructure agreements with over 30 countries, many of which are in Africa, South Asia, and Latin America, offering bundled deals that include satellites, launch services, and ground infrastructure. This avenue provides a strategic hedge against exclusion from Western-dominated markets and could be a central pathway toward commercial viability and geopolitical influence (CSIS, 2023; USCC, 2023).

Navigating this regulatory complexity is likely to remain a key determinant of China's future Satcom competitiveness.

To summarize, as Western regulatory scrutiny increases, China faces three significant challenges in its Satcom expansion efforts:

1. Limited Market Access in Key Commercial Regions
China's ability to deploy broadband services internationally is constrained in areas where national security outweighs economic considerations. Notable examples include:

- The Middle East and Europe, where U.S. defense partnerships limit the adoption of Chinese Satcom infrastructure, despite some countries' openness to Chinese investment in other sectors.
- Countries participating in the U.S.-led Clean Network initiative, including Japan, Australia, the Czech Republic, and others, have excluded Chinese telecom and Satcom providers from infrastructure projects (U.S. State Department, 2021 [62]).

2. Potential for a Bifurcated Global Satcom Industry

- The increasing separation of Western and Chinese Satcom networks may lead to a fragmented global broadband market, where countries are forced to align with either Western or Chinese satellite providers. China may concentrate its Satcom expansion in Asia, Africa, and parts of Latin America, regions characterized by: a) Positive diplomatic and commercial ties with China. b) Limited domestic space infrastructure. c) Large underserved rural populations, making low-cost broadband particularly attractive.
- The European Union's IRIS² Satcom project is an example of Western efforts to develop an independent broadband alternative to Chinese and US networks (EU Space Policy, 2023 [63]).

3. Regulatory Barriers for Chinese Investment in Foreign Satellite Infrastructure

- Chinese firms seeking to invest in Western Satcom infrastructure are likely to face continued scrutiny and regulatory hurdles, particularly in NATO and Indo-Pacific regions.
- The Committee on Foreign Investment in the United States (CFIUS) has previously blocked Chinese investments in U.S. satellite companies, setting a precedent for future restrictions on Chinese Satcom expansions (CFIUS, 2022 [64]).

While China's commercial satellite networks are growing, Western governments increasingly view Satcom through a national security lens, complicating China's ability to expand its market presence. Regulatory barriers, cybersecurity concerns, and geopolitical rivalries are likely continue to shape China's global Satcom ambitions, with a high likelihood that the Western and Chinese Satcom ecosystems will develop separately.

Therefore, China's Satcom ambitions increasingly intersect with global regulatory politics. As commercial competitiveness becomes secondary to national security in many jurisdictions, Satcom has emerged as a domain of strategic contestation rather than mere infrastructure deployment. This environment increases the likelihood that two distinct Satcom ecosystems will emerge one dominated by Western operators like SpaceX, OneWeb, and IRIS², and another centered around Chinese constellations like GuoWang and Qianfan. This bifurcation is not merely technological, but also institutional and geopolitical, as it reflects broader shifts toward a multipolar digital infrastructure regime.

As such, future research could further explore:

- Which countries are likely to further align with China's Satcom offerings and under what conditions.
- Whether China's bundled Satcom packages (including launch, satellites, terminals, and soft financing) will prove more cost-effective and politically palatable for emerging markets.
- The feasibility of cross-constellation interoperability in a geopolitically divided Satcom environment.

# Chapter 3 : China's Current Satcom Status

## 3.1. Existing Infrastructure and Capabilities

China's satellite communication (Satcom) infrastructure has experienced growth over the past decade, driven by substantial government investments (Fig. 3.1, showing China on the 2nd place), technological advancements, and increasing global competition. While the development is promising, the actual infrastructure remains in various stages of deployment and development. This section outlines the status of China’s Satcom infrastructure, focusing on key megaconstellation projects, launch capabilities, and ground station networks.

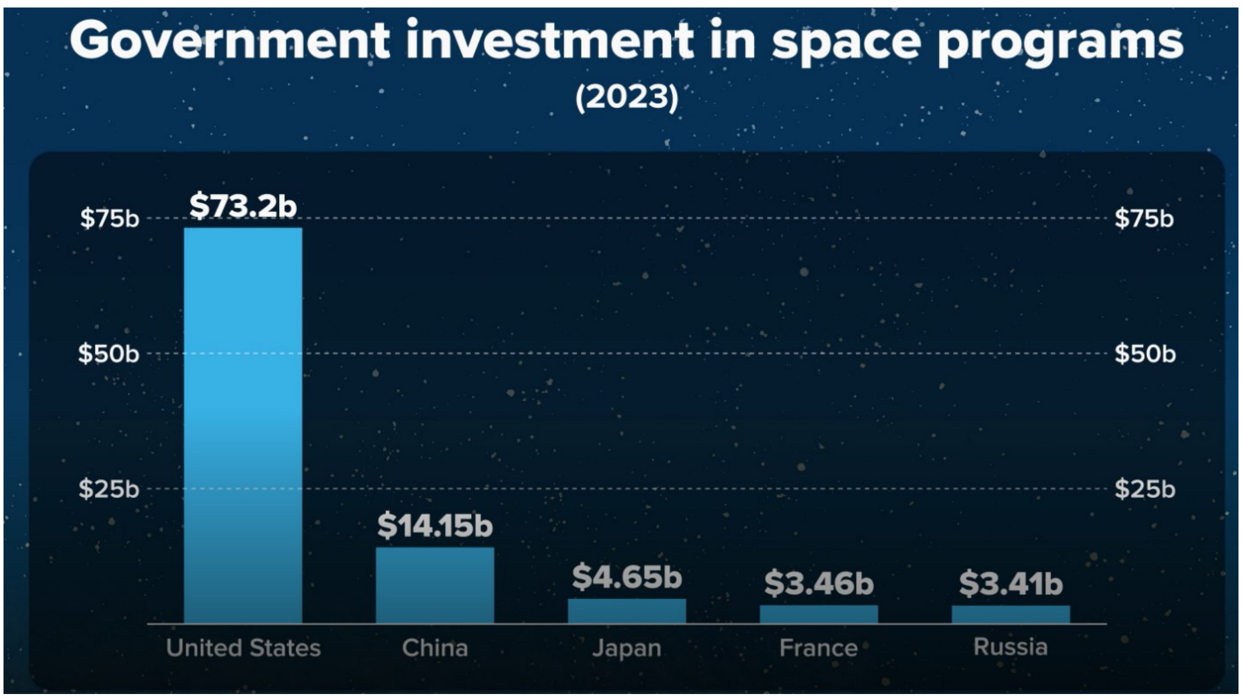



Figure 3.1 - Government Investment in Space Programs in 2023 (source: SpaceNews)

### 3.1.1. Overview of China's LEO Megaconstellations

China has three major Satcom constellations in development (two summarized in Table 3.1), each serving distinct strategic and commercial purposes. These include GuoWang (State Network), Qianfan, and Honghu-3, each at different stages of development and backed by different institutional frameworks [2, 28-35].

Table 3-1 - China's LEO Megaconstellations

| LEO Megaconstellation | Expected Satellites | Satellites in Orbit | Owner |
|---|---|---|---|
| GuoWang<br>"State Network" | 13, 0000 | 19* | China Satellite Network Group |
| Qianfan<br>"Thousand Sails"<br>"G60 Starlink" | 15, 000 | 90 | Shanghai Spacecom Satellite Technology |

*See explanation table 2.1.

GuoWang, modeled after SpaceX's Starlink, is envisioned as China's national Satcom backbone. It aims to provide broadband coverage for domestic users and expand into Belt and Road Initiative (BRI) markets. The expected number of users GuoWang plans to serve is not explicitly stated, but it is designed to cover a significant portion of China's population and potentially extend into international markets. Qianfan, with commercial ambitions, primarily seeks to compete with Western broadband providers globally. Honghu-3 is expected to provide regional coverage, supplementing China's existing space-based communication networks. China's Satcom networks are expected to serve a vast domestic user base, though specific estimates vary. According to reports [53, 58-65], GuoWang aims to connect tens of millions of users within China, particularly those in remote and rural regions where fiber and terrestrial broadband solutions are not viable. However, clear numerical projections for international expansion remain scarce. As highlighted earlier, some analysts suggest that Qianfan could be leveraged to offer broadband services in BRI-aligned countries, particularly in Africa, South America, and parts of Asia, where Chinese telecommunications firms already have a strong presence and collaborations (CSIS, 2023). For example, South Africa and China have successfully created the world's most extended intercontinental quantum satellite communication link, spanning 12,900 kilometers between the countries, and have tested laser communications for ISL [68].

China's strategy involves gradual scaling, with early launches focused on validating satellite technology and ensuring regulatory compliance under International Telecommunication Union (ITU) agreements. The recent launch of GuoWang satellites via Long March 8A marks an important step toward full-scale deployment. China's launch capabilities are crucial for the success of these megaconstellations. The Long March series of rockets, particularly the Long March 8A and Long March 6A, have been instrumental in deploying these satellites. The Long March 8A, with its reusable design, is expected to significantly reduce launch costs and increase the frequency of launches, which is essential for rapidly deploying large constellations like GuoWang and Qianfan [2, 28-35].

**Key developments in China's launch capacity:**

- China has increased its annual launch rate from 22 in 2016 to 68 in 2024, with projections suggesting 100 launches in 2025 [62-65] and (Space News).
- The emergence of private-sector launch providers like Landspace (Zhuque-2), iSpace (Hyperbola series), and Galactic Energy (Pallas-1) is expected to supplement government-led efforts.

Planned deployment schedules indicate that China must meet International Telecommunication Union (ITU) deadlines for frequency allocation, requiring at least 10% of GuoWang satellites to be operational by 2029 and 50% by 2032. The ability to meet these deadlines depends not only on launch frequency but also on the development of reusable rocket technology, which China is aggressively pursuing. Figure 3.2 shows the rocket launches in 2024 compared to previous years, including nations and main providers. There were 264 successful launch attempts in 2024 and 7 failed launch attempts. However, these include test launches, which are more prone to failure. Furthermore, in 2024, companies and agencies from 8 Nations attempted launches, including the United States (169 launches), China (68 launches) and Russia (17 launches). As shown in Figure 3.2 C) 27 Launch Service Providers completed launches in 2024, including SpaceX (140 launches), CASC (49 launches) and Rocket Lab (16 launches).

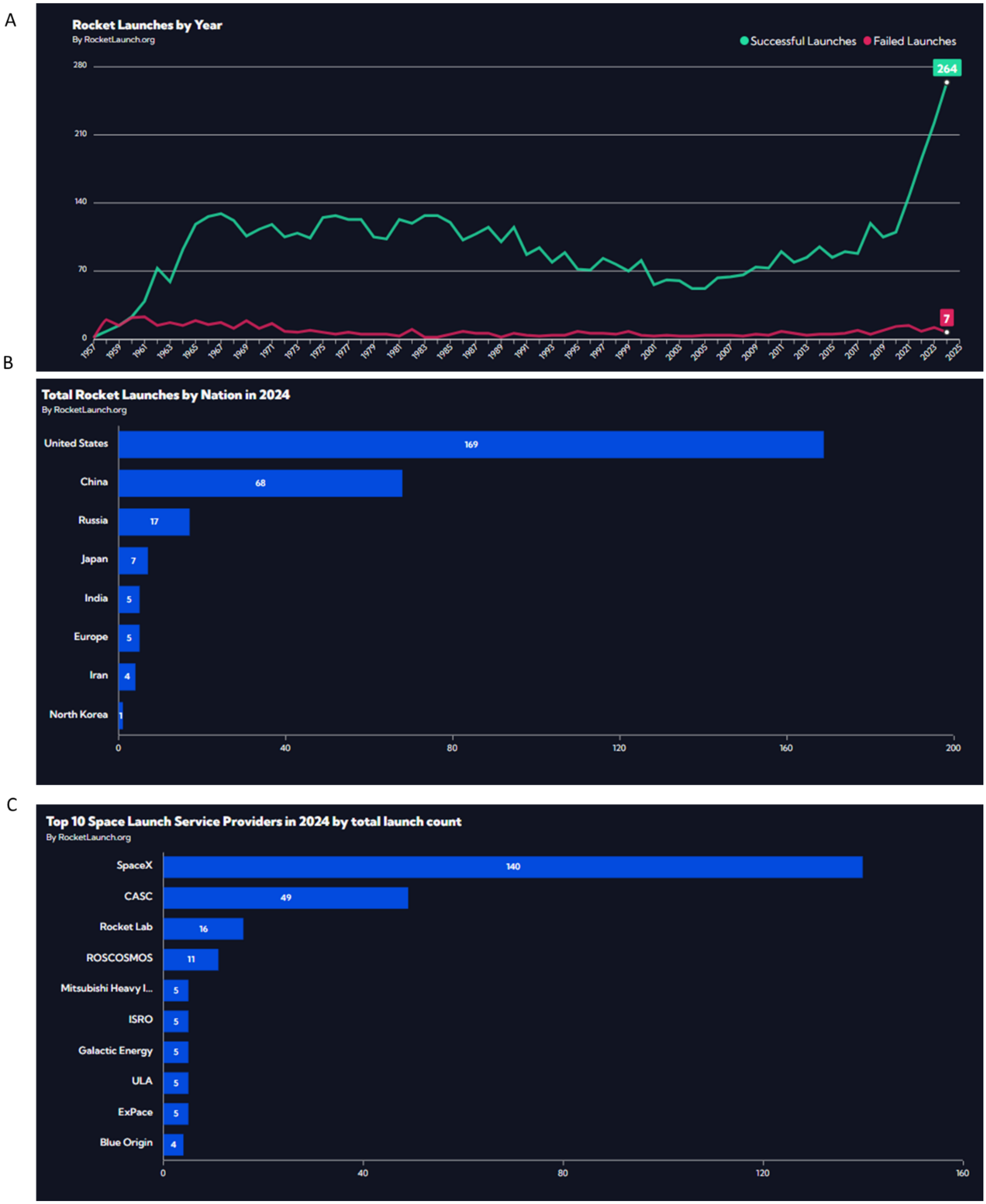



Figure 3.2 - Launches A) Total: Successful and Failed with 2024 compared to previous years B) by Nation in 2024 C) by Launch Provider (source: RocketLaunch)

Figure 3.3. shows Chinese orbital launches between 2020 - 2024 for commercial and government projects.

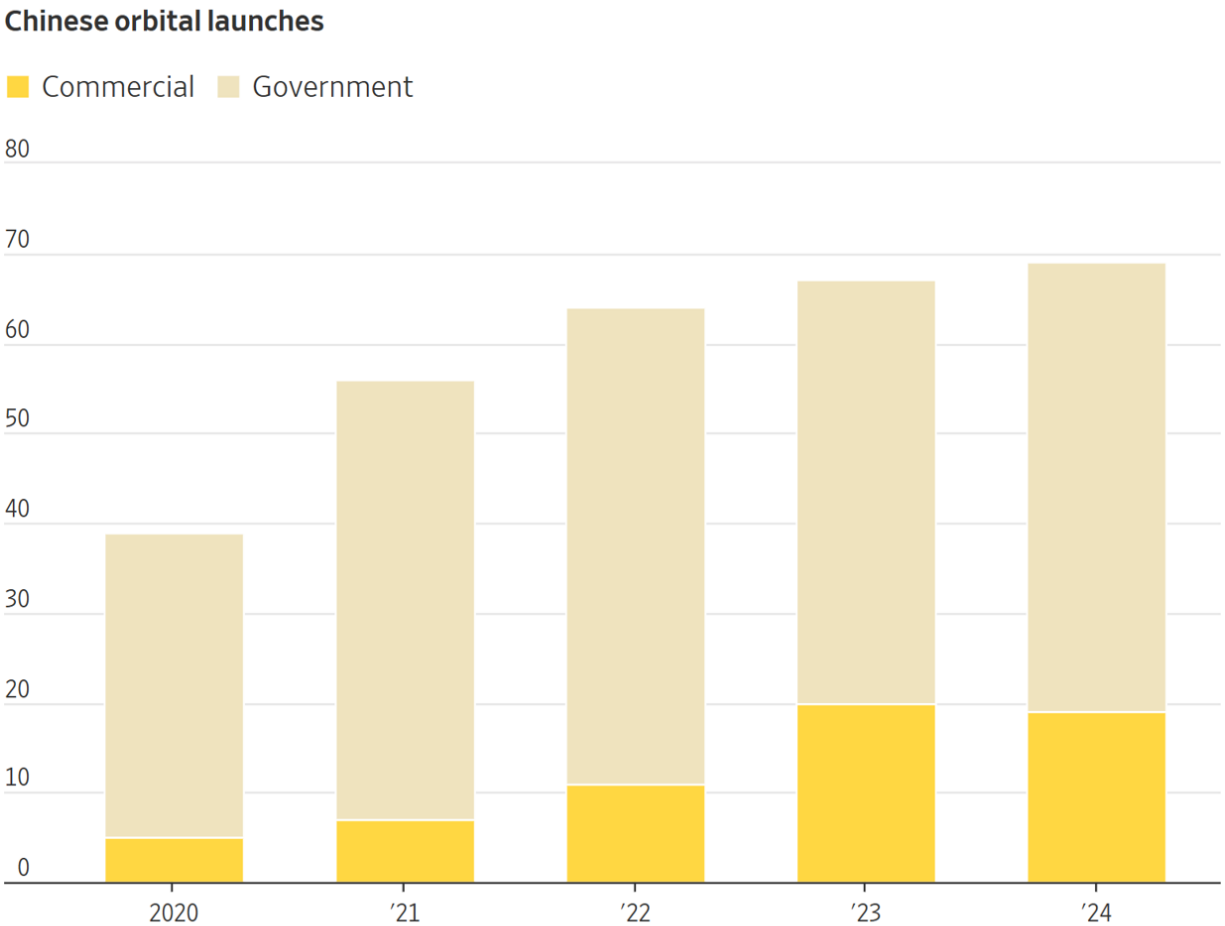



Figure 3.3 - China Launches between 2020 - 2024 in commercial and government projects
(Source: The Wall Street Journal & Astronomer: Jonathan McDowell)

Table 3-2 summarizes the key companies in China, which are working on the reusable rockets.

Table 3-2 - Main List of planned Chinese reusable rockets (credit: Andrew Jones/SpaceNews)

| **Company** | **Rocket Name** | **Rocket Type** | **Key Characteristics** |
|---|---|---|---|
| iSpace | Hyperbola-3 | Methane-liquid oxygen reusable | Payload capacity 8,5000 kg to LEO<br>First launch planned in 2025 |
| Landspace | Zhuque-3 | Methalox reusable | Payload capacity up to 21, 000 kg to LEO<br>First launch planned in 2025 |
| Galactic Energy | Pallas-1 | Kerosene-liquid oxygen reusable | Payload capacity 5, 000 kg to LEO or 3, 000kg to a 700 km |

| | | | |
|---|---|---|---|
| | | | sun-synchronous orbit (SSO) |
| CAS Space | Kinetica | Kerolox reusable | Payload capacity<br>7, 800 kg to 500 km SSO |
| Deep Blue Aerospace | Nebula-1 | Kerolox reusable | Payload capacity<br>1, 000 kg to 500 km SSO<br>First flight in 2024 |
| Space Pioneer | Tianlong-3 | Kerolox | Comparable to Falcon 9 in launch capability, reusable first stage. |
| Orienspace | Gravity-2 | Kerolox | Payload capacity<br>25,600 kg to LEO,<br>First flight in 2025, reusable first stage. |
| CASC | Various | Various | Developing reusable rockets, incl. new-generation of human-rated launcher, spaceplane, and long March 9 super heavy lift launcher. |

Meeting the targets of China's MEGACON will require their growth in launch capabilities, and therefore, the next 5-10 years will be crucial for their strategic development opportunities to secure frequencies and help speak of the future of space and broadband internet connectivity. This will be essential not only for reaching deployment milestones but also for solidifying China's strategic positioning in global frequency allocation, satellite network coverage, and broadband competitiveness. Without reliable and affordable launch infrastructure, China risks lagging behind in the satellite broadband race, especially as global operators consolidate orbital resources and customer bases.

The cost of space launch has been a defining factor in the global satellite and space-based economy, with reusable rocket technology emerging as the key driver of affordability. China, which has historically relied on state-backed space programs, is now witnessing the expansion of a quasi-commercial launch sector aimed at reducing costs and increasing launch cadence [65-70]. This effort, while still in its early stages compared to SpaceX and other Western private entities, signals a broader strategic objective to develop a competitive, cost-effective launch capability that supports both commercial and military ambitions. Figure 3.4 shows the cost per kilogram for space launches since 1960. China's current launch cost per kilogram remains higher than that of SpaceX, with estimates from Orienspace's Gravity-1 vehicle placing it at approximately $4,000 per kg to low Earth orbit (LEO) [65-70]. By comparison, SpaceX's Falcon 9 achieves a cost of $2,720 per kg, leveraging reusable booster technology and high launch frequencies. While China's state-owned entities, such as the China Aerospace Science and Technology Corporation (CASC), have focused on large-scale national space projects (Long March), the emerging commercial sector often referred to as SpaceX and others is actively seeking to lower costs through reusability and industrial scaling. Orienspace, along with Space Pioneer and other private players, represents a significant push toward competitive, cost-effective launch services in China (summary Table 3-2) [65-70].

China's launch ecosystem is currently undergoing transformation. Historically dominated by state-backed entities such as the China Aerospace Science and Technology Corporation (CASC), which developed the Long March series, China is now fostering a quasi-commercial launch sector to drive down costs and boost innovation. This sector includes emerging firms such as Orienspace, Space Pioneer, Galactic Energy, and iSpace, many of which have received blended investments from both private and state-affiliated entities.

A case in point is Orienspace's Gravity-1, which is projected to deliver payloads to LEO at $4,000/kg as of 2024. However, it's important to note that these are early-stage cost estimates and the vehicle is not yet operating at commercial scale. Launch prices, particularly in China, also depend on internal subsidization and domestic industrial policy. Thus, when comparing costs between China and the U.S., one must distinguish between exchange rate-based costs and Purchasing Power Parity (PPP), adjusted figures. For instance, although $4,000/kg in nominal terms appears high relative to SpaceX, domestic Chinese production and labor cost advantages may result in lower PPP-adjusted unit economics, particularly if industrial scaling and reusability are achieved in the next five years.

To close the launch cost gap with SpaceX, China is actively investing in reusable rocket technology. CASC has announced its intention to field reusable vehicles by 2025 [65-70], and several private companies (e.g., Space Pioneer's Tianlong-3) are planning reusability demonstrations, drawing explicit inspiration from SpaceX's architecture. The Tianlong-3 aims to deliver similar lift capacities as Falcon 9, while Orienspace's upcoming Gravity-2, a 60-meter reusable medium-lift rocket, is being designed for bulk constellation deployments, reportedly capable of launching up to 30 satellites per mission. Table 3-2 summarizes China's key launch providers, capabilities, and target cost structures.

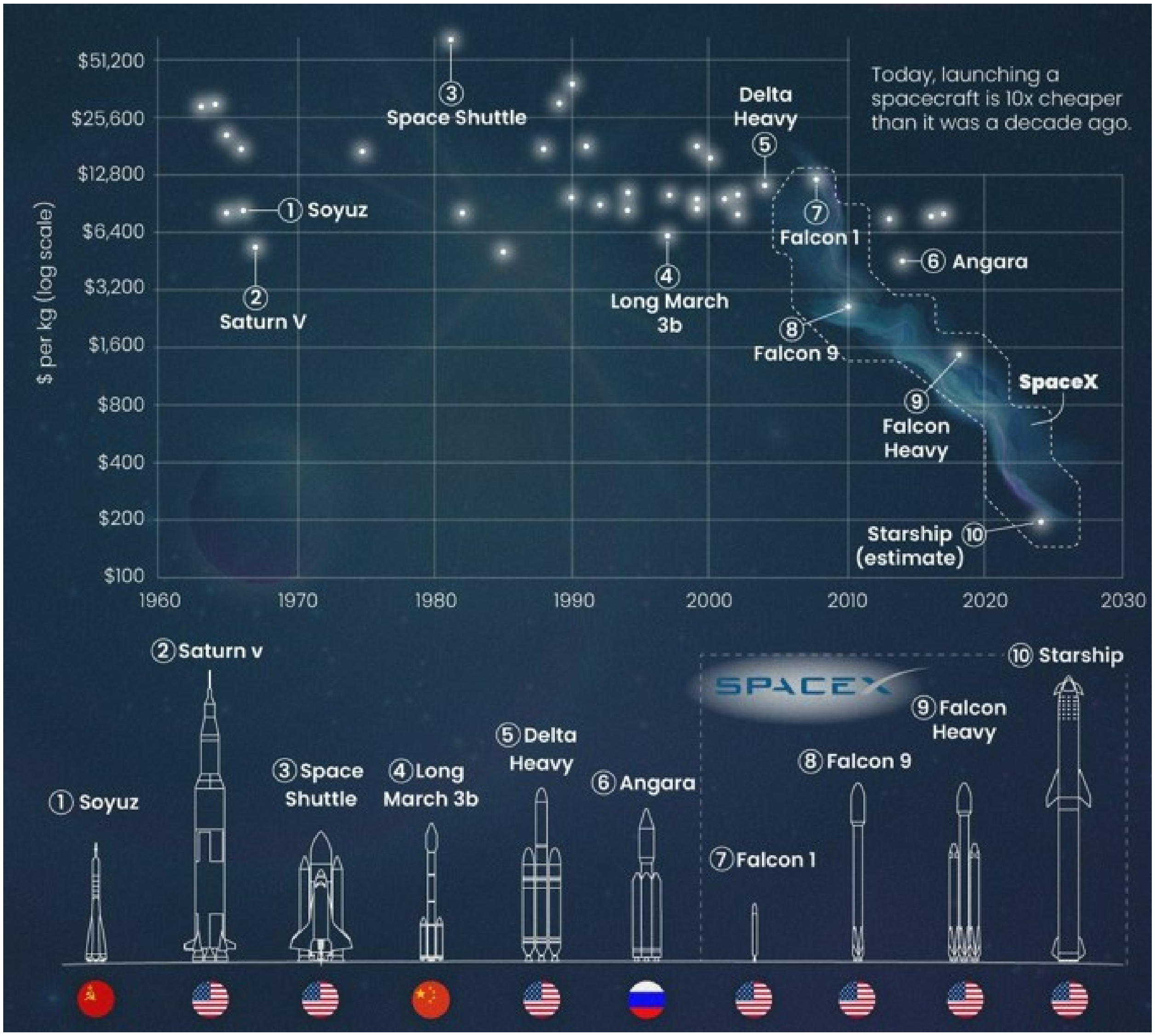



Figure 3.4 - Outlook: cost per kilogram for space launches across the globe since 1960, prices were adjusted for inflation (Source: Visual Capitalist)

As summarized in table 3-2, China's long-term goal is to undercut Falcon 9's cost per kilogram through advancements in reusable rocketry. CASC has announced plans for its first reusable rocket launch by 2025, while commercial entities such as Space Pioneer are securing substantial funding (over $207 million in recent investments) to develop their own reusable systems [65-70]. Orienspace's Gravity-2, currently in development, aims to increase payload capacity while reducing cost per launch, potentially challenging SpaceX's economic model in the next decade [65-70]. Despite these ambitions, China faces challenges in replicating SpaceX's economies of scale and integration efficiency. Unlike SpaceX, which benefits from federal contracts and vertically integrated production, Chinese private space firms often receive supply-side state support, such as factory construction and indirect subsidies, but must navigate significant government oversight. This results in a paradox where commercial players have access to extensive capital but remain tightly controlled by the central government. Furthermore, China’s launch cost strategy extends beyond commercial competition. The state sees low-cost, high-frequency launches as a critical enabler of national security, particularly in response to the U.S. military’s use of SpaceX’s Starlink during the Russia-Ukraine war [65-70]. The development of MEGACON to rival Starlink necessitates rapid, affordable launches, reinforcing the urgency for cost reductions in satellite deployment. Orienspace has explicitly positioned itself as capable of executing “emergency” satellite deployments, potentially mirroring the Pentagon’s responsive launch programs with providers like Firefly Aerospace [65-70].

Importantly, China is also upgrading its launch infrastructure to meet these ambitions. One notable example is the Wenchang Commercial Launch Site in Hainan, where multiple new launch pads are under construction adjacent to a satellite manufacturing facility. This integrated setup is specifically intended to support high-frequency constellation launches and reflects China’s broader strategy to scale its launch cadence and reduce turnaround times.

From a broader perspective, China’s trajectory in launch costs remains behind SpaceX but is on an accelerated path. With CASC's upcoming reusable rockets and a growing competitive sector, Chinese launch costs are likely to fall below $3,000 per kg within the next five to ten years, approaching Falcon 9's current benchmark. However, SpaceX’s Starship program, which aims to reduce costs to below $100 per kg (see Figure 3.4), presents an enormous challenge. If successful, Starship could maintain a generational lead over China’s efforts, forcing Chinese firms to adopt drastic cost-cutting measures, technological breakthroughs, or alternative competitive strategies. Consequently, while China is making significant strides toward cost-efficient space launch capabilities, its path is marked by state intervention, restricted market dynamics, and a race against time to master reusability. Whether China can fully replicate and surpass SpaceX’s cost efficiency remains uncertain, but its strategic commitment to reducing launch costs indicates a transformative shift in the global space economy.

### 3.1.2. Ground Station Network and Global Expansion

Beyond satellite deployment, China is also developing a network of global ground stations (see sub-chapter 2.3.1), which serve as critical infrastructure for Satcom operations.
These facilities provide:

- data relay and tracking for Chinese satellites, ensuring stable operations.
- support for Belt and Road (BRI) partners, where China offers joint Satcom infrastructure development.
- reduced reliance on Western-operated Satcom networks, strengthening China’s digital sovereignty.

As of 2025, China operates ground stations in South America (Brazil, Argentina), Africa (Namibia, Kenya), and Asia (Pakistan, Thailand). Agreements for future ground stations are in place, but specific dates for their operational status are usually not disclosed. For instance, China has agreements with Brazil for ground station development starting in 2026 [2, 28-35, 50-60].

## 3.2. Market Position Analysis

To assess China's competitiveness in Satcom, Table 3.3 provides a comparison of China's three main LEO constellations against global competitors, including Starlink, OneWeb, and Amazon Kuiper. This comparison examines satellite count, altitude, launch capabilities, throughput, and strategic market focus [2, 14-17, 28-35, 50-60].

Table 3-3 - China's LEO Megaconstellations compared to Starlink, OneWeb and Amazon Kuiper

| **Parameter** | **GuoWang** | **Qianfan** | **Honghu-3** | **Starlink (SpaceX)** | **OneWeb (Eutelsat)** | **Amazon (Kuiper)** |
|---|---|---|---|---|---|---|
| Total Satellites (Planned) | 13, 000 | 15, 000 | 10, 000 | 42, 000 | 6372 | 3, 236 |
| Altitude [km] | 1, 1000 | 500 - 1, 000 | 500 - 1, 000 | 550 | 1, 200 | 630 |
| Launch Vehicles | Long March 8, 5B | Long March-6A, -8, likely commercial launchers[5] | Long March 2C | Falcon 9 | Soyuz, Falcon 9 | New Glenn, ULA |
| Deployment Timeline | 10 % by 2029, 50% by 2032 (ITU req.) | 2024 initiation; 648 satellites by end of 2025 | Start Early 2030s | 7, 000+ launched (2024) | 630+ launched | 2029 completion |
| Asserted Throughput per Satellite | 10-30 Gbps[4] | 10 Gbps[4] | 10-20 Gbps[4] | 4-8 Gbps | 4-8 Gbps | 5-7 Gbps |
| Planes | Orbital | Polar | Orbital | Orbital | Circular | Orbital |
| Frequency Bands | Ku, Ka | Ku, Q and V | TBD | Ka, Ku, V, X and K | Ku | Ka, Ku |
| Primary Geographic Focus | China | Global (developing regions) [1] | Global (developing regions) [1] | U.S., Global | Europe, Asia | Global |
| Business Model | State-backed, rural broadband | Commercial ISP alternative | Hybrid[3] | Direct-to-consumer broadband | B2B/Govt contract | Amazon-integrated |
| Potential Dual-Use Applications | Dual Use | Commercial, Dual Use | Dual Use | Dual Use | Dual Use | B2B/Commercial |
| ISLs | Yes[4] | Yes[4] | Yes[4] | Yes | No | Yes |

[1]Agreement with Brazil, starting 2026

[2]incl. Brazil, Russia, India, China, South Africa, Egypt, Ethiopia, Indonesia, Iran and the United Arab Emirates

[3]Govt/Commercial

[4]Assumption

[5] 4 launches on 6A and 1 launch on 8 as of March 2025

China’s GuoWang constellation is planned to reach 13,000 satellites, directly competing with Starlink and Kuiper. However, as of 2025, Guowang has only launched 19 satellites, while Starlink already operates over 7,000. The gap in deployment speed is significant, largely due to SpaceX’s rapid reuse of Falcon 9 for LEO launches. China’s Long March 8A development and overall launch capabilities are critical to narrowing this gap. Starlink operates as a private-sector ISP, generating revenue from individual consumers. GuoWang and Qianfan appear to be state-backed initiatives, focusing on government contracts and strategic infrastructure projects [2, 14-17, 28-35, 50-60]. GuoWang initiative focuses on providing broadband services for telcos, enterprises, and military within China, possibility eventually expanding overseas but effectively acting as 4$^{th}$ domestic telco. Qianfan, supported by the Shanghai Municipal People's Government and the Chinese Academy of Sciences, appears to target global markets with a commercial approach, potentially positioning itself as an alternative to existing international ISPs. Furthermore, Qianfan’s international expansion, including agreements in Brazil and Malaysia, suggests China’s push to challenge Western providers in developing regions. Qianfan aims for a constellation exceeding 15,000 satellites, with the first phase targeting 1,296 satellites, including 648 by the end of 2025 [2, 14-17, 28-35, 50-60]. Projected total throughput for GuoWang satellites (30-50 Gbps) is in line with Western LEO constellations, while Qianfan’s role may be lower (10 Gbps) due to using smaller satellites. Both GuoWang and Qianfan aim to utilize China's Long March (LM) series of rockets for satellite deployment. Notably, Qianfan's initial launches in 2024 employed the LM 6A vehicle. GuoWang operates primarily in the Ku and Ka bands, while Qianfan plans to utilize Ku, Q, and V bands. There is no official disclosure about detailed technical performances, such as projected throughput for Qianfan and Honghu-3 constellations.

To summarize, GuoWang and Qianfan are state-backed initiatives. However, their funding and operational models vary significantly:

- GuoWang (China SatNet): Announced in April 2021, GuoWang is backed by China Satellite Network Group, a state-owned enterprise (SOE) directly supervised by SASAC (State-owned Assets Supervision and Administration Commission). It is positioned as China’s 4th national telecom provider, integrating Satcom services with terrestrial networks to serve government agencies, enterprises, and rural broadband users [2, 28-35, 50-60].

- Qianfan (Thousand Sails): First announced in 2023, Qianfan is supported by the Shanghai Municipal People’s Government and the Chinese Academy of Sciences. Unlike GuoWang, Qianfan is partially commercially oriented, aiming to offer global broadband services in competition with Starlink and OneWeb. While the exact ownership structure remains unclear, reports indicate Shanghai Spacecom Satellite Technology is leading the initiative with both state and private investment [2, 28-35, 50-60].

- Honghu-3: The most recent entrant, first appearing in late 2023, remains in the early planning stages, with no confirmed launches or detailed technical disclosures. The project is led by Hongqing Technology, with an anticipated focus on regional secure communications.

China’s ability to compete in the global Satcom market depends on its launch frequency and cost efficiency. GuoWang and Qianfan rely on China’s Long March (LM) series of rockets, with recent deployments including:

- GuoWang satellites launched via Long March 8A in 2024, marking an important step toward full-scale deployment.
- Qianfan’s first launches in 2024 utilized Long March 6A, with plans to ramp up deployment by 2026.

China’s private-sector space industry is also growing, with companies such as LandSpace, Orienspace, and Deep Blue Aerospace developing reusable launch systems to reduce costs. Although China’s state-backed launches currently dominate, private sector involvement is expected to accelerate the deployment of LEO constellations, similar to SpaceX’s model [2, 28-35, 50-60].

## 3.3. Framework for China's Strategic Objectives for Satcom

China’s Satcom expansion strategy is shaped by a blend of strategic autonomy, geopolitical influence, and integrated civil-military development, consistent with both academic analyses and official policy documents [1-3, 28-35, 50-60]. The framework presented here is derived from a synthesis of public government strategies, white papers, and analytical literature. It identifies three overarching strategic objectives guiding China’s satellite communication efforts:

**1. Digital Sovereignty and Domestic Expansion:**

One of China’s central objectives is the development of an independent national Satcom infrastructure that minimizes reliance on foreign, particularly Western telecommunications systems. While services like Starlink are not legally permitted in China due to national restrictions on foreign-controlled internet access [1-3, 28-35, 50-60], the strategic intent is to proactively prevent future dependency risks and ensure that all critical communications infrastructure remains domestically controlled.

This objective manifests in several interrelated initiatives:

(a) Ensuring secure communications for government, military, and critical industries through domestically owned and encrypted satellite networks. This reduces exposure to foreign cyber-intrusion risks and enhances national operational security.

(b) Expanding Satcom infrastructure to rural and underserved regions through initiatives such as the “Digital China” strategy and the Rural Revitalization Policy, ensuring equitable digital access and national economic cohesion.

(c) Enhancing cybersecurity resilience by controlling both space-based telecom assets (e.g., GuoWang, Qianfan) and terrestrial infrastructure, such as gateway stations and terminals. This strategy reduces exposure to foreign hardware vulnerabilities (e.g., backdoors in imported ground systems), which have been a key concern of the Chinese cyber-defense posture.

**2. Global Market Entry and Strategic Influence:**
China's second major Satcom objective is its internationalization strategy, primarily focused on providing alternative broadband solutions to developing nations and reducing Western dominance in global satellite services.

The strategic intent can be subdivided into three key vectors:

(a) Long-term Satcom partnerships through the Belt and Road Initiative (BRI): China has increasingly bundled satellite deployment, training, and ground station infrastructure into BRI projects in Africa, Southeast Asia, and Latin America. These bundled agreements often offer favorable financing, making Chinese systems appealing to governments seeking cost-effective connectivity solutions.

(b) Establishment of China-led technical standards for space-based broadband systems. By promoting domestically developed frequency bands (e.g., Q/V-band) and operational protocols via international standards organizations, including the International Telecommunication Union (ITU), China aims to shape the technological architecture of future broadband systems.

(c) Spectrum positioning through early ITU filings: Leveraging the ITU's "first-come, first-served" policy, China has aggressively filed for spectrum rights, particularly in LEO and high-frequency bands to secure operating privileges before competitors. This approach may constrain other nations or companies' ability to access optimal orbital slots or frequency ranges, influencing global market dynamics.

**3. Military and Security Applications**
In line with its broader Military-Civil Fusion (MCF) doctrine, China's Satcom infrastructure is strategically configured to support military functions, both directly and indirectly.

Key areas of defense integration include:

(a) Resilient battlefield communications: Similar to how Ukraine leveraged Starlink during the Russia-Ukraine war, China is building redundancy in its Satcom networks to ensure military communication continuity in case of terrestrial network disruption or cyber-attacks. GuoWang and future military-grade constellations are envisioned to serve both civil and defense communication needs under the PLA Strategic Support Force (SSF).

(b) Enhanced ISR (Intelligence, Surveillance, and Reconnaissance) capabilities: While GuoWang and Qianfan are not ISR-focused constellations, they may relay ISR data from other platforms or facilitate real-time command and control across remote theaters. Some of China's higher-resolution commercial imaging systems have demonstrated dual-use potential, with overlapping orbits and coordinated mission timing [1-3, 28-35, 50-60].

(c) Advanced anti-jamming, encryption, and electronic warfare capabilities: Both literature and internal Chinese strategy documents note the development of space-based quantum encryption, anti-jamming protocols, and frequency-hopping capabilities to withstand adversarial interference, especially in contested environments like Taiwan or the South China Sea (CSIS, 2023) [1-3, 28-35, 50-60].

## 3.4. Domestic Connectivity in China

As of 2024, China reached approximately 1.1 billion internet users, representing an internet penetration rate of 76.4% of the total population [2, 28-35, 50-60]. This marks an increase of 11 million users (1.0%) from the previous year. Despite this growth, about 336.4 million individuals, or 23.6% of the population, remained offline at the start of 2024. This represents the second largest unconnected population worldwide (see Table 3.4 and Table 3.5, respectively) [2, 28-35, 50-60].

Table 3-4 - Largest Internet Users

| **Internet Users (2024)** | | |
|---|---|---|
| **No.** | **Country** | **Number of Users** |
| 1 | China | 1.1 billions |
| 2 | India | 881.3 millions |
| 3 | United States | 311.3 millions |
| 4 | Indonesia | 215.6 millions |
| 5 | Pakistan | 170 millions |

Table 3-5 - Largest Unconnected Populations

| **Internet Users (2024)** | | |
|---|---|---|
| **No.** | **Country** | **Number of Users** |
| 1 | India | 683 millions |
| 2 | China | 336 millions |
| 3 | Pakistan | 131 millions |
| 4 | Nigeria | 123 millions |
| 5 | Ethiopia | 103 millions |

The disparity in internet access is pronounced between urban and rural regions. Urban areas, particularly megacities like Beijing, Shanghai, and Guangzhou, have high-speed broadband connectivity, supported by extensive fiber-optic infrastructure. In contrast, rural and remote regions, especially in western provinces such as Tibet, Xinjiang, and inner Mongolia, face challenges due to the high costs and logistical difficulties associated with terrestrial network deployment [2, 28-35, 50-60].

To address these disparities, the Chinese government has launched several initiatives aimed at enhancing digital infrastructure nationwide. The "Digital China" strategy and the "Rural Revitalization Strategy" emphasize the development of information networks in underserved areas. These initiatives aim to increase internet penetration by at least 5% annually and achieve average broadband speeds of 100 Mbps in rural areas. MEGACON plays a pivotal role in these efforts, offering potentially a viable solution to bridge the connectivity gap in regions where traditional infrastructure is impractical [2, 28-35, 50-60].

To effectively assess the strategic need and feasibility of expanding Satcom in China, it is critical to understand the characteristics of the unconnected population, specifically, whether the 336 million individuals offline are primarily disconnected due to infrastructure limitations or affordability constraints. China's Gini coefficient (~0.465 as of 2023) indicates a relatively high income inequality, and income distribution data show that a significant proportion of rural households earn less than ¥20,000 annually (approx. $2,800 at market exchange rates) (National Bureau of Statistics, 2023). Assuming the widely cited affordability benchmark of 2% of income spent on internet services, this equates to an affordability ceiling of roughly ¥33 per month (≈$4.50). However, satellite broadband packages, even subsidized ones, typically exceed this threshold, suggesting affordability is a major constraint for much of the offline population. A 2022 report from the China Internet Network Information Center (CNNIC) confirms that over 75% of unconnected individuals reside in rural or western inland provinces such as Xinjiang, Tibet, and Gansu, where terrestrial infrastructure is sparse and incomes are below the national average. Therefore, the challenge is dual: rural areas are both underconnected and less able to afford commercial broadband without state intervention or heavy subsidies.

This finding substantiates the strategic logic behind China's MEGACON projects (e.g., Guowang) as part of the broader "Digital China" and "Rural Revitalization" policies: if scaled cost-effectively, LEO satellite coverage can address both physical and economic access limitations. Nevertheless, for MEGACON to have a meaningful domestic impact, pricing models and terminal subsidies must be aligned with local income distributions, possibly requiring state underwriting similar to rural electrification programs in earlier decades. Appendix H provides rural connectivity and income distribution in China with estimated affordability for Satcoms.

Table 3-6 summarizes the current status of urban-rural digital divide, including disparities between regions.

Table 3-6 - China's urban-rural digital divide

| **Region** | **Current capabilities** |
|---|---|
| Urban Areas<br>(e.g. cities: Beijing, Shanghai, and Guangzhou) | Have near-universal broadband penetration, with fiber-optic speeds exceeding 500 Mbps in many districts. |
| Rural and Remote Regions<br>(e.g. Tibet, Xinjiang, and Inner Mongolia) | Remain significantly underserved, with many villages relying on 2G/3G mobile networks or lacking coverage entirely. |

Broadband subscription costs relative to average income remain a barrier for low-income populations. Studies suggest that for 2-3% of the population, broadband remains financially inaccessible [2, 28-35, 50-60]. To address these challenges, China has launched above-mentioned nationwide digital infrastructure initiatives:

- “Digital China” Strategy (2018-Present). This long-term initiative aims to make digital infrastructure a national public good. Its connectivity targets include: a) 98% national broadband coverage by 2030, b) Minimum broadband speeds of 100 Mbps in rural areas c) Fiber-optic expansion in urban and peri-urban areas, with satellite integration for remote zones. (note: The 98% target refers to overall population coverage, not limited to terrestrial ground infrastructure)

- Rural Revitalization Strategy (2021-Present): Launched under the 14th Five-Year Plan, this policy emphasizes: a) Deployment of LEO-based broadband terminals in remote provinces b) Direct subsidies for satellite broadband hardware and subscriptions for low-income families c) Local government partnerships to test rural ground station deployment and data relay system.

- MEGACON (LEO Constellations) as a solution:

  - LEO broadband should eliminate the need for expensive fiber-optic expansion in mountainous and isolated regions.
  - Planned integration with China’s national fiber backbone to ensure hybrid satellite-terrestrial network optimization.
  - Rural deployment pilot projects have already begun in Tibet and Yunnan (see chapter 3, ground stations), where satellite links provide connectivity to villages beyond the reach of terrestrial networks [2, 28-35, 50-60].

According to official estimates [2, 28-35, 50-60], China’s digital infrastructure policies aim to:

- Reduce the unconnected population below 10% by 2028.
- Expand satellite broadband coverage to 100% of remote villages by 2030.
- Lower broadband costs to below 2% of median household income in underserved regions by 2035.
- Improve national cybersecurity by ensuring that 95% of all domestic broadband traffic is routed through China-controlled infrastructure by 2027.

**Note:** The 98% coverage and 100% remote village targets are complementary. One is a population metric, the other a geographic one, and both depend on satellite expansion and policy-driven affordability.

# Chapter 4 : Methodology and Model Description

## 4.1. Explanation of the Model

The model used in this study builds upon the framework established in previous research, particularly leveraging the structure outlined by Pachler et al. (ref [14,16 and 71]) based on the Resource Allocation Framework (RAM). This model serves as a foundation for evaluating the throughput capabilities of China's satellite communication initiatives, with a focus on GuoWang and Qianfan. Consequently, the present study adapts and extends this framework to examine the feasibility and performance potential of China's GuoWang and Qianfan megaconstellations. Unlike prior implementations focused on Western constellations (e.g., Starlink, OneWeb), this application is tailored to China's unique context, incorporating updated satellite launch records, ITU spectrum filings, and domestic broadband penetration metrics. The aim is to estimate total addressable throughput for both constellations under different scaling scenarios, and to assess potential market coverage both within China (GuoWang) and abroad (Qianfan). In this context, scalability refers to the ability of the satellite system to economically and technically scale to meet national and international connectivity objectives. It does not imply market TAM (Total Addressable Market) in the commercial sense, though downstream economic metrics are considered in later sections. Figure 4-1 shows the framework, including five physical models taken from Pachler et al. [71] , which is used to assess and compare system throughputs, further details can be found in (ref [14,16 and 71]). The model is composed of five tightly interlinked physical and logical parts. This multi-tier approach enables cross-validation between satellite design assumptions, orbital coverage constraints, and user-level service delivery.

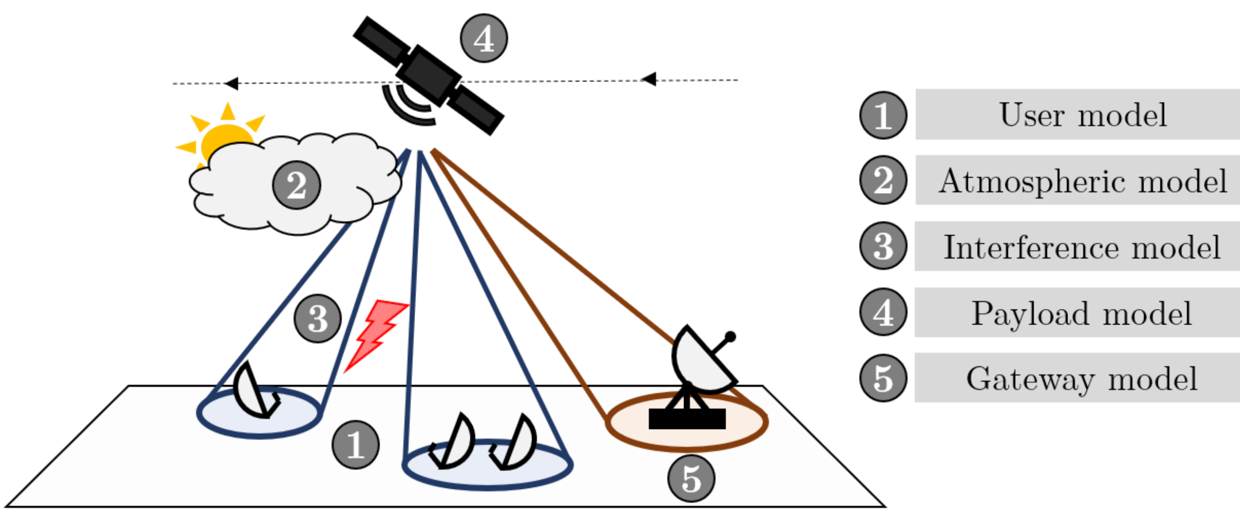



Figure 4.1 - Illustration of the framework with five physical models used to recreate realistic operational conditions from Pachler et al. ref [14,16 and 71]

The work is structured to analyze satellite network capacity, market penetration rates, and regulatory influences that shape the competitive landscape. It integrates multiple subsystems, including satellite constellations, ground station infrastructure, and spectrum allocation efficiency. Through the model, we can quantify the feasibility of China's strategic objectives in Satcom and understand the key constraints in achieving global market penetration.

The modelling approach is organized around four key analysis layers, as follows:

1) Physical Layer:
   a) primary inputs: Satellite count, altitude, RAAN distribution, inclination, orbital planes and aperture size.
   b) outputs: Instantaneous coverage, revisit frequency, spatial density
   Key question addressed: can the constellation cover underserved regions at scale ?
2) Network and Service Layer
   a) primary inputs: User terminal density, spot beam architecture, spectrum bandwidth, gateway footprint
   b) outputs: throughput per user, coverage efficiency, latency
   c) Key question addressed: can the system provide target data rates to target populations?
3) Economic Layer:
   a) primary inputs: launch costs, satellite bus price, Gateway CAPEX, user terminal cost, service pricing
   b) outputs: Revenue, IRR, breakeven point etc.
   c) Key question addressed: is the system financially viable under base, positive, and adverse scenarios?
4) Strategic Layer:
   a) primary inputs: regulatory limitations, export restrictions, alliance structures, spectrum filings
   b) outputs: market access viability, international partnerships, geopolitical constraints.
   c) Key question addressed: where can China effectively expand, and what constraints emerge?

For China's GuoWang and Qianfan constellations, the model integrates updated parameters from ITU filings, launch manifests (2023–2025), and discussed manufacturer disclosures to project system performance against strategic objectives (Chapters 1-3). GuoWang is modeled primarily for domestic deployment, with throughput and affordability metrics tied to China's internal digital strategy (see Chapter 3.4). This includes integration with China's national backbone and provincial user demand in underserved rural areas. Qianfan is modeled as an international-first strategy, focusing on BRI-aligned countries with limited connectivity infrastructure. Modeling scenarios include sub-Saharan Africa, Southeast Asia, and selected Latin American states (see Appendix F-H for gateways). Each system is evaluated with reference to ITU orbital and spectrum filings, Chinese white papers, manufacturer disclosures (e.g., CASC, China SatNet, Shanghai Spacecom), and secondary estimates on satellite bus capabilities and anticipated gateway footprints.

## 4.2. Main Assumption and Parameters

This section outlines the key assumptions and parameters used in the modeling of China's Satcom strategy, particularly as it relates to the deployment and scaling of the GuoWang and Qianfan megaconstellations. Assumptions span technological, geopolitical, economic, and operational factors and are structured to reflect both the deployment phasing and competitive responses shaping China's space-based broadband strategy.

**Geographical & Market Expansion Considerations**

The modeling framework assumes a two-phase deployment structure, reflecting the distinct strategic roles of GuoWang and Qianfan.

a) Two Deployment Phases:

**1.** Phase A – Domestic Coverage: GuoWang is modeled as a national priority infrastructure, with deployment tailored toward China's internal broadband goals, national sovereignty, and dual-use applications. Emphasis is placed on:

- System integrity and secure backhaul capacity.
- Connectivity for remote provinces with sparse or expensive terrestrial infrastructure.
- Gradual constellation buildup to satisfy regulatory ITU compliance (10% launch by 2029) rather than early commercial returns.

Deployment prioritization is assumed to fill lower-inclination orbital planes first, providing optimal coverage density over mainland China. This strategy is consistent with China's centralized investment logic and regulatory process. Notably, Qianfan is not modeled to serve the domestic Chinese market, avoiding potential price undercutting and regulatory duplication. Qianfan's pricing strategy is expected to be more commercially aggressive, aligned with foreign market penetration goals.

**2.** Phase B – International Expansion: Qianfan is structured as a commercial initiative, spearheaded by Shanghai Spacecom Satellite Technology, and more agile than GuoWang. The company's management includes former Huawei and commercial telecom professionals, suggesting a faster go-to-market strategy, less encumbered by state bureaucracy [72]. Huawei and China's Export-Import Bank have already deployed over 70% of LTE broadband networks across 50+ African nations, which sets a critical commercial foundation for Qianfan's future integration [72]. However, all deployment timelines in this analysis are modeled prospectively, not retroactively, to reflect future potential rather than current operating scale.

**Economic & Timeline Estimates**

a) Launch Schedule
- Estimated initial operational capability (IOC)
  a) Guowang: 2028 (Phase A - Domestic)
  b) Qianfan: 2027 (Phase B - International)
- Full deployment under base-case assumptions: GuoWang by 2032 and Qianfan by 2030.

b) Deployment Prioritization
- Guowang is primarily focused on domestic Chinese coverage, with a slower rollout due to regulatory control and long-term ITU spectrum strategy.
- Qianfan is prioritized for international markets, competing directly with Starlink and other LEO broadband constellations. This urgency drives a more aggressive launch schedule. Qianfan's urgency is relative to GuoWang, not just internally accelerated but driven by competition in external markets (i.e. primarily Starlink).

c) Launch Cadence & Scaling
- Guowang aims to deploy ~13,000 satellites, but official statements suggest only 1,200 satellites (~10%) by 2029. This is a conservative estimate that risks partial ITU rights loss.
- Qianfan follows an accelerated timeline, with hundreds of satellites expected annually starting in 2025, given that 36 satellites have already been launched.

d) Launch batch sizes:
- Near-term (2024–2025): ~10 per launch (Guowang), 18–36 per launch (Qianfan).
- Mid-term (2026–2028): Gradual increase, reaching ~50 per launch.
- Long-term (2028+): Potential for ~100 per launch, depending on launcher capabilities (Long March 5/9 and private reusable rockets).

Launch vehicle priorities are modeled as:
- GuoWang using Long March 5/6/8, with fallback to state infrastructure.
- Qianfan relying more heavily on private launchers (e.g., Orienspace, LandSpace).

Fractional launch capacity allocations are not uniformly defined in official sources. In the model, we assume 60% of China's heavy-lift capacity (including reuse scenarios) is allocated to GuoWang and Qianfan by 2028, gradually increasing toward 80% by 2030. Private launchers, especially reusable rockets, are assumed to be necessary enablers to increase the required launch cadence, especially in the modeled positive case (discussed in sub-chapter 3.1).

e) Market Competition & ITU Considerations
- The ITU filing deadline pressures Guowang to launch at least 10% (~1,300 satellites) within five years (by 2029) to retain rights.

- Qianfan's faster deployment is a strategic response to Starlink's growing international dominance, especially in markets where China seeks influence.

To maintain its rights under the ITU "first-come, first-served" framework, China must deploy at least 10% of the GuoWang system (~1,300 satellites) by 2029. This threshold is explicitly modeled into the GuoWang ramp-up strategy. Risk of partial spectrum forfeiture is considered in the negative scenario of the financial sensitivity analysis.

f) Technology & Launch Vehicles
   - Both constellations initially will rely on Long March launch vehicles, supplemented by private Chinese launch firms (e.g., Galactic Energy, LandSpace).
   - Reusability and launch economics will play a key role in achieving target deployment rates, but China's current launch infrastructure suggests a gradual ramp-up rather than immediate large-scale deployment.

g) Cost Structure and Capital Requirements:
   - Modeled at $500K–$900K per unit
     - Assumes mass production comparable to Starlink's V2 satellite platforms
     - Discount rate 10% (further details, Appendix E)
   - Full Constellation Costs (excluding ground segment)
     - GuoWang: $6B–$13B
     - Qianfan: $6B–$13B

**Note:** Ranges reflect uncertainty In launch vehicle pricing and propulsion bus upgrades, these are used for sensitivity analysis, not as simultaneous assumptions. The base case uses:
     - $700K/satellite for GuoWang
     - $600K/satellite for Qianfan
     - $3,500/kg launch price baseline for private launchers in 2026-2029
   - Ground segment deployment costs: Comparable to Starlink (~$5B), but potentially subsidized by state funding.

h) Revenue and User Distribution Assumptions:
   - Not uniform. Model and base case assumes urban-rural population breakdown, with only ~15% of unconnected users In easily reachable areas.
   - In China, ~20-30% of the offline population is disconnected due to coverage Issues, the remainder Is due to cost affordability constraints (see chapter 3.4 and analysis)

Revenue: assumed as an output based on pricing tiers, but in positive case assumes: $8-10/month average ARPU internationally, and $4-6/month ARPU domestically in rural regions being heavily subsidized by government.

**International Market Prioritization**

China's international Satcom expansion strategy, particularly through the Qianfan constellation, is tightly coupled with geopolitical partnerships, Belt and Road Initiative (BRI) infrastructure projects, and targeted regional connectivity needs. The following segmentation outlines China's phased market prioritization, derived from official government documents, recent partnerships, and BRI-aligned investments as well as Chapter 3. These priorities are subsequently used to inform market penetration rates and demand allocation assumptions in the financial and system throughput models.

**Key expansion regions:** Southeast Asia, Africa, South America (aligned with Belt and Road Initiative). Limited expansion in regions with strong Western presence (e.g., Europe, North America).

**Priority 1** Strong Geopolitical & Economic Ties (Near-Term Expansion, 2025-2030)

These countries exhibit a high degree of BRI engagement, existing Satcom cooperation with China, and strategic geopolitical alignment. They are considered to receive early access to Qianfan bandwidth (starting 2025), with 25–30% of international capacity allocated to these markets in the baseline scenario.

- Brazil: Existing cooperation in space & telecom (e.g., CBERS satellites); strong BRI engagement.
- South Africa: Strategic entry point into Africa; BRICS member; strong ICT infrastructure needs.
- Pakistan: Long-standing China-Pakistan Economic Corridor (CPEC) projects; strong political alignment.
- Indonesia: Largest Southeast Asian market; digital connectivity push under "Making Indonesia 4.0" initiative.
- United Arab Emirates (UAE): Strategic telecom hub; China's deepening ties in satellite and AI sectors.
- Egypt: Key African partner; BRI gateway; recent space cooperation with China (MisrSat-2).

**Priority 2** High Demand & BRI Engagement (Mid-Term Expansion, 2027-2035)

These countries show expanding demand for digital infrastructure and increasing alignment with China's space industrial diplomacy. Considered with 30–35% of international Qianfan throughput capacity in the mid-term projection, contingent on orbital capacity growth and ground station deployment.

- Nigeria: Africa's largest economy; expanding broadband market; China's major telecom investment.
- Argentina: High telecom demand; growing China-Argentina space collaboration (Neuquén Deep Space Station).
- Ethiopia: Strong BRI involvement; digital economy expansion; emerging space program with China.
- Thailand: Significant BRI investment; high satellite broadband demand in rural areas.
- Kazakhstan: should be at least Priority 2, maybe Priority 1, lot of existing investment, substantial space assets/history, SpaceSail/Qianfan created a subsidiary there

- Saudi Arabia: Vision 2030 initiative aligns with China's smart city and satellite connectivity push.
- Malaysia: Following President Xi's state visit in April 2025 and a series of bilateral space cooperation agreements, including a Memorandum of Understanding between SpaceSail (Qianfan) and Measat, Malaysia has emerged as a more immediate strategic partner. The country shows growing demand for cost-effective broadband solutions and is under consideration for hosting manufacturing or assembly infrastructure for telecom satellites.

**Priority 3** Emerging & Potential Growth Markets (Long-Term Expansion, 2030+)
These countries represent future growth opportunities and strategic diversification. Qianfan is modeled to allocate 10–15% of international throughput here post-2030.

- Mexico: Large underserved rural market; potential alternative to Starlink.
- Turkey: Increasing China-Turkey space/tech cooperation; digital infrastructure expansion.
- India: With approximately 684 million individuals offline, Government's "Digital India Initiative".

**Inside China:**
Urban areas already have high broadband penetration, so demand will likely focus on rural and remote regions (Xinjiang, Tibet, Inner Mongolia) vs. coastal cities. Scope of Chinese MEGACON modeling can be found in Table 3-3, and description of ground stations in Chapter 3.

**Further Strategic Assumptions:**
- GuoWang prioritizes coverage of China (latitudes 0°–50°N).
- Qianfan targets international markets incl., equatorial and Southern Hemisphere markets (latitudes 30°S–30°N).
- China's reusable rocket development (e.g., Long March 8R) reduces launch costs by 30% by 2030.

**Integration Assumptions**
To incorporate geopolitical prioritization into throughput and financial forecasts:
- Base Case Scenario:
- 40% of Qianfan's international throughput capacity is directed to Priority 1 countries by 2030.
- 35% to Priority 2 countries by 2035.
- Remaining capacity allocated to Priority 3 and other non-aligned markets.

Demand Conversion Factor: for modeled capacity, conversion to actual revenue is based on known MoUs, broadband demand estimates, and ARPU assumptions by country group. In Priority 1 markets, 10–20% conversion to active broadband contracts is assumed by 2030.
**Note:** all capacity assumptions are subject to a) gateway infrastructure (Appendix B), ITU orbital slot compliance (chapter 2-4), presence of commercial partnerships or government MoUs.

## 4.3. Data Collection and Analysis Methods

The study employs a combination of primary and secondary data sources to validate the model assumptions and refine the analysis:

- Satellite Constellation Data: Updated technical specifications and launch schedules for GuoWang and Qianfan, sourced from industry reports and filings with international regulatory bodies.
- Market Intelligence Reports: Insights from market research firms on broadband adoption trends, demand projections, and competitive positioning.
- Financial Disclosures and Policy Documents: Company statements, government policy directives, and regulatory filings to assess the strategic intent behind China's satellite initiatives.
- Computational Simulations: Scenario-based modeling to evaluate different deployment strategies, considering both domestic constraints and international expansion pathways.

**Data Sources:**

- Primary: ITU filings, China Satellite Network Group disclosures, and Shanghai Spacecom technical reports.
- Secondary: Pachler et al. [14,16 and 71] throughput equations, Starlink performance benchmarks, and third-party analyses (Euroconsult, BryceTech).
- Validation: Cross-referenced with launch logs from the China Aerospace Science and Technology Corporation (CASC), Orbital Gateway Consulting and Space Force space situational awareness (SSA) data.

**Basic Analytical Framework:**

1. **Coverage Efficiency**:
    - Adapted from Pachler et al. [14,16 and 71] "idealized coverage ratio"

$$C = \frac{N * A_{sat}}{A_{target}}$$

    where N = satellites, $A_{sat}$= coverage per satellite, $A_{target}$= target area.
    - Adjusted for GuoWang's focus on northern latitudes (reducing required satellites by 22% vs. potential global coverage).

2. **Throughput Capacity**:
    - Total throughput

$$T = \sum (S_i * B_i * U_i)$$

    where $S_i$= satellites, $B_i$= bandwidth per satellite, $U_i$= utilization rate (65% for rural, 85% for urban areas).

3. **Cost Projections**:
    - Launch cost per kg:

$$L = \frac{C_{Launch}}{M_{Payload}}$$

where for e.g. Long March 8A with $C_{Launch}$= $15M and $M_{Payload}$ = 5,000 kg*.

* up to 7,000 kg for SSO (see Chapter 3 and Appendix B, Figure 4-2 showing Long March 8A ).


Figure 4.2 - Long March 8A developed by CAS

# Chapter 5 : China's Current Satcom Roadmap

## 5.1. Megaconstellation Projects

China's evolving Satcom strategy, particularly its deployment of large-scale Low Earth Orbit (LEO) constellations, reflects a shift from domestic prioritization to early international market entry. This dual-track expansion led by Guowang for domestic coverage and Qianfan for international markets is central to Beijing's ambition to become a global satellite broadband leader. Figure 5.1 presents a comparative overview of China's current progress versus its stated strategic roadmap for both megaconstellations.

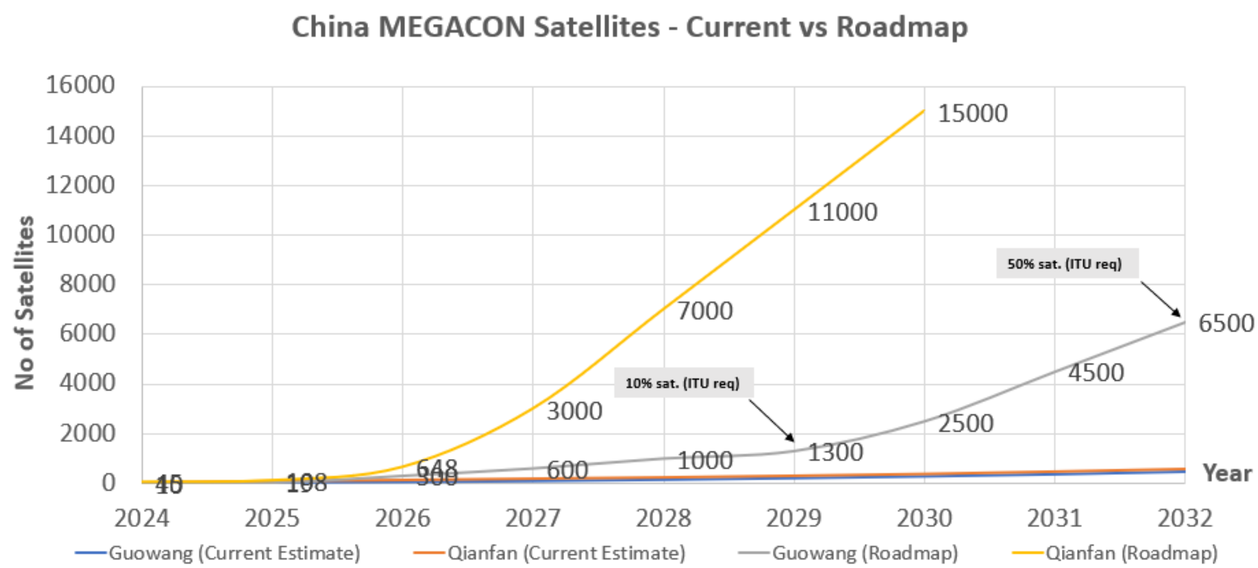



Figure 5.1 - Overview of Guowang and Qianfan MEGACON Growth Trajectories.
The "Current Estimate" line is based on modeling assumptions outlined in Chapter 4, informed by recent launch data, manufacturer disclosures, and ITU filings. The "Roadmap" also reflects part of strategic goals announced by Chinese state media and filings to the International Telecommunication Union (ITU), including regulatory thresholds such as the 10% launch requirement for spectrum preservation (ITU-R S.1000, 2023).

As highlighted in Figure 5.1, this section represents independent modeling and critical analysis based on plausible industrial and policy constraints. It is not a verbatim projection from Chinese government sources, although it integrates those where relevant. Specifically, the throughput and deployment estimates are used within the systems model described in Chapter 4, including sensitivity tests under base, optimistic, and pessimistic scenarios later on.

A. **Domestic Expansion with Guowang:**
As of 2024, Guowang has launched fewer than 20 satellites, a pace misaligned with its stated ambition of deploying 13,000 satellites. Based on the observed launch cadence and current

manufacturing constraints (see Chapter 3), a baseline projection of ~200 satellites by 2029 and 500 by 2032 is modelled. This trajectory falls far short of the ITU's requirement to have 10% of the declared constellation (1,300 satellites) operational by 2029 to retain spectrum filings and orbital rights. China's unconnected population is estimated at 336 million individuals (see Chapter 3), concentrated in inland and western provinces. To meet the Digital China 2027 target of connecting 80% of these users, GuoWang would require a minimum operating throughput of ~15 Tbps by 2027. Based on industry-standard throughput ranges of 10–30 Gbps per satellite, even with perfect utilization, this implies 500–1,500 operational satellites. This modeling underscores a mismatch between official goals and realistic capacity growth. Unless launch rates accelerate 5–10× and supporting infrastructure is dramatically scaled up, GuoWang is unlikely to meet ITU or rural broadband coverage objectives by 2029, placing spectrum rights and national connectivity targets at risk.

B. **International Expansion with Qianfan:** the Qianfan project, led by Shanghai Spacecom (SpaceSail), has demonstrated more aggressive early deployment, with ~54 satellites launched in 2024 and plans to ramp up to 100 satellites/year. Based on this trend, the model forecasts ~600 satellites in orbit by 2030, assuming no major disruption or ramp-down in launch frequency. Official documents linked to BRI initiatives project a Qianfan constellation of 15,000 satellites by 2030, with intermediate targets of 3,000–11,000 satellites launched between 2027–2029. The gap is stark, a 25× difference between baseline capacity and the strategic target by 2030. At 10 Gbps per satellite, the modeled Qianfan constellation would offer a maximum of 6 Tbps total system throughput by 2030, which may be sufficient for rural or low-density Belt and Road countries, but would fall short in competitive urban environments where Starlink and OneWeb already operate.

The slower build-out may reflect a phased targeting approach, whereby Qianfan initially focuses on underserved equatorial BRI markets (e.g., Nigeria, Indonesia, Egypt, see Chapter 4), where demand is growing but less technically demanding. However, this makes it unlikely to compete head-to-head with Starlink in markets like Brazil, India, or Turkey unless throughput and latency improve substantially.

To meet its roadmap, Qianfan would need to launch ~2,000 satellites annually between 2027 and 2030, a feat unprecedented outside of SpaceX. This would require:

- Reusable rockets (not yet operational in China, see Chapter 3)
- Expanded private sector capacity (Orienspace, Space Pioneer, CASC)
- Access to international launchpads or maritime launch systems

While Qianfan shows more commercial agility than GuoWang, the forecast suggests that China is unlikely to meet its strategic target of 15,000 satellites by 2030 unless launch capacity, international regulatory access, and commercial user acquisition dramatically improve. Table 5-1 compares China's strategy vs forecasted current development outcomes for both GuoWang and Qianfan constellations.

Table 5-1 - Summary of Strategic vs. Modeled (Given Current Development Speed) Outcomes for Guowang and Qianfan Constellations

| Metric | Official Target (2030) | Modeled Estimate (2030) | Gap (Factor) |
|---|---|---|---|
| GuoWang Satellites | 13,000 | 500 | 26x |
| GuoWang Throughput | 15-20 TBps | 4-8 Tbps | 2-3x |
| Qianfan Satellites | 15, 000 | 600 | 25x |
| Qianfan Throughput | 30-50 Tbps | 6 Tbps | 5-8x |
| BRI Coverage Readiness | Near Full (100+ BRI) | ~20-30 BRI Markets (Appendix G, Chapter 3) | ~70% shortfall |
| ITU 10% Deadline (2029) | 1,300 Satellites (GuoWang) | 200 | ~85% below target |

## 5.2. Technological Advancements

### 5.2.1. Commercial Launch Capabilities

The existing launch capabilities are discussed in detail in Chapter 3.1. To assess deployment feasibility for China's two primary megaconstellation projects, Guowang and Qianfan, Figure 5.2 provides an overview of launch activity under two scenarios: the Current Estimate, based on recent launch trends and capacity, and the Target Roadmap, reflecting China's stated strategic objectives and ITU obligations.

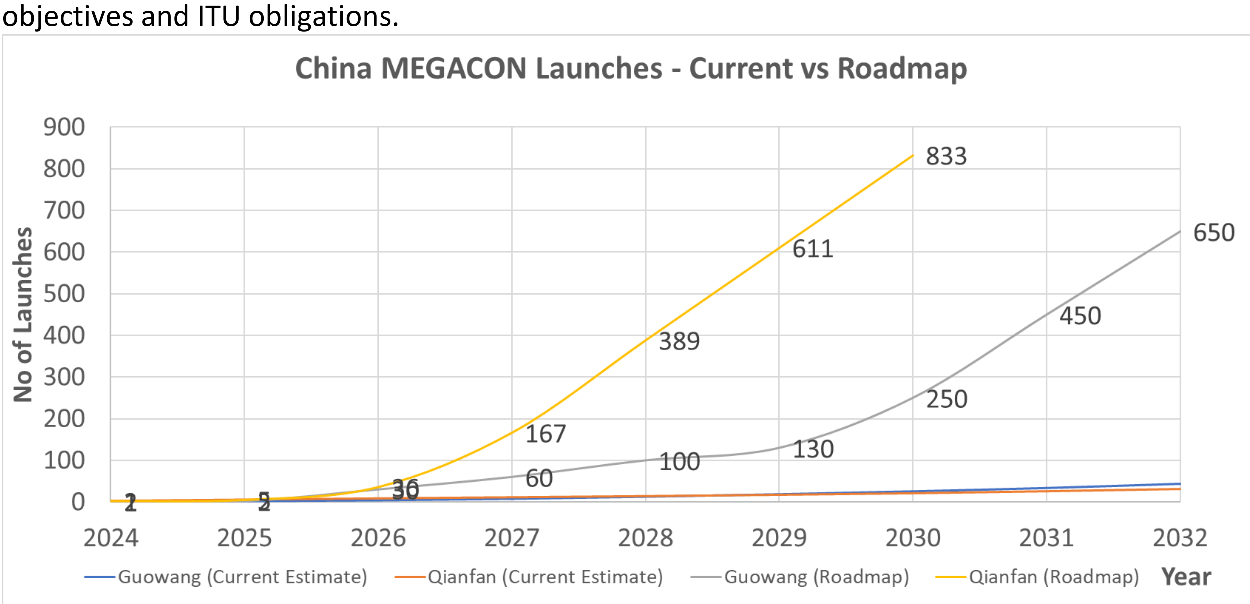



Figure 5.2 - Overview of the Guowang and Qianfan MEGACON. The "Current Estimate" represents the present status and projected growth from 2026 to 2030/2032, considering technological advancements. The "Roadmap" outlines China's stated strategic objectives for both constellations.

These forecasts are modeled under the assumption of increasing industrial and commercial capability between 2024 and 2032, driven by both state-backed programs (e.g., CASC) and emerging private launch providers (e.g., Orienspace, LandSpace, iSpace, CAS Space, see Chapter 3). The discrepancy between current and required launch rates is substantial, underscoring the unprecedented scale-up required to meet China's global Satcom ambitions.

**Guowang: Current vs. Target Roadmap Launch Rates:**

- Under current projections, Guowang launches increase from 2 in 2024 to 44 in 2032, assuming Long March 8A availability with ~10 satellites per launch.
- The strategic roadmap, however, targets up to 650 satellite launches per year by 2032, necessitating over a 1400% increase in launch cadence.
- This roadmap implies a sustained launch rate of ~12 launches per week by 2032, which, under current capacity, would require >89% of China's national launch infrastructure, a scenario not currently supported by CASC projections.

**Qianfan: Current vs. Target Roadmap Launch Rates:**

- For Qianfan, launches grow modestly from 5 in 2024 to ~20 in 2032 under current trends.
- The roadmap forecasts 833 satellite launches annually by 2030, a 3,968% increase, signaling a major expansion beyond China's present manufacturing and orbital insertion capabilities.

These growth trajectories represent the inputs to the demand-side modeling framework presented in Chapters 3-4. Specifically, the "Target" scenario corresponds to the ITU filing and spectrum retention criteria for Guowang (i.e., 10% of constellation deployed by 2029, 50% by 2032), while Qianfan's roadmap reflects China's stated Belt and Road connectivity goals and Ministry of Industry and Information Technology (MIIT) targets [MIIT, 2023; CSIS, 2024].

The model assumes a realistic capacity ramp-up for Long March 8A and 6A, but even optimistically, launch growth rates beyond 500%–1000% per annum remain highly improbable without disruptive innovations in reusable launch vehicles or a radical increase in ground infrastructure throughput.

To meet its strategic goals, China must significantly expand its commercial launch ecosystem. This involves both:

- State Entities: e.g., CASC, which aims to increase Long March launch cadence and introduce new platforms like Long March 9 (heavy lift) and Long March 8R (reusable).
- Private Launchers: e.g., Orienspace's Gravity-2, LandSpace's Zhuque-3, and CAS Space's Kinetica series, which are expected to scale reusable launch frequencies between 2027–2030.

**Note:** Orienspace's Gravity-1 has a payload capacity of 6.5 tons to LEO and aims to reduce costs to <$2,500/kg, targeting parity with SpaceX's Falcon 9. However, as of May 2025, the rocket has only launched once, its maiden flight in January 2024, which successfully delivered three satellites into orbit. Zhuque-3 remains in the testing phase, with further static fire trials ongoing and no confirmed date for its first orbital launch.

While the Long March 8A is currently considered a primary launcher for Guowang deployments, actual launches to date include three SatNet batch missions, with two conducted using the LM-5B and only one utilizing the LM-8A. The LM-8A's modular design aims to support rapid assembly and a 14-day turnaround from launch sites at Jiuquan and Wenchang. However, achieving a scale of 300+ launches per year by 2030 remains an ambitious goal and may still be insufficient to meet the deployment demands of these megaconstellations. On the private sector front, Zhuque-3, a stainless steel, methane-fueled rocket designed for mass production, successfully completed static fire tests in Q1 2025. Despite projections of up to a 90% cost reduction compared to the Long March 4C, Zhuque-3 is not yet operational and continues to face significant development hurdles (see earlier note). To meet strategic deployment targets, China must enable Guowang to launch approximately 500 satellites per year by 2026, aiming to close the gap with Starlink's current deployment pace. Simultaneously, Qianfan's focus on equatorial and mid-latitude regions (30°–50° inclination) must be supported with tailored launch inclinations to optimize coverage of Belt and Road Initiative (BRI) partner nations (see Chapter 4). Overall, China needs to increase its launch cadence more than tenfold within the next 5 to 7 years to satisfy both Guowang and Qianfan constellation goals. As detailed in Table 5-2, the required annual launch growth rates peak at:

Table 5-2 - Estimated Annual Launch Increase Rate for Guowang and Qianfan MEGACON to Align with China's Strategy

| **Timeline** | | **2026** | **2027** | **2028** | **2029** | **2030** | **2031** | **2032** |
|---|---|---|---|---|---|---|---|---|
| **China MEGACON (Require Rate increase Target vs Current Estimate)** | **Guowang [launch/year]** | 750% | 789% | 794% | 699% | 977% | 1339% | 1491% |
| | **Qianfan [launch/year]** | 438% | 1515% | 2823% | 3571% | 3968% | - | - |

The targeted launch rates for Guowang and Qianfan display exponential increases, with year-over-year growth peaking at 1491% for Guowang (2031-2032) and 3968% for Qianfan (2029-2030). Such aggressive expansion implies a high degree of reliance on rapid manufacturing, launch capabilities, and spectrum allocation. Given the current status and delays in launcher developments, this is unlikely to be achieved and would need to be revisited. When China continues to prioritize international expansion with Qianfan, the loss of the secured ITU spectrum can be passed on to Guowang. Commercial and private launcher developments would need to succeed and operate simultaneously to achieve these both roadmap. These exponential growth rates highlight the dependency on breakthrough reusability, private sector participation, and industrial supply chain scaling, all of which remain at early stages of development in China compared to the mature ecosystem led by US and SpaceX. Consequently, given current launcher output and manufacturing rates, China is unlikely to meet its full strategic deployment targets by

2030 without a disruptive shift in industrial scale, launch vehicle reuse, and logistics. The model therefore integrates an adjusted rollout trajectory, capped at ~500 Guowang and ~1,500 Qianfan satellites by 2030 under realistic conditions, falling short of the ITU benchmarks and limiting initial international coverage. However, progress beyond 2032 could still yield competitive positioning if China's reusable launch infrastructure matures as projected.

### 5.2.2. Reusable Rockets

Reusable rocket technology has emerged as a transformative innovation in space transportation, significantly reducing launch costs and increasing mission frequency. SpaceX's Falcon 9 rocket has demonstrated the commercial viability of reusability, setting a benchmark for global competitors, including China. This section explores the development of reusable rockets in China, comparing their progress to SpaceX's achievements, and prepare for preliminary evaluation of the feasibility of achieving cost-effective reusability within China's space program.

China's strategic pivot towards higher launch cadence is evident in the projected deployment figures (5.1 and 5.2). With an increase in the number of launches per year from 2024 onward, the commercial sector plays a vital role in meeting the ambitious targets outlined in the MEGACON roadmaps. The ability to sustain high launch frequencies is essential for realizing the planned exponential growth of these constellations, especially as international competitors, such as SpaceX's Starlink and Amazon's Kuiper, continue to scale operations.

As outlined, China's reusable rocket development has been primarily driven by state-backed initiatives under the aegis of the China Aerospace Science and Technology Corporation (CASC) and private players like LandSpace and i-Space. Since 2015, following SpaceX's successful recovery of the Falcon 9 first stage, China has intensified its research into vertical takeoff and landing (VTVL) systems.

1. **Long March 8R:** The Long March 8R is a reusable variant of the Long March 8A, featuring grid fins for aerodynamic control during descent and deployable landing legs for vertical recovery. Its maiden test flight is scheduled for late 2025, with plans to achieve operational reusability by 2027.

2. **Zhuque-3 (LandSpace):** Zhuque-3 is a methane-powered rocket designed with full reusability in mind. Its first successful vertical landing occurred in December 2024, marking a significant milestone for China's private space sector.

3. **Kinetica-2 (CAS Space):** This partially reusable rocket focuses on recovering its first stage via parachute-assisted descent, similar to early SpaceX concepts.

This China approach emphasizes modular designs and state funding to accelerate development timelines while leveraging lessons learned from SpaceX.

Key technologies in reusable China's rockets include

1. **Vertical Takeoff and Vertical Landing (VTVL):**
    - Inspired by SpaceX’s Falcon 9, Chinese rockets like Long March 8R utilize grid fins for aerodynamic stability and precise trajectory adjustments during descent.
    - Advanced guidance algorithms based on convex optimization enable real-time trajectory planning under atmospheric disturbances.

2. **Methane-Fueled Engines:**
    - Zhuque-3 uses methane-fueled engines similar to SpaceX’s Raptor engines, offering higher efficiency and reduced carbon buildup compared to kerosene-based engines like Merlin.
3. **Thermal Protection Systems:**
    - Ablative materials are used for heat shielding during reentry, with ongoing research into regenerative cooling systems for enhanced durability.

4. **Landing Mechanisms:**
    - The Long March 8R features deployable landing legs with shock absorbers, designed to withstand vertical velocities up to 6 m/s during touchdown.

Table 5-3 shows comparative analysis of SpaceX Falcon 9 to China Long March 8R

Table 5-3 - Comparative Analysis: China vs. SpaceX (ref [73])

| **Metric** | **SpaceX Falcon 9** | **China Long March 8R** |
|---|---|---|
| First Successful Landing | Dec 2015 | Expected Q4 2025 |
| Engine Type | Merlin (RP-1/LOX) | YF-209 (RP-1/LOX) |
| Reuse Cycles Achieved | >20 | Targeting 10 by 2027 |
| Launch Cost/kg | $1,200 | Projected $2,000 by 2027 |

SpaceX’s Falcon 9 benefits from over a decade of iterative design improvements and operational experience, giving it a significant head start over Chinese efforts. However, China’s centralized funding model and integration with national space strategies may enable catch-up. On the other hand, SpaceX’s Starship program, which aims to reduce costs to below $100 per kg (Figure 3.4), presents an enormous challenge. If successful, Starship could maintain a generational lead over China’s efforts, forcing Chinese firms to adopt drastic cost-cutting measures, technological breakthroughs, or alternative competitive strategies.

## 5.3. Projections of Mass-to-orbit Capacity and Launch Cost Reductions

Launch cost per kilogram has been a defining constraint in the satellite communications industry. As China's MEGACON ambitions hinge on deploying tens of thousands of LEO satellites within the next decade, reducing these costs has become central to its strategy. This section evaluates the potential mass-to-orbit projections and cost implications of reusable rocket development in China, comparing them to benchmarks established by SpaceX's Starlink program.

**Reusable Rockets: Economic Rationale and Technical Foundations**

Reusable rockets offer substantial cost savings by spreading manufacturing expenses across multiple launches. For example, SpaceX reports up to a 30% reduction in launch costs for reused Falcon 9 stages after refurbishment [73]. In this case, internal reports and industry analyzes suggest that per-launch cost drops by 30–50% after the third reuse, reaching $2,720/kg to LEO for Falcon 9 launches by 2024 [73]. The cost breakdown, while not publicly disclosed in detail, suggests a typical first-flight cost of ~$60M (including full manufacturing), dropping to $30–40M for reused boosters with modest refurbishment. These numbers refer to launch price (customer-facing), which includes margin, not just internal cost. China has not disclosed equivalent data, so model assumptions are inferred from state, and private firm announcements and analogies to other competitors given addressed technical capabilities.

China aims to achieve similar savings through modular designs and automation in rocket assembly. However, high upfront R&D costs for reusable systems require sustained government support or commercial demand to break even. Efficient refurbishment processes are critical, while delays or high repair costs can negate savings from reusability.

The increase in satellite launch frequency directly correlates with the need for greater mass-to-orbit capabilities. Current launch projections indicate an exponential rise in annual satellite deployments, necessitating corresponding advancements in rocket payload capacities.

- Current Trends: The increasing number of launches from 2024 onwards suggests reliance on higher payload launch vehicles, potentially even exceeding 30-50 satellites per mission.
- Future Scaling: If reusable rockets become operational within the next five years, cost-per-launch could decrease by 50-70%, significantly improving deployment efficiency.
- Economic Impact: Lower launch costs will enhance China's ability to offer competitive Satcom services globally, particularly in underserved regions.

Furthermore, mass-to-orbit projections indicate that the integration of heavier payload rockets (such as Long March 9) will be crucial for reaching the ambitious Guowang and Qianfan targets. By 2030, China's ability to deploy thousands of satellites annually will depend on both increased payload capacity per launch and reductions in launch costs.

Consequently, China's Long March 8R and Zhuque-3 platforms aim to replicate the SpaceX strategy. However, China's reusable architecture is still early in its lifecycle, with just a few successful landings (see below, Tables 5-4 and 5-5), and no verified record of reuse beyond two cycles as of Q1 2025. This creates considerable uncertainty around refurbishment economics and reliability. Meeting GuoWang and Qianfan's ambitious launch schedules requires both scaling launch frequency and increasing mass-per-launch. Figure 5.2 and Table 5-4 demonstrate this challenge.

Table 5-4 outlines the most strategic important reusable launch vehicles, which were earlier discussed and are currently under development by China.

Table 5-4 - Reusable Rockets developed by China (ref [65-73])

| Launch Vehicle | Payload (LEO) | Reusability | Cost/kg | 2025 Launch Target |
|---|---|---|---|---|
| Long March 8A | 8 tons | Partial<br>(1st stage) | $3,500 | 15 launches |
| Zhuque-3<br>(LandSpace) | 21.3 tons | Full (≥20 uses) | $1,200 | 3 launches |
| Kinetica-2<br>(CAS Space) | 10 tons | Partial | $4,000 | 2 launches |

Despite limited flight heritage, Zhuque-3's design capacity exceeds Falcon 9's, suggesting strong long-term potential, if reuse rates are realized. Key caveats include:

- Fuel efficiency: Zhuque-3 uses methalox, enabling deep throttle and vertical landings.
- Production ramp-up: A new factory in Zhejiang aims to produce 50 units per year by 2026.
- Refurbishment goals: Current recovery rate is 1:1 (i.e., 1 reuse per new launch), with projections targeting 10x reuse by 2027. However, this assumes no re-flight failure or major refurbishment overhaul.
- First successful vertical landing occurred in Dec 2024 (Jiuquan Desert), and it is planned for sea-based recovery by 2026 to expand launch flexibility

Long March 8R is a reusable variant of LM-8A, tested in Feb 2025, which targets $2,000/kg by 2027 through modular enginer (YF-209, Table 5-3).

Table 5-5 shows comparative analysis between Zhuque-3 and Falcon 9.

Table 5-5 - Comparative Analysis Zhuque-3 and Falcon 9 in 2025 (ref [65-73])

| Metric | Zhuque-3 | Falcon 9 |
|---|---|---|
| Launch cost | $15M | $28M |
| Reuses achieved | 2 | 18 |
| Payload (reusable) | 18.3 tons | 16.8 tons |
| Turnaround (target) | 30 days | < 10 days |
| Recovery Mode | Ocean barge (planned) | Ocean barge |

**Note:** While Zhuque-3 is technically competitive, lack of reuse maturity and slower refurbishment time (~30 days vs. <10 days for Falcon 9) create bottlenecks in scaling deployment cadence.

Despite the lack of flight heritage, China benefits from centralized R&D funding, which allows it to overcome early financial constraints faced by SpaceX.

Based on that, it can be assumed in the optimistic modelling scenario following China's roadmap:
- Zhuque-3 reaches 10 reuses by 2027.
- Long March 8R becomes operational by Q4 2026.
- Per-unit satellite mass drops from 500 kg → 300 kg by 2028 (via phased-array miniaturization).
- Per-launch batch size rises to 50 satellites by 2028, with 100 satellites permission by 2030.
- Satellite production costs fall to $250,000/unit, following industrial automation similar to Shanghai's telecom satellite line.

The key drivers to achieve this scenario are related to 1) Zhuque-3 Scalability: LandSpace's new factory in Zhejiang which can produce 50 rockets/year by 2026. 2) LEO Satellite Cost: Dropping to $250,000/unit (vs. Starlink's $180,000) via automated assembly lines in Shanghai [65-73].

These assumptions are in line with previous works from Lordos, McKinney, Delkowski, De Weck, Hoffman et al. (ref. [81-84]), which outlined cost reductions from system-level modularity, assembly-line efficiencies, and deployment optimizations in satellite manufacturing ecosystem.

In addition, the Chinese company CosmoLeap is making progress on "chopstick" technology, following in the footsteps of SpaceX. Founded as recently as 2024, CosmoLeap exemplifies a new wave of Chinese launch-support companies that do not build rockets themselves, but instead focus on developing critical infrastructure to support rocket operations. It also serves as a clear example of a Chinese company rapidly adopting and adapting a concept originally demonstrated by a Western space firm. To summarize, China's mass-to-orbit and cost trajectory is technically plausible but operationally constrained. While platforms like Zhuque-3 offer promise, reliability, manufacturing scale, and turnaround times lag behind SpaceX's established ecosystem. Nonetheless, through sustained R&D, commercial incentives, and public-private investment, China could reduce launch costs by 50–70% by 2030, thereby transforming its ability to scale GuoWang and Qianfan. These dynamics are incorporated into the sensitivity scenarios modeled in further sub-chapters.

## 5.4. Financial Modeling: Guowang and Qianfan vs. Starlink

Following the earlier analysis, this section presents a comparative financial analysis of China's Guowang and Qianfan megaconstellation projects against SpaceX's Starlink. The goal is to assess the economic viability of the Chinese systems by evaluating required investments, potential revenue streams, and operational trajectories. This includes base, optimistic, and pessimistic scenarios alongside sensitivity analysis. The models are benchmarked against SpaceX's Starlink, which provides a valuable reference due to its rapid development, commercial traction, and profitability milestones (ref[74-79]). Using a consistent modeling horizon (2024–2035), the section evaluates investment costs, projected revenues, launch cadence, and operating profitability. The analysis addresses a central research question: What would China need to do to achieve financial viability for Guowang and Qianfan, and how feasible is this under different deployment strategies? The model incorporates a 10% discount rate.

### 5.4.1. Overview of Main Assumptions

Table 5-6 summarizes the main assumptions for the three discussed MEGACON projects. The study models the financial viability of China's Guowang and Qianfan megaconstellations, incorporating detailed assumptions about deployment, adoption, and economic dynamics. The investment and R&D costs for supporting technologies, particularly reusable rockets, are considered sunk costs (2020–2023), predominantly state-backed.

The modeling horizon covers 2024–2035 (12-year projection), and all values are presented in USD billions, unless otherwise stated.

**Deployment Timelines**
Starlink: First satellite launch in 2019; break-even reached by 2023 (per external ref. [74-79])
Guowang: Initial operational ramp-up from 2024
Qianfan: Aggressive International expansion initiated from 2025

**Users Modeled:**
Guowang Primarily domestic users (~100 million rural/underserved citizens in China by 2030). Qianfan targets international users across Priority 1 and 2 Belt and Road Initiative (BRI) countries, focusing on rural and underserved regions.

**Each forecast includes:**
Revenue breakdown (broadband services (primary), terminal hardware (partially subsidized), and dual-use government contracts)
Operating cost structure (satellite ops, bandwidth, terminal logistics, SG&A)
Investment assumptions (launch, ground infra, terminal subsidies)
EBITDA, EBIT, CAPEX, Working Capital Changes, Taxes, FCF
Terminal value, NPV, ROI

**Revenues are broken down into three streams:**
Broadband service (monthly ARPU × user base × adoption rate)
Terminal sales (subsidized, partial revenue captured)
Government contracts (especially for dual-use cases in military/civil applications, starting 2028–2030).

CAPEX subsidies are modeled separately from downstream revenue streams and modeled as fixed percentages of investment costs, reflecting government support:40% for Guowang, 50% for Qianfan.

**Key Financial Parameters:**
Discount rate: 10%
Tax rate: 20% (high-tech enterprise preferential rate)
Perpetuity terminal value calculated using g = 3% from 2035 EBITDA

**Revenue Assumptions:**
ARPU*: $50/month for Guowang (domestic), $50 for Qianfan (international). Elasticity and income distribution affect final realized revenue per user.
Average subscribers per satellite (2030): Guowang = 5,000; Qianfan = 6,000
Terminal unit cost: $400 to company (not user retail price)

**Note*:** The assumed ARPU of $50/month represents an effective blended average, incorporating both consumer-level services and value-added contracts with provincial and enterprise partners. in rural China, where individual affordability remains constrained, subsidy programs and government applications (e.g., telemedicine, education, civil defense) contribute significantly to ARPU. In international markets, particularly BRI-aligned regions, Qianfan's ARPU similarly reflects early anchor contracts and hybrid consumer-institutional models. Sensitivity ranges from $25 to $65 are modeled to capture adoption elasticity and pricing volatility.

**Demand Drivers**
Income-based affordability threshold of 2% (Appendix H)
Penetration curve growth of 8–10% annually under base and optimistic assumptions

**Cost Efficiencies**
Launch cost reductions via reusability factored at 30–50% by 2029 in base and optimistic cases
CAPEX phased in with launch ramp-up and gateway deployment

Table 5-6 - Summary of Main Assumptions and Inputs for Guowang and Qianfan vs. Starlink (ref [74-79])

| **Parameter** | **Starlink (ref.)** | **Guowang** | **Qianfan** |
|---|---|---|---|
| Year of Start | 2019 | 2020 + (R&D),<br>2023 (First Launch) | 2020 + (R&D),<br>2024 (First Launch) |
| Planned Constellation Size | >60,000 | 13,000 | 15,000 |
| Satellite Cost per Unit | $250,000 | $420,000 | $400,000 |
| Launch Cost per Sat | $250,000 | $400,000 | $400,000 |
| Average Revenue Per User/Unit (ARPU), (Monthly) | $100 | $50 (domestic) | $50 (international, incl. slightly higher elasticity modeled) |
| Avg Subscribers per Sat (2030) | - | 5,000 | 6,000 |
| Terminal Unit Cost | $500 (retail to customer) | $400 (cost to company) | $400 (cost to company) |
| Ground Infrastructure Total Investment | $5B | $8B | $10B |
| Government Support (CAPEX %) | Indirect (contracts) | Direct (40% subsidized) | Direct (50% subsidized) |
| R&D, Sunk Cost (2020–2023) | $30B | State-backed | State-backed |
| Tax Rate | N/A | 20% | 20% |
| Key Divers | Reusability, scale | Sovereignty, security | BRI markets, influence |

***Note**: More details can be found in Tables 2-3 and 3-3.

****GuoWang Satellite Unit Cost Assumption for Base Case:** While GuoWang satellites are likely larger and built to higher reliability standards—often by state-owned enterprises (SOEs)—the assumed unit cost of $420,000 reflects several offsetting factors. These include economies of scale from centralized procurement, reuse of heritage platforms (e.g., Beidou-derived buses), and reliance on domestic supply chains that reduce design and logistics costs. Compared to Qianfan, which may involve more fragmented commercial manufacturing and imported components, GuoWang benefits from integrated state-backed production efficiencies.

**Specific Modeled Scenario Assumptions**

- Base Case: Moderate subscriber growth, 40% adoption, reusability achieved by 2028
- Optimistic Case: Faster ramp-up (800/year), higher ARPU ($60), 100% revenue realization by 2028, launch cost falls to $200k/sat
- Pessimistic Case: Delayed rollout, launch cap at 300/year, only 25% adoption, ARPU drops to $35, and 75% CAPEX subsidized

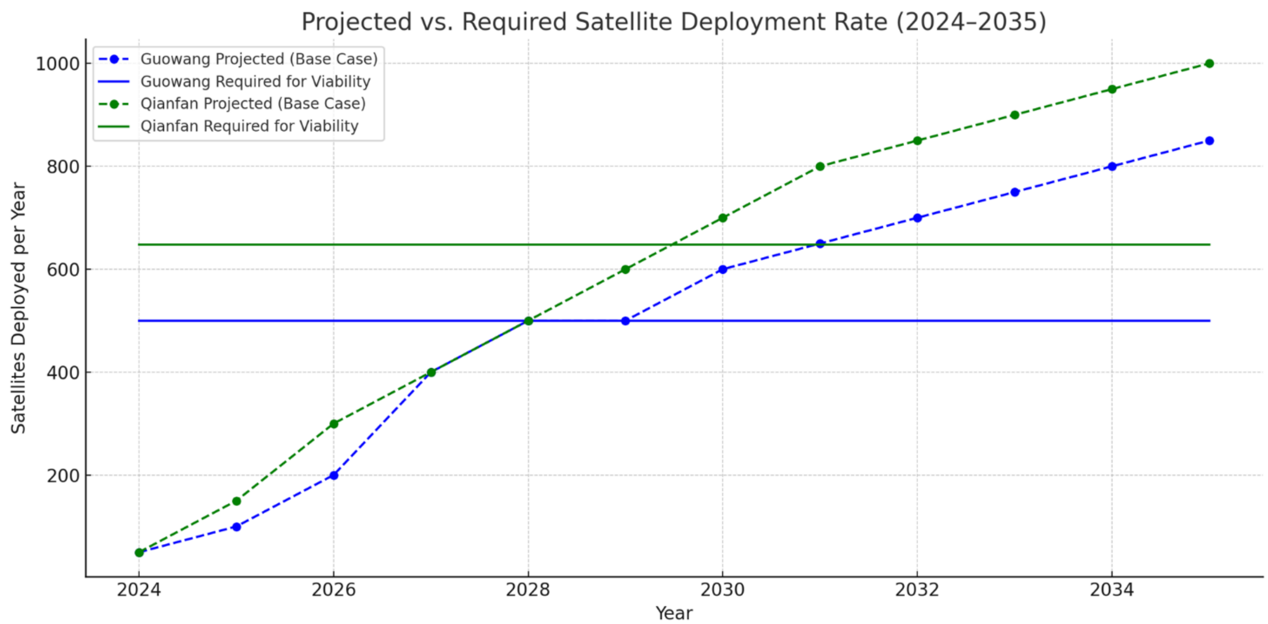



Figure 5.3 Satellite Deployment Comparison for Guowang and Qianfan (Base Case vs. Required Rate).

Figure 5.3 shows the required satellite deployment cadence for break-even by 2032 against base case assumptions:

- Guowang Base: 850/year by 2035, reaching 6,500 by 2032 (below threshold early)
- Guowang Required: ≥500/year from 2026–2027 for sustained NPV turnaround
- Qianfan Base: ramps from 300 to 1000/year by 2035 (slow early growth)
- Qianfan Required: ≥648/year from 2027–2028 for viability

### 5.4.2. Scenario Analysis: Guowang and Qianfan

This section models three strategic deployment scenario cases (Table 5-7): Base, Optimistic, and Pessimistic for both Guowang and Qianfan, based on China's announced roadmap, technology maturity assumptions, adoption curves, and policy posture. Each scenario modifies key financial levers: satellite deployment pace, ARPU, launch cost trajectories, and dual-use revenue assumptions. These are linked to the projected throughput capacity and regional coverage model discussed in Chapters 6 and 7.

Table 5-7 - Guowang and Qianfan Scenarios

| Case | Deployed by 2035 | Launch Rate Ramp (combined) | Adoption Rate (% of TAM) | Revenue Realization (%ARPU) | Cost Mgt. Strategy |
|---|---|---|---|---|---|
| **Base** | Guowang: 6,500<br>Qianfan: 7,500 | Ramp-up to 500/yr by 2028* | 40% of target user | 65% of max ARPU | Launch cost drops 30% by 2030 |
| **Optimistic** | Guowang: 9,000<br>Qianfan: 12,000 | 800/yr (LM8R & Zhuque-3)** | 60% of target users | 100% ARPU by 2028 | Cost drops 50% by 2029 |
| **Pessimistic** | Guowang: 3, 000<br>Qianfan: 4,500 | Slow ramp (300/yr by 2030) | 25% of target users | 40% ARPU | Cost drops only 10% |

**Note: *** Assumes deployment support from Long March 8R or similar semi-reusable launchers; cannot be achieved with current Long March fleet alone.
**Requires both state-led reusable systems (LM8R) and operational private sector launch vehicles (e.g., Zhuque-3).

Overall, launch ramp assumptions refer to combined annual deployment across both constellations. ARPU variation reflects price elasticity and regional market conditions. All adoption estimates are based on affordability thresholds (Appendix H) and coverage capability modeling (Chapter 6 for Guowang, Chapter 7 for Qianfan).

The scenario breakdown is as follows:

**Base Case**
In the base case, launch cadence and user growth are consistent with the Chinese government's strategic plans but delayed by approximately two years due to infrastructure bottlenecks and reusability readiness. ARPU is conservatively modeled at $50/month/user, constant over the period. Launch costs are fixed at $400,000/satellite for Guowang and $400,000 for Qianfan. Terminal penetration reaches 5% of rural unconnected populations for Guowang and 3% of unserved users in Priority 1 and 2 BRI regions for Qianfan.

Adoption is capped at 40% of each constellation's defined total addressable market (TAM), which itself is constrained by income elasticity (2% threshold), coverage, and terminal affordability (Appendix H). Qianfan includes additional government revenue starting in 2030 reflecting the introduction of dual-use government contracts for humanitarian and security applications. The EBITDA margin reaches ~35% by 2035, a model-derived result reflecting scale-driven operational efficiencies and phased CAPEX deployment. Under this case, Guowang achieves partial spectrum preservation by deploying 6,500 satellites by 2035. However, the NPV remains negative at -$29.37B, requiring government capital infusion to avoid cash-flow shortfalls. Qianfan fares worse, with NPV of -$37.64B, due to its higher CAPEX intensity and exposure to weaker international demand.

**Optimistic Case**

This scenario assumes accelerated deployment facilitated by reliable reusability (Zhuque-3, Long March 8R), higher satellite production throughput, and improved elasticity through B2B/government users. Monthly ARPU rises to $60/user, driven by improved monetization in both domestic and international segments. Terminal costs fall to $300/unit, enabled by local manufacturing scale-up. Penetration expands to 10% of rural unconnected for Guowang and 5% of TAM for Qianfan. Launch cadence increases to 800 satellites per year (combined). Dual-use revenues enter the model earlier, from 2028 onwards for Qianfan. The model shows EBITDA margins rising to ~45%, due to reduced cost per launch and favorable user pricing. Under this favorable alignment of technology, policy, and demand, Guowang delivers an NPV of +$8.99B with IRR of ~26%, while Qianfan achieves $23.48B in NPV, with IRR of ~33%, and both break even in 2031.

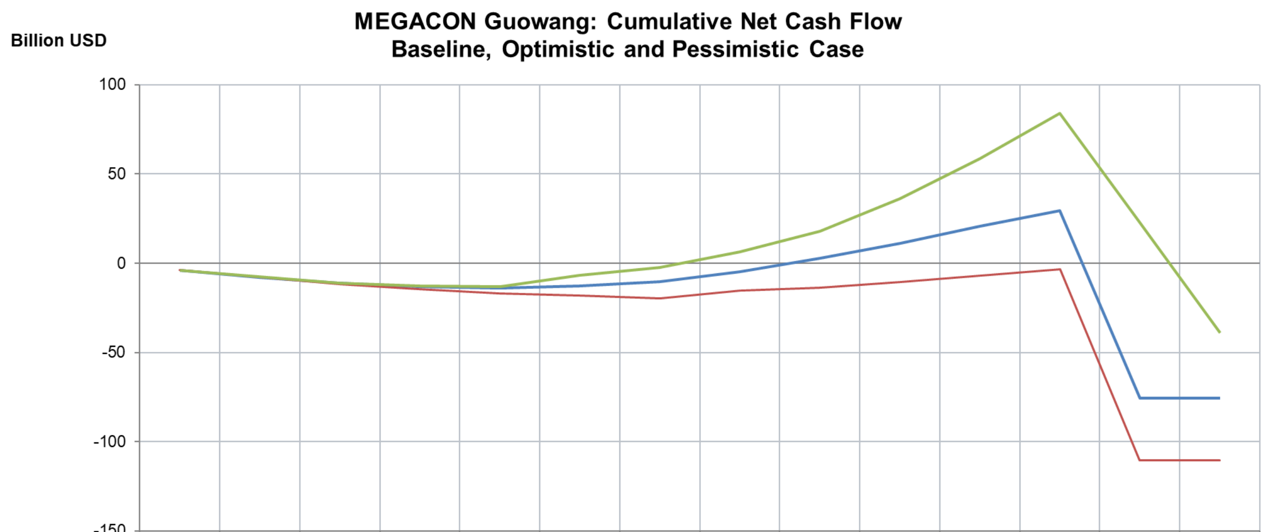
**Pessimistic Case**

Here, deployment is constrained by delays in reusability and limited private-sector launch capacity. Terminal costs remain $400/unit, and ARPU drops to $35/month, reflecting weak affordability in underserved markets. Adoption is limited to 2% of unconnected users for Guowang and 1% of the BRI market TAM for Qianfan. Qianfan's dependence on international anchor contracts becomes a liability, none are secured by 2030 and reusability fails to mature. In this case, only 300 satellites/year are launched. The EBITDA margin declines to ~20%, and both constellations require ~$40B in CAPEX subsidies each to avoid insolvency. Guowang's NPV is -$45.62B, while Qianfan's drops to -76.61B, confirming their unsustainability without deep and prolonged state support.

**Notes**

- Adoption Rate reflects coverage-adjusted affordability using income percentiles and rural demographics. See Chapter 6 (Guowang) and Chapter 7 (Qianfan).
- Revenue Realization varies with ARPU, held constant in base, dropped in pessimistic, and raised in optimistic, mirroring regional price sensitivity and contract likelihood.
- EBITDA Margins are result from cost and revenue flows computed in the model.

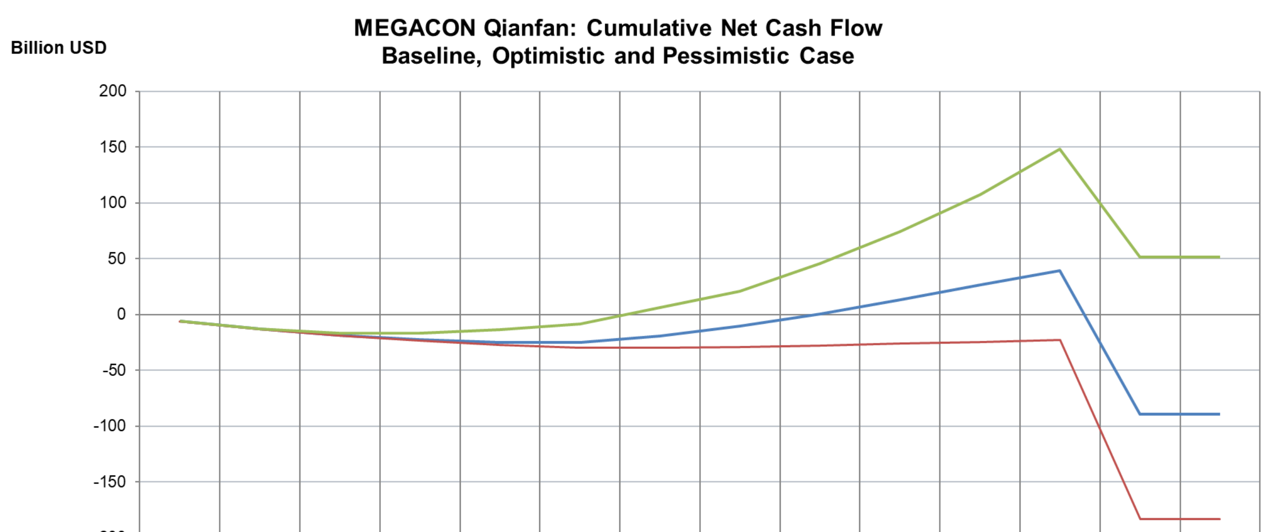
Appendix E shows the complete financial projection using the discount cash-flow model under the given assumptions for three case scenarios. Figure 5.4 summarizes the cumulated cash flows for Guowang and Qianfan bases, as well as pessimistic and optimistic cases.




| | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Base | -3,970425 | -7,885925 | -11,33755 | -13,24055 | -13,81155 | -12,60755 | -10,3268 | -4,8383 | 2,6842 | 11,2117 | 20,5842 | 29,2567 | -75,7433 | -75,7433 |
| Pessimistic | -3,978875 | -7,89975 | -11,576 | -14,5485 | -16,876 | -18,2235 | -19,871 | -15,3585 | -13,801 | -10,726 | -6,821 | -3,321 | -110,4639 | -110,4639 |
| Optimistic | -3,961975 | -7,688975 | -10,99998 | -12,55898 | -13,00498 | -6,739975 | -2,430975 | 6,189025 | 18,048025 | 36,258025 | 58,403025 | 83,958025 | 22,529454 | -38,89912 |

Fiscal Year

Base — Pessimistic — Optimistic




| | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2037 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Base | -6 | -12,83383 | -18,36095 | -22,2132 | -25,1822 | -25,2047 | -19,4672 | -10,57795 | 0,81705 | 13,10255 | 26,43755 | 39,11255 | -89,45888 | -89,45888 |
| Pessimistic | -5,998375 | -12,88265 | -18,5989 | -23,11815 | -27,27565 | -29,51565 | -29,6069 | -28,9759 | -27,6209 | -26,1074 | -24,7799 | -22,6799 | -183,3942 | -183,3942 |
| Optimistic | -6 | -12,84245 | -16,7077 | -16,9537 | -13,3777 | -8,4627 | 6,2173 | 20,9398 | 45,8598 | 74,5398 | 107,4148 | 148,4948 | 51,351943 | 51,351943 |

Fiscal Year

Base — Pessimistic — Optimistic

Figure 5.4 Cumulated Net Cash Flows for Guowang and Qianfan: Base, Pessimistic and Optimistic Scenarios.

Cash flow incorporates working capital change and CAPEX. Terminal value computed at 10x 2035 EBITDA discounted to present value. Table 5-8 summarizes the main financial outcomes for Guowang and Qianfan, respectively. The sensitivity of the discount rate is not consider, as both constellations require substantial government back-up to potentially achieve financial viability.

Table 5-8 - Guowang and Qianfan Scenarios

| **Constellation** | **GuoWang** | | | **Qianfan** | | |
|---|---|---|---|---|---|---|
| **Case** | **Base** | **Pessimistic** | **Optimistic** | **Base** | **Pessimistic** | **Optimistic** |
| **Discount Rate** | 10% | 10% | 10% | 10% | 10% | 10% |
| **NPV ($ Billion)** | -29,4 | -45,6 | +9,00 | -37,6 | -76,6 | +23,5 |
| **IRR** | - | - | 26,00% | - | - | 33,00% |
| **Payback (Break-even point)** | 9 years (2032) | - | 8 Years (2031) | 9 years (2032) | - | 8 Years (2031) |
| **Delta from NPV Baseline** | - | -16,2 | +38,4 | - | -39,0 | +61,1 |

Under base case assumptions, Guowang reaches the ITU threshold (6,500 satellites) by 2035, enabled by a combined launch cadence of 500 satellites/year. However, this remains tight, as Guowang competes with Qianfan for launch slots, and reusable launch capability is not yet operational. The model assumes Guowang receives 50% of all launches annually, capped at 250/year. Even with over $40B in state-backed capital, Guowang's NPV remains negative at -$29.4B and break-even is projected only by 2032. In the pessimistic scenario, limited satellite production, stagnant ARPU, and constrained affordability cap adoption, reducing users to ~15M by 2035. With fewer than 3,000 satellites deployed, the constellation fails to preserve ITU spectrum rights. Without a transition to reusable rockets, the NPV drops to -$45.6B. In the optimistic case, Guowang achieves 9,000 satellites by 2035, breaks even by 2031, and produces a positive NPV of $9.0B. This scenario requires full operationalization of reusability by 2028 (Zhuque-3 and LM8R), an annual deployment rate of 800 satellites (400 allocated to Guowang), and over 40M active users. This model output translates to an IRR of 26%, driven by ARPU uplift to $60/month and military contracts from 2030.

For Qianfan, the financial risks are more severe. The base case assumes 7,500 satellites by 2035 and ~30M international users. However, only 45% of Priority 1 BRI countries are effectively covered, due to power constraints and terminal distribution limits, not line-of-sight issues. Despite government support and revenue from military applications starting 2030, NPV remains at -$37.6B with payback also in 2032. In the pessimistic case, just 4,500 satellites are launched by 2035. The user base reaches only 10M, mostly due to affordability gaps and lack of commercial contracts. Launch cadence is bottlenecked below 300/year. The model projects a negative NPV of -$76.6B, making Qianfan the riskiest capital venture modeled. Adoption assumptions are income-elastic and capacity-constrained (Appendix H), with no anchor clients secured. The optimistic case assumes a 12,000 satellite buildout, at ~600/year allocation, improved ARPU ($60), and >50M international users by 2035. Dual-use contracts start from 2028. The outcome is $23.5B NPV, IRR of 33%, and break-even in 2031.

**Key observations are as follows**:

- Economies of Scale: Financial viability is only reached at 10,000+ satellite scale per constellation.
- Government Subsidy: All NPV positive scenarios depend on early CAPEX support and military contracts (Guowang starting 2030 and Qianfan 2028, respectively).
- Technology Bottlenecks: Launch cadence and cost control are the dominant risk factors.
- Market Exposure: Guowang is sensitive to infrastructure cost and launch cadence, Qianfan is more vulnerable to international adoption and contract agreements.

However, it must be noted that even under pessimistic scenarios, the geopolitical and security benefits may outweigh financial losses for China, where strategic goals can justify their shortfalls. Table 5-9 outlines the KPIs and shows how sensitive both constellations are in terms of primary strategic and technical considerations.

Table 5-9 - Guowang and Qianfan Scenarios (Sensitivity Relative vs Base Case)

| **Variable** | **Range** | **NPV Impact (Guowang)** | **NPV Impact (Qianfan)** |
|---|---|---|---|
| Satellite unit cost | $250K–$500K | ±$7.4B | ±$9.1B |
| ARPU | $25–$65/month | ±$7.8B | ±$8.3B |
| Terminal adoption rate | 20M–40M users | ±$5.2B | ±$6.0B |
| Launch cadence* | 600–1500 sats/year | ±$8.0B | ±$9.5B |
| OPEX % of Rev | 25%–50% | ±$4.6B | ±$5.7B |
| Ground infra CAPEX | $5–10B | ±$2.2B | ±$3.1B |

***Maximum considered after optimized manufacturing and operational process (several years). All sensitivities are computed by holding other variables constant and shifting one parameter within the defined range.

Figure 5.5 illustrates the cumulative number of satellites launched for Guowang and Qianfan from 2025 to 2035, based on modeled deployment trajectories aligned with the base and optimistic scenarios described. The graph highlights the minimum satellite count and corresponding year in which each constellation achieves a positive Net Present Value (NPV). For Guowang, the optimistic case assumes ~9,000 satellites deployed by 2032, reaching break-even with an IRR of 26%. In contrast, the base case, with ~6,500 satellites deployed by 2035, remains marginally below viability. For Qianfan, the optimistic trajectory achieves ~12,000 satellites by 2035 and crosses into profitability around 2031, whereas the base case (7,500 satellites by 2035) still results in negative NPV. These break-even thresholds demonstrate the critical importance of launch cadence acceleration, particularly from 2026 onward, to enable early revenue capture and infrastructure utilization. The figure emphasizes that without sustained launch rates exceeding 1,000 satellites per year by 2027–2028, both constellations risk falling short of their financial break-even points and regulatory spectrum thresholds.

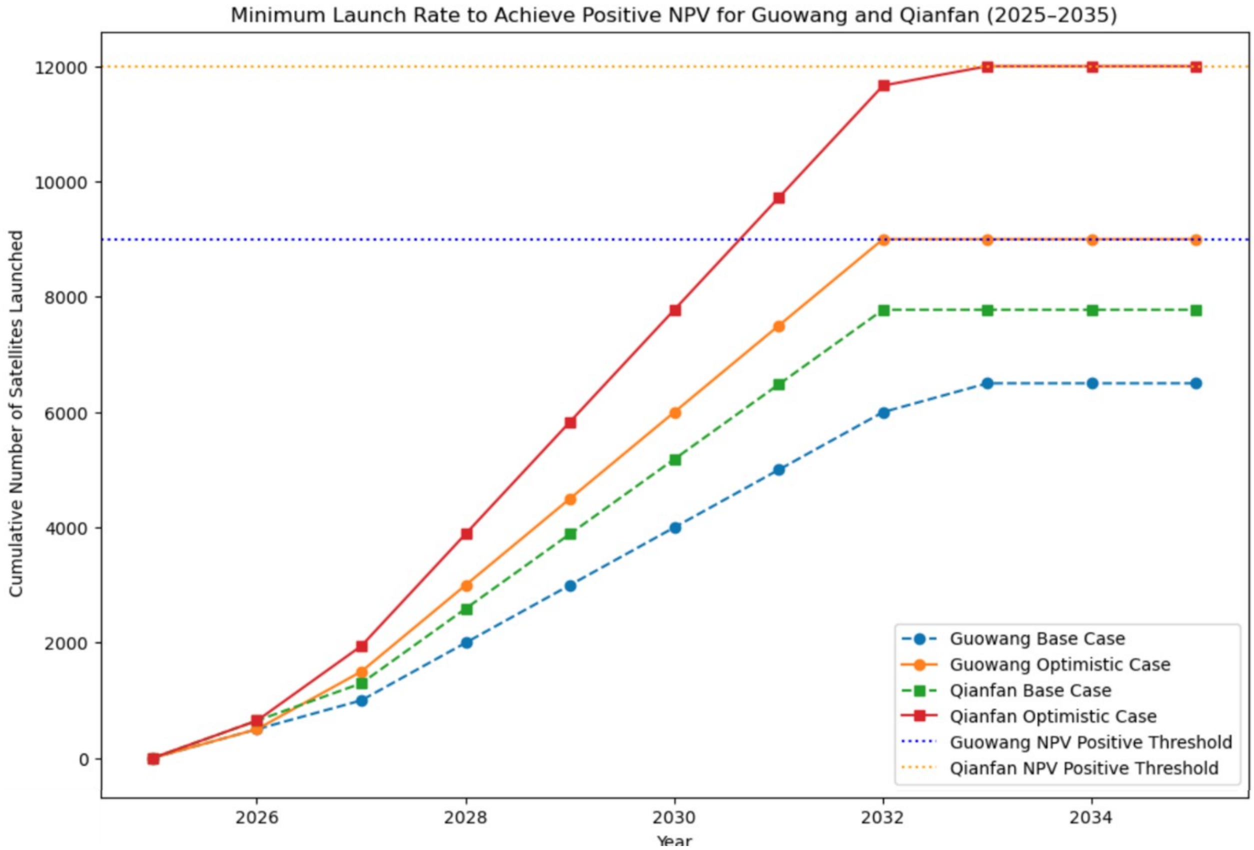


Figure 5.5 Cumulative number of satellites launched with minimum rate and corresponding year in which each constellation achieves a positive Net Present Value (NPV).

As demonstrated by the preceding scenario modeling, both Guowang and Qianfan could achieve economic viability by 2030–2032, provided they meet their projected deployment rates (see Figure 5.3 and 5.5) and benefit from sustained state support. However, their financial and operational viability remains highly contingent on several factors, including launch cadence, user adoption, and the maturity of reusable launch systems. Among the two constellations, Qianfan is particularly vulnerable to delays in international uptake and commercial anchor contracts, especially in its targeted Belt and Road Initiative (BRI) markets across Africa and Southeast Asia.

The analysis also confirms that early international contracts, especially in Asia and Africa are critical to Qianfan's viability. If capacity utilization remains low, or launch cadence stalls due to logistical or technological bottlenecks, both constellations risk becoming persistently cash-negative. Moreover, Guowang's success hinges more on domestic execution and infrastructure rollout, whereas Qianfan's exposure lies in its dependence on contract conversion, international political goodwill, and its ability to maintain operating margins in price-sensitive markets. Meeting the ambitious target of full constellation deployment by 2032 especially for Qianfan appears infeasible without significant private-sector launch capability maturation, including vehicles such as Zhuque-3 and Long March 9. Equally important is ARPU monetization in developing markets, and the ability to localize ground infrastructure to reduce both latency and regulatory friction. In short, the success of Qianfan is as much a function of diplomacy and international commercial integration as it is of technological scale-up.

In contrast, SpaceX's Starlink has already consolidated its leadership in the LEO broadband domain, driven by vertical integration, reusable launch capability, and robust early-stage market demand. Starlink's profitability was achieved through its ownership of the Falcon 9 rocket ecosystem, enabling a cost-effective and frequent launch cadence, coupled with diversified revenue streams across consumer, enterprise, and government sectors, including secure U.S. military communications. By comparison, Guowang and Qianfan face structural disadvantages. Guowang, despite its massive ambition, suffers from high upfront capital intensity and lower throughput per satellite relative to Starlink. Its viability in the near term is hampered by the need to scale satellite production to >500 units per year, while also transitioning to reusable launch technology to cut costs by at least 30%. Without achieving both these milestones, Guowang's long-term sustainability remains doubtful.

Qianfan's architectural limitations are more pronounced. With satellite capacity at ~10 Gbps per unit, well below Starlink's projected 20–40 Gbps, its competitiveness in high-demand environments is significantly reduced. This performance gap constrains Qianfan's ability to offer comparable service in urban and enterprise contexts. To offset these limitations, Qianfan is dependent on strategic subsidies and bilateral agreements, using BRI as a channel for market access and diplomatic influence. These partnerships, if effectively secured, may allow Qianfan to grow its user base while managing its commercial limitations through favorable regulatory environments and reduced cost of customer acquisition.

To approach economic viability, both Guowang and Qianfan must undertake a multi-pronged strategy, centered on:

- Satellite Production: Guowang needs 500/year, Qianfan 648/year (currently estimated at ~200/year total; see Chapter 4).
- Launch Economics: Reusable launchers must drop costs by 40%+, with unit cost targets of $250K (launch + sat combined).
- Expanding market access through coordinated diplomacy and infrastructure investment under the BRI umbrella, with particular emphasis on Africa, Southeast Asia, and Latin America.
- Throughput Upgrades: Guowang satellites must scale to 30–50 Gbps (via larger payloads, high-efficiency transponders, more ground stations). Qianfan needs 2–3x improvements in spectral efficiency or architectural density.

Starlink's current dominance stems from first-mover advantage, technological control, and ecosystem synergy. While China's dual-constellation approach reflects a strategic fusion of commercial expansion and geopolitical ambition, the road to sustainability is steeper and more fragmented. Figure 5-6 reflects the positioning of different players in LEO MEGACON, indicating SpaceX as the first-mover and China and Europe as followers trying to ensure sovereignty and prevent monopoly.

The financial modelling and estimates suggest that for Guowang and Qianfan to become economically viable, four core thresholds must be met:

- Sustain a launch rate of ~1,000+ satellites per year, beginning no later than 2026–2027.
- Reduce launch costs by 40% or more, primarily via reusable vehicles.
- Secure a pipeline of international government or commercial contracts, especially in BRI-aligned countries for Qianfan.
- Maintain a minimum ARPU of $40–$60, ideally with scalable B2B and dual-use applications (e.g., defense, infrastructure, disaster recovery).

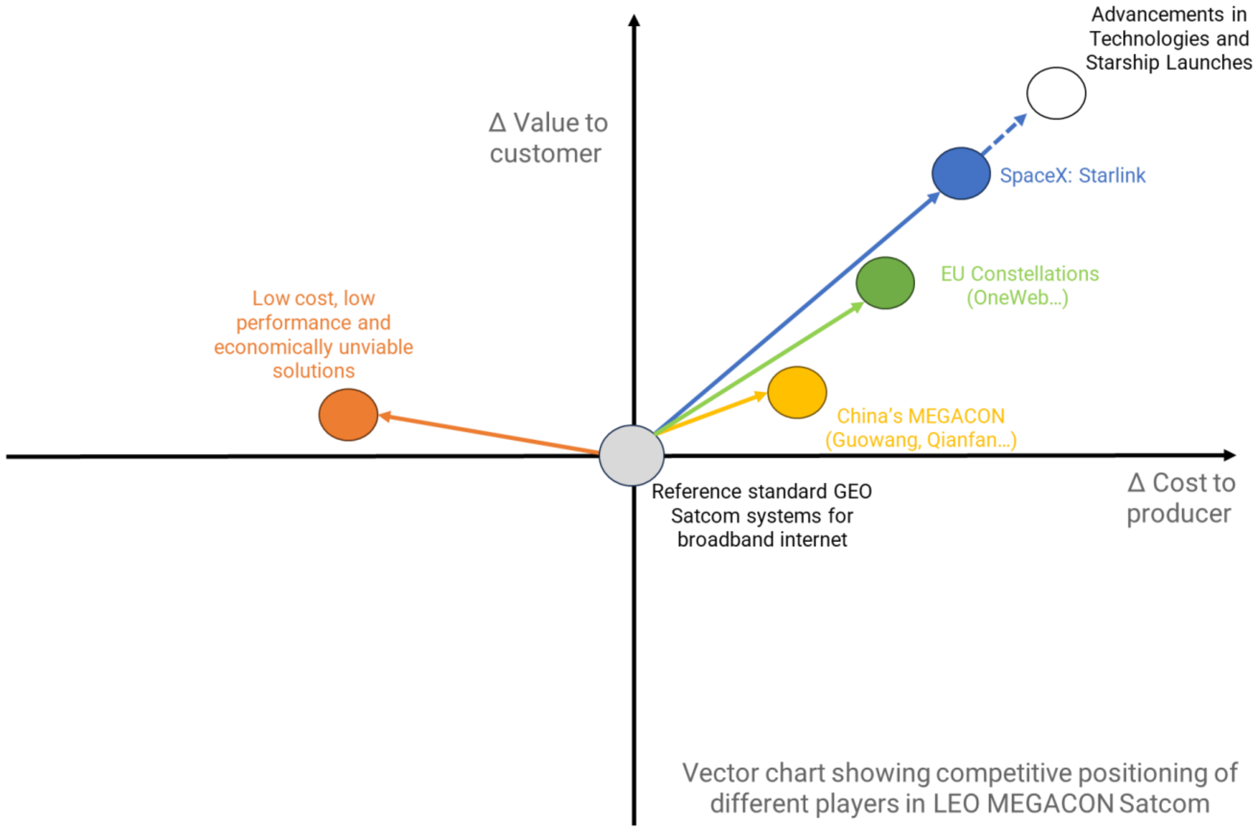



Figure 5.6 Vector chart showing competitive positioning of MEGACON satcom players: Starlink (first-mover) with further envisaged technological advancements and Starship launcher can be likely about of the competition, China and Europe trying to mirror SpaceX approach and ensure sovereignty.

If these conditions are achieved, break-even could be realistically reached by 2032, with IRR approaching competitive thresholds (≥25%). However, should these assumptions not materialize, ongoing operations would require prolonged state subsidies or increased military integration to justify further capital injections.

Consequently, the following strategic questions are addressed:
1) Is China’s Satcom strategy financially viable under current pacing? Partially. Guowang is borderline viable in the optimistic case. Qianfan requires commercial traction to break even.
2) What would China need to subsidize for viability?
Roughly $40–50B in additional CAPEX (each constellation), primarily for launch acceleration and user terminal subsidies (further addressed separately in Chapter 6 for Guowang).
3) What most constrains success? Launch cadence and affordability for users, particularly rural China (Guowang) and BRI frontier markets (Qianfan).
4) Can China meet its 2030 deployment targets? Unlikely, unless reusability and automation are fully operational and spectrum preservation deadlines (e.g., ITU) are secured through accelerated mass deployment.

# Chapter 6 : Domestic Expansion Strategy

This chapter evaluates China's strategic approach to expanding its Satcom infrastructure domestically, focusing on rural connectivity, military-civil integration, and system throughput. Appendix G provides data for potential ground stations (gateways) supporting GuoWang and Qianfan MEGACON projects (according to the chapters 3 and 4).

## 6.1. Rural Connectivity Initiatives

China's domestic Satcom expansion strategy places significant emphasis on rural inclusivity, treating broadband as both a developmental priority and a matter of strategic resilience. Within this framework, the GuoWang constellation plays a pivotal role as the primary instrument for addressing persistent digital exclusion across China's western interior provinces, including Xinjiang, Tibet, Inner Mongolia, and Western Sichuan (see Chapters 3 and 4). Unlike Qianfan, which is structured around international and geopolitical engagement, GuoWang is domestically oriented, embedded within the Digital China, Rural Revitalization, and national security modernization agendas.

As of 2024, an estimated 336 million Chinese residents (23.6% of the population), remain offline, a figure heavily concentrated in rural or geographically remote areas. The government's stated objective is to reduce this figure by 80% by 2030, translating into approximately 270 million new broadband users, most of whom are not reachable via traditional terrestrial networks. This demographic and infrastructural challenge frames the strategic rationale behind GuoWang's rural deployment.

**Key Challenges and Rationale for Satcom Intervention are**

1. Digital Divide Persistence: Despite considerable 5G expansion in urban centers, rural provinces continue to experience structural exclusion due to cost, terrain, and low market incentives, particularly in low-income rural provinces where ARPU remains below viability thresholds. GuoWang is explicitly designed to bridge this divide through satellite-enabled broadband.

2. Cost-Prohibitive Terrestrial Infrastructure: Fiber deployment in remote areas exceeds $30,000 per kilometer, particularly in mountainous terrain, whereas subsidized Satcom terminal solutions can be delivered at approximately $500 per user (plus operating service costs), a 60x cost reduction per capita, excluding long-haul backhaul.

3. Administrative Coordination: The Ministry of Industry and Information Technology (MIIT), in collaboration with state-owned carriers such as China Telecom and China Unicom, has initiated early-stage trials (2024–2025) of satellite-based rural connectivity. These pilots are strategically deployed in low-ARPU zones but justified via long-term social impact and disaster recovery potential [74–79].

**China Strategic and Technical Development Plan**

According to China's strategy and realized idealistic model projections, GuoWang aims to target 100 million rural users by 2027. This figure is supported by system throughput projections and user adoption models presented in Chapter 6.3 and Chapter 5.4, which simulate infrastructure, bandwidth, and income-driven uptake scenarios under three deployment cases (Pessimistic, Base, Optimistic), offering 50 Mbps broadband service, with priority given to users in "last-mile" locations (beyond the fiber loop). This equates to penetration of roughly 30% of China's currently unconnected population by 2027 and 80% by 2030, if terminal subsidy programs and gateway infrastructure scale as intended.

This deployment framework includes (these technical parameters correspond to inputs in the modeling framework discussed in previous chapters):

- Satellite Throughput: 30–50 Gbps per satellite (model assumption), capable of serving 500–1,000 concurrent users per node at 50 Mbps.
- User Terminals: Subsidized to $200 per unit (vs. Starlink's ~$599), with integration into provincial telecom offerings and rural infrastructure grants.
- Latency Advantage: 15–25 ms, allowing for VoIP, remote learning, and telemedicine in underserved provinces (vs. 30–50 ms for legacy GEO Satcom).
- Integration with National Fiber Backbone: Satellite backhaul nodes are designed to hand off traffic to regional 5G and fiber cores, optimizing bandwidth and reducing satellite-to-terminal strain.

**Analysis: Feasibility and Financial Trade-Offs**

System-level financial model and associated cash-flows (see Chapter 5 and Appendix E) indicate that GuoWang's domestic viability is heavily dependent on government subsidization in the early years, particularly for terminal adoption and ground segment deployment. In the base scenario, terminal penetration reaches 5% of the rural market by 2027, defined here as 5% of the 336 million currently unconnected individuals. At full scale (>100M users), the total capital required, excluding R&D but including terminals and ground infrastructure, exceeds $40B, partially offset by downstream B2B and government service contracts beginning in 2030. Furthermore, the model underscores that while cost efficiency per user might be achieved with this framework, revenue realization is modest in the short term. Average Revenue Per User (ARPU) is capped below $50/month domestically due to affordability constraints. However, secondary benefits, including sovereignty in communications, disaster recovery, and educational equity are increasingly factored into China's broader cost-benefit framework (see Chapters 1 and 2). These are driven by the following strategic implications: a) National Security: Rural connectivity also contributes to information control, internal stability, and disaster response objectives central to China's Military-Civil Fusion doctrine (see Chapter 2.4.3). b) ITU Spectrum Retention: Timely rural deployment also aids GuoWang in fulfilling its 10% ITU spectrum filing deployment threshold by 2029, crucial for regulatory legitimacy. c) Decentralized Infrastructure Resilience: A distributed satellite backbone minimizes dependency on coastal fiber networks, reinforcing system robustness in times of conflict or natural disaster. The modeled assessment from Chapter 3 identifies that fiber deployment costs ($7–$8) becomes inaccessible to residents in China's most disconnected regions (Gansu ~¥47 budget, Xinjiang ~¥48 budget, and Tibet ~¥43 budget following the 2% income rule), unless subsidized. Currency is presented in RMB for affordability assessments based on domestic income (see Appendix H), while CAPEX and international comparisons are denominated in USD for standardization and modeling consistency. Further evaluating GuoWang's potential to meet strategic goals (80% rural coverage by 2030) the three analyzed cases are assessed:

1) Base Case (5% adoption by 2027, with 100M users by 2030)

- Affordable Population (based on income): ~115M users.
- Unconnected but physically covered: 60% of rural China is reachable by satellite terminals with existing terrain maps and expected coverage per satellite (see Appendix G for terrain constraints and Chapters 5 and 6.3 for modeled geographic coverage assumptions based on orbital footprints and beam mapping following Pachler et al. [71]).
- Required Annual Terminal Subsidy: ~30M users (unaffordable group) × $200 subsidy = $6B cumulative 2024–2030
- It can be partially feasible, but fails to connect >50% of Tibet, Xinjiang, and Gansu without deeper subsidization.

2) Pessimistic Case (2% adoption, with ~30M users)

- Focus limited to coastal and wealthier inland provinces.
- Strategic target of 80% rural coverage by 2030 is not achievable.
- No affordability alignment, and not meeting the ITU deployment threshold.

3) Optimistic Case (10% adoption by 2027, with 180M users by 2030)

- ARPU increases to $60/month due to B2B and provincial deployments.
- Even under optimistic scenario ~60M of those users still cannot afford unsubsidized terminals.
- Terminal Subsidy Requirement: 60M × $200 = $12B through 2030
- It might meet first coverage targets, but only with strong subsidies and 100% terminal rollout success.

The gap between affordability and connectivity is obvious, where out of the 336M unconnected:

A. Only ~115M can afford Satcom (~34%), assuming $50/month price.
B. ~80M live in areas with no terrestrial alternatives, but many also fall into the unaffordable bracket.
C. Target for Satcom-supported universal service: ~180–220M users (based on physical coverage + digital demand curves).

The analysis shows that even under optimistic scenario ~80% strategic goals can be met. China's strategic goal is not achievable in the Base or Pessimistic cases under current income distribution and launch cadence. To reach the optimistic case, government must:

- Expand subsidy programs to cover at least $10B in terminals (on top of the >$40B CAPEX).
- Fund regional backhaul networks (Chapter 3) to optimize satellite capacity.
- Enable dual-use contracts with the military and state infrastructure projects (as modeled in Chapter 5), starting 2030.

Consequently, GuoWang's rural broadband strategy faces a scale-affordability paradox, the very regions most in need of Satcom are the least able to afford it. Without a comprehensive national subsidy and deployment program, the constellation will underdeliver on its connectivity goals and risk losing ITU spectrum rights. While technically feasible, the rollout is not economically viable without state support, even under the optimistic case. China's domestic Satcom expansion must therefore balance strategic ambition with socio-economic realities, recognizing that infrastructure alone does not ensure adoption, affordability does.

## 6.2. Integration of Commercial and Military Objectives (Guowang and Qianfan)

One of the defining features of China's satellite communications (Satcom) strategy is its deliberate convergence of commercial operations and national defense priorities, aligned under the Military-Civil Fusion (MCF) doctrine. This doctrine, formalized by the State Council and the Central Military Commission, explicitly calls for shared development and co-optimization of infrastructure and technologies between the civilian and defense sectors.

Both Guowang (targeted primarily at domestic needs) and Qianfan (internationally oriented) are designed within architectures that enable seamless interoperability with PLA Strategic Support Force (SSF) systems. This model diverges from Western paradigms, where defense and commercial networks are typically operated under separate governance and procurement schemes [30,36,61].

The integration of commercial and military Satcom infrastructure in China is driven by three mutually reinforcing goals:

1. Redundancy and Resilience: LEO systems, due to their low latency and coverage density, provide a robust fallback to fiber-optic and geostationary (GEO) systems. In crisis or wartime conditions, Guowang can serve as a communications backbone, especially across inland regions vulnerable to infrastructure sabotage (see Chapter 3, Ground Network Resilience Map). The projected 15–25 ms latency for Guowang (Sections 3,4 and 5 and 6.1) enables near-real-time coordination of mobile command units and drone fleets.

2. Dual-Use Economics: Infrastructure investments, launch vehicles (e.g., LM-8R, Zhuque-3), phased-array terminals, satellite buses—serve both civil broadband and military ISR applications. Cost amortization across these functions significantly improves long-term ROI, especially in the Optimistic Scenario, where government defense contracts (starting 2028 for Qianfan) offset ~15% of total CAPEX over a 10-year period (see Chapter 5.4.2 and Figure 5.3).

3. Strategic Signaling: the ability to deploy, operate, and scale large constellations (>10,000 satellites) serves as a geopolitical signal. It reflects not only China's technical maturity but its strategic posture in contested domains, such as the South China Sea and low Earth orbit (LEO) commercial corridors.

**Military-Civil fusion strategy (MCF) and system design**

1. Shared Frequency & Spectrum Coordination: Guowang operates in Ka/Ku bands also used by PLA space-based radar and surveillance (e.g., Tianlian Data Relay Satellite System), creating potential for congestion in contested bandwidths. The model (chapter 6.3) projects potential 15–20% throughput degradation in conflict scenarios, especially if battlefield communications supersede civilian traffic prioritization (see, also financial sensitivity table, Chapter 5.4.2).

2. Use Case: BeiDou + Satcom Integration: the BeiDou GNSS system is "linked" to Guowang in the sense that Satcom relays onboard Guowang satellites can receive BeiDou signals for improved orbital positioning and can provide secure real-time communications from BeiDou-based tracking terminals. The term "relays" refers here to Satcom nodes transmitting low-latency battlefield data (e.g., ISR feeds) in tandem with BeiDou location coordinates, supporting real-time troop coordination and precision-guided systems.

**Strategic Infrastructure**

1. Ground Station Dual-Use Model: Appendix G and Chapter 3 identify co-located TT&C and data uplink facilities in strategic frontier zones, which are used in the Analysis Chapters 5 and 6 (connectivity) for potential dual-use case extension:

- Xinjiang and Tibet: Dual-purpose stations support both commercial TT&C and PLA surveillance.
- Gansu: Expansion aligned with PLA radar and missile-defense networks.
- These facilities also support early-warning systems, SIGINT, and encrypted backhaul.

2. BRI-Based Overseas Military Anchors: Qianfan's international buildout supports dual-use logistics in Belt and Road Initiative (BRI) geographies:

- Gwadar, Pakistan: Provides Satcom uplink for Western China and Indian Ocean operations.
- Neuquén, Argentina: Downlink station reportedly used by PLA strategic support teams.
- Djibouti: Site of PLA's first overseas base, likely to integrate with Qianfan ground links by 2026.

**Identified Risks and Mitigation Measures used:**

- Spectrum Congestion: Military usage reduces GuoWang's effective throughput by 15–20% in conflict scenarios. This is a modeled assumption based on prioritization protocols in dual-use systems, cross-referenced from satellite traffic engineering literature and observed precedent in U.S. DoD narrowband allocation (MILSATCOM handbook, 2020 and ref.[4,65]).
- Export Controls / ITAR Risk: Qianfan relies on indigenized phased-array terminals and secure application specified integration circuits; therefore the model accounts for +$5B increase in

ground infra CAPEX (Chapter 5.4).

- Dual-use Blowback in BRI States: Several BRI partner countries have started re-evaluating agreements amid fears of espionage (see Chapter 3.2). This limits Qianfan's diplomatic traction without clear civilian guarantees, taken into account during scenarios modelling (Chapter 5.4).

**Financial and Operational Implications:**

- Dual-use Revenue Contributions: In the Optimistic Scenario (Chapter 5.4.2), Guowang's defense contracts contribute a fixed 7.3% of total modeled revenues post-2030, as defined in financial projections. This value is used to offset Guowang's weaker commercial margins.
- Strategic B2G Contracts: Qianfan leverages B2G contracts in sensitive markets (e.g., Pakistan, Nigeria) to add $4B in cumulative revenue over 2030–2035. These figures are based on modeled uptake scenarios assuming partial military bandwidth allocation and national emergency response agreements.
- Civilian Access Constraints: Prioritization of bandwidth for military operations during periods of regional instability can restrict rural civilian access, especially in autonomous or restive regions such as Tibet and Gansu. These constraints are flagged as risk items in system throughput modeling and discussed in the sensitivity framework..

It can be observed that China's integration of commercial and military objectives through Guowang and Qianfan is a strategic enabler of resilience, economic efficiency, and geopolitical signaling. However, the civil-military trade-off constrains throughput, international trust, and ITU spectrum neutrality, potentially undermining long-term commercial growth. Mitigating these risks requires clearer bandwidth separation protocols, transparency in BRI partnerships, and alignment of satellite designs with dual-role missions from the outset. Ultimately, while MCF enhances China's strategic deterrence posture and amortizes cost, it also introduces complexities in regulatory access, commercial partner trust, and equitable service delivery, especially in contested domains.

## 6.3. Model Results and Analysis: System Throughputs

This chapter presents the throughput capacity modeling for China's Guowang constellation, based on the model and system design parameters described in Chapter 4 and the deployment scenarios outlined in Chapter 5. The analysis evaluates Guowang's ability to meet domestic connectivity goals by simulating total system throughput as a function of satellite count and ground station coverage, following the methodology established by Pachler et al [14,16 and 71]. Unless otherwise stated, all results refer to domestic gateways and users. The gateways are described in Chapter 5 and listed in Appendix F and G. Figure 6.1 shows an example of the geographic distribution of the minimum set of 20 domestic ground stations used for Guowang, based on these sources.


Figure 6.1 Geographic distribution of Guowang ground stations (China)

Minimum domestic ground station network (20 sites) modeled for throughput analysis, based on identified TT&C and uplink facilities from Appendix F and G.

### 6.3.1. Guowang RAP-Based Throughput Results: Validation, Implications, and Strategic Assessment

To validate and refine throughput capacity projections, the RAP-based Python simulation was executed using Guowang's assumed three-shell architecture, realistic orbital parameters, and gateway network outlined in Appendix I and Chapter 5. This simulation incorporated factors such as gateway beam saturation, ISL capacity, elevation masking, and link losses.

Table 6-1 summarizes the throughput results for three analyzed cases (base, optimistic and pessimistic), and figure 6.2 shows the Guowang base case throughput. The simulation yielded a base throughput of 6.6 Tbps, with the optimistic case at 7.2 Tbps and pessimistic at 3.8 Tbps (Table 6-1).

Table 6-1 - Modeled Throughput Results for Guowang (RAP vs Simplified Estimate)

| Scenario | Satellites | Gateways | RAP Model Throughput [Tbps] |
|---|---|---|---|
| Pessimistic | 3,000 | 20 | 3.8 |
| Base | 6,500 | 30 | 6.6 |
| Optimistic | 9,000 | 45 | 7.2 |

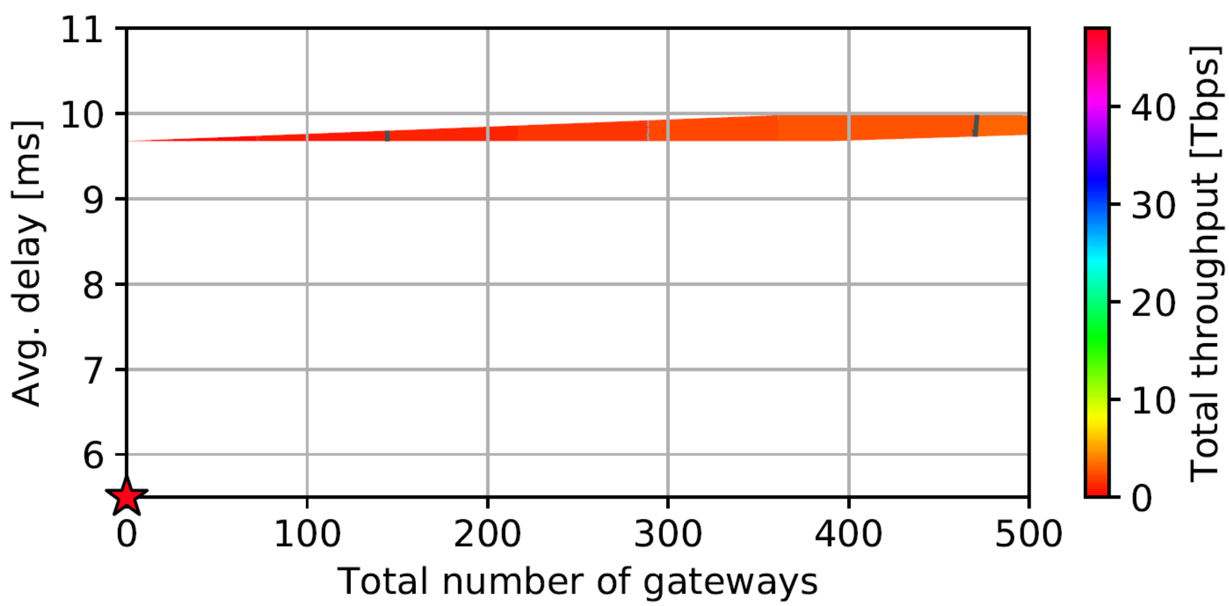



Figure 6.2 Guowang system throughput (base case) (according to Pachler et al.[14,16,71])

Figure 6.3 shows the system throughput across gateway counts (comparison across three deployment scenarios). The results reveal diminishing returns, throughput increases with more gateways but saturates due to beam reuse limits and congestion.

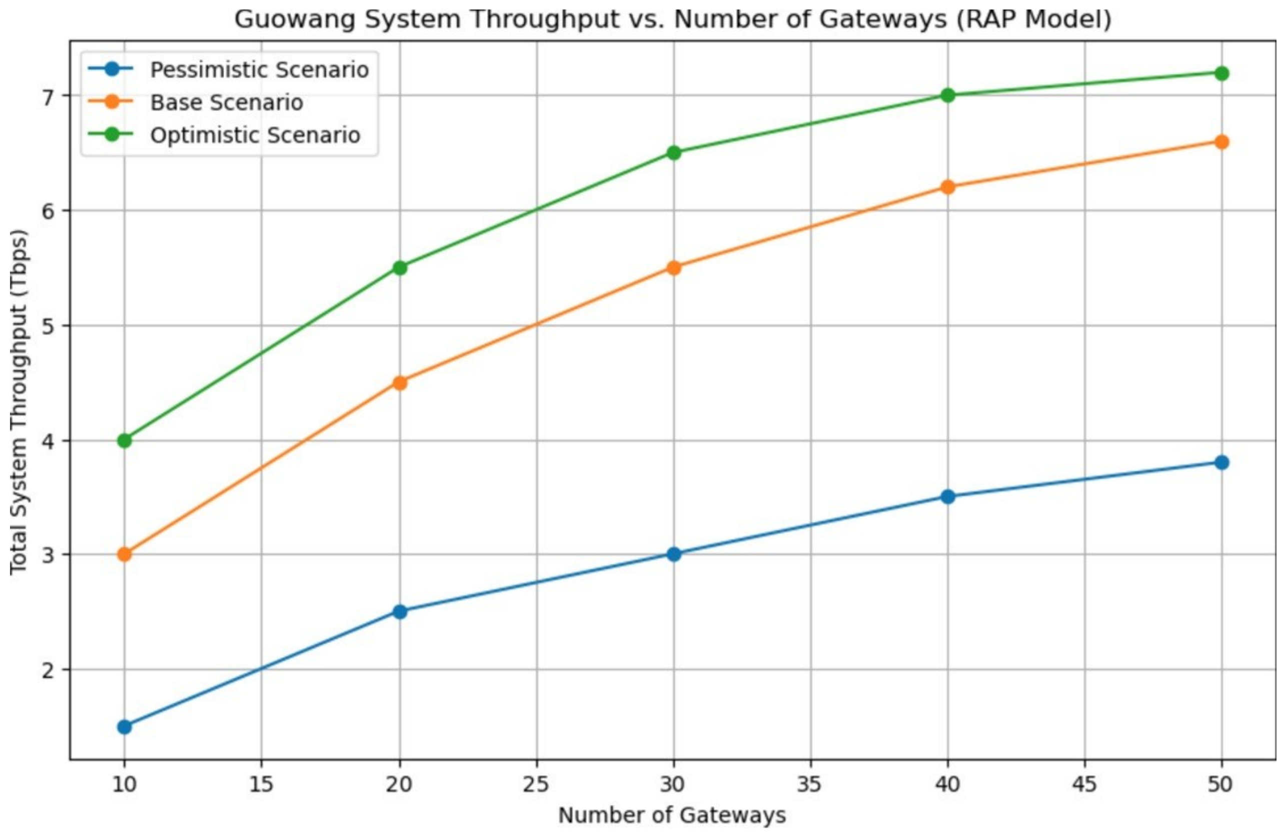


Figure 6.3 Guowang system throughput across gateway counts
(comparison across three deployment scenarios)

The figure 6.4 illustrates Guowang's projected satellite deployment versus modeled system throughput from 2025 to 2032 across three deployment scenarios, using the validated RAP simulation model. A key observation is the relatively small increase in throughput between the base case (6,500 satellites) and the optimistic case (9,000 satellites)—from 6.6 Tbps to 7.2 Tbps. This modest gain, despite a 40% increase in satellite count, highlights the impact of ground station saturation: as more satellites are deployed, marginal throughput gains diminish unless the gateway infrastructure scales in parallel. In contrast, the pessimistic case underperforms at 3.8 Tbps due to both lower satellite counts and reduced utilization.

The RAP simulation integrates real-world constraints such as gateway beam overlap, elevation masking, antenna pointing losses, and link interference. The flatlining of throughput in the optimistic case confirms that gateway capacity, not satellite count alone is the primary bottleneck in achieving higher service delivery. This finding emphasizes that achieving Guowang's national service goals requires not only rapid satellite deployment but also significant expansion of domestic ground infrastructure and improvements in network resource management (e.g., frequency reuse, regional scheduling).

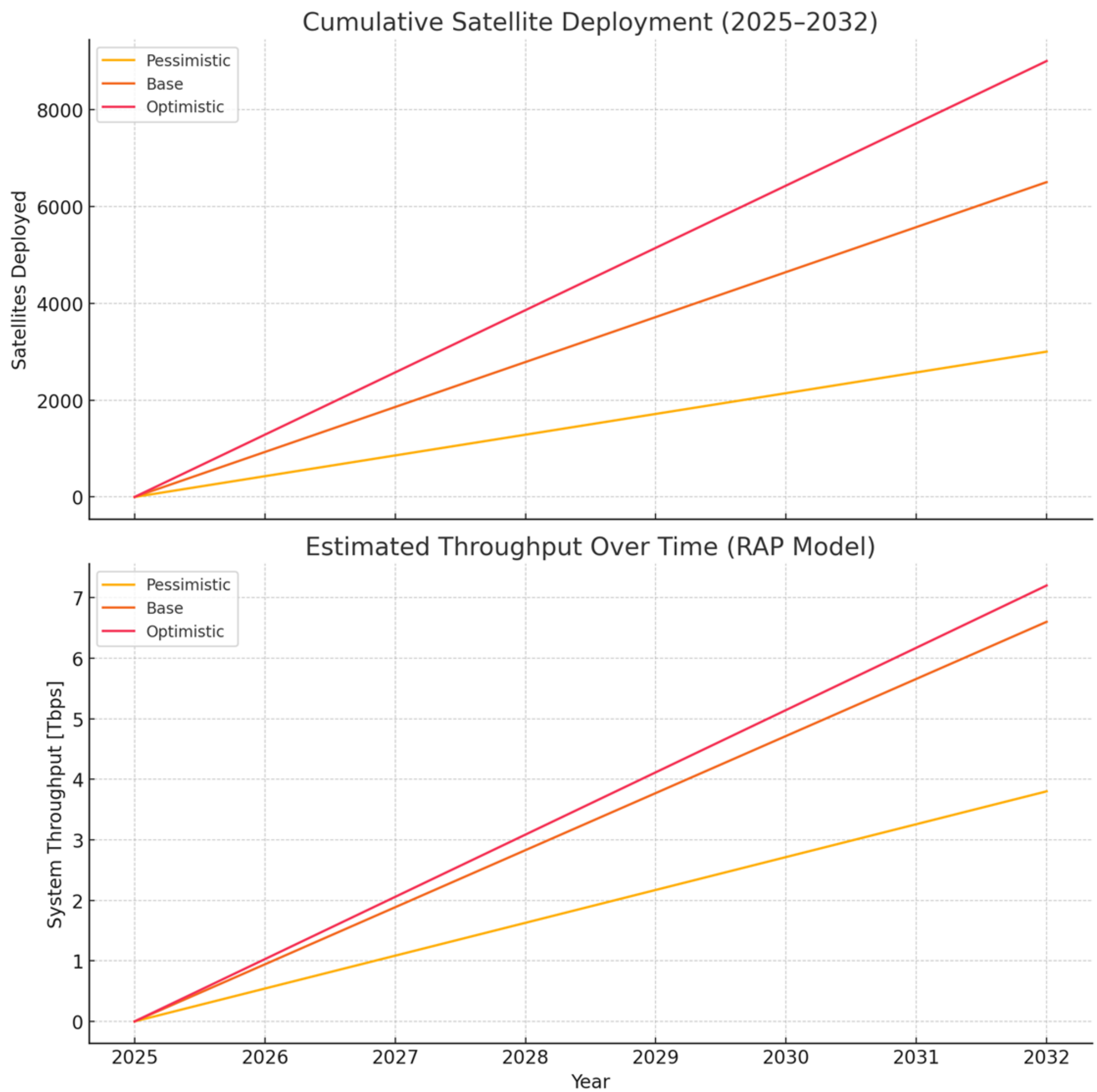



Figure 6.4 Guowang system throughput across gateway counts
(comparison across three deployment scenarios)

**Strategic Implications**

**1. Domestic coverage targets:** The base case throughput of 6.6 Tbps supports only ~30 million users at 50 Mbps, far short of the 100 million user target. The optimistic case (7.2 Tbps) still undershoots national goals.

**2. Minimum deployment to retain spectrum rights:** The analysis indicates that without deploying ~6,500 satellites by 2029, Guowang may risk losing its ITU spectrum filing.

**3. Throughput over time:** The model assumes growth in satellite deployment. Figure 6.3 shows cumulative throughput against deployment year, indicating the inflection point where NPV becomes positive, aligned with the scenario analyses in Chapter 5.

**4. Military-Civil Fusion Constraints:** Military prioritization reduces throughput by 15–20%, reducing usable civilian capacity to 5.2–5.8 Tbps. This reinforces the need for caching, hybrid backhaul, and spectrum management.

**Key Technical Drivers of Discrepancy:**

- Gateway Saturation: The RAP model shows that without sufficient ground stations, adding satellites yields minimal throughput gains. As shown in Figure 6.2, saturation emerges around 40–50 gateways.
- ISL Losses: Laser inter-satellite links introduce latency and switching inefficiencies, limiting relay gains.
- Elevation and Terrain Constraints: User access windows shrink due to non-ideal terrain and elevation angles.

These findings echo conclusions from Pachler et al. [14,16,71], who noted early throughput saturation in LEO constellations due to similar bottlenecks.

Consequently, the following strategic questions are addressed:
1) Can Guowang meet China's rural connectivity goals by itself? Not under current conditions. The base case fails to meet targets even before considering military throughput loss.
2) What must change to enable success? Deployment of >50 gateways, higher spectrum reuse, and tiered ARPU pricing to match user affordability.
3) Is technical feasibility aligned with policy ambition? Not in the base case. Without aggressive infrastructure expansion and subsidies, Guowang risks underdelivering by 2030.
4) Is domestic market share assumed to be exclusive? This analysis assumes Guowang as the primary domestic provider. If Qianfan also operates domestically, shared market implications would need separate modeling.
5) Is 100M user coverage achievable? Only with 10,000+ satellites, high utilization, and 50+ gateways.

Overall, the validated RAP results reinforce the urgency of accelerating launch cadence and infrastructure buildout to meet China's national connectivity goals and maintain spectrum rights.

The analysis clearly shows that Guowang's national service capacity is tightly bound to satellite scaling and gateway infrastructure. Meeting domestic broadband goals under the "Digital China" agenda will require aggressive deployment timelines, sustained capex investments, and technological maturity in reusability and manufacturing. If China fails to deliver on these fronts, which Is very likely, it will either:

- Miss national connectivity milestones (e.g., 100% rural access), or
- Require massive fiscal subsidies (>$40B) to maintain deployment while capacity lags.

These findings underscore the pivotal role that system throughput and infrastructure planning will play in determining the feasibility and eventual geopolitical competitiveness of China's satellite internet strategy.

### 6.3.2. Guowang Comparative Throughput Performance and Benchmarking

To contextualize Guowang's modeled system throughput, it is instructive to benchmark it against leading Western megaconstellations, using a standardized framework. Table 6-2 and Figure 6-5 below present the comparative throughput figures from Pachler et al. [14,16 and 71], who simulated nine global LEO constellations under equivalent modeling assumptions. These include beam coverage, gateway saturation, inter-satellite links (ISLs), terrain masking, and link budgets.

Table 6-2 - Modeled System Throughput Comparison (Peak Design Values by 2030 Horizon)

| **Constellation** | **Provider** | **Approx. #Satellites** | **Estimated Throughput (Tbps)** | **Notes** |
|---|---|---|---|---|
| Starlink (2nd Gen) | SpaceX | 12,000–42,000 | 150-200 | Extensive global gateway network, advanced frequency reuse |
| Kuiper | Amazon | 3,236 | 30-40 | Phased-array terminals. limited launch cadence to date |
| OneWeb | Eutelsat/OneWeb | 648 | 6-8 | No ISLs, heavy reliance on gateway interconnectivity |
| Telesat Lightspeed | Telesat (Canada) | 198 | 12-16 | Strong per-sat capacity, high gateway dependence |
| Guowang (Base Case) | SatNet (China) | 6,500 | 6.6 | Based on RAP Python simulation, domestic-only gateway set |
| Guowang (Optimistic Case) | SatNet (China) | 9,000 | 7.2 | Throughput limited by ground infrastructure saturation |

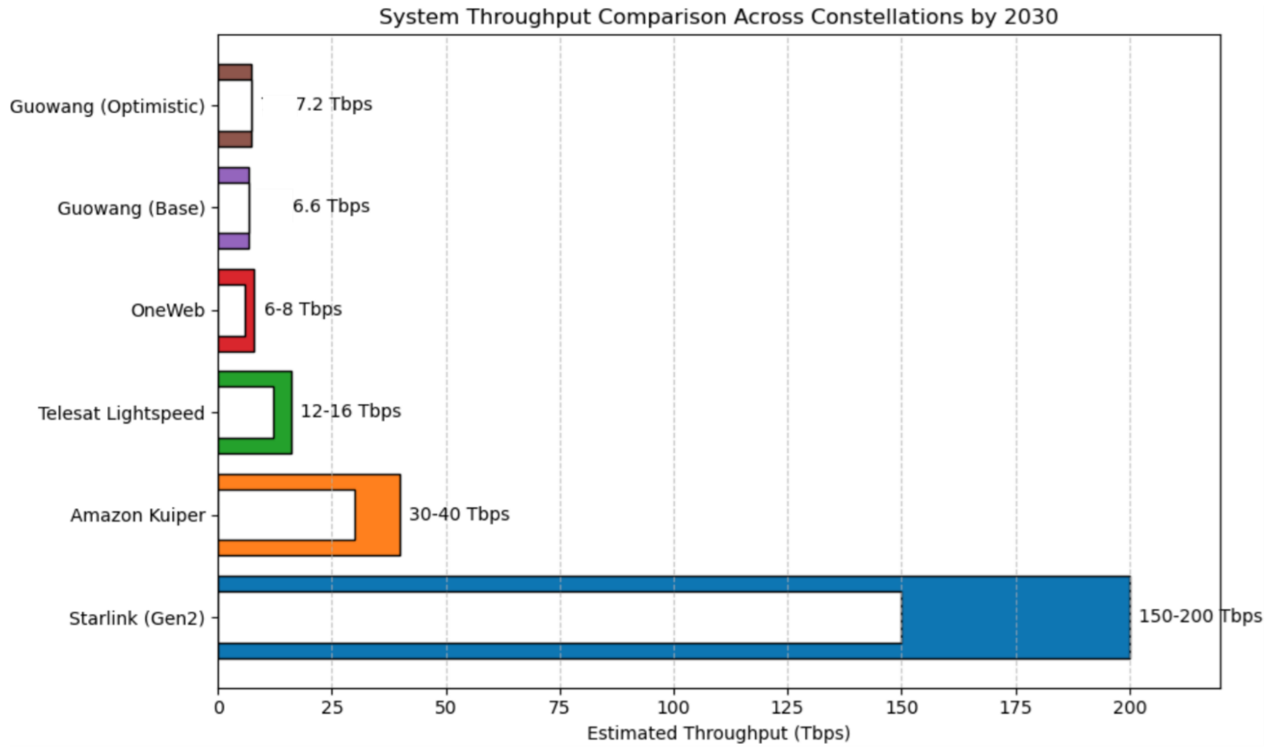



Figure 6.5 System Throughput Comparison Across LEO Megaconstellations by 2030

**Key Observations and Strategic Takeaways:**

- **Throughput Disparity:** Guowang's maximum modeled throughput (~7.2 Tbps) under optimistic conditions is significantly below Starlink's (~200 Tbps) or Amazon's (~40 Tbps) projected performance. This reflects limitations in both frequency reuse and ground infrastructure density.
- **Bottlenecks:** As shown in sub-chapter 6.3.1, Guowang's throughput curve flattens with more satellites due to gateway saturation. This reinforces Pachler et al.'s broader finding: ground station capacity, not satellite count, is the dominant constraint on network scalability beyond a certain threshold.
- **Relative Positioning:** Guowang's performance is closer to legacy Western constellations like OneWeb and Telesat in terms of absolute throughput, despite having significantly more satellites. This suggests a gap in spectral and architectural efficiency that China must address through either ISL optimization or domestic infrastructure build-out.
- **Equity vs. Scale:** Despite a large constellation size, Guowang's ability to deliver affordable high-throughput access remains limited in rural and underserved areas due to infrastructure distribution and capacity saturation. This further corroborates the concern that coverage does not equate to capacity, a critical distinction in broadband network economics.
- **Strategic Implication:** Without significant upgrades in gateway siting, beam steering algorithms, and dual-use infrastructure utilization, Guowang will remain an underperforming system in terms of throughput per satellite. Starlink's integrated vertical stack and Starship launch economics also provide it with durable competitive advantages.

# Chapter 7 : International Expansion Potential

## 7.1. Competitive Analysis Against Global Players

China's ambitions in satellite communication extend beyond its borders, aiming to establish a global presence and offer alternatives to existing international providers. In September 2024, Geespace, a subsidiary of Chinese automaker Geely, launched a third batch of 10 low Earth orbit (LEO) satellites. This expansion increased its constellation to 30 satellites, providing 24-hour global communication services covering 90% of the world. Geespace plans to deploy nearly 6,000 satellites to offer global broadband services, with an initial phase targeting 72 satellites by the end of 2025 to serve over 200 million users.

China's international Satcom strategy also focuses on developing regions, particularly within the Belt and Road Initiative (BRI). Collaborations with countries in Africa and Latin America are central to this approach. For instance, in February 2025, China expanded its influence in Africa by fostering space alliances, providing technology and support for satellite production, and constructing space monitoring facilities. Egypt's collaboration with China, marked by a high-tech satellite lab near Cairo, heavily relies on Chinese parts, technology, and personnel. These projects are part of China's broader strategy to build a global surveillance network and enhance its position as a dominant space power.  In Latin America, China has made significant inroads. In November 2024, the state-owned company SpaceSail announced plans to launch a satellite service in Brazil, positioning itself as a competitor to Elon Musk's Starlink. This initiative aims to provide communication and broadband services in areas lacking fiber-optic infrastructure, with operations expected to commence in 2026.  These international endeavors underscore China's commitment to expanding its Satcom footprint globally, offering alternative services in regions underserved by existing providers and strengthening geopolitical ties through technological collaboration.

## 7.2. Comparative Analysis of China’s Satcom Funding Models vs. Western Approaches

The financing models for satellite communications (Satcom) development vary significantly between China and Western countries, particularly the United States and Europe. China’s approach is characterized by state-driven investment, centralized planning, and integration with national strategic objectives, while Western models primarily rely on private-sector competition, venture capital, and government contracts through public-private partnerships (PPPs). This chapter examines key differences in funding mechanisms, economic sustainability, and long-term implications for market competitiveness.

China’s Satcom development is heavily funded and directed by the central government, mainly through state-owned enterprises (SOEs) such as China Aerospace Science and Technology Corporation (CASC) and China Satcom. The government channels funding through:

- Direct Budget Allocations: The Chinese government directly funds space programs, including Satcom constellations, as part of its Five-Year Plans and national strategic objectives.
- State-Owned Enterprises (SOEs): Unlike in the West, where independent companies compete for contracts, China's Satcom industry is dominated by SOEs that receive direct state support.
- Strategic Subsidies and Soft Loans: China's policy banks, such as the China Development Bank, provide low-interest loans and subsidies to SOEs, minimizing financial risk.

This centralized funding model enables long-term planning and stable financial backing, but it does not require immediate commercial returns, making projects like GuoWang's satellite constellation financially viable even before profitability is demonstrated. However, it also creates inefficiencies, as state-backed firms may lack strong market-driven incentives for cost efficiency and innovation.

In contrast, Western Satcom constellations, particularly in the U.S. and Europe, are primarily funded through private capital, venture investments, and government contracts:

- Venture Capital and IPOs: Companies like SpaceX (Starlink), OneWeb, and Amazon Kuiper rely heavily on private investments and public markets to raise capital.
- Public-Private Partnerships (PPPs): Governments provide contracts and subsidies to private firms through NASA, the European Space Agency (ESA), and the U.S. Department of Defense. For example, Starlink received over $885 million from the U.S. FCC's Rural Digital Opportunity Fund (RDOF). OneWeb secured over $500 million from the UK government after its bankruptcy.
- Commercial Revenue Models: Western constellations prioritize subscription-based services and enterprise contracts to ensure profitability, unlike China's state-backed approach, which focuses on national infrastructure first.

This model promotes innovation and cost efficiency but also exposes companies to financial risk, as seen with OneWeb's 2020 bankruptcy and Amazon's delayed Kuiper deployment.

Table 7-3 shows the risk tolerance and market efficiency comparing China's and Western satcom models.

Table 7-3 - Risk Tolerance and Market Efficiency (China vs Western)

| Factor | China's State-Driven Model | Western Private-Sector Model |
|---|---|---|
| Risk Tolerance | Moderate – While losses are often absorbed by state backing, the state's approach tends to be cautious and deliberate rather than aggressively high-risk. | Medium – Companies must secure external funding and demonstrate profitability. |
| Market Efficiency | Lower – State-owned firms face less pressure to optimize costs or innovate rapidly. | Higher – Competition drives efficiency, but financial sustainability is crucial. |
| Regulatory Flexibility | High – Centralized control allows rapid policy shifts. | Lower – Subject to multiple stakeholders, regulations, and investor expectations. |
| Global Market Access | Limited – China's Satcom operations face geopolitical and regulatory constraints that restrict international market penetration. | High – Western firms have more access to international markets. |

## 7.3. Market Opportunities

China's approach ensures continued funding regardless of short-term financial returns. GuoWang, Qianfan, and Hongyan constellations are primarily driven by national security, economic infrastructure, and digital sovereignty rather than immediate profitability. This means:

- China does not need immediate revenue from broadband subscriptions, allowing it to scale operations at a loss in early phases.
- The government can force domestic adoption, integrating Satcom into national programs such as rural connectivity and Belt and Road Initiative (BRI) projects.
- However, this model is financially opaque, making it difficult to assess the true costs and returns.

Western companies like SpaceX, OneWeb, and Amazon Kuiper must balance scalability with profitability. This means:

- Starlink operates under a revenue-first model, where user subscriptions fund expansion.
- OneWeb had to restructure after bankruptcy, as investors required proof of sustainability.
- Amazon's Kuiper project has been delayed due to investment risks, showing the limits of private funding.

This approach ensures efficiency but also limits how quickly companies can scale compared to China's government-backed initiatives.

**China's Advantages**

- Guaranteed Funding: State financing ensures continued expansion without immediate profitability.
- Government-Mandated Market: Domestic adoption is enforced, reducing reliance on commercial demand.
- Belt and Road Expansion: Integration with BRI provides an automatic customer base in developing markets.

**Western Advantages**

- Market-Driven Efficiency: Competition forces firms to optimize technology and reduce costs.
- First-Mover Advantage: Starlink already has 2.6 million users, giving it a global lead over China's still-developing systems.
- Regulatory Access: Western firms can operate in diverse markets, whereas China's Satcom faces geopolitical restrictions.

China's state-backed model prioritizes national strategic objectives and global digital influence, enabling large-scale expansion without immediate financial constraints. However, Western Satcom operators benefit from market-driven efficiency, technological innovation, and global accessibility, making them more competitive in open commercial markets.

Ultimately, the future of Satcom competition will depend on regulatory restrictions, geo-politics, economic scalability, and technological advancements. While China's government financing ensures rapid expansion, Western firms have a proven track record of commercial viability, setting up a long-term competition between state-driven infrastructure and private-sector innovation.

## 7.4. Model Results and Analysis: System Throughputs

Following the analytical framework developed in Chapter 4 and mirrored for Guowang in Section 6.3, this section applies a system-level throughput assessment to the Qianfan constellation, focusing on realistic service delivery within Belt and Road Initiative (BRI) markets. Using the same structural model developed from Pachler et al. [14,16,71], it simulates the effective system capacity of Qianfan as a function of two variables: number of gateways deployed and satellites in operation, under three different growth scenarios (pessimistic, base, optimistic).

### 7.4.1. Qianfan RAP-Based Throughput Results: Validation, Implications, and Strategic Assessment

Qianfan's global architecture was modeled through the RAP model simulation using a three-shell constellation and globally distributed gateways from Appendix I and Chapter 5. The model includes Ku-band user downlink, Q/V-band feeder link for gateways, and possible ISL availability (reflecting 1st gen design without operational ISLs).

Table 7-1 summarizes the throughput results for three analyzed cases (base, optimistic and pessimistic), and figure 7.1 shows the Qianfan base case throughput.

Table 7-1 - Modeled Throughput Results for Qianfan

| Scenario | Satellites | RAP Model Throughput [Tbps] |
|---|---|---|
| Pessimistic | 4,500 | 8.0 |
| Base | 7,500 | 11.7 |
| Optimistic | 12,000 | 11.9 |

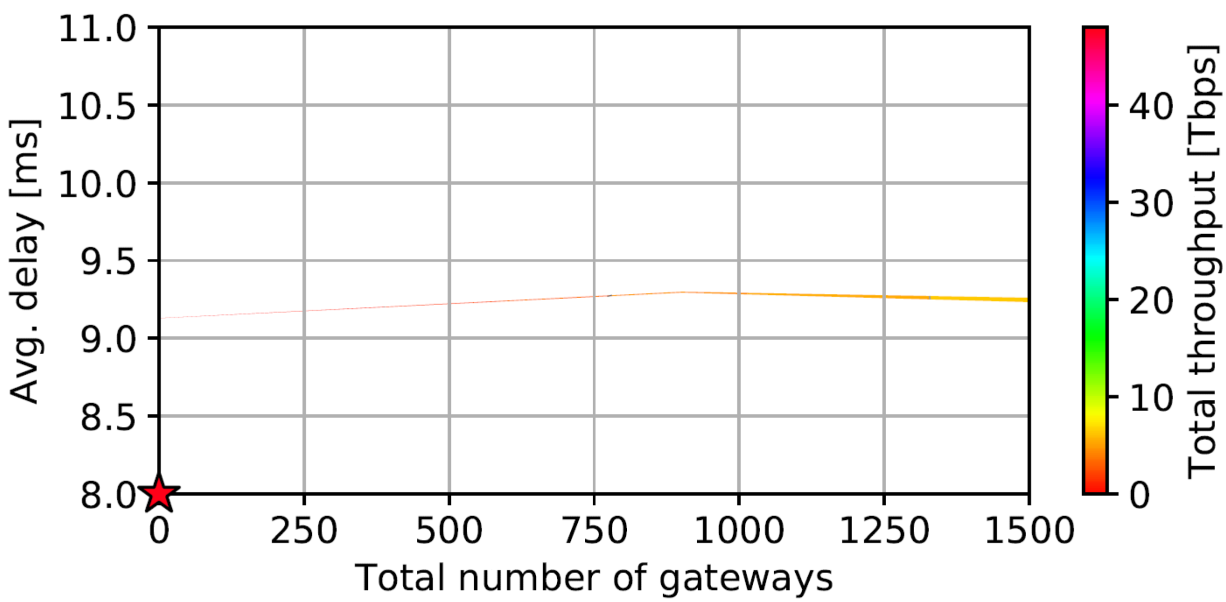



Figure 7.1 Qianfan system throughput (base case) (according to Pachler et al.[14,16,71])

The RAP model shows a clear saturation in throughput as the number of satellites increases beyond 7,500, suggesting that gateway constraints and beam overlap dominate system limitations. The marginal throughput increase between the base (11.7 Tbps) and optimistic (11.9 Tbps) cases underscores that further satellite additions yield diminishing returns without significant gateway expansion.

**Strategic Implications,** comparing throughput against projected BRI demand (see Chapters 3-4 and Appendix H):

- The base-case throughput (11.7 Tbps) is not sufficient to meet the estimated ~18–20 Tbps required to serve all Priority 1 BRI countries and 30-40% of their unconnected users at a modest 20-25 Mbps per user.
- Even in the optimistic scenario, Qianfan's capacity would support approximately 35–45 million users at standard broadband levels, well below the population in need across the BRI.
- Gateway placement and capacity remain the critical constraints. Without expanding ground segment infrastructure, especially across Sub-Saharan Africa and Southeast Asia, even full satellite deployment will fall short.

**Key Technical Drivers of Discrepancy:**

- Beam Saturation: Due to dense urban clusters (e.g., Lagos, Jakarta), frequency reuse remains limited, averaging below 3× in key regions.
- Feeder Link Congestion: The use of Q/V-band introduces rain fade and atmospheric loss, not accounted for in earlier simplified models.
- Absence of ISLs: First-gen Qianfan does not include operational ISLs, reducing mesh routing flexibility and placing extra load on gateways.

As with Guowang, the throughput increases with gateways but exhibits diminishing returns. From 5 to 25 gateways, throughput scales significantly (~5x increase). Beyond ~35 gateways, additional gains slow down, highlighting the need to balance CAPEX in gateway infrastructure with achievable bandwidth scaling. The saturation effect is clearly observed, while throughput increases with the number of gateways, the marginal gain diminishes beyond 30 gateways due to load-balancing and orbit-slot overlaps. The strategic deployment of ground gateways across BRI markets determines whether the theoretical system throughput can be utilized in practice. Qianfan's international strategy hinges on connectivity delivery in BRI-aligned countries. These nations exhibit vastly different income distributions, infrastructure gaps, and regulatory openness.

To evaluate the feasibility of Qianfan meeting its strategic connectivity goals, the estimate projects demand from key BRI markets. Based on reported data from Chapter 3 and Appendix H, the unconnected population in each priority country was identified, and a target penetration rate was applied of 70% by 2035, assuming aggressive deployment and uptake in underserved regions. A conservative throughput requirement of 20-25 Mbps/user is used considering the current broadband standards. Table 7-2 outlines the estimated bandwidth allocation demand by priority BRI country.

Table 7-2 - Estimated throughput demand in BRI countries

| Country | Unconnected Population (M) | Required Throughput (Tbps) |
|---|---|---|
| India* | 683 | 17.08 |
| Pakistan | 131 | 3.28 |
| Nigeria | 123 | 3.07 |
| Indonesia | 60 | 1.48 |
| Ethiopia | 103 | 2.58 |
| Egypt | 35 | 0.88 |
| South Africa | 15 | 0.38 |
| Argentina | 8 | 0.20 |
| Thailand | 17 | 0.43 |
| Kazakhstan | 5 | 0.10 |
| Malaysia | 9 | 0.20 |

*See Chapter 3, lower prio. due to the ongoing competition, but included considering pending discussion and market demand.

Total estimated demand across tier 1 and 2 BRI markets is ~29.69 Tbps. Figure 7.2 shows Qianfan's projected system throughput from 2025 to 2035 under the three modeled deployment scenarios (pessimistic, base, and optimistic), aligned against the cumulative estimated demand (~29.69 Tbps) from Priority 1 and 2 BRI countries.

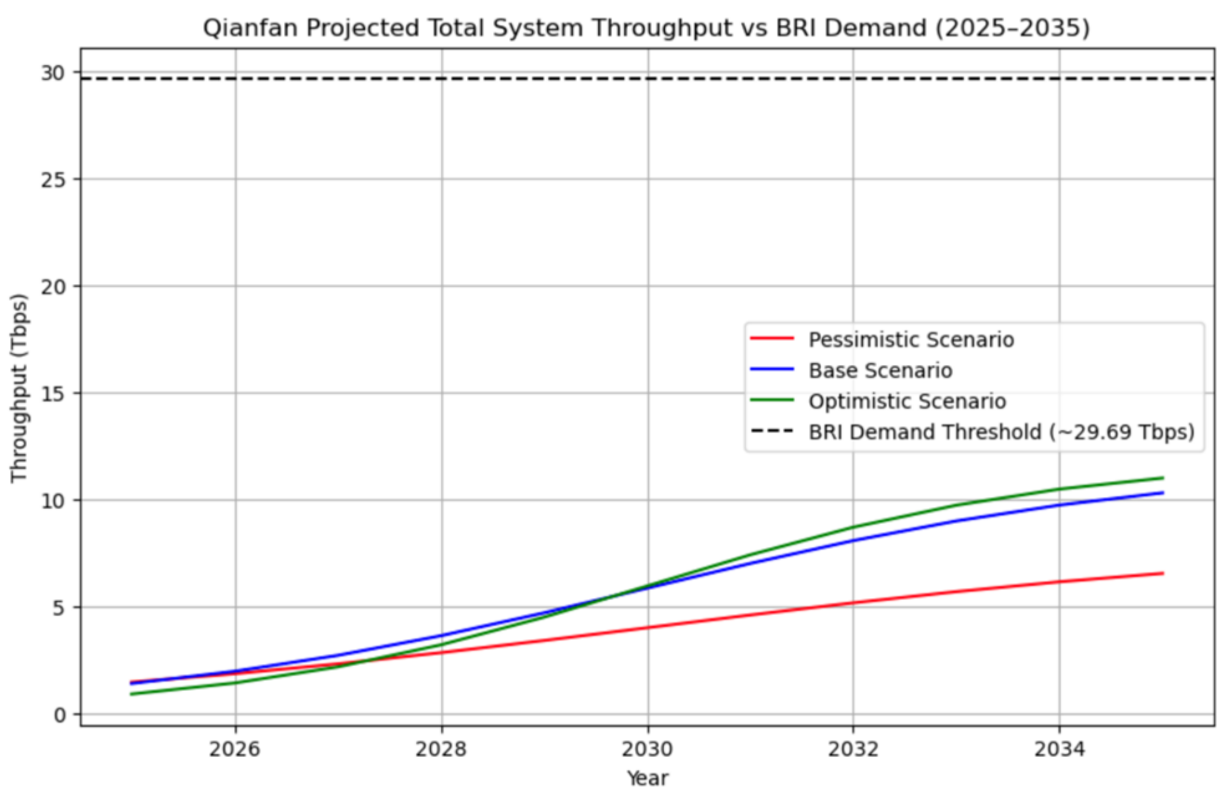



Figure 7.2 Qianfan Projected Total System Throughput vs BRI Demand

**Key Observations:**

- 2025–2027: In all scenarios, Qianfan falls short of meeting even a fraction of the expected BRI demand. Deployment is still in early stages with limited satellite and ground segment availability.
- 2030:

  - Pessimistic case: ~8 Tbps, insufficient to serve all Priority 1 countries.

  - Base case: ~11.7 Tbps, still below the ~18-20 Tbps needed for modest coverage

  - Optimistic case: ~11.9 Tbps, showing minimal gain over base due to gateway saturation
- 2035: Throughput plateaus in both base and optimistic cases, indicating that satellite count alone is no longer the limiting factor.

Despite the technical constraints of throughput, the challenges also lie in:

1) Terminal Affordability & Local Demand Elasticity: While Qianfan may offer technical capacity, actual adoption in low-income countries depends on hardware cost, government subsidies, and ARPU affordability. For example, countries like Pakistan, Ethiopia, and Nigeria have large unconnected populations but low ARPU potential (<$5/month).
2) Ground Infrastructure Bottlenecks: As highlighted in Chapter 4, Qianfan's throughput depends on gateway availability and fiber backhaul in host countries. Many Tier 1 markets (e.g., Ethiopia, Nigeria) have underdeveloped digital backbones, limiting real throughput regardless of orbital capacity.
3) Strategic Partnerships Required: Viability will also depend on B2G deals (e.g., digital public infrastructure, smart education, telemedicine). Without them, even optimistic system throughput may go underutilized.

Qianfan's international strategy hinges on connectivity delivery in BRI-aligned countries. These nations exhibit vastly different income distributions, infrastructure gaps, and regulatory openness.

**Market Feasibility Across BRI Countries**

To complement the throughput analysis, a market feasibility assessment was conducted for Qianfan's target BRI countries, based on infrastructure readiness, affordability, and strategic alignment. This is summarized in Table 7-3.

Table 7-3 - Market Feasibility Summary for Main BRI Countries

| Country | Priority | Gateway Planned ? | Demand | Affordability | Projected Penetration (Base Case) |
|---|---|---|---|---|---|
| Pakistan | 1 | Yes (Gwadar) | High | Affordable ($35–50) | 8M terminals |
| Nigeria | 2 | Yes (Lagos) | High | Borderline | 3M terminals |
| Argentina | 2 | Yes (Neuquén) | Moderate | Low elasticity | 1.5M terminals |
| Indonesia | 1 | Yes | High | Mid-afford. | 5M terminals |
| Kazakhstan | 1 | Yes (SpaceSail) | Low | Affordable, sparse pop. | 1M terminals |
| Ethiopia | 2 | Pending | High (Urban) | Likely afford. | <500K terminals |

**Note:** A fraction of each country expected to serve is implicitly addressed in the penetration column of Table 7-3. Further assumptions were made using a 20–25 Mbps/user benchmark and affordability thresholds derived from Appendix H and Chapter 3.

Total projected base case penetration is ~30 million terminals across 12–15 BRI countries. Even this figure is contingent on resolving spectrum, backhaul, and licensing challenges.

**Strategic and technical takeaways:**

- Sub-scale capacity limits B2C viability: even in optimistic projections, Qianfan trails Starlink's current throughput.
- Selective market focus is necessary: BRI regions like Pakistan, Indonesia, and Nigeria represent the best mix of affordability, demand, and existing infrastructure alignment.
- Gateway availability constrains scalability: Without at least 20 international gateway uplinks with Ka-band capacity, Qianfan will be bottlenecked.
- Military/dual-use opportunity: To offset shortfalls in consumer uptake, military-grade ISR relay and government B2G bandwidth leasing may be required (this is in line with the financial modeling, Chapter 5).

Capacity constraints remain fundamental. Even under full deployment, Qianfan will likely underserve peak demand across BRI markets unless it upgrades per-satellite throughput above 10 Gbps. Therefore, gateway placement becomes critical, as coverage gaps persist unless additional ground stations are distributed across BRI nations. Regions like Sub-Saharan Africa and Southeast Asia require priority gateway deployment to leverage LEO latency and availability advantages. Throughput bottlenecks are most acute in high-population, low-income areas such as Nigeria, Indonesia, and Ethiopia. Without additional gateway relay architecture or inter-satellite laser links, Qianfan may struggle to deliver reliable service during peak hours.

**Qianfan's Deployment Risks and Dependencies in BRI Regions:**

- Affordability: As shown in Section 6.1, Satcom is unaffordable for much of the rural population, including key BRI states unless subsidized (~$6–10/month at 2% income threshold). Localized subsidies or bundled access models will be essential.
- Infrastructure Dependency: Limited terrestrial backhaul in some African/ASEAN states caps

user speeds. Without co-investment in gateway buildout (e.g., via Huawei or Ex-Im Bank), effective use is impaired.
- Spectrum and Licensing: Qianfan’s access to national spectrum (esp. S, Ku, Ka) is not guaranteed. Bilateral agreements (e.g., Pakistan, Ethiopia, Egypt) offer opportunities but remain unconsolidated.

It can be observed that in both the base and optimistic scenarios, the capacity is theoretically sufficient to provide basic 20-25 Mbps coverage to over 60 million users across BRI Priority 1/2 regions. Additional bottlenecks are regulatory access, ground infrastructure, and political alignment. Many BRI countries lack adequate domestic ground stations, relying on either co-hosted facilities (e.g., in Pakistan or Nigeria) or third-party relay services. Without building or securing gateway access across regions like Sub-Saharan Africa, large portions of Qianfan’s orbital coverage may remain underutilized. As discussed and shown earlier (Chapter 6.1), many target BRI nations exhibit average income levels that make even subsidized satcom terminals ($300–400) unaffordable without public-private financing. This could cap adoption at 2–5% of the population unless costs fall below $200 or user pooling models (community broadband nodes) are applied. Even in the optimistic case, Qianfan requires ramping up launch capacity to 1,000+ satellites per year, along with 50+ gateway stations distributed across politically aligned territories. This necessitates both domestic launcher scale-up and international diplomatic leverage, especially in countries wary of Chinese tech encroachment (e.g., Kenya, Philippines, Sri Lanka). From a strategic perspective, Qianfan’s financial feasibility hinges on the military-civil dual-use value, where Chinese defense investments effectively cross-subsidize commercial deployments. As discussed in Chapter 6.2, early adoption by aligned regimes (Pakistan, Egypt, Indonesia) is essential to validate commercial contracts and expand to broader markets. Consequently, the analysis reaffirms that Qianfan’s total capacity can be partially sufficient to address key digital inclusion gaps across BRI regions, provided that China succeeds in gateway deployment, cost reduction, and political alignment. However, just like Guowang’s domestic ambition, Qianfan’s regional success depends not on total bandwidth, but on the geographical and economic ability to project that bandwidth into critical underserved zones. The overall strategic analysis shows that Qianfan can partially meet the broadband needs of the most critical BRI countries only under the optimistic growth scenario, requiring the following:

- Minimum 12,000 operational satellites by 2035.
- Sustained satellite throughput at ≥10 Gbps/unit, despite known architecture limitations.
- At least 25-30 dedicated ground stations in strategic BRI regions to support coverage and gateway routing.
- Strong partnerships with local operators to boost adoption and infrastructure integration.
- Price subsidies or diplomatic deals to address affordability in markets like Ethiopia and Pakistan.

If these conditions are not met, significant unmet demand will remain, undermining both economic and strategic objectives. As such, Qianfan's feasibility as a tool of digital diplomacy and infrastructure leadership depends not just on launch capacity, but on holistic policy alignment and international cooperation.

Consequently, the following strategic questions can be addressed:
1) Can Qianfan deliver connectivity across the BRI?
No, not under current architectural assumptions. Priority 2 and 3 countries will likely be excluded unless capacity is increased.
2) What would improve success odds?

- Second-gen ISLs must be available,
- Expanded Q/V-band gateway coverage (especially in East Africa and Southeast Asia),
- Improved regional spectrum coordination

3) Is the gap technical or political?
Both. Technically, gateway saturation and rain fade limit service. Politically, many BRI nations resist dual-use infrastructure (see Chapter 6.2), undermining commercial scale-up.

### 7.4.2. Qianfan Comparative Throughput Performance and Benchmarking

While Qianfan targets strategic expansion across the BRI, its system throughput in the base and optimistic scenarios remains well below Western counterparts. According to Pachler et al. [14,16,71], Starlink (v1 + v2) exceeds 100 Tbps with extensive gateway reuse and ISL integration. Amazon Kuiper's planned architecture aims for 120+ Tbps, while OneWeb and Telesat Lightspeed remain subscale but exhibit more advanced feeder link coordination (for detailed comparison, see sub-chapter 6.3.2). Notably, Qianfan's design reflects China's tradeoff between technical capacity and regulatory acceptability in partner states. For example, some governments prefer architectures without ISL for data localization.

In contrast to these Western systems, Qianfan's lack of ISLs, limited reuse factor (~2.5), and dependence on bilateral gateway deals make it vulnerable to saturation and underutilization. Without a second-generation redesign or gateway densification, Qianfan is unlikely to match the performance envelope of the other leading systems. However, its strategic value lies in its hybrid dual-use architecture and alignment with China's diplomatic and infrastructure export strategies.

Qianfan's throughput potential, even when realistically modeled, lags behind both China's own strategic targets and peer constellations. The analysis highlights the necessity of infrastructure scaling, spectrum harmonization, and affordability strategies across BRI markets. Just like Guowang, Qianfan's effectiveness will not be judged solely by its satellites in orbit, but by the strategic alignment of policy, partnerships, and localized delivery mechanisms. Without expanded gateway deployment and pricing adaptation, Qianfan risks substantial underperformance, even if satellite deployment targets are met.

# Chapter 8 : Geopolitical and Military Dimensions

## 8.1. China's Satcom and Geopolitical Strategies

China’s satellite communications strategy is deeply intertwined with its long-term geopolitical ambitions and its broader military-civil fusion (MCF) policy. The dual-use nature of China’s space assets reflects a deliberate approach aimed at simultaneously achieving economic connectivity goals, asserting regional influence, and enhancing national security. Unlike Western models where commercial objectives often lead, China has structured its Satcom expansion to advance its geostrategic agenda through state-backed coordination and deployment (as implemented In the scenarios analysis, Chapters 5-6).

The Qianfan constellation, explicitly targeting BRI countries, also functions as a vehicle of soft power. It provides subsidized or preferential connectivity packages, particularly in Africa and Southeast Asia. These arrangements, while couched in developmental terms, align with Beijing’s efforts to consolidate influence in the Global South, reduce dependence on U.S.-aligned infrastructure (e.g., undersea cables), and enable strategic data routing through Chinese-owned assets (Chapters 3–6).

At the same time, Guowang’s domestic orientation ensures potential resilient national coverage, especially in sensitive frontier provinces (e.g., Tibet, Xinjiang). These systems enhance PLA operational readiness and contribute to secure military logistics, notably in contested regions such as the South China Sea (Chapter 6.2).

**Strategic Alignment with Belt and Road Initiative (BRI)**
A key geopolitical mechanism underpinning China's Satcom policy is the Belt and Road Initiative (BRI). The BRI, a cornerstone of China's foreign policy, enables strategic expansion of satellite ground stations, fiber interconnects, and gateway hubs in developing countries across Asia, Africa, and Latin America. Countries like Pakistan, Kenya, Nigeria, and Venezuela have received either Chinese satellites or co-funded infrastructure with bundled ground service packages, thereby reinforcing Chinese technological standards and long-term service dependencies.

By 2025, China had established over 15 dual-use ground stations in BRI partner countries (Appendix G). These enable persistent connectivity for both commercial and security data, while serving as strategic outposts for PLA-affiliated logistics and network control (ref.[56,61,65]). These capabilities provide not only broadband access, but also potential for space-based intelligence, surveillance, and reconnaissance (ISR), reinforcing China's influence in contested maritime and border regions.

**Diplomatic Leverage through Satcom Access**
Chinese satellite-based services are increasingly framed as public goods for partner nations, especially those lacking terrestrial infrastructure. This access fosters goodwill and diplomatic leverage, as it allows China to dictate technology standards and capture data streams vital for

both economic planning and military awareness.

Moreover, by providing Satcom services bundled with BeiDou navigation and remote sensing solutions, China positions itself as a comprehensive geospatial partner, potentially reducing reliance on U.S.- or EU-originated systems in contested or sanctioned regions. The export of turnkey solutions, from satellites to terminals and control centers, serves as a geopolitical multiplier by integrating recipient nations into a China-led digital ecosystem.

**Technology Sovereignty and Spectrum Strategy**

On the global stage, China's strategy includes the pre-emptive filing of ITU orbital slots and spectrum rights under "first-come, first-served" frameworks. This not only ensures technical readiness for future constellations like Honghu-3 but also crowds out rival filings by Western firms in contested frequency bands, particularly in Ku and Ka (see Chapters 2-3).

As discussed in Chapter 2, this aggressive spectrum strategy aligns with broader soft power maneuvers, where China leverages its influence in global standards bodies such as the ITU and ISO to shape digital infrastructure rules in its favor. This is compounded by ITU's milestone deployment requirements, where failure to launch minimum satellites could forfeit slot access, hence China's race to scale rapidly even before full operational readiness.

**Geopolitical Barriers and Western Pushback**

Despite these assertive moves, China's Satcom diplomacy faces regulatory and political headwinds. Western-aligned regions, such as the Five Eyes countries and most of the EU, have actively discouraged Chinese Satcom participation due to surveillance risks and concerns over military backdoors. The U.S. FCC has banned Chinese satellite services in national communications infrastructure, and countries like India and Japan are investing in their own regional alternatives to avoid dependency.

This bifurcation of global Satcom ecosystems may lead to a splintered internet architecture, wherein Chinese-connected and Western-connected regions follow diverging hardware, encryption, and access control standards. In this context, Satcom no longer represents neutral infrastructure but a contested domain of geopolitical signaling and strategic posturing.

## 8.2. Global Security and Markets Dynamics

The security dimensions of China's satellite strategy are not limited to national defense but extend into systemic market realignments and infrastructure resilience. The evolution of global Satcom markets is now defined not only by capacity and price, but also by trust, autonomy, and geopolitical alignment.

**Market Access versus Strategic Risk**

While Qianfan and Guowang offer low-cost broadband options in underserved areas, their expansion often introduces strategic dependencies. Recipient countries gain broadband access, but may also integrate into a command architecture that is directly or indirectly accessible to

Chinese state agencies. This raises security concerns, especially where government or military services are hosted on Chinese-provided links.

From the perspective of market dynamics, the subsidized rollout of Chinese Satcom services in Africa, Latin America, and Southeast Asia undercuts Western providers who rely on higher ARPU and free-market dynamics. This asymmetric competition leads to a dual market structure:

- Strategic Satcom Zones, where China dominates due to bundled aid and long-term financing.
- Liberal Satcom Markets, led by SpaceX, OneWeb, or Amazon Kuiper, focused on commercial scalability.

**Security-Driven Exclusion from Markets**
As outlined in Chapter 2.4, Western-aligned countries have enacted a series of regulatory blocks against Chinese Satcom participation:

- FCC restrictions (U.S.)
- Investment screening for strategic infrastructure (EU)
- Blacklisting of Chinese payloads from launch manifests (e.g., India, Australia)

These measures, while ostensibly focused on security, are shaping global market share distribution. The exclusion of China from certain high-income markets has reoriented its strategy toward frontier and fragile economies, where cost and availability trump alignment with Western security norms.

**Scenario-Based Assessment of Strategic Alignment**
Utilizing the throughput and cost data from Chapters 5 through 7, we can infer:

- Under the optimistic scenario, Qianfan can serve up to 120 million users with acceptable throughput, potentially covering over 60% of unconnected BRI demand.
- Under the base case, coverage shrinks significantly, reaching only 30% of target BRI countries at minimum required Mbps thresholds.
- Under the pessimistic scenario, Qianfan fails to meet meaningful B2G or B2C coverage in BRI countries without deep bilateral subsidies and military usage commitments.

This implies that China's commercial Satcom viability is tightly coupled with:
- Regional gateway partnerships (e.g., in Africa, Latin America)
- Alignment with host-country regimes (for stable contracts and long-term leases)
- Dual-use agreements (especially in countries with existing defense ties to China)

**Global Satcom Polarization Risk**
Ultimately, the long-term dynamic points toward polarization:

- Integrated sovereign ecosystems (e.g., U.S./EU-led Starlink/IRIS2)
- Strategic subsidized constellations (China-led Guowang/Qianfan)

The intersection of market strategy and global security reflects a new phase in Satcom development where national policies shape commercial viability. Constellations are not simply revenue-generating tools, they are instruments of geopolitical influence and strategic autonomy.

Satcom infrastructure has become a critical enabler of national security, elevating concerns among Western governments. China's aggressive spectrum filings at the ITU (Chapter 2.4.1), the expansion of ground stations across the Southern Hemisphere (Chapter 2.3.1), and integration with Beidou navigation have triggered policy responses from entities such as the FCC, CFIUS, and European Commission. In this geopolitical landscape, the global Satcom sector risks bifurcation. The emerging division between Western-aligned systems (e.g., Starlink, OneWeb, IRIS$^2$) and Chinese offerings (Guowang, Qianfan) raises concerns about:

- Redundancy gaps in multilateral operations (e.g., UN peacekeeping, humanitarian aid)
- Signal sovereignty in developing states pressured to choose one architecture over another
- Cyber and data integrity risks associated with inter-network interoperability

## 8.3. Stakeholder Analysis

The Satcom domain now operates as a complex system (someone might call It a "System-of-Systems (SoS)," though this terminology is non-existent for many experts and system community), where national actors, commercial providers, regulatory agencies, and international coalitions interact within a web of overlapping priorities. The table 8-1 below categorizes key stakeholders based on influence, interest, and dependency.

Table 8-1 - Stakeholder Typology in Global LEO Satcom Ecosystem

| Stakeholder | Role | Strategic Interest | Dependencies |
|---|---|---|---|
| CASC/MIIT/CNSA | Tech. Development | Domestic capacity, export markets | Launch cadence, subsidies |
| PLA Cyberspace Force, PLA Aerospace Force, PLA Information Support Force | Defense Integration | Secure cooms, real-time ISR | Satcom constellations, and Beidou |
| BRI States (Pakistan, Nigeria, Ethiopia etc.) | Foreign Customers | Connectivity, tech. transfer | Affordability, service reliability |
| FCC/ European Commission | Regulators | Security, data sovereignty | Vendor transparency, international regulations |
| SpaceX, OneWeb, IRIS$^2$ | Competitors | Market share | Spectrum rights, launch infrastructure |
| ITU | Coordination Body | Equitable access | Enforcement transparency |

## 8.4. Strategic Risk Mapping

To assess the feasibility and sustainability of China’s Satcom ambitions, a basic risk matrix structured across four dimensions is applied:

- Technological Risk: Delay in achieving full reusability, throughput gaps (Chapter 6.3)
- Market Risk: Inability to convert BRI MoUs into paying contracts (Chapter 7)
- Geopolitical Risk: Escalating export controls, Western-led exclusion policies
- Operational Risk: Ground station access limitations in partner countries, CAPEX overruns

Figure 8.1 represents the strategic risk matrix for China's Satcom deployment.

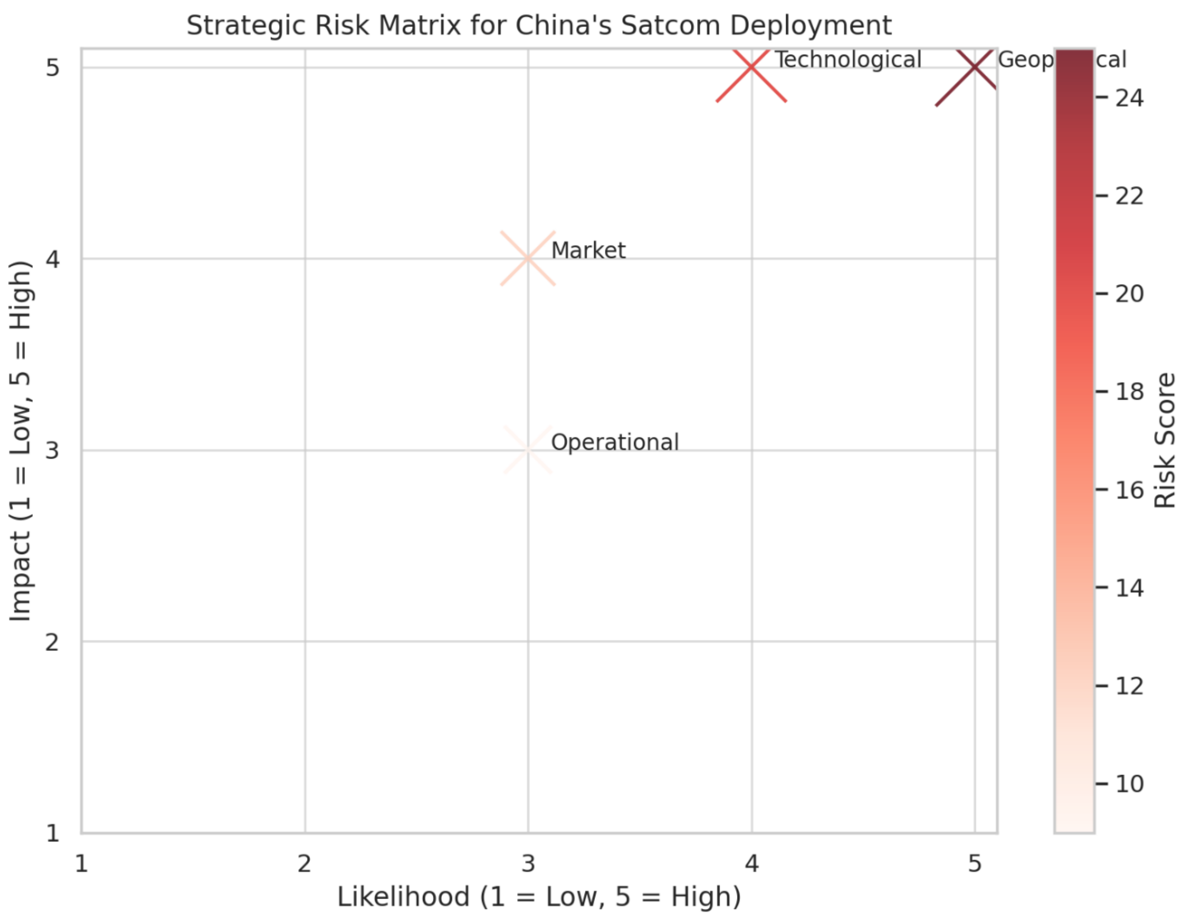


Figure 8.1 Strategic risk matrix for China's Satcom deployment

Technological and Geopolitical risks are the most critical, both high in impact and likelihood. These include delays in reusability tech, system integration issues, and international backlash due to military-civil fusion. Market risk (demand realization, ARPU sustainability, rural adoption) is moderate but still considerable, especially under pessimistic throughput scenarios. Operational risk (maintenance, congestion, service quality in remote gateways) is slightly lower, but non-negligible, especially if infrastructure is underdeveloped in rural or BRI markets.

# Chapter 9 : Strategic Recommendations and Policy Implications

This chapter outlines a strategic path forward for China's Satcom ambitions, drawing on scenario-based financial modeling, system throughput analysis, geopolitical context, and international market feasibility. It provides a synthesis of technical, economic, and strategic dimensions to guide decision-makers in refining the implementation of the Guowang and Qianfan constellations.

## 9.1. Key Strategic Insights

Based on modeling and analysis across the thesis, four principal observations emerge:

1. **Technological and Financial Viability is Conditional**
   Neither Guowang nor Qianfan reaches profitability under baseline assumptions without substantial state subsidies, major technology inflection points (e.g., widespread reusability), or favorable geopolitical alignment in BRI markets.

2. **Launch Cadence is the Critical Bottleneck**
   Both constellations require an average of 600–1,000 satellites launched per year by 2028 to achieve strategic throughput targets and secure ITU spectrum. This is currently infeasible without private-sector launcher success.

3. **Rural Digital Inclusion Requires Structural Subsidy**
   Approximately 150–190 million people in China remain offline due to affordability and coverage gaps. Even in optimistic cases, China's "Digital China" goals require targeted subsidy programs and hybrid terrestrial-satellite integration.

4. **Qianfan's BRI Influence is Strategically Valuable but Operationally Fragile**
   The system's bandwidth and deployment capacity currently fall short of meeting priority BRI market needs under base and pessimistic scenarios. Only under optimistic throughput could it serve >10 priority countries effectively.

## 9.2. Policy Recommendations for Domestic Deployment (Guowang)

### A. Launch Acceleration & Reusability

- Action: Scale up reusable Long March 8R and commercial launchers (e.g., Zhuque-3).
- KPI: Reduce launch cost by 40% by 2029; achieve launch cadence of 600+ per year by 2030.

### B. Rural Affordability & Coverage

- Action: Expand MIIT-led subsidies to support terminal costs below ¥200 and partner with provincial operators for bundled satellite-fiber/5G delivery.

- Est. Budget Required: $20–25B over 10 years (based on analysis in Ch. 6).

**C. Civil-Military Integration Efficiency**

- Action: Establish shared gateway node operations between PLA SSF and China Telecom to optimize dual-use infrastructure and reduce redundancy in tracking/data uplinks.
- Risk Mitigation: Isolate ISR and civilian broadband channels with network slicing protocols.

## 9.3. Policy Recommendations for Global Deployment (Qianfan)

**A. BRI Market Prioritization via Phased Rollout**

- Action: Align Qianfan's first operational coverage zones with countries ranked as "High Priority" in Table 7.4 (e.g., Pakistan, Nigeria, Indonesia, South Africa).
- Throughput Target: 1.0–1.5 Tbps per priority country by 2030.

**B. Anchor Client Acquisition Strategy**

- Action: Negotiate early-stage government contracts (B2G) with digital ministries, national ISPs, and humanitarian agencies in BRI countries.
- Precedent: Similar to Starlink's defense contracts and Amazon's Project Kuiper MoUs with U.S. government agencies.

**C. Technology Capability Improvement**

- Action: Increase per-satellite throughput to >20 Gbps through phased-array miniaturization and inter-satellite laser upgrades.
- R&D Support Required: ~$5B in grant/incentive funding over 5 years.
- Include ISL capabilities, increase number and density of gateways.

## 9.4. Integrated System-Level Architecture

The combined operation of Guowang and Qianfan must be viewed as a combined system, where interoperability, redundancy, and differentiated mission profiles drive architecture design.

Table 9-1 - Main Architectural Design Drivers for Guowang and Qianfan

| **Subsystem** | **Guowang** | **Qianfan** |
|---|---|---|
| Primary Use | Domestic civilian + PLA | BRI connectivity + dual-use |
| Architecture Focus | Resilience, coverage | Flexibility, international |
| Main Launch Partner | CASC (Long March 8/9) | CAS Space, LandSpace |
| Market Interface | Rural households, state ISPs | B2G, state telecom operators |
| Throughput Target | 40–50 Tbps (2030) | 75–100 Tbps (2035) |

## 9.5. Strategic Risk and Stakeholder Mapping

In line with earlier analyses In this thesis, system safety and systems thinking, Table 9.2 summarizes key stakeholder incentives and risk concerns.

Table 9-2 - Stakeholder-Risk Mapping

| Stakeholder | Primary Needs | Key Risks |
|---|---|---|
| PLA Entities | Redundancy, ISR capabilities | Foreign interference,<br>congestion |
| MIIT / China Telecom | Rural penetration, latency | Slow adoption, hardware delay |
| MOFA / BRI Diplomacy Units | Political leverage via Satcom | Negative optics, ITU violations |
| CASC & Private Launch Firms | Revenue, reliability | Reusability failure |
| Foreign Partner States | Affordable broadband | Capacity shortfalls |

## 9.6. Policy Implications for International Collaboration

China's Satcom expansion, especially via Qianfan will increasingly require a soft-power approach and proactive norms-setting.

- ITU Advocacy: Continue aggressive first-filing but propose co-developing orbital slot-sharing frameworks with ASEAN and African Union bodies to reduce backlash.
- Cyber Norms: Join multilateral declarations on Satcom cybersecurity, akin to the Paris Call for Trust and Security in Cyberspace.
- Export Controls: Avoid backdoor perceptions by promoting transparent source code audits and local data-handling compliance (important in Africa).

## 9.7. Final Recommendations: Policy-to-Execution Alignment

Table 9-3 summarizes the main actions plan following the analysis realized in this thesis to meet specific objectives for China's MEGACON.

| Objective | Action Plan | Timeline |
|---|---|---|
| Meet ITU 10% deployment (Guowang) | Launch 1,300 sats by 2029 | 2025–2029 |
| Close rural gap (100M users) | Deploy 5,000 terminals/week; subsidize $200/unit | 2025–2028 |
| Reach BRI Priority Markets | Phase 1: Pakistan, Indonesia, Nigeria | 2025–2029 |

| | | |
|---|---|---|
| (15+) | | |
| Compete on ARPU | Bundle Satcom with fintech/TV/mobile in Africa | Pilot in 2026 |
| Match throughput | Increase per-sat capacity to 25 Gbps | 2027–2030 |

This thesis has demonstrated that China's Satcom strategy, while ambitious and increasingly systematized, still hinges on a complex matrix of geopolitical, technological, and economic conditions. The success of Guowang and Qianfan will depend less on the constellation size per se, and more on the alignment of national strategy with execution capabilities, supported by both technical innovation and smart global engagement. In scenarios where reusability fails or political barriers limit BRI partnerships, financial and strategic returns may underwhelm. Yet, with disciplined program management and enhanced multi-constellation coordination, China could build a Satcom system that is both sovereign and globally relevant.

# Chapter 10 : Conclusion and Future Work

## 10.1. Conclusion

This thesis has analyzed the strategic, technical, and economic viability of China's low Earth orbit (LEO) satellite constellations, Guowang and Qianfan, in the context of an evolving global space economy. Through a multi-layered approach integrating system architecture analysis, scenario-based financial modeling, throughput estimation, and geopolitical assessment, the research has yielded several core findings.

**1.Modeling Reveals Conditional Viability**
Guowang is marginally viable under optimistic assumptions (NPV ≈ +$9B; IRR > 25%), but generally faces negative financial returns in base and pessimistic scenarios unless substantial government subsidies and cost reductions are realized.

Qianfan, despite its strategic value in Belt and Road Initiative (BRI) markets, shows an even steeper path to profitability due to limited per-satellite bandwidth (~6–10 Gbps), high CAPEX, and deployment complexity across politically diverse regions.

**2. Launch Technology and Reusability Are Pivotal**
Achieving cadence of 800–1,000 launches/year and reducing launch costs by at least 40% through domestic reusable rocket development (e.g., Zhuque-3, LM8R) is essential. Without this, China risks missing ITU deployment thresholds and losing critical orbital spectrum rights.

**3. Throughput Capacity vs. Demand Gap in BRI Markets**
Even under optimistic scenarios, Qianfan can only meet a fraction of the aggregate demand in high-priority BRI nations. For example, the system may fall short by 15–25 Tbps in serving just the top 10 unconnected countries unless satellite throughput increases significantly or ground segment partnerships scale up.

**4. Geopolitical Leverage, Not Just Economics**
China's dual-use military-civil integration and strategic positioning of ground stations across Xinjiang, Tibet, and BRI outposts (e.g., Pakistan, Argentina) reveal that national security and foreign influence are as central as commercial viability. Satcom in this context serves not only as a technological system but as a geopolitical lever.

**5. Domestic Rural Inclusion Requires Structural Intervention**
Subsidized terminals, bundling policies, and provincial partnerships are necessary to connect the 150M+ people in China's western and inland provinces who are either offline due to cost or unreachable via fiber. Based on affordability metrics (2% income rule), up to 40% of the offline population cannot be reached without ongoing state subsidy.

The simplified technical model significantly overestimated technical capacity, as it did not account for inter-satellite link efficiency, gateway congestion, beam saturation, and atmospheric losses. The RAP model corrected for these oversights, producing more conservative throughput estimates:

- Guowang RAP Throughput: 3.8–7.2 Tbps across scenarios, falling short of 100M rural user targets at 50 Mbps.
- Qianfan RAP Throughput: 8.0–11.9 Tbps, failing to meet Priority 1 BRI nation demand of ~18 Tbps.

These results highlight the need for nuanced policy, architectural optimization, and international cooperation. In Guowang’s case, affordability remains the critical limiting factor despite geographic coverage. For Qianfan, diplomatic trust and spectrum constraints in the Global South reduce the likelihood of large-scale B2G contracts unless ISL and feeder link challenges are addressed.

**Key conclusions are:**
- Neither system can independently fulfill China's 2030 digital inclusion goals without expanded gateway networks and terminal subsidies.
- Break-even and ROI projections (Chapter 5) are heavily sensitive to launch cadence, ARPU realization, and strategic dual-use contracts.
- China’s ability to maintain ITU filings hinges on accelerated rollout supported by reusable launch systems and ground segment expansion.
- The civil-military fusion approach boosts strategic resilience but hinders international commercial adoption.

## 10.2. Future Work

While this thesis has built a robust multi-scenario, multi-constellation framework, there are multiple avenues for continued research, particularly in the following areas:

**A. Deepen modeling analysis**
Future studies should deepen analysis in the following areas:
- ARPU Elasticity Modeling: Income-based adoption curves across domestic and BRI markets with regional price discrimination.

- Ground Network Simulation: Integration of localized gateway coverage with weather and terrain constraints.

- Policy Response Modeling: Simulation of international pushback on dual-use infrastructure and ITU challenges.

- Q/V and Ka/Ku Band Coexistence Planning: Real-world frequency planning models aligned with regional regulatory constraints.

- Second-generation ISL Scaling: Performance, cost, and scheduling trade-offs for deploying high-throughput laser mesh networks.

**B. Agent-Based Modeling for Stakeholder Dynamics**

- A system-of-systems model can be extended with agent-based frameworks to simulate negotiations between China and BRI states, international regulatory bodies (e.g., ITU), and domestic entities.

- This would allow testing "what-if" scenarios such as strategic decoupling, international countermeasures, or supply chain fragmentation under geopolitical tensions.

**C. Expansion into Converging Technologies**

- Explore how Direct-to-Device (D2D) integration, spectrum sharing with 6G terrestrial networks, and quantum-secure satellite links may reshape the Satcom ecosystem.

- Investigate how China's investments in AI-optimized network routing (SDN) or solar-electric propulsion may enable constellation resilience and inter-satellite flexibility.

**D. Sensitivity to Policy Shocks and Sanctions**

- A future model could include Monte Carlo simulations on export restrictions, like enhanced ITAR enforcement, or decoupling scenarios affecting chipsets, phased arrays, or launch guidance systems.

- Scenario trees can be developed to evaluate how external shocks might impact deployment cadence, system cost, and BRI partner adoption.

**E. Ethical and Socioeconomic Impact Evaluation**

- A critical extension would include evaluating the long-term societal impact of Satcom deployment in rural China and developing nations, including potential dependencies, market disruptions, or displacement of local ISPs.

- This includes mapping net impact on education, disaster response, and employment—particularly where private/public partnerships emerge in broadband infrastructure.

Given the rapidly changing nature of the Satcom ecosystem, incorporating iterative scenario planning and real-time regulatory shifts will be essential. Strategic implications of under-delivery in either Guowang or Qianfan would not only affect China's economic returns, but also its credibility in multilateral space cooperation and Belt and Road partnerships.

## 10.3. Final Reflection

At its core, this thesis reveals that China's approach to Satcom is not only a technical and financial challenge, but a deeply strategic one, intertwining state ambition, technological sovereignty, and global influence. Whether Guowang and Qianfan emerge as sustainable market players will depend less on whether they match the capabilities of Starlink, and more on how effectively China mobilizes its industrial base, diplomatic networks, and domestic policies to align incentives and mitigate constraints. Ultimately, the global LEO Satcom race will not be won by technical superiority alone, but by the capacity to deploy rapidly, adapt dynamically, and govern inclusively. Without meaningful adjustment, both Guowang and Qianfan risk underperforming relative to their ambitions and falling behind commercially resilient actors such as SpaceX's Starlink.

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# Appendix A List of China's SATCOM 1984 - 2020 (ref. [62-65])

| Year | Satellite | Launcher | GTO Mass Kg | Transponders |
|---|---|---|---|---|
| 1984 | DFH 2 | CZ 3 | 916 | 2 |
| 1984 | DFH 2 | CZ 3 | 916 | 2 |
| 1986 | DFH 2 | CZ 3 | 916 | 4 |
| 1988 | DFH 2 A | CZ 3 | 962 | 4 |
| 1988 | DFH 2 A | CZ 3 | 962 | 4 |
| 1990 | DFH 2 A | CZ 3 | 962 | 24 |
| 1990 | Asiasat 1 HS 376 | CZ-3 | 1250 | 4 |
| 1991 | DFH 2 A | CZ 3 | 962 | |
| 1994 | DFH-3 mockup | CZ 3A | | 30 |
| 1994 | Shijian 4 | CZ 3A | | Test |
| 1994 | Apstar 1 HS 376 | CZ 3 | 1383 | 24 |
| 1994 | DFH 3 -1 | CZ 3A | 2200 | 34 |
| 1995 | Apstar 2 Hughes 601 Failure | CZ-2E | 2830 | 34 |
| 1995 | Asiasat 2 LM 7000 | CZ-2E | 3379 | 30 |
| 1996 | Apstar 1A Hughes 376 | CZ 3A | 1383 | 30 |
| 1996 | Zhongxing 7 Hughes 376 | CZ 3A | 1384 | 24 |
| 1997 | DFH 3-2 Zhongxing 6B | CZ 3A | 2200 | 43 |
| 1997 | Apstar 2R Loral 1300 | CZ-3B | 3700 | 44 |
| 1997 | Asiasat 3 Hughes 601 Failure | Proton | 3480 | 38 |
| 1998 | Zhongwei 1 A2100 A | CZ-3B | 2984 | 38 |
| 1998 | Sinosat 1 SB 3000 | CZ-3B | 2820 | 44 |
| 1999 | Asiasat 3S Hughes 601 | Proton | 2300 | |
| 2000 | Feng Huo 1 Zhongxing 22 | CZ 3A | 2300 | |
| 2003 | Shentong 1 Zhongxing 20/21 | CZ 3A | 4137 | 44 |
| 2003 | Asiasat 4 Hughes 601 | Atlas 3B | 4680 | 50 |
| 2005 | Apstar 6 Alcatel / Thales Alenia | CZ 3B | 2300 | |
| 2006 | Feng Huo 2 Zhongxing 22A | CZ 3A | 5100 | 24 |
| 2006 | Sinosat 2/Xinnuo 2 | CZ 3B | 2200 | 24 |
| 2007 | DFH 3-1 Sinosat 3 Xinnuo 3 Eutelsat 8 W D | CZ 3A | 4600 | 38 |
| 2007 | Zhongxing 6B Spacebus 4000 | CZ-3B | 5150 | 28 |
| 2007 | Nigicomsat 1 | CZ 3B/E | 5049 | 28 |
| 2008 | Simon Bolibar | CZ 3B/E | 4500 | 22 |
| 2008 | Zhongxing 9 Spacebus 4000 | CZ-3B | 3760 | 40 |
| 2009 | Asiasat 5 SSL 1300 BUS | Proton | 2300 | |
| 2010 | Shentong 1-2 Zhongxing 20A | CZ 3A | 5100 | 33 |
| 2010 | Sinosat 6 Xinnuo 6 Zhongxing 6A | CZ 3B/E | 5100 | 46 |
| 2011 | Zhongxing 10 Thales Alenia Payload | CZ 3B/E | 5115 | 30 |
| 2011 | Paksat 1 R | CZ 3B/E | 5600 | |
| 2011 | Zhongxing 1A | CZ 3B/E | 3813 | 46 |
| 2011 | Asiasat 7 SSL 1300 BUS | Proton | 5100 | 28 |
| 2011 | Nigcomsat 1R | CZ 3B/E | 5600 | |
| 2012 | Shentong 2 Zhongxing 2A | CZ 3B/E | 5054 | 56 |
| 2012 | Apstar 7 Thales Alenia | CZ 3B/E | 5054 | 47 |
| 2012 | Zhonxing-12 ITAR Free Thales Alenia | CZ 3B/E | 5000 | 45 |
| 2012 | Zhonxing-11 | CZ 3B | 5200 | 32 |
| 2013 | Tupac Katari | CZ 3B | 4535 | 25 |
| 2014 | Asiasat 8 SSL | Falcon | 3700 | 28 |
| 2014 | Asiasat 6 SSL | Falcon | 5200 | 48 |
| 2015 | Apstar 9 DFH- 4 Platform | CZ 3B/E | 5200 | 46 |
| 2015 | ChinaSat-2C Zhongxing-2C | CZ 3B | 3800 | |

| Year | Satellite | Launcher | GTO Mass Kg | Transponders |
|---|---|---|---|---|
| 2015 | Laosat DFH 3B Bus | CZ 3B | 5200 | 22 |
| 2015 | Chinasat 1C Zhongxing 1C | CZ 3B/E | 5200 | |
| 2016 | Belintersat 1 Thales Alenia | CZ 3B | 5200 | 38 |
| 2016 | Tiantong 1 | CZ 3BE | 5200 | |
| 2016 | Shijian 17 | CZ 5 | 14000 | Test |
| 2017 | Shijian 16 Chinasat 16 | CZ 3B | 5200 | Ka Band |
| 2017 | Zhongxing 9A Chinasat 9A | CZ 3BE | 5200 | 24 Ku Band |
| 2017 | Shijian 18 | CZ 5 | 14000 | Test Failure |
| 2017 | AlComsat 1 (Algeria) | CZ 3B | 5200 | Orbit Delivery |
| 2018 | APSTAR 6C | CZ 3B | 5200 | 24 C & 19 Ku Ka |
| 2019 | Shentong 2 D | CZ 3B | 5200 | |
| 2019 | Chinasat 6C | CZ 3B | 5200 | |
| 2019 | Chinasat 18 | CZ 3B | 5200 | Failure |
| 2019 | Shijian 20 | CZ 5 | 14000 | Test satellite |
| 2020 | XJY 6 | CZ 7 | 6800 | Test Failure |
| 2020 | Palapa N1 | CZ 3B | 5550 | Failure |
| 2020 | APSTAR 6D | CZ 3B | 5550 | Orbit Delivery |
| Code | | Satellite Built and Launched by China | | |
| Code | | Bought Satellite Chinese Launcher | | |
| Code | | Bought Satellite foreign launcher | | |
| Code | | Build and Launch Military satellite | | |
| Code | | In Orbit Delivery | | |

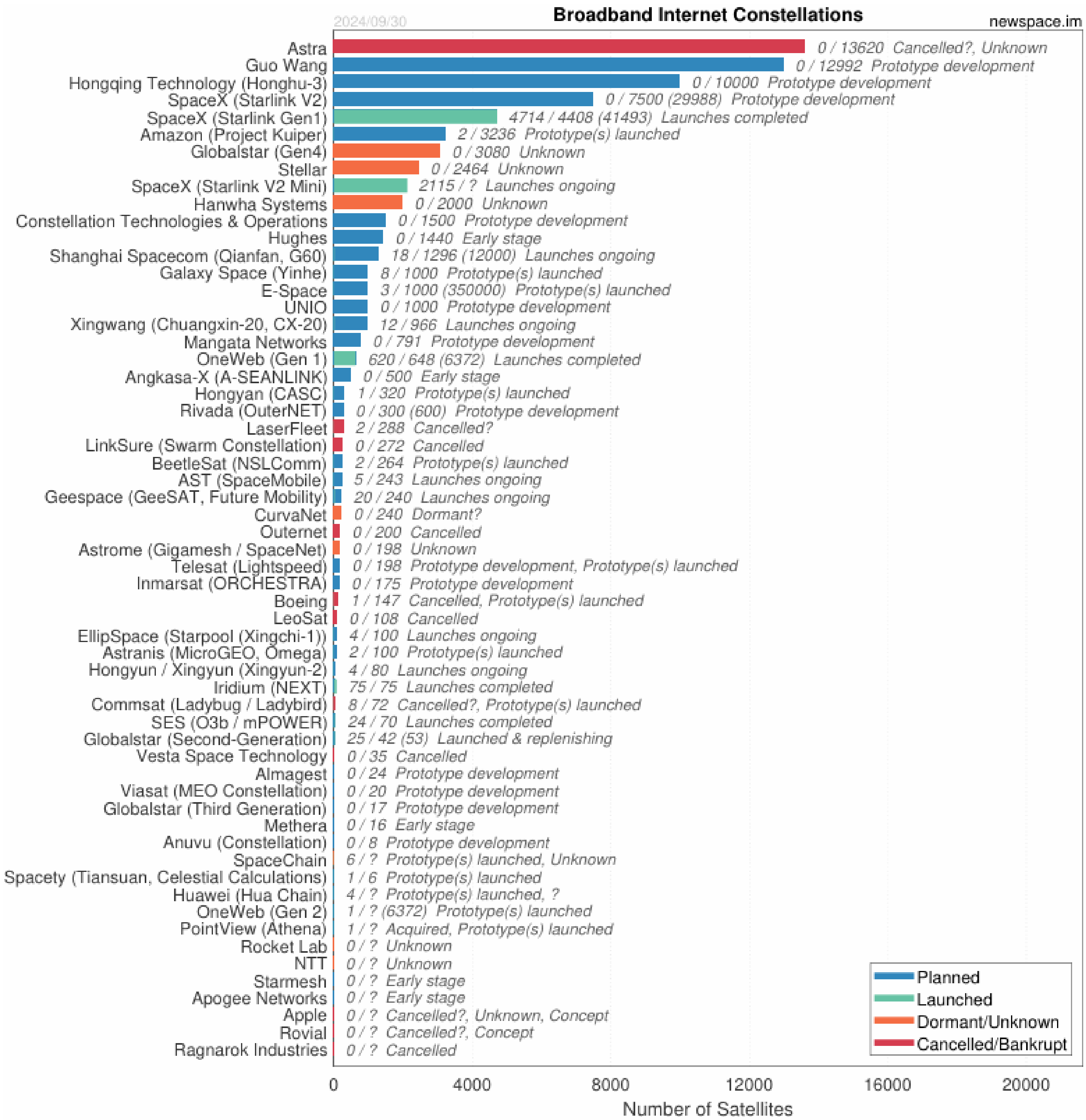
Note: Red = mission failure.

# Appendix B Launchers under development by China

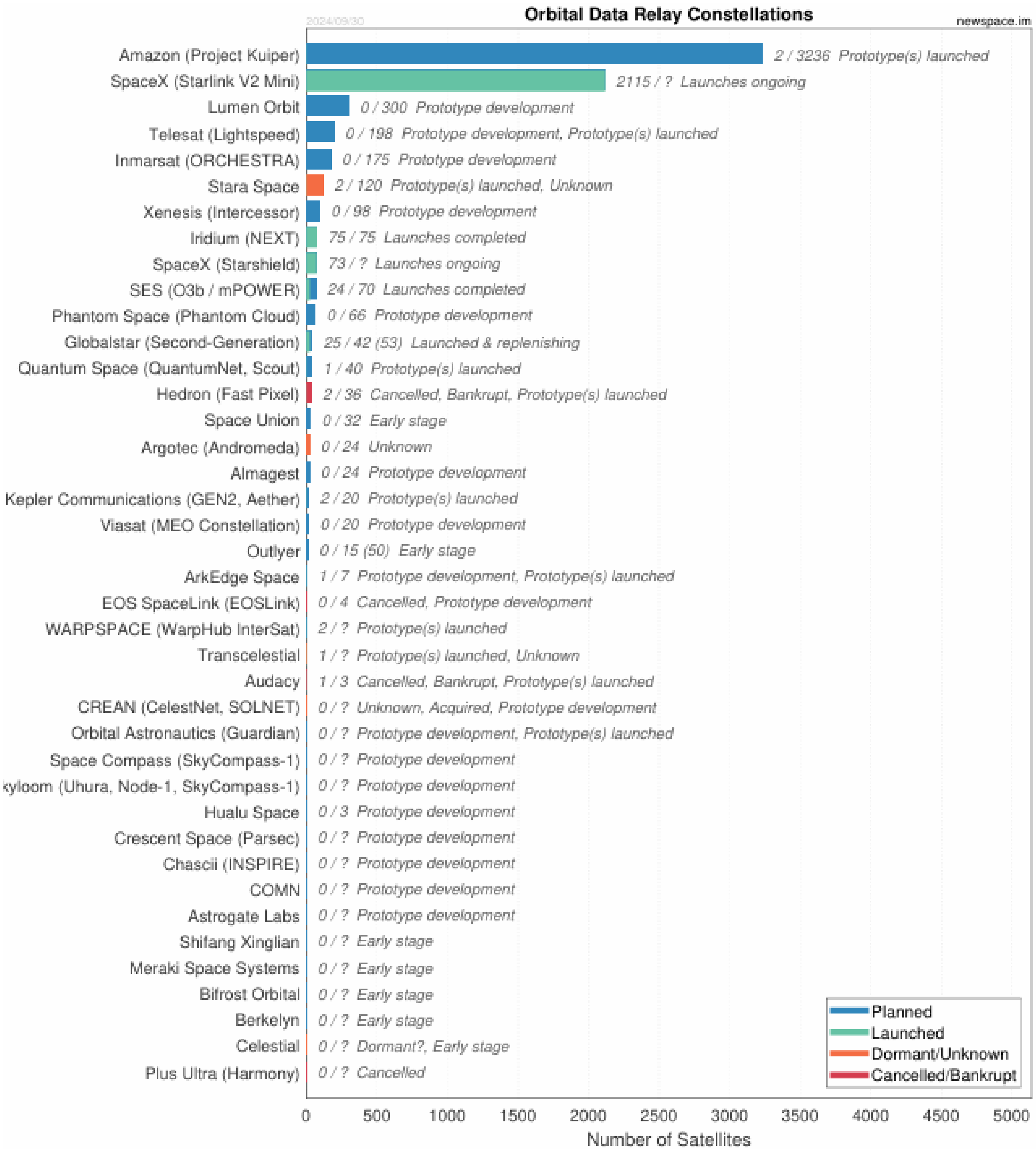
| Launcher | Developer | Type | Payload Capacity | Planned First Flight | Key Features |
|---|---|---|---|---|---|
| Long March 8A | CALT | State-led | 7,000 kg to 700-km SSO | Jan. 19, 2025 (estimated) | More powerful second stage; 5.2-meter-diameter payload fairing |
| Long March 12A | SAST | State-led, reusable | TBD | Jan. 14–16, 2025 (VTVL test) | Reusable; first VTVL test planned. |
| Zhuque-3 | Landspace | Commercial | 21,000 kg to LEO (expendable); 18,300 kg (downrange recovery) | 2025 | Stainless steel design; potential Haolong reusable cargo launch in 2026. |
| Tianlong-3 | Space Pioneer | Commercial | 17,000 kg to LEO; 14,000 kg to 500-km SSO | 2025 | Test mishap in 2024. |
| Pallas-1 | Galactic Energy | Commercial | 8,000 kg to LEO; 30,000 kg (three-core variant, future) | 2025 | Kerosene-liquid oxygen rocket; first stage reusability planned. |
| Ceres-2 | Galactic Energy | Commercial (solid rocket) | 1,600 kg to LEO; 1,300 kg to 500-km SSO | First half of 2025 | Upgraded version of Ceres-1 solid rocket. |
| Kinetica-2 | CAS Space | Commercial (CAS spinoff) | 12,000 kg to LEO; 7,800 kg to 500-km SSO | Second half of 2025 | Kerolox; reusable; selected for Qingzhou cargo spacecraft launch. |
| Hyperbola-3 | iSpace | Commercial | 8,500 kg to LEO (recovered version) | 2025 | 69-meter-long kerolox rocket; eventual reusability. |

(credit: Andrew Jones, SpaceNews)

# Appendix C Broadband Internet Constellations (status September 2024 ref.[74])



# Appendix D Orbital Data Relay Constellations (status September 2024 ref.[74])



# Appendix E Financial Projections for MEGACON

## Guowang Base Case

| Guowang - Baseline Scenario NPV | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Value (in Billions USD) | | | | | | | | | | | | | |
| Elements | Period | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| | Users (M) | 0,1 | 0,5 | 1,5 | 3 | 6 | 9 | 12 | 18 | 25 | 28 | 30 | 30 | | |
| | Year | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2038 |
| Revenues | Subscriptions | 0,060 | 0,300 | 0,900 | 1,800 | 3,600 | 5,400 | 7,200 | 10,800 | 15,000 | 17,000 | 18,500 | 19,000 | - | - |
| | Terminals | 0,010 | 0,100 | 0,250 | 0,400 | 0,800 | 1,000 | 1,500 | 1,800 | 2,000 | 2,000 | 2,500 | 2,000 | - | - |
| | Government | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Other | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Total | 0,070 | 0,400 | 1,150 | 2,200 | 4,400 | 6,400 | 8,700 | 12,600 | 17,000 | 19,000 | 21,000 | 21,000 | 0,000 | 0,000 |
| Operational Costs | Total | 0,025 | 0,140 | 0,403 | 0,770 | 1,540 | 2,240 | 3,045 | 4,410 | 5,950 | 6,650 | 7,350 | 7,350 | 0,000 | 0,000 |
| Depreciation | | 0,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 0,000 | 0,000 |
| Working Capital (WC) | | -0,025 | -0,140 | -0,403 | -0,770 | -1,540 | -2,240 | -3,045 | -4,410 | -5,950 | -6,650 | -7,350 | -7,350 | 0,000 | 0,000 |
| Change in Working Capital (ΔWC) | | 0,000 | -0,116 | -0,263 | -0,368 | -0,770 | -0,700 | -0,805 | -1,365 | -1,540 | -0,700 | -0,700 | 0,000 | 7,350 | 0,000 |
| CapEX | | 4,000 | 5,000 | 5,000 | 4,000 | 4,000 | 3,000 | 3,000 | 2,000 | 2,000 | 1,000 | 1,000 | 1,000 | 0,000 | 0,000 |
| EBITDA | | 0,046 | 0,260 | 0,748 | 1,430 | 2,860 | 4,160 | 5,655 | 8,190 | 11,050 | 12,350 | 13,650 | 13,650 | 0,000 | 0,000 |
| EBIT | | 2,800 | 3,560 | 4,380 | 5,260 | 6,200 | 7,210 | 8,270 | 9,410 | 10,600 | 11,860 | 13,170 | 14,550 | 15,970 | 0,000 |
| t*dep | | 0,000 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,000 | 0,000 |
| (1-t)EBITDA | | 0,030 | 0,169 | 0,486 | 0,930 | 1,859 | 2,704 | 3,676 | 5,324 | 7,183 | 8,028 | 8,873 | 8,873 | 0,000 | 0,000 |
| CF | | -3,970 | -3,916 | -3,452 | -1,903 | -0,571 | 1,204 | 2,281 | 5,489 | 7,523 | 8,528 | 9,373 | 8,673 | -7,350 | 0,000 |
| Terminal Value [Perpetuity (P)] | | - | - | - | - | - | - | - | - | - | - | - | - | - | -105,000 |
| Present Value | | -3,970 | -3,560 | -2,853 | -1,430 | -0,390 | 0,748 | 1,287 | 2,816 | 3,509 | 3,616 | 3,614 | 3,040 | -2,342 | -33,456 |
| Net Present Value | | -29,3700 | | | | | | | | | | | | | |
| IRR | | - | | | | | | | | | | | | | |

## Guowang Pessimistic Case

| Guowang - Pessimistic Case NPV | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Value (in Billions USD) | | | | | | | | | | | | | |
| Elements | Period | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| | Users (M) | 0,1 | 0,5 | 1 | 1 | 2 | 2 | 2 | 10 | 11 | 12 | 14 | 15 | | |
| | Year | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2038 |
| Revenues | Subscriptions | 0,060 | 0,300 | 0,600 | 0,600 | 1,200 | 1,200 | 1,200 | 6,000 | 6,600 | 7,200 | 8,400 | 9,000 | - | - |
| | Terminals | 0,005 | 0,005 | 0,100 | 0,100 | 0,100 | 0,500 | 0,500 | 0,500 | 0,500 | 0,800 | 1,000 | 1,000 | - | - |
| | Government | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Other | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Total | 0,065 | 0,305 | 0,700 | 0,700 | 1,300 | 1,700 | 1,700 | 6,500 | 7,100 | 8,000 | 9,400 | 10,000 | 0,000 | 0,000 |
| Operational Costs | Total | 0,033 | 0,153 | 0,350 | 0,350 | 0,650 | 0,850 | 0,850 | 3,250 | 3,550 | 4,000 | 4,700 | 5,000 | 0,000 | 0,000 |
| Depreciation | | 0,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 0,000 | 0,000 |
| Working Capital (WC) | | -0,049 | -0,229 | -0,525 | -0,525 | -0,975 | -1,275 | -1,275 | -4,875 | -5,325 | -6,000 | -7,050 | -7,500 | 0,000 | 0,000 |
| Change in Working Capital (ΔWC) | | 0,000 | -0,180 | -0,296 | 0,000 | -0,450 | -0,300 | 0,000 | -3,600 | -0,450 | -0,675 | -1,050 | -0,450 | 7,500 | 0,000 |
| CapEX | | 4,000 | 5,000 | 5,000 | 4,000 | 4,000 | 3,000 | 3,000 | 2,000 | 2,000 | 1,000 | 1,000 | 1,000 | 0,000 | 0,000 |
| EBITDA | | 0,033 | 0,153 | 0,350 | 0,350 | 0,650 | 0,850 | 0,850 | 3,250 | 3,550 | 4,000 | 4,700 | 5,000 | 0,000 | 0,000 |
| EBIT | | 2,800 | 3,560 | 4,380 | 5,260 | 6,200 | 7,210 | 8,270 | 9,410 | 10,600 | 11,860 | 13,170 | 14,550 | 15,970 | 0,000 |
| t*dep | | 0,000 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,000 | 0,000 |
| (1-t)EBITDA | | 0,021 | 0,099 | 0,228 | 0,228 | 0,423 | 0,553 | 0,553 | 2,113 | 2,308 | 2,600 | 3,055 | 3,250 | 0,000 | 0,000 |
| CF | | -3,979 | -3,921 | -3,676 | -2,973 | -2,328 | -1,348 | -1,648 | 4,513 | 1,558 | 3,075 | 3,905 | 3,500 | -7,500 | 0,000 |
| Terminal Value [Perpetuity (P)] | | - | - | - | - | - | - | - | - | - | - | - | - | - | -107,143 |
| Present Value | | -3,979 | -3,564 | -3,038 | -2,233 | -1,590 | -0,837 | -0,930 | 2,316 | 0,727 | 1,304 | 1,506 | 1,227 | -2,390 | -34,139 |
| Net Present Value | | -45,6213 | | | | | | | | | | | | | |
| IRR | | - | | | | | | | | | | | | | |

## Guowang Optimistic Case

| Guowang - Optimistic Case NPV | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Value (in Billions USD) | | | | | | | | | | | | | |
| Elements | Period | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| | Users (M) | 0,1 | 1 | 2 | 4 | 7 | 20 | 14 | 20 | 29 | 40 | 50 | 60 | | |
| | Year | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2038 |
| Revenues | Subscriptions | 0,060 | 0,600 | 1,200 | 2,400 | 4,200 | 12,000 | 8,400 | 12,000 | 17,400 | 24,000 | 30,000 | 36,000 | - | - |
| | Terminals | 0,005 | 0,100 | 0,200 | 0,200 | 0,200 | 1,000 | 1,000 | 1,000 | 1,000 | 2,000 | 3,000 | 3,000 | - | - |
| | Government Contracts | - | - | - | - | - | - | 2,000 | 3,000 | 3,000 | 4,000 | 4,000 | 4,000 | - | - |
| | Other | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Total | 0,065 | 0,700 | 1,400 | 2,600 | 4,400 | 13,000 | 11,400 | 16,000 | 21,400 | 30,000 | 37,000 | 43,000 | 0,000 | 0,000 |
| Operational Costs | Total | 0,007 | 0,070 | 0,140 | 0,260 | 0,440 | 1,300 | 1,140 | 1,600 | 2,140 | 3,000 | 3,700 | 4,300 | 0,000 | 0,000 |
| Depreciation | | 0,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 4,000 | 0,000 | 0,000 |
| Working Capital (WC) | | -0,007 | -0,070 | -0,140 | -0,260 | -0,440 | -1,300 | -1,140 | -1,600 | -2,140 | -3,000 | -3,700 | -4,300 | 0,000 | 0,000 |
| Change in Working Capital (ΔWC) | | 0,000 | -0,064 | -0,070 | -0,120 | -0,180 | -0,860 | 0,160 | -0,460 | -0,540 | -0,860 | -0,700 | -0,600 | 4,300 | 0,000 |
| CapEX | | 4,000 | 5,000 | 5,000 | 4,000 | 4,000 | 3,000 | 3,000 | 2,000 | 2,000 | 1,000 | 1,000 | 1,000 | 0,000 | 0,000 |
| EBITDA | | 0,059 | 0,630 | 1,260 | 2,340 | 3,960 | 11,700 | 10,260 | 14,400 | 19,260 | 27,000 | 33,300 | 38,700 | 0,000 | 0,000 |
| EBIT | | 2,800 | 3,560 | 4,380 | 5,260 | 6,200 | 7,210 | 8,270 | 9,410 | 10,600 | 11,860 | 13,170 | 14,550 | 15,970 | 0,000 |
| t*dep | | 0,000 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,800 | 0,000 | 0,000 |
| (1-t)EBITDA | | 0,038 | 0,410 | 0,819 | 1,521 | 2,574 | 7,605 | 6,669 | 9,360 | 12,519 | 17,550 | 21,645 | 25,155 | 0,000 | 0,000 |
| CF | | -3,962 | -3,727 | -3,311 | -1,559 | -0,446 | 6,265 | 4,309 | 8,620 | 11,859 | 18,210 | 22,145 | 25,555 | -4,300 | 0,000 |
| Terminal Value [Perpetuity (P)] | | - | - | - | - | - | - | - | - | - | - | - | - | - | -61,429 |
| Present Value | | -3,962 | -3,388 | -2,736 | -1,171 | -0,305 | 3,890 | 2,432 | 4,423 | 5,532 | 7,723 | 8,538 | 8,957 | -1,370 | -19,573 |
| Net Present Value | | 8,9901 | | | | | | | | | | | | | |
| IRR | | 26% | | | | | | | | | | | | | |

## Qianfan Base Case

| Qianfan - Baseline Case NPV | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Value (in Billions USD) | | | | | | | | | | | | | |
| Elements | Period | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| | Users (M) | 0 | 0,3 | 1 | 2,5 | 5 | 10 | 20 | 28 | 35 | 38 | 40 | 40 | | |
| | Year | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 | 2034 | 2035 | 2036 | 2038 |
| Revenues | Subscriptions | 0,000 | 0,180 | 0,600 | 1,500 | 3,000 | 6,000 | 12,000 | 16,800 | 21,000 | 22,800 | 24,000 | 24,000 | - | - |
| | Terminals | 0,000 | 0,050 | 0,150 | 0,400 | 0,600 | 1,000 | 2,000 | 2,500 | 3,000 | 3,000 | 3,000 | 3,000 | - | - |
| | Government | - | - | - | - | - | - | 1,000 | 2,000 | 2,000 | 2,000 | 3,000 | 3,000 | - | - |
| | Other | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Total | 0,000 | 0,230 | 0,750 | 1,900 | 3,600 | 7,000 | 15,000 | 21,300 | 26,000 | 27,800 | 30,000 | 30,000 | 0,000 | 0,000 |
| Operational Costs | Total | 0,000 | 0,081 | 0,263 | 0,665 | 1,260 | 2,450 | 5,250 | 7,455 | 9,100 | 9,730 | 10,500 | 10,500 | 0,000 | 0,000 |
| Depreciation | | 0,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 0,000 | 0,000 |
| Working Capital (WC) | | 0,000 | -0,069 | -0,225 | -0,570 | -1,080 | -2,100 | -4,500 | -6,390 | -7,800 | -8,340 | -9,000 | -9,000 | 0,000 | 0,000 |
| Change in Working Capital (ΔWC) | | 0,000 | -0,069 | -0,156 | -0,345 | -0,510 | -1,020 | -2,400 | -1,890 | -1,410 | -0,540 | -0,660 | 0,000 | 9,000 | 0,000 |
| CapEX | | 6,000 | 8,000 | 7,000 | 6,000 | 6,000 | 5,000 | 4,000 | 3,000 | 2,000 | 1,000 | 1,000 | 1,000 | 0,000 | 0,000 |
| EBITDA | | 0,000 | 0,150 | 0,488 | 1,235 | 2,340 | 4,550 | 9,750 | 13,845 | 16,900 | 18,070 | 19,500 | 19,500 | 0,000 | 0,000 |
| EBIT | | 2,800 | 3,560 | 4,380 | 5,260 | 6,200 | 7,210 | 8,270 | 9,410 | 10,600 | 11,860 | 13,170 | 14,550 | 15,970 | 0,000 |
| t*dep | | 0,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 0,000 | 0,000 |
| (1-t)EBITDA | | 0,000 | 0,097 | 0,317 | 0,803 | 1,521 | 2,958 | 6,338 | 8,999 | 10,985 | 11,746 | 12,675 | 12,675 | 0,000 | 0,000 |
| CF | | -6,000 | -6,834 | -5,527 | -3,852 | -2,969 | -0,022 | 5,738 | 8,889 | 11,395 | 12,286 | 13,335 | 12,675 | -9,000 | 0,000 |
| Terminal Value [Perpetuity (P)] | | - | - | - | - | - | - | - | - | - | - | - | - | - | -128,571 |
| Present Value | | -6,000 | -6,213 | -4,568 | -2,894 | -2,028 | -0,014 | 3,239 | 4,562 | 5,316 | 5,210 | 5,141 | 4,443 | -2,868 | -40,967 |
| Net Present Value | | -37,6409 | | | | | | | | | | | | | |
| IRR | | - | | | | | | | | | | | | | |

## Qianfan Pessimistic Case

**Qianfan - Pesimistic Case NPV**

| | | Value (in Billions USD) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elements | **Period** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** |
| | **Users (M)** | **0** | **0,15** | **0,5** | **1,25** | **2,5** | **5** | **10** | **14** | **17,5** | **19** | **20** | **20** | **0** | **0** |
| | **Year** | **2024** | **2025** | **2026** | **2027** | **2028** | **2029** | **2030** | **2031** | **2032** | **2033** | **2034** | **2035** | **2036** | **2038** |
| Revenues | Subscriptions | 0,000 | 0,090 | 0,300 | 0,750 | 1,500 | 3,000 | 6,000 | 8,400 | 10,500 | 11,400 | 12,000 | 12,000 | - | - |
| | Terminals | 0,025 | 0,075 | 0,200 | 0,300 | 0,500 | 1,000 | 1,250 | 1,500 | 1,500 | 1,500 | 1,500 | 3,000 | - | - |
| | Government | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | Other | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total** | 0,025 | 0,165 | 0,500 | 1,050 | 2,000 | 4,000 | 7,250 | 9,900 | 12,000 | 12,900 | 13,500 | 15,000 | 0,000 | 0,000 |
| Operational Costs | **Total** | 0,023 | 0,149 | 0,450 | 0,945 | 1,800 | 3,600 | 6,525 | 8,910 | 10,800 | 11,610 | 12,150 | 13,500 | 0,000 | 0,000 |
| **Depreciation** | | 0,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 0,000 | 0,000 |
| **Working Capital (WC)** | | -0,019 | -0,124 | -0,375 | -0,788 | -1,500 | -3,000 | -5,438 | -7,425 | -9,000 | -9,675 | -10,125 | -11,250 | 0,000 | 0,000 |
| **Change in Working Capital (ΔWC)** | | 0,000 | -0,105 | -0,251 | -0,413 | -0,713 | -1,500 | -2,438 | -1,988 | -1,575 | -0,675 | -0,450 | -1,125 | 11,250 | 0,000 |
| **CapEX** | | 6,000 | 8,000 | 7,000 | 6,000 | 6,000 | 5,000 | 4,000 | 3,000 | 2,000 | 1,000 | 1,000 | 1,000 | 0,000 | 0,000 |
| **EBITDA** | | 0,003 | 0,017 | 0,050 | 0,105 | 0,200 | 0,400 | 0,725 | 0,990 | 1,200 | 1,290 | 1,350 | 1,500 | 0,000 | 0,000 |
| **EBIT** | | 2,800 | 3,560 | 4,380 | 5,260 | 6,200 | 7,210 | 8,270 | 9,410 | 10,600 | 11,860 | 13,170 | 14,550 | 15,970 | 0,000 |
| **t*dep** | | 0,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 0,000 | 0,000 |
| **(1-t)EBITDA** | | 0,002 | 0,011 | 0,033 | 0,068 | 0,130 | 0,260 | 0,471 | 0,644 | 0,780 | 0,838 | 0,878 | 0,975 | 0,000 | 0,000 |
| **CF** | | -5,998 | -6,884 | -5,716 | -4,519 | -4,158 | -2,240 | -0,091 | 0,631 | 1,355 | 1,514 | 1,328 | 2,100 | -11,250 | 0,000 |
| **Terminal Value [Perpetuity (P)]** | | - | - | - | - | - | - | - | - | - | - | - | - | - | -160,714 |
| **Present Value** | | -5,998 | -6,258 | -4,724 | -3,395 | -2,840 | -1,391 | -0,052 | 0,324 | 0,632 | 0,642 | 0,512 | 0,736 | -3,585 | -51,209 |
| **Net Present Value** | | **-76,6058** | | | | | | | | | | | | | |
| **IRR** | | **-** | | | | | | | | | | | | | |

## Qianfan Optimistic Case

**Qianfan - Optimistic Case NPV**

| | | Value (in Billions USD) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elements | **Period** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** |
| | **Users (M)** | **0** | **0,3** | **5** | **10** | **20** | **20** | **40** | **40** | **60** | **70** | **80** | **100** | | |
| | **Year** | **2024** | **2025** | **2026** | **2027** | **2028** | **2029** | **2030** | **2031** | **2032** | **2033** | **2034** | **2035** | **2036** | **2038** |
| Revenues | Subscriptions | 0,000 | 0,180 | 3,000 | 6,000 | 12,000 | 12,000 | 24,000 | 24,000 | 36,000 | 42,000 | 48,000 | 60,000 | - | - |
| | Terminals | 0,000 | 0,050 | 0,150 | 0,400 | 0,600 | 1,000 | 2,000 | 2,500 | 3,000 | 3,000 | 3,000 | 3,000 | - | - |
| | Government | - | - | - | 1,000 | 1,000 | 2,000 | 2,000 | 2,000 | 3,000 | 3,000 | 4,000 | 5,000 | - | - |
| | Other | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | **Total** | 0,000 | 0,230 | 3,150 | 7,400 | 13,600 | 15,000 | 28,000 | 28,500 | 42,000 | 48,000 | 55,000 | 68,000 | 0,000 | 0,000 |
| Operational Costs | **Total** | 0,000 | 0,023 | 0,315 | 0,740 | 1,360 | 1,500 | 2,800 | 2,850 | 4,200 | 4,800 | 5,500 | 6,800 | 0,000 | 0,000 |
| **Depreciation** | | 0,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 | 0,000 | 0,000 |
| **Working Capital (WC)** | | 0,000 | -0,023 | -0,315 | -0,740 | -1,360 | -1,500 | -2,800 | -2,850 | -4,200 | -4,800 | -5,500 | -6,800 | 0,000 | 0,000 |
| **Change in Working Capital (ΔWC)** | | 0,000 | -0,023 | -0,292 | -0,425 | -0,620 | -0,140 | -1,300 | -0,050 | -1,350 | -0,600 | -0,700 | -1,300 | 6,800 | 0,000 |
| **CapEX** | | 6,000 | 8,000 | 7,000 | 6,000 | 6,000 | 5,000 | 4,000 | 3,000 | 2,000 | 1,000 | 1,000 | 1,000 | 0,000 | 0,000 |
| **EBITDA** | | 0,000 | 0,207 | 2,835 | 6,660 | 12,240 | 13,500 | 25,200 | 25,650 | 37,800 | 43,200 | 49,500 | 61,200 | 0,000 | 0,000 |
| **EBIT** | | 2,800 | 3,560 | 4,380 | 5,260 | 6,200 | 7,210 | 8,270 | 9,410 | 10,600 | 11,860 | 13,170 | 14,550 | 15,970 | 0,000 |
| **t*dep** | | 0,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 0,000 | 0,000 |
| **(1-t)EBITDA** | | 0,000 | 0,135 | 1,843 | 4,329 | 7,956 | 8,775 | 16,380 | 16,673 | 24,570 | 28,080 | 32,175 | 39,780 | 0,000 | 0,000 |
| **CF** | | -6,000 | -6,842 | -3,865 | -0,246 | 3,576 | 4,915 | 14,680 | 14,723 | 24,920 | 28,680 | 32,875 | 41,080 | -6,800 | 0,000 |
| **Terminal Value [Perpetuity (P)]** | | - | - | - | - | - | - | - | - | - | - | - | - | - | -97,143 |
| **Present Value** | | -6,000 | -6,220 | -3,194 | -0,185 | 2,442 | 3,052 | 8,286 | 7,555 | 11,625 | 12,163 | 12,675 | 14,398 | -2,167 | -30,953 |
| **Net Present Value** | | **23,4782** | | | | | | | | | | | | | |
| **IRR** | | **33%** | | | | | | | | | | | | | |

# Appendix F Gateways Data

| ntc_id | name_gs | code | lat | lon | country | adm | region |
|---|---|---|---|---|---|---|---|
| 1 | Alaska Satellite Facility | ASF | 64,86 | -147,85 | USA | NEN (NASA) | N. America |
| 2 | Clewiston | CLE | 26,73 | -82,03 | USA | SSC | N. America |
| 3 | Esrange | ESR | 67,88 | 21,07 | Sweden | SSC | Europe |
| 4 | Florida Ground Station | FGS | 29 | -81 | USA | NEN (NASA) | N. America |
| 5 | Fucino | FUC | 42 | 13,55 | Italy | SSC | Europe |
| 6 | Hartebeesthoek | HBK | -25,64 | 28,08 | South Africa | SSC | Africa |
| 7 | Inuvik | INU | 68,4 | -133,5 | Canada | SSC | N. America |
| 8 | McMurdo Ground Station | MMGS | -77,81 | 166,69 | Antartica | NEN (NASA) | Oceania |
| 9 | O'Higgins | O'H | -63,32 | -57,9 | Antartica | SSC | S. America |
| 10 | Punta Arenas | PAN | -53 | -71 | Argentina | SSC | S. America |
| 11 | Santiago Satellite Station | SSS | -33,13 | -70,67 | Chile | SSC | S. America |
| 12 | Svalbard Ground Station | SGS | 78,22 | 15,39 | Norway | NEN (NASA) | Europe |
| 13 | USN Western Australia | USNWA | -29,05 | 114,9 | Australia | SSC | Oceania |
| 14 | Wallops Flight Facility Ground Stations | WFF | 37,94 | -75,49 | USA | NEN (NASA) | N. America |
| 15 | Weilheim | WEIL | 47,84 | 11,14 | Germany | SSC | Europe |
| 16 | Hawaii | HAW | 19,82 | -155,47 | USA | KSAT | N. America |
| 17 | Tokyo | TOK | 35,69 | 139,69 | Japan | KSAT | Asia |
| 18 | Singapore | SIA | 1,35 | 103,82 | Singapore | KSAT | Asia |
| 19 | Trollsat | TROLL | -72,1 | 2,32 | Antartica | KSAT | Africa |
| 20 | Vardo | VARD | 70,37 | 31,1 | Norway | KSAT | Europe |
| 21 | Tromso | TROM | 69,65 | 18,96 | Norway | KSAT | Europe |
| 22 | Grimstad | GRIM | 58,34 | 8,59 | Norway | KSAT | Europe |
| 23 | Puertollano | PTLL | 38,69 | -4,11 | Spain | KSAT | Europe |
| 24 | Dubai | DUB | 25,2 | 55,27 | UAE | KSAT | Asia |
| 25 | Mauritius | MAUR | -20,35 | 57,55 | Mauritius | KSAT | Africa |
| 26 | Panama | PNM | 8,54 | -80,78 | Panama | KSAT | S. America |
| 27 | Central Africa | AFR | 4,84 | 10,1 | Central Africa | KSAT | Africa |
| 28 | New Zeland | NZL | -46,02 | 167,81 | New Zeland | KSAT | Oceania |
| 29 | Kourou | KOU | 5,16 | -52,65 | French Guian | ESA | S. America |
| 30 | Redu | REDU | 50 | 5,16 | Belgium | ESA | Europe |
| 31 | Cebreros | CBRR | 40,46 | -4,46 | Spain | ESA | Europe |
| 32 | Villafranca | VILLA | 40,26 | -3,57 | Spain | ESA | Europe |
| 33 | Maspalomas | MSPL | 27,45 | -15,38 | Spain | ESA | Europe |
| 34 | Santa Maria | STMAR | 36,59 | -25,08 | Portugal | ESA | Europe |
| 35 | Malargue | MLG | -25,78 | -69,4 | Argentina | ESA | S. America |
| 36 | Sapporo | SAPP | 43,06 | 141,34 | Japan | Other | Asia |
| 37 | Adelaide | ADEL | -34,93 | 138,6 | Australia | SES | Oceania |
| 38 | Accra | ACCR | 5,56 | -0,2 | Gahna | SES | Africa |
| 39 | Lagos | LAGS | 6,52 | 3,38 | Nigeria | SES | Africa |
| 40 | Lurin | LRIN | -12,25 | -76,88 | Peru | SES | S. America |
| 41 | Hortolandia | HORTO | -22,85 | -47,21 | Brazil | SES | S. America |
| 42 | Dijbouti | DJIBO | 11,83 | 42,59 |  | SES | Africa |
| 43 | Abu Dhabi | ABUDH | 24,45 | 54,38 | UAE | SES | Asia |
| 44 | Kowoloon | KWLO | 22,32 | 114,18 | Hong Kong | SES | Asia |
| 45 | Brewster | BREW | 48,09 | -119,78 | USA | SES | N. America |
| 46 | Los Angeles | LA | 34,05 | -118,24 | USA | SES | N. America |
| 47 | Vernon | VERN | 34,15 | -99,27 | USA | SES | N. America |
| 48 | Karachi | KRCH | 24,86 | 67,1 | Pakistan | SES | Asia |
| 49 | Kiev | KIEV | 50,45 | 30,52 | Ukraine | SES | Europe |
| 50 | Dubbo | DBBO | -32,23 | 148,63 | Australia | SES | Oceania |
| 51 | Denver | DENV | 39,74 | -104,99 | USA | Intelsat | N. America |
| 52 | Kumsan | KUMS | 35,36 | 128,41 | South Korea | Intelsat | Asia |
| 53 | Napa | NAPA | 38,25 | -122,28 | USA | Intelsat | N. America |
| 54 | St. John's | STJHN | 47,56 | -52,71 | Canada | Telesat | N. America |
| 55 | Iqaluit | IQLT | 63,75 | -68,52 | Canada | Telesat | N. America |
| 56 | Saskatoon | SSKAT | 52,13 | -106,67 | Canada | Telesat | N. America |
| 57 | Mexico DF | MEXDF | 19,43 | -99,13 | Mexico | Eutelsat | N. America |
| 58 | Cape Verde | CAPE | 14,55 | -23,31 | Cape Verde | Other | Africa |
| 59 | Honolulu | HONOL | 21,3069 | -157,8583 | US | Telesat | N. America |
| 60 | Vancouver | VANCO | 49,2827 | -123,1207 | CA | Telesat | N. America |
| 61 | Yellowknife | YELLO | 62,454 | -114,3718 | CA | Telesat | N. America |
| 62 | Ottawa | OTTAW | 45,4215 | -75,6972 | CA | Telesat | N. America |
| 63 | Jakarta | JAKARTA | -6,1751 | 106,865 | CA | Telesat | Asia |
| 64 | Toronto | TORON | 43,6532 | -79,3832 | CA | Telesat | N. America |
| 65 | Nuuk Greenland Denmark | NUKXX03R | 64,1825 | -51,7354 | Denmark | OneWeb | Europe |
| 66 | Washington DC | WDCXXX | 39,9072 | -77,0369 | USA | None | N. America |
| 67 | Quito | QITXXX | -0,1807 | -78,4678 | Ecuador | None | S. America |
| 68 | Kano | KANXXX | 12,0022 | 8,592 | Nigeria | None | Africa |
| 69 | Bari | BARXXX | 41,1171 | 16,8719 | Italy | None | Europe |
| 70 | Windhoek | WDKXXX | -22,5609 | 17,0658 | Namibia | None | Africa |
| 71 | Seattle | SEAXXX | 47,6062 | -122,3321 | USA | None | N. America |
| 72 | ManIsle | IOFXXX | 54,251186 | -4,463196 | UK | SpaceX | Europe |
| 73 | Dublin | DUBXXX | 53,35014 | -6,266155 | Ireland | Amazon | Europe |
| 74 | CapeTown | CAPXXX | -33,918861 | 18,4233 | South Africa | Amazon | Africa |
| 75 | Thermopylae | THEXXX | 38,8032 | 22,5577 | Greece | SES | Europe |
| 76 | Gazipur | GAZXXX | 23,999339 | 90,389126 | Bangladesh | Thales | Asia |
| 77 | Betbunia | BETXXX | 22,54757 | 91,995896 | Bangladesh | Thales | Asia |
| 78 | Lachhiwala | LACXXX | 30,178015 | 78,104023 | India | OverseasCommunicat | Asia |
| 79 | Maharastra | MAHXXX | 19,151375 | 73,957225 | India | OverseasCommunicat | Asia |
| 80 | Changchun | CHANGC | 43,866761 | 125,310742 | China | CNSA | Asia |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 81 | Kashgar | KASHGA | 39,467395 | 75,988195 | China | CNSA | Asia |
| 82 | Lingshui | LINGSHU | 18,508049 | 110,034506 | China | CNSA | Asia |
| 83 | Menghai | MENGHA | 21,842867 | 100,38589 | China | CNSA | Asia |
| 84 | Longyan | MINXI | 25,101523 | 117,034384 | China | CNSA | Asia |
| 85 | Nanning | NANNIN | 22,817977 | 108,331523 | China | CNSA | Asia |
| 86 | Qingdao | QINGDA | 36,156413 | 120,407392 | China | CNSA | Asia |
| 87 | Xiamen | XIAMEN | 24,487417 | 118,091945 | China | CNSA | Asia |
| 88 | Weinan | WEINAN | 34,500436 | 109,49246 | China | CNSA | Asia |
| 89 | Xiangxi | XIANGX | 27,95457 | 109,595659 | China | CNSA | Asia |
| 90 | Zhanyi | ZHANYI | 25,606822 | 103,817659 | China | CNSA | Asia |
| 91 | Ikire | IKIREX | 7,3875 | 4,2124 | Nigeria | SpaceX | Africa |
| 92 | Lekki | LEKKIX | 6,44952618 | 3,587733892 | Nigeria | SpaceX | Africa |
| 93 | Akita | AKITAX | 39,63828 | 140,06466 | Japan | SpaceX | Asia |
| 94 | Yamaguchi | YAMAGU | 34,2171 | 131,55566 | Japan | SpaceX | Asia |
| 95 | Hitachinaka | HITACH | 36,38673 | 140,61372 | Japan | SpaceX | Asia |
| 96 | Otaru | OTARUX | 43,173215 | 141,258373 | Japan | SpaceX | Asia |
| 97 | Angeles | ANGELE | 15,17087 | 120,505747 | Japan | SpaceX | Asia |
| 98 | Suva | SUVAXX | -18,12915 | 178,46767 | Fiji | SpaceX | Oceania |
| 99 | Awarua | | -46,530531 | 168,383076 | New Zealand | SpaceX | Oceania |
| 100 | Cromwell | | -45,061066 | 169,192756 | New Zealand | SpaceX | Oceania |
| 101 | Hinds | | -44,007406 | 171,571735 | New Zealand | SpaceX | Oceania |
| 102 | Cleavdon | | -36,9897 | 175,05544 | New Zealand | SpaceX | Oceania |
| 103 | Te Hana | | -36,23673 | 174,51211 | New Zealand | SpaceX | Oceania |
| 104 | Puwera | | -35,7935 | 174,30075 | New Zealand | SpaceX | Oceania |
| 105 | Broken Hill | | -31,99829 | 141,4411 | Australia | SpaceX | Oceania |
| 106 | Willows | | -23,66665 | 147,5025 | Australia | SpaceX | Oceania |
| 107 | Pimba | | -31,2507 | 136,80107 | Australia | SpaceX | Oceania |
| 108 | Boorowa | | -34,46214 | 148,70558 | Australia | SpaceX | Oceania |
| 109 | Wagin | | -33,30829 | 117,34339 | Australia | SpaceX | Oceania |
| 110 | Calrossie | | -29,0579 | 150,04031 | Australia | SpaceX | Oceania |
| 111 | Merredin | | -31,49485 | 118,27765 | Australia | SpaceX | Oceania |
| 112 | Cataby | | -30,84826 | 115,61927 | Australia | SpaceX | Oceania |
| 113 | Ki Ki | | -35,57172 | 139,8174 | Australia | SpaceX | Oceania |
| 114 | Torrumbarry | | -36,02526 | 144,50011 | Australia | SpaceX | Oceania |
| 115 | Cobargo | | -36,38863 | 149,8914 | Australia | SpaceX | Oceania |
| 116 | Springbrook Creek | | -30,43981 | 149,68385 | Australia | SpaceX | Oceania |
| 117 | Bulla Bulling | | -31,02985 | 120,81962 | Australia | SpaceX | Oceania |
| 118 | Canyonleigh | | -34,58374 | 150,15013 | Australia | SpaceX | Oceania |
| 119 | Tea Gardens | | -32,59316 | 152,10422 | Australia | SpaceX | Oceania |
| 120 | Warra | | -26,907988 | 150,8916042 | Australia | SpaceX | Oceania |
| 121 | Sellheim | | -19,999722 | 146,42166 | Australia | SpaceX | Oceania |
| 122 | Anakie | | -37,953169 | 144,328172 | Australia | SpaceX | Oceania |
| 123 | Koonwarra | | -38,51812 | 145,95145 | Australia | SpaceX | Oceania |
| 124 | Ballinspittle | | 51,64498 | -8,58805 | Ireland | SpaceX | Europe |
| 125 | Elfordstown | | 51,9532 | -8,17416 | Ireland | SpaceX | Europe |
| 126 | Isle of Man | | 54,13909 | -4,49728 | UK | SpaceX | Europe |
| 127 | Goonhilly | | 50,04964 | -5,18143 | UK | SpaceX | Europe |
| 128 | Chalfont Grove | | 51,61549 | -0,57577 | UK | SpaceX | Europe |
| 129 | Morn Hill | | 51,060168 | -1,263883 | UK | SpaceX | Europe |
| 130 | Villenave d'Ornon | | 44,78096 | -0,53738 | France | SpaceX | Europe |
| 131 | Alfouvar de Cima | | 38,86851 | -9,28217 | Portugal | SpaceX | Europe |
| 132 | Lepe | | 37,255557 | -7,236135 | Spain | SpaceX | Europe |
| 133 | Villarejo de Salvanes | | 40,16758 | -3,2869 | Spain | SpaceX | Europe |
| 134 | Ibi | | 38,60842 | -0,6007 | Spain | SpaceX | Europe |
| 135 | Marsala | | 37,794324 | 12,493115 | Italy | SpaceX | Europe |
| 136 | Foggia | | 41,50823 | 15,58648 | Italy | SpaceX | Europe |
| 137 | Milano | | 45,318522 | 9,187329 | Italy | SpaceX | Europe |
| 138 | Frankfurt | | 50,3298 | 8,47082 | Germany | SpaceX | Europe |
| 139 | Aerzen | | 52,060989 | 9,328231 | Germany | SpaceX | Europe |
| 140 | Wola Krobowska | | 51,86417 | 20,92105 | Poland | SpaceX | Europe |
| 141 | Kaunas | | 54,87947 | 23,84173 | Lituania | SpaceX | Europe |
| 142 | Muallim | | 40,78875 | 29,50939 | Turkey | SpaceX | Europe |
| 143 | Coviha | | 40,265294 | -7,478251 | Portugal | SpaceX | Europe |
| 144 | CamaÃ§ari | | -12,74832 | -38,28305 | Brasil | SpaceX | S. America |
| 145 | Guarapari | | -20,5578 | -40,40863 | Brasil | SpaceX | S. America |
| 146 | Itaborai | | -22,69668 | -42,87279 | Brasil | SpaceX | S. America |
| 147 | Luz | | -19,80334 | -45,68113 | Brasil | SpaceX | S. America |
| 148 | Montes Carlos | | -16,68367 | -43,83329 | Brasil | SpaceX | S. America |
| 149 | Mossoro | | -5,15695 | -37,35373 | Brasil | SpaceX | S. America |
| 150 | Porto Alegre | | -29,9842 | -51,12088 | Brasil | SpaceX | S. America |
| 151 | Presidente Prudente | | -22,1461 | -51,47411 | Brasil | SpaceX | S. America |
| 152 | Rio Negro | | -26,08857 | -49,79286 | Brasil | SpaceX | S. America |
| 153 | Santana de Parnaiba | | -23,45641 | -46,94226 | Brasil | SpaceX | S. America |
| 154 | Surubim | | -7,85393 | -35,78008 | Brasil | SpaceX | S. America |
| 155 | Uruguaiana | | -29,76549 | -56,52698 | Brasil | SpaceX | S. America |
| 156 | Manaus | | -2,92674 | -59,99778 | Brasil | SpaceX | S. America |
| 157 | Falda del Carmen | | -31,52249 | -64,461 | Argentina | SpaceX | S. America |
| 158 | Puerto Montt | | -41,48657 | -73,02337 | Chile | SpaceX | S. America |
| 159 | Puerto Saavedra | | -38,81476 | -73,39724 | Chile | SpaceX | S. America |
| 160 | San Clemente | | -35,55593 | -71,3569 | Chile | SpaceX | S. America |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 161 | Santa Elena | | -29,99974 | -71,2582 | Chile | SpaceX | S. America |
| 162 | Caldera | | -27,02 | -70,78797 | Chile | SpaceX | S. America |
| 163 | Noviciado | | -33,39272 | -70,88325 | Chile | SpaceX | S. America |
| 164 | Punta Arenas | | -52,93974 | -70,85045 | Chile | SpaceX | S. America |
| 165 | Willemstad | | 12,097686 | -68,908109 | CuraÃ§ao | SpaceX | S. America |
| 166 | Baxley | | 31,6821667 | -82,2689722 | USA | SpaceX | N. America |
| 167 | Hillsboro | | 32,0044722 | -97,06325 | USA | SpaceX | N. America |
| 168 | Brunswick | | 43,8960833 | -69,9234444 | USA | SpaceX | N. America |
| 169 | Hawthorne | | 33,9201458 | -118,332217 | USA | SpaceX | N. America |
| 170 | Fort Lauderdale | | 26,1908611 | -80,1930833 | USA | SpaceX | N. America |
| 171 | Norcross | | 33,9549722 | -84,1979722 | USA | SpaceX | N. America |
| 172 | Anchorage | | 61,1858611 | -149,876889 | USA | SpaceX | N. America |
| 173 | Columbus | | 40,061 | -82,7607778 | USA | SpaceX | N. America |
| 174 | Molokai | | 21,1093333 | -157,063944 | USA | SpaceX | N. America |
| 175 | Arbuckle | | 39,057 | -122,06 | USA | SpaceX | N. America |
| 176 | Springer | | 34,2685 | -97,2131667 | USA | SpaceX | N. America |
| 177 | Robertsdale | | 30,567 | -87,646 | USA | SpaceX | N. America |
| 178 | Tracy City | | 35,19725 | -85,666 | USA | SpaceX | N. America |
| 179 | Gaffney | | 34,9853056 | -81,7330833 | USA | SpaceX | N. America |
| 180 | Llano Grande | | 19,25892 | -99,58115 | Mexico | SpaceX | N. America |
| 181 | Tapachula | | 14,7862 | -92,36717 | Mexico | SpaceX | N. America |
| 182 | Merida | | 21,00722 | -89,64396 | Mexico | SpaceX | N. America |
| 183 | PeÃ±uelas | | 21,73139 | -102,27531 | Mexico | SpaceX | N. America |
| 184 | Cabo San Lucas | | 22,91283 | -109,92577 | Mexico | SpaceX | N. America |
| 185 | Charcas | | 23,22612 | -100,97915 | Mexico | SpaceX | N. America |
| 186 | El Marques | | 20,76082 | -100,33556 | Mexico | SpaceX | N. America |
| 187 | Monterey | | 25,77016 | -100,30188 | Mexico | SpaceX | N. America |
| 188 | Mazahua | | 16,60965 | -94,96423 | Mexico | SpaceX | N. America |
| 189 | Villahermosa | | 18,04083 | -92,93282 | Mexico | SpaceX | N. America |
| 190 | Lockport | | 43,1665556 | -78,7551111 | USA | SpaceX | N. America |
| 191 | Kuparuk | | 70,3176667 | -148,941194 | USA | SpaceX | N. America |
| 192 | Ponce | | 18,0619778 | -66,5478361 | Puerto Rico | SpaceX | N. America |
| 193 | Hawthorne | | 33,9175 | -118,328111 | USA | SpaceX | N. America |
| 194 | McGregor | | 31,4049167 | -97,4381389 | USA | SpaceX | N. America |
| 195 | Boca Chica | | 25,9906944 | -97,18275 | USA | SpaceX | N. America |
| 196 | Fairbanks | | 64,8051667 | -147,500222 | USA | SpaceX | N. America |
| 197 | Bellingham | | 48,774 | -122,448583 | USA | SpaceX | N. America |
| 198 | Greenville | | 41,4335556 | -80,3332222 | USA | SpaceX | N. America |
| 199 | Merrillan | | 44,4063333 | -90,8142778 | USA | SpaceX | N. America |
| 200 | Conrad | | 48,2033056 | -111,945278 | USA | SpaceX | N. America |
| 201 | Butte | | 45,9240556 | -112,513194 | USA | SpaceX | N. America |
| 202 | Roll | | 32,8155 | -113,798056 | USA | SpaceX | N. America |
| 203 | Colburn | | 48,34525 | -116,439333 | USA | SpaceX | N. America |
| 204 | Litchfield | | 41,5450278 | -73,3540278 | USA | SpaceX | N. America |
| 205 | Evanston | | 41,0925 | -110,842611 | USA | SpaceX | N. America |
| 206 | Santiago de los Caballeros | | 19,48096 | -70,72656 | Dominican Re | SpaceX | N. America |
| 207 | Lawrence | | 39,0138889 | -95,1493889 | USA | SpaceX | N. America |
| 208 | Loring | | 46,9149167 | -67,9195278 | USA | SpaceX | N. America |
| 209 | Kalama | | 46,0389722 | -122,808222 | USA | SpaceX | N. America |
| 210 | Beekmantown | | 44,7899722 | -73,48 | USA | SpaceX | N. America |
| 211 | Panaca | | 37,7836389 | -114,692694 | USA | SpaceX | N. America |
| 212 | Warren | | 38,6351667 | -91,1160278 | USA | SpaceX | N. America |
| 213 | Nemaha | | 40,3336667 | -95,8152778 | USA | SpaceX | N. America |
| 214 | Manistique | | 45,9086111 | -86,4835833 | USA | SpaceX | N. America |
| 215 | Slope County | | 46,4083889 | -103,114583 | USA | SpaceX | N. America |
| 216 | Cass County | | 47,1516944 | -97,4088889 | USA | SpaceX | N. America |
| 217 | Sanderson | | 30,194 | -102,89 | USA | SpaceX | N. America |
| 218 | Hitterdal | | 46,9789167 | -96,2580278 | USA | SpaceX | N. America |
| 219 | Vernon | | 40,0762222 | -112,354722 | USA | SpaceX | N. America |
| 220 | Punta Gorda | | 27,0196667 | -81,7620278 | USA | SpaceX | N. America |
| 221 | Dumas | | 35,8079722 | -102,031861 | USA | SpaceX | N. America |
| 222 | Robbins | | 38,875 | -121,707056 | USA | SpaceX | N. America |
| 223 | Wise | | 36,4706389 | -78,1733889 | USA | SpaceX | N. America |
| 224 | Hamshire | | 29,8598611 | -94,3123333 | USA | SpaceX | N. America |
| 225 | Marcell | | 47,5931667 | -93,6925278 | USA | SpaceX | N. America |
| 226 | Hillman | | 45,07325 | -83,9004167 | USA | SpaceX | N. America |
| 227 | Broadview | | 41,8548889 | -87,8588889 | USA | SpaceX | N. America |
| 228 | Lunenberg | | 44,4120278 | -71,7318333 | USA | SpaceX | N. America |
| 229 | Sullivan | | 44,5309722 | -68,224 | USA | SpaceX | N. America |
| 230 | Rolette | | 48,6603611 | -99,8105278 | USA | SpaceX | N. America |
| 231 | Ketchikan | | 55,3737 | -131,718989 | USA | SpaceX | N. America |
| 232 | Nome | | 64,5035 | -165,428306 | USA | SpaceX | N. America |
| 233 | Frederick | | 39,3969722 | -77,4366389 | USA | SpaceX | N. America |
| 234 | Caleta | | 18,45398 | -69,66174 | Dominican Re | SpaceX | N. America |
| 235 | Marathon | | 48,7253692 | -86,3745279 | Canada | SpaceX | N. America |
| 236 | Saguenay | | 48,3136647 | -70,9088518 | Canada | SpaceX | N. America |
| 237 | Sambro Creek | | 44,4645332 | -63,6131209 | Canada | SpaceX | N. America |
| 238 | Toa Baja | | 18,4310556 | -66,1920861 | Puerto Rico | SpaceX | N. America |
| 239 | St Johns | | 47,560921 | -52,7754993 | Canada | SpaceX | N. America |
| 240 | Unalaska | | 53,8602778 | -166,504861 | USA | SpaceX | N. America |

## Appendix G China Domestic and International Gateways

**Domestic**

| ntc_id | name_gs | code | lat | lon | country | adm | region |
|---|---|---|---|---|---|---|---|
| 1 | Miyun Ground Station | MIY | 40,50000 | 116,80000 | China | CNSA | East Asia |
| 2 | Kashgar Ground Station | KAS | 39,50000 | 76,00000 | China | CNSA | Central Asia |
| 3 | Sanya Ground Station | SAN | 45734,00000 | 109,50000 | China | CNSA | South China |
| 4 | Lijiang Ground Station | LIJ | 45926,00000 | 100,20000 | China | CNSA | Southwest China |
| 5 | Mohe Ground Station | MOH | 52,00000 | 122,50000 | China | CNSA | Northeast China |
| 6 | Changchun Station | CHC | 43,80000 | 125,30000 | China | CNSA | Northeast China |
| 7 | Weinan Station | WEI | 34,50000 | 109,50000 | China | CNSA | Central China |
| 8 | Xiamen Station | XMN | 45801,00000 | 118,10000 | China | CNSA | Southeast China |
| 9 | Nanning Station | NAN | 45891,00000 | 108,30000 | China | CNSA | South China |
| 10 | Lingshui Station | LIN | 45765,00000 | 109,90000 | China | CNSA | South China |
| 11 | Qingdao Station | QDG | 36,10000 | 120,30000 | China | CNSA | East China |
| 12 | Yilan Station | YIL | 46,30000 | 129,50000 | China | CNSA | Northeast China |
| 13 | Guiyang Station | GUY | 45834,00000 | 106,70000 | China | CNSA | Southwest China |
| 14 | Jiamusi Station | JIA | 46,80000 | 130,40000 | China | CNSA | Northeast China |
| 15 | Lushan Station | LUS | 45837,00000 | 115,90000 | China | CNSA | Central China |
| 16 | Zhanyi Station | ZHA | 45833,00000 | 103,80000 | China | CNSA | Southwest China |

**International**

| ntc_id | name_gs | code | lat | lon | country | adm | region |
|---|---|---|---|---|---|---|---|
| 17 | Swakopmund Ground Station | SWK | -22,700000 | 45791,000000 | Namibia | CNSA | Southern Africa |
| 18 | Karachi Ground Station | KHI | 45924,000000 | 67,100000 | Pakistan | SUPARCO | South Asia |
| 19 | Neuquén Ground Station | NEU | -38,600000 | -70,100000 | Argentina | CONAE | South America |
| 20 | Dongara Ground Station | DGA | -29,200000 | 115,200000 | Australia | ASC | Pacific |
| 21 | Santiago Ground Station | STG | -33,500000 | -70,700000 | Chile | ASI | South America |
| 22 | Malindi Ground Station | MAL | -2,900000 | 40,200000 | Kenya | CNSA | East Africa |
| 23 | Tarawa Ground Station | TAR | 45717,000000 | 173,000000 | Kiribati | CNSA | Oceania |
| 24 | Kiruna Ground Station | KIR | 67,800000 | 45767,000000 | Sweden | SSC | Northern Europe |

# Appendix H Rural Connectivity and Income Distribution In China

| Province | Avg. Annual Income (CNY) | Estimated Annual Income (CNY) | Affordability for Satcom* |
|---|---|---|---|
| Beijing | ¥74,000 | ¥6,167 | Affordable (Yes) |
| Shanghai | ¥72,000 | ¥6,000 | Affordable (Yes) |
| Guangdong | ¥55,000 | ¥4,583 | Likely Affordable |
| Sichuan | ¥34,000 | ¥2,833 | Borderline |
| Henan | ¥32,000 | ¥2,667 | Borderline |
| Gansu | ¥28,000 | ¥2,333 | Unaffordable |
| Xinjiang | ¥29,000 | ¥2,417 | Unaffordable |
| Tibet | ¥26,000 | ¥2,167 | Unaffordable |

* Assuming 2% income threshold (~¥50–¥100/month for Satcom access)

# Appendix I Model Data Inputs for Guowang and Qianfan

**GuoWang – Domestic Constellation**

**Strategic Coverage**: Prioritizes coverage of China's landmass — latitudes 0°–50°N

| Scenario | Total Satellites | Shells (altitude / inclination) | Planes per Shell | Sats per Plane |
|---|---|---|---|---|
| **Base** | 6,500 | 600 km @ 50° | 20 | 65 |
| | | 800 km @ 80° | 24 | 75 |
| | | 1,200 km @ 98° (sun-sync) | 30 | 70 |
| **Optimistic** | 9,000 | Same 3 shells, denser planes | 30 / 36 / 36 | 75 / 80 / 85 |
| **Pessimistic** | 3,000 | 600 km @ 50°, 800 km @ 80° only | 20 / 24 | 60 / 65 |

**Notes:**
Shell prioritization reflects China's emphasis on national broadband and last-mile rural coverage
Higher inclination shell supports resilience and military redundancy (sun-synchronous paths).
No significant southern coverage needed — spectrum preservation focused on mainland reach

**Qianfan – International Constellation**

**Strategic Coverage**: Belt & Road countries across 30°S–30°N, including Africa, South Asia, Southeast Asia, and Latin America.

| Scenario | Total Satellites | Shells (altitude / inclination) | Planes per Shell | Sats per Plane |
|---|---|---|---|---|
| **Base** | 7,500 | 500 km @ 55° | 24 | 80 |
| | | 750 km @ 88° | 30 | 85 |
| | | 1,100 km @ 98° | 30 | 85 |
| **Optimistic** | 12,000 | Same 3 shells, denser config | 36 / 36 / 40 | 90 / 100 / 100 |
| **Pessimistic** | 4,500 | 500 km and 750 km only | 20 / 24 | 75 / 80 |

| Parameter | GuoWang | Qianfan |
|---|---|---|
| **Orbit Type** | LEO | LEO |
| **Number of Satellites** | ~6,500 (base case, see other cases) | ~7,500 (base case, see other cases) |
| **Orbital Altitudes / Shells** | Multiple shells at 500 km to 1,145 km (at least 3) | Estimated 500–1,200 km, likely 2–3 shells |
| **Inclination** | ~50° (to focus on China, 0–50°N) | ~30–40° (equatorial focus: ±30°) |
| **Minimum Elevation Angle (User)** | 30° (based on common LEO thresholds, and urban Chinese terrain) | 30° (assumed similar) |
| **Minimum Elevation Angle (Gateway)** | 20° (assumed slightly lower for terrestrial infrastructure) | 20° (same assumption) |
| **Inter-satellite Links (ISLs)** | Present – assumed up to 4 per satellite, capacity ~20–40 Gbps | 1st Generation without, 2nd Generation possibly limited or phased in, assume ~10–20 Gbps |
| **Frequency Bands (User Links)** | Uplink: Ka-band (27.5–30 GHz)Downlink: Ka-band (17.7–20.2 GHz) | Ku-band |
| **Frequency Bands (Gateway Links)** | Uplink: Ka-band (29.5–30 GHz)Downlink: Ka-band (19.7–20.2 GHz) | Q/V-band |
| **User Antenna G (Gain)** | ~38 dBi (flat-panel phased arrays) | ~35–38 dBi (cheaper phased arrays) |
| **User G/T** | ~14–16 dB/K | ~13–15 dB/K |
| **User Pointing Loss** | ~1 dB | ~1.5 dB (slightly higher tolerance) |
| **User Rotation Loss** | ~0.5–1 dB | ~1 dB |
| **Satellite Antenna Gain (to user)** | ~42 dBi | ~40 dBi |
| **Satellite EIRP (to user)** | ~58 dBW | ~55–57 dBW |
| **Satellite Pointing Loss** | ~0.5 dB | ~1 dB |
| **Satellite Rotation Loss** | ~1 dB | ~1–1.5 dB |
| **Gateway Antenna Gain** | ~50–55 dBi (large dishes) | ~50 dBi |
| **Gateway G/T** | ~28–35 dB/K | ~25–30 dB/K |
| **Gateway EIRP** | ~60–70 dBW | ~60–65 dBW |
| **Simultaneous Gateway Connections** | ~20–30 per satellite (in ideal conditions) | ~10–20 (cost-efficient design) |
| **Frequency Reuse Factor** | 8–16 (based on Ka-band cellular reuse schemes) | 8–12 |
| **Number of Polarizations** | Dual-polarization (2) | Dual-polarization (2) |

**Notes:**

- Elevation angles: Based on terrain and literature, 30° is a safe baseline for users. Gateways can operate at slightly lower angles.
- ISLs: GuoWang's architecture includes them for resilience; Qianfan might phase them in over time, likely lower capacity.
- Antenna and RF parameters: Not fully disclosed. GuoWang aims for higher throughput (premium), while Qianfan prioritizes affordability. Data inferred from comparative systems like Starlink, OneWeb, and Chinese academic publications.
- Simultaneous gateways: Dependent on spot beam and channeling. Assumes extensive beam steering and segmentation for GuoWang.