

THE SATELLITE SERIES, SERVICE BY SERVICE

# The Sky as a Network

*Constellations and direct to device*

A satellite service in 2026 is a network, not a satellite: a space segment, user devices, gateways, a core network, spectrum rights and an operator, each possibly owned by a different party under a different state's law. Services differ on eight choices that can be named and compared one by one. A reader who places a service on those axes and fills one Link Ledger page for it can build a shortlist and name what acceptance still needs.

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## CONTENTS


BEFORE THE SERVICES

Reader's Brief: Eight Axes, Four Status Fields, One Ledger

Prologue: One Message, Four Ways Up

**01** A Service Is a Network: The Parts, the Axes, the Owners and the Words

PART I: BROADBAND

**02** Shells and Coverage: How Many Satellites, and Where

**03** Broadband from Low Orbit: Two Reference Patterns and Their Hybrids

**04** The Terminal, the Gateway and the Network Service

**05** Geostationary and Medium Orbit Broadband: What the High Orbits Sell

PART II: MOBILE AND MIXED

**06** Mobile Satellite Services as Sold Today: Handhelds, Small Terminals and Safety

**07** More Than One Orbit: Ships, Aircraft, Enterprises and Governments

PART III: DIRECT TO DEVICE

**08** Direct to Device, Part 1: The Phone's Budget and the Standard

**09** Direct to Device, Part 2: The Two Spectrum Roads

**10** Direct to Device, Part 3: Devices, Operators and the Meaning of "In Service"

PART IV: SMALL MESSAGES AND CHOOSING

**11** Narrowband Satellite IoT: Small Messages from Anywhere

**12** Which Service Fits Which Need: From a Requirement to a Shortlist

**13** Supplier, Spectrum and Sovereignty Risk

Epilogue: The Register Will Change, the Questions Will Not

APPENDICES

**A** The Link Ledger: Blank Page, Index of Worked Ledgers, the Supplier Questions

**B** Cases: Who Was Selected, Under Which Test, Who Was Sought and Not Sourced

**C** Glossary

**D** Dated Register: Fleets, Owners, Spectrum and Service Status as of 2026-11-23

**E** Sources

BEFORE THE SERVICES

# Reader's Brief: Eight Axes, Four Status Fields, One Ledger




On 23 November 2026, the date this book is fixed to, a buyer can send a bit through a satellite from a flat terminal on a roof, a dish pointed at one spot in the sky, an ordinary phone in a pocket, or a battery sensor in a field. Each of those is sold by a different kind of company, on a different license, through ground stations in different countries. This book is about choosing among them, and about knowing what the choice depends on.

## The series in one paragraph

Every satellite link divides power, antenna area, processing, money and risk between the user's end, the satellite and the ground. The series asks of every system how that work was divided, what limits drove the split, and whether it worked. Here the question is asked of services a reader can buy today.

It asks six questions of every system:

1. What must be delivered, and by when?
2. How is the work divided between user, space and ground?
3. Does each hop close, with what margin, under which assumptions?
4. Who owns each end, and who gave permission?
5. How does it fail, who can interfere, and what would show us?
6. What can I use or rent before I build?

## Four buying categories, eight axes

A buyer usually arrives with one of four needs: **broadband** to a fixed or moving terminal; a **mobile satellite service** to a handheld or a small terminal; a service **direct to a phone**; or **narrowband IoT** to a module in a sensor. These are reading routes, not a classification: one service can sit in two of them.

Services are classified on eight axes instead, each a choice a buyer can ask about: the orbit and the number of satellites; the payload; routing between satellites; the gateways; the spectrum and whose license it is; the air interface; the user's device; and the delivery model. Chapter 1 defines each axis and gives its values.

## Four status fields, kept apart

Announced, authorized, in orbit and in service are four separate fields, each with its own proof: a dated statement for **announced**; the instrument, the jurisdiction, the band and the generation for **authorized**; three separate counts for **in orbit** (launched, in orbit, working), each with its date and who counted; and for **in service**, the country, the operator, the device and the date, plus a qualifier: trial, preview, limited commercial, general commercial, intermittent, suspended or retired. "Available" and "live" are not used.

Every count carries the number, the date and who counted. A fact has three dates, and the dated register in Appendix D keeps all three: when the event happened, when the source was published, and when the source was read. Dates are written in Coordinated Universal Time; where a source gives a local date that differs, both are given.

## One form, filled one service at a time

The series tool is a two-page form called the Link Ledger. Its page 1 describes a service in ten fields, from the requirement and the path to who owns each end, how it fails, the shape of the cost and the numbers that carry the argument. Page 2 is the hop budget, which the first book of this series, *The Bit's Path*, explains with the radio theory behind it.

This book fills page 1 for each worked service (Appendix A lists them) and prints no hop budget for a named service, because today's operators rarely publish the numbers a budget needs. One worked page describes one configuration: one terminal class, one plan, one geography and one path. Where the sources read do not fix one of those four, the page says which it leaves for the buyer to fill.

Every number on a worked page carries a source, a date and one of seven classes: measured, calculated, simulated, operator claim, standard, assumption (printed "assumption, to verify") and published history. The blank form in Appendix A and the glossary define each. Most numbers in this book are operator claims, and the pages say so; none was measured by its author.

## Three verdicts and three kinds of control

"Does it work?" has three answers, and the book keeps them apart. **The link:** does the signal arrive with the quality the receiver needs, at a stated operating point? **The service:** do users get what was promised, where and when it was promised? **The business:** do the owners recover what they spend? The book does not rank operators or name winners; where it compares two designs, it names the objective the comparison is made against.

"Who controls it?" also has three answers. **Technical command access** is holding the credentials that command the satellites, the network and the terminals. **Contractual control** is what a carrier, reseller or integrator can do to the service under its contract. **Lawful authority** is what the licensing state, the state that hosts a gateway and the user's state can compel or forbid. A state with lawful authority does not thereby hold the command credentials, though it may compel the party that does.

## What the notes cover, and how to read the rules

Each numbered chapter carries a security note in three parts: who can interfere or command, which covers, where the sources say, who may use and command the system, who can intercept and how a user or a station is authenticated; how misuse or interference is seen; and how service is recovered. The notes rest only on what is publicly documented, and some answers are "not in the sources read". A buyer who needs operational assurance has to get it by contract or from the authority concerned.

Each numbered chapter also carries a sourced failure, incident or trade-off and ends with a **Monday rule**, one sentence to act on the next working week. The Monday rules are the author's practice, not a method proven by trials.

## What this book holds, and what it leaves to the others

*The Bit's Path* holds the radio: orbits and passes, the hop budget, bands, modulation and coding, delay and Doppler, payload types and link security. The second book of this series, *From Telstar to the Phone in Your Pocket*, holds the history of how each architecture came to be. This book starts at the service as sold on 23 November 2026 and refers back to those two in one sentence where it needs them. The law of the sky (treaties, filings, licensing by jurisdiction, debris rules) and the buyer who rents capacity to build a mission are covered in depth later in this series.

This is a method for choosing, not a catalogue of offers: most worked pages print "not checked", and no price is printed. The records lean on United States filings, which could be read; a system missing from a table is not thereby unimportant (Appendix B lists what was sought and not read).

# Prologue: One Message, Four Ways Up




On 23 November 2026 a short report has to leave a place that no ground network reaches: a field station, a road between towns, a mooring far from a mast. The report is the same in every case. The ways it can leave are not. Four are sold today, and they differ first in their radio and then in almost everything else.

## Four ways up

**A flat terminal on a low orbit broadband service.** A panel the size of a small table sits on the ground with a clear view of the sky. It steers its beam electronically toward satellites a few hundred kilometers up, each in view for minutes, and the service hands the connection from one satellite to the next. The report leaves as a few packets among many; the panel can also carry a video call.

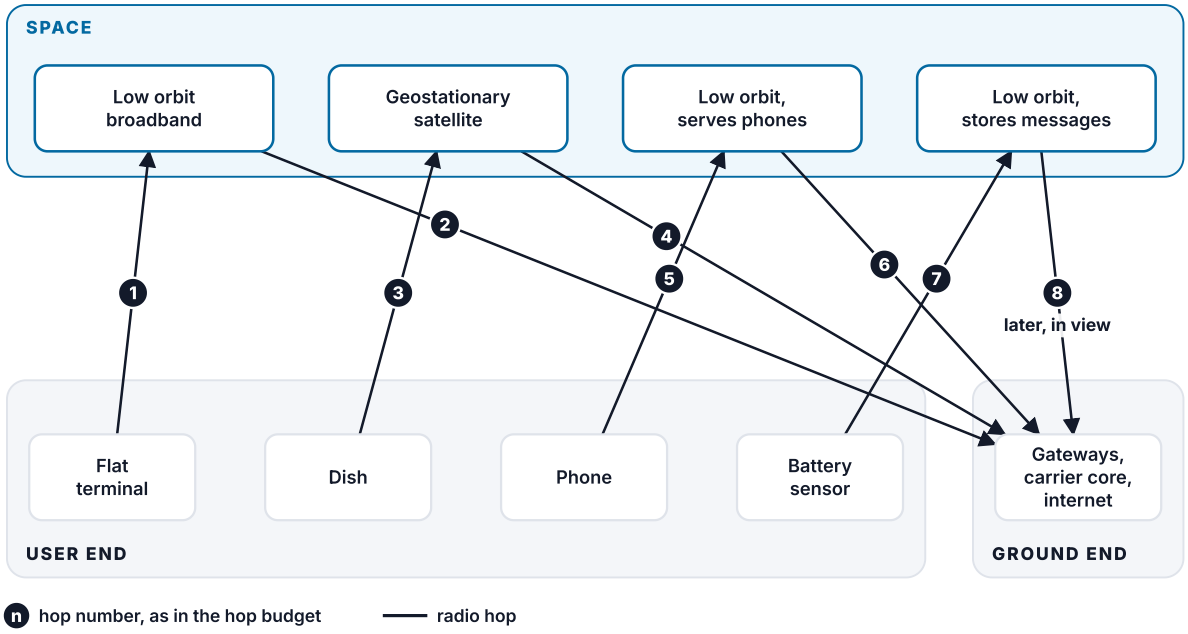
**A dish on a geostationary service.** A dish points at one fixed spot in the sky, a satellite about 36,000 kilometers up that stays over one point of the equator. Once aligned, a fixed dish does not need to track. The report leaves the same way as on the flat panel, as packets on a broadband link, but every reply waits for the signal to travel up and down twice.

**The phone in the reporter's pocket.** No extra device. The phone finds no tower, and on some phones, with some carriers, in some countries, it can reach a satellite instead. The phone's antenna is small and its transmitter weak, so the satellite or the network around it must make up the difference. The report may leave as a short text, and the reporter may have to stand where the sky is open and wait.

**A battery sensor that sends, in this example, forty bytes twice a day.** A module the size of a matchbox wakes, sends a few dozen bytes to a satellite passing overhead, and sleeps. The satellite may not be able to reach the ground at that moment; it can hold the message and pass it down later. The report here is not prose but a reading: a level, a temperature, a position. Such designs accept delivery in minutes or hours and aim for a battery that lasts years; whether a given device reaches that depends on its coverage, retries and power draw (chapter 11).

FIGURE P.1

## One report, four ways up: the user's end carries a different share of the work in each




Four generic paths, no operator named: a flat terminal and a low orbit broadband satellite (1, 2); a dish and a geostationary satellite (3, 4); a phone and a low orbit satellite serving phones (5, 6); a sensor and a low orbit satellite that may store the message until a ground station is in view (7, 8).

*Author's diagram; generic paths, no operator's design. The radio of each hop is worked in The Bit's Path.*

### The radio decides what each device can do at all

The four devices differ in **antenna gain** (how strongly an antenna concentrates power toward one direction, and favors a signal from it), transmit power, the bandwidth they can use and the **margin** they can keep, the spare signal held against rain, blockage and motion. A panel or a dish concentrates power into a narrow beam and hears a faint signal from that direction well; a phone's small antenna spreads its power widely, in a pattern that changes with how the phone is held. A satellite that serves a phone makes up the difference with some mix of a larger antenna, a lower orbit, more power and a much lower rate than a satellite that serves a dish. The sensor buys years of battery by sending very little, very rarely, and by accepting a wait. None of this is a ranking: each device is a different answer to how much of the work the user's end will carry.

The first book of this series, *The Bit's Path*, works those numbers hop by hop. This book uses its results and starts where they stop.

### Then everything that is not radio

Once the radio says a way is possible, five other questions decide whether a buyer can depend on it.

- **The device the user must own.** A dedicated terminal, a phone that supports the service, or a module; each is bought, installed and replaced by someone.
- **The license the traffic rides on.** The right to transmit on a band may be held by the satellite operator, or by a mobile carrier that leases its use to the satellite operator; each right is granted country by country, with conditions, and the two roads carry different rights and different duties.
- **The gateway country.** The report comes down at a ground station in some state, under that state's law, before it reaches the internet or a carrier's core.
- **The company that can end the service.** An operator can change its terms, be bought or stop selling a device; a reseller in between adds a second company with that power.
- **What the service is on the day.** Announced, authorized, in orbit and in service are four separate facts, and "in service" needs a country, an operator, a device, a date and a qualifier.

Both halves matter. A link that closes on a service the buyer cannot depend on is not a solution, and a service with good terms is useless where its link cannot close.

### What the book does with the four

The rest of the book takes each way apart in the same order: the architecture first, without operator names; then the operators as cases, each chosen by a stated test; then one page of the series form, filled for one configuration; then the failure, the security note and the rule for the next working week. By the last chapter a reader should be able to start from a requirement like this report, and reach one or two services worth a trial, with the questions a supplier must answer in writing before the trial starts.

CHAPTER ONE

# A Service Is a Network: The Parts, the Axes, the Owners and the Words




On 23 July 2025 T-Mobile, a US mobile carrier, announced in its own release that compatible phones could send text messages through SpaceX's Starlink satellites when no tower is in reach, from that day, with app capabilities to follow in October. In May 2026 the FCC described such service as having brought text connectivity to consumers in places with no tower. The phone belonged to the customer, the spectrum license and the core network to the carrier, and the satellites to another company. One service, at least three owners. This chapter gives the reader the parts, the axes and the words to describe any satellite service that way before judging it.

## Six parts, and who can hold each

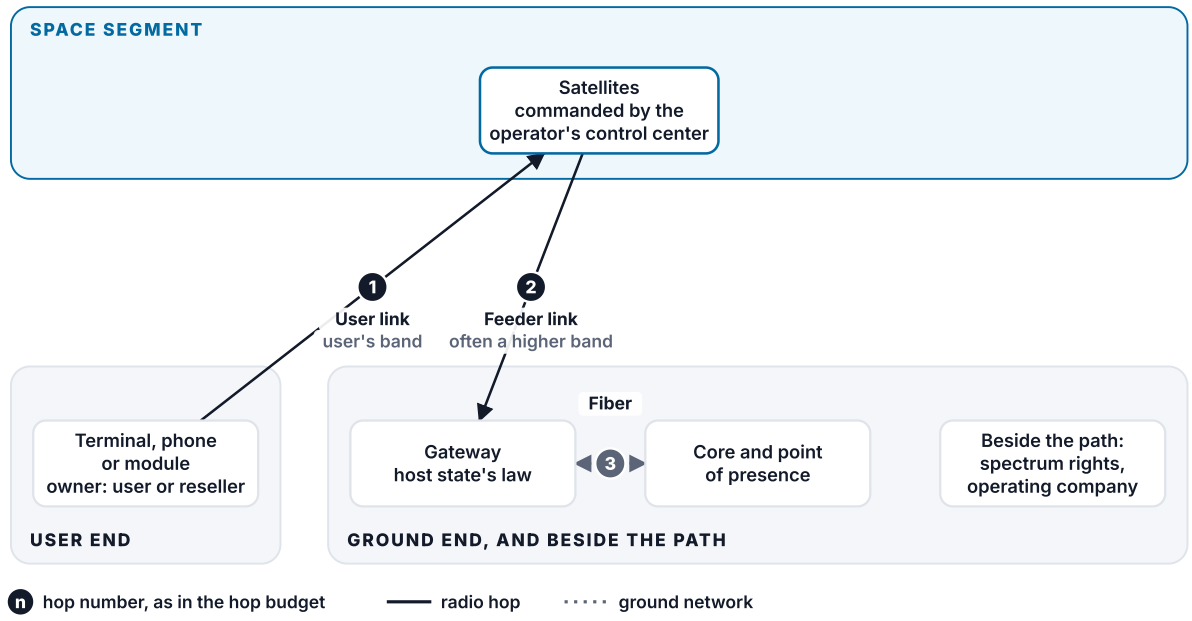
A satellite service in 2026 is a network with six parts. Each can be owned by a different party, under a different state's law.

- **The space segment:** the satellites, their command links and the control center that flies them.
- **The user's device or terminal:** a flat panel, a dish, a phone or a module, bought, installed and replaced by someone.
- **The gateways and the feeder link:** the ground stations where traffic comes down from the satellites, usually in a higher band than the user's link, with fiber onward.
- **The core network and its points of presence:** the systems that authenticate users, route their traffic and hand it to the internet or to a carrier, and the places where that handover happens.
- **The spectrum rights:** the licenses that allow each hop to transmit, which may belong to the satellite operator, to a carrier or to both.
- **The operating company:** the firm that sells the service and decides its terms, with its own suppliers of satellites and launches.

Figure 1.1 places the four physical parts on the canvas this book uses for every path. The two that are not places, the license and the company, appear in a box beside it, and in the table that follows, because they can change the service as surely as a broken satellite can.

FIGURE 1.1

## A service has six parts; four are places on the path and two are not




The space segment, the user's terminal, the gateway with its feeder link, and the core with its point of presence are places on the path; the spectrum rights and the operating company sit beside it and can change the service as surely as a failed satellite.

*Author's diagram based on the part names of this chapter; 3GPP, Non-Terrestrial Networks (NTN) overview, for the terms service link and feeder link. Checked 2026-11-23.*

Beside each part, a buyer can write three names. The table below gives the typical answers; a real service fills them from its own documents.

**Who holds it: owner, lawful authority and command access, part by part**

| Part | Typical owner | State with lawful authority | Who holds command access |
|---|---|---|---|
| Space segment | The satellite operator | The state that licenses the satellites; the state that filed them with the ITU | The operator's control center |
| User device or terminal | The user, or a reseller that rents it | The user's state (import, use, radio approval) | Whoever provisions it and signs its software updates, often the operator or the device maker |
| Gateways and feeder link | The operator, or a ground station company it contracts | The state that hosts the site | The gateway's owner, under the operator's network control |
| Core network and points of presence | The operator, or a mobile carrier for phone services | The state where the core sits, and the user's state | The core's owner |
| Spectrum rights | The operator, a carrier, or both under a lease | The licensing state of each band, inside the ITU framework | Not a technical role: the license holder decides what may transmit |
| Operating company | Shareholders, possibly another company or a state | The state of incorporation, and each state where it sells | Decides the terms; may sit above every row in this table |

## Eight axes

Services differ on eight choices that can be named and compared one at a time. Each axis below is a question a buyer can put to a supplier, with the values the book uses.

1. **Orbit and number of satellites.** Low orbit (below 2,000 km, many satellites, each in view for minutes), medium orbit (thousands of kilometers, fewer satellites, tracked for hours) or geostationary (35,786 km, one satellite fixed in the sky over the equator). Chapter 2 explains why each needs the number it needs.
2. **Payload.** The standards body for mobile networks, 3GPP, defines a **transparent** payload as "an analogue RF repeater with no on-board processing" and a **regenerative** payload as one that demodulates, switches and modulates on board. This book uses three payload

classes: transparent, digital transparent and regenerative. A digital transparent processor is still a transparent payload: it divides and routes channels in digital form without recovering the bits, as a 2024 survey of high-throughput satellite systems in *IEEE Communications Surveys and Tutorials* describes. Regenerative does not have to mean a whole mobile base station in orbit.

3. **Routing.** Links between satellites (crosslinks), or none. Without crosslinks, a satellite that relays a user's traffic in real time must see a gateway at the same moment; a satellite that stores messages can carry them to a gateway later.
4. **Gateways.** How many, where, and whose; the gateway decides the country in which traffic first lands.
5. **Spectrum road and license.** Spectrum allocated to satellites and licensed to the satellite operator, or a mobile carrier's terrestrial spectrum used from space under a lease; chapter 9 sets out both roads.
6. **Air interface.** A published standard, such as 3GPP's non-terrestrial network specifications, or a proprietary link that only the operator's own devices speak.
7. **User device.** A dedicated terminal, a phone built for satellite bands, an ordinary phone served on its carrier's band, or a module in a sensor.
8. **Delivery model.** Sold direct to consumers and businesses, wholesale through carriers and integrators, or integrated across several orbits by one company or by the customer.

FIGURE 1.2

## The eight axes against the four buying categories: typical values, not exclusive ones

| Axis | Broadband | Mobile satellite service | Direct to a phone | Narrowband IoT |
|---|---|---|---|---|
| Orbit and number | Low orbit, hundreds to thousands; medium orbit, tens; geostationary, one per region | Low orbit, tens; or geostationary, a few | Low orbit, from a few to hundreds; or partner geostationary satellites | Low orbit, a few to tens; or geostationary |
| Payload | Transparent, digital transparent or regenerative | Regenerative or transparent | Transparent or regenerative; the base station behind the gateway or in orbit | Regenerative with storage, or transparent |
| Routing | Crosslinks, or none | Crosslinks, or none | Mostly none; crosslinks in some designs | None; storage carries messages to a later gateway pass |
| Gateways | Many, in many countries | A few, regional | The carrier's or the operator's | Few; a pass may wait for one |
| Spectrum road | Satellite bands (Ku, Ka, higher), operator's license | L and S band satellite spectrum, operator's license | A carrier's terrestrial band under a lease, or satellite spectrum | Satellite spectrum, UHF or L band, or a standard's satellite band |
| Air interface | Proprietary or a satellite standard (DVB family) | Proprietary | 3GPP non-terrestrial, or a proprietary link, or LTE with a modified network | Proprietary, or 3GPP NB-IoT over satellite |

| Axis | Broadband | Mobile satellite service | Direct to a phone | Narrowband IoT |
|---|---|---|---|---|
| User device | Flat panel or dish, fixed or in motion | Satellite handheld or small terminal | A phone: built for satellite bands, or ordinary | A module in a sensor |
| Delivery model | Direct, wholesale through partners, or across orbits | Through service providers, often wholesale | Through the mobile carrier or the phone maker | Through integrators, or a mobile operator's core |

Each cell gives values a buyer will meet in that category; a real service is placed on the axes from its own documents, and one service can sit in two categories.

*Author's table; payload terms from 3GPP, Non-Terrestrial Networks (NTN) overview; values are generic and are sourced case by case in chapters 3 to 11. Checked 2026-11-23.*

Figure 1.2 sets the eight axes against the four buying categories of the Reader's Brief with example values. The values are typical, not exclusive: a category usually takes several values on an axis, and the book's cases show which.

## Four buying categories, read as routes

A buyer arrives with a need, not an axis. Broadband to a fixed or moving terminal, mobile satellite service to a handheld or small terminal, a service direct to a phone, and narrowband IoT to a module are the four routes into this book. They tell a reader which chapter to open first: chapters 2 to 5 for broadband, chapter 6 for mobile satellite service, chapters 8 to 10 for a phone, chapter 11 for IoT, and chapter 7 for a need that spans orbits. They do not classify a service, because one service can sit in two routes: a low orbit mobile satellite operator can sell voice to handhelds and small messages to modules from the same satellites, and a broadband constellation can carry a phone service on separate satellites under the same brand. The axes do the classifying; the routes do the reading.

## Four status fields, each with its proof

The words a buyer most needs are the ones news reports blur. This book records four status fields separately. One system can be in several at once, in different countries and generations.

- **Announced:** a dated statement by a company or agency. Telesat's results release of 29 October 2026 raised the planned Lightspeed constellation from 156 to 225 satellites and said it expected high-latitude commercial service around the end of the first quarter of

2028, an operator's forecast; by the release, no satellite of the Lightspeed constellation was in orbit on that date.

- **Authorized:** an instrument, a jurisdiction, a band and a generation. The FCC's first-generation authorization for Amazon Leo (the service formerly called Project Kuiper, renamed on 13 November 2025) covers 3,232 satellites in the Ka band, with milestones of 1,616 satellites by 30 July 2026 and all 3,232 by 30 July 2029, as FCC order DA 26-553 restates.
- **In orbit:** launched, in orbit and working are three counts. Amazon's own progress page, read on 23 November 2026, says it has launched "nearly 400" satellites across 14 missions; that is a count of launches by the operator, not of working satellites.
- **In service:** country, operator, device and date, with a qualifier. The service of this chapter's opening shows how the field is filled and where it is thin: the United States, T-Mobile with SpaceX's satellites, compatible phones, messages first. Its start date, 23 July 2025, is the carrier's own claim in its release of that day; the newest primary record read, the FCC's order of 12 May 2026, describes the service but does not speak for the book's date. Its status on 23 November 2026 is therefore "not checked", the word this book uses when no source for the date was read.

FIGURE 1.3

**Four status fields, each proved by a different record; "in service" takes a qualifier**

| Field | What proves it | What it does not prove |
|---|---|---|
| Announced | A dated statement by the company or the agency | That money, a license or a satellite exists |
| Authorized | The instrument (order or license number), the jurisdiction, the band and the generation it covers | Authorization in any other country; that a satellite has flown |
| In orbit | Three counts, each with its date and who counted: launched, in orbit, working | That any service is sold; a launch count is not a working count |
| In service | Country, operator, device or terminal, date, and one qualifier: trial, preview, limited commercial, general commercial, intermittent, suspended or retired | Service in another country, on another device, or on another date |

The fields are recorded separately and never added; one system can hold several at once in different countries and generations.

*Author's table based on the book's status rules; the qualifiers are the book's own words. Checked 2026-11-23.*

Figure 1.3 lists what proves each field, and the seven qualifiers that "in service" takes. The four fields are never added together, and "in service" is never inferred from the other three: a satellite can be working in orbit for months before a service is sold through it, and a service can be suspended while every satellite works.

## The counting rule, worked once

A count is printed with the number, the date, who counted, and what was counted. China's Guowang constellation shows why all four matter. In October 2026 an independent tracker, KeepTrack, listed 222 Guowang satellites in the public catalog and estimated about 258 when launches whose objects were not yet sorted are included. For Qianfan, the other Chinese constellation, the same tracker listed 251 objects, of which it classified 233 as working; that is the tracker's own classification, not the operator's. Neither number is the

operator's; neither is wrong; they count different things. A text that prints "about 250 satellites" for either system, with no date and no counter, has thrown away what a buyer needs to judge it.

The same care applies to an operator's own number. "Nearly 400" on Amazon's page is a launch count. A count of working satellites from the same operator would be a different field, and a subscriber count is a third kind of number whose definition differs from company to company. Subscriber counts of two operators are not compared in this book unless both define a subscriber the same way.

## Three kinds of control, and how a case gets a section

Who controls a service has three answers, and the table in this chapter's first section already used them. **Technical command access** is holding the credentials that command the satellites, the network and the terminals. **Contractual control** is what a carrier, reseller or integrator can do to the service under contract: suspend an account, change a plan, stop supporting a terminal. **Lawful authority** is what a licensing state, a gateway's host state and the user's state can compel or forbid. A state with lawful authority over an operator does not thereby hold its command credentials; it holds power over the party that does.

The book's cases are chosen by a test that can be checked, applied to companies and state programs alike. A case gets a section when three conditions hold: **decision relevance** (it answers a buyer's question the chapter asks), **public evidence** (its architecture and status can be stated from a primary source: its own terms, a regulator's record or a securities filing) and a **distinct contribution** (an architecture, ownership model or delivery model no other case in the chapter shows). Fleet size and news volume are not in the test; two labeled exceptions are (the only case of its region; trade press dating or describing a case whose own page could not be read). An announcement alone makes a table row, never a section. Appendix B lists every case, its test and the cases sought and not sourced.

## Three verdicts, and the operator's word as the operator's word

The link, the service and the business are judged separately. A capacity rating is a claim about the link, not about the throughput a customer in a busy cell receives. A service in general commercial service in one country says nothing about the next country. A company's revenue growth says nothing about whether a user's messages arrive. When a source is the operator, the book prints the number as an operator claim and says whose claim it is. That is not suspicion; it is the only class the evidence supports until someone independent checks it.

The blank page 1 of the series form, in Appendix A, is the place to do all of this at once. Fields 1 to 3 hold the requirement, the ends and the orbit; field 4 the band and whose license; field 6 the owners of each end, which this chapter's table expands; field 7 the trust;

field 10 the numbers, each with its class. A reader who fills those fields for a service in front of them has already done most of what this book asks.

THE SYSTEM'S FAILURE

A schedule can fail before a service exists. The FCC authorized Amazon's first-generation constellation of 3,232 satellites with an interim milestone of 1,616 satellites by 30 July 2026. In January 2026, when it had launched 180 satellites, Amazon asked for a 24 month extension or a waiver, and represented that it would not meet the milestone; it estimated about 700 by the deadline. On 5 June 2026 the FCC's Space Bureau granted a conditional waiver in order DA 26-553: the authorization was not cut back to the satellites in orbit on the milestone date, but satellites not deployed and operating by 30 July 2026 lose their processing-round priority until half the system is deployed or until 30 March 2028, whichever comes first, and the surety bond is forfeited if the milestone is missed. Amazon's own page counted "nearly 400" launched in November 2026. What failed was the deployment schedule, by the operator's own account because of launch delays; the source says nothing about the link or about a service, and none had been sold generally. This is a US case under US rules; the law of milestones is covered in depth later in this series.

SECURITY NOTE

**Who can interfere or command.** Six parts are six points to attack or to switch off: the terminal, the satellites and their command links, the gateways, the core, the licenses and the company. For a generic service, the five questions are: who is authorized to use it and to command it; who can intercept its traffic; who can interfere with its radio; how a user or a station is authenticated; and how service is recovered. "Who can command" has three answers, technical, contractual and lawful, and a state's lawful authority is not possession of command credentials, though it can compel the party that holds them. **How it is seen.** A user sees an outage, and terminal logs or the user's own measurements can narrow it down; the operator's monitoring and, for radio interference, a regulator's geolocation are usually needed to say which part failed and why, and the sources read show neither for the operators in this book. **How it is recovered.** By whoever holds the failed part: the operator for the satellites and the core, the gateway's owner for a site, the license holder for a spectrum dispute, the user or a reseller for a terminal that must be replaced by hand, and, where the design has them, failover to another gateway or network. A buyer who cannot name those parties cannot plan a recovery.

**Monday rule:** for any service in front of you, write the six parts and, beside each, the owner, the state with lawful authority and who holds command access, before reading a coverage map.

CHAPTER TWO

# Shells and Coverage: How Many Satellites, and Where




On 27 April 2021 the FCC released an order that lowered most of SpaceX's authorized first-generation broadband satellites from the 1,100 to 1,300 km range to 540 to 570 km. With one shell already authorized at 550 km, the authorized system of 4,408 satellites was arranged in shells inclined at 53, 53.2, 70 and 97.6 degrees; an authorization says where satellites may fly, not how many are there. The order records the reasons the Commission accepted: lower altitude, a lower minimum elevation for user terminals, and high-inclination satellites to improve service at high latitudes. Every number in that sentence is a design choice a buyer can read and ask about. This chapter explains why one design needs tens of satellites, another thousands, and a third only three, and what the reader should ask instead of "how many".

## What the first book gave

The first book of this series, *The Bit's Path*, works out what an orbit does to a link: the higher the satellite, the longer each pass and the larger the area it sees, but the longer the signal travels and the weaker it arrives; a satellite below 2,000 km crosses the sky in minutes and its signal shifts in frequency as it moves; a geostationary satellite stays still in the sky and costs about a quarter second one way, half a second for a reply. This chapter takes those results as given and asks the next question: how many satellites, arranged how, does a service need?

## From one satellite to a shell

A **shell** is a set of satellites at one altitude and one inclination (the angle between the orbit and the equator). In the regular arrangement that the FCC's records describe, the satellites fly in several **planes**, orbits that share the inclination but are turned from one another around the Earth's axis, with the same number of satellites in each plane, spaced evenly

along it. A real shell can depart from that pattern while it is being filled, or when spares are added. How satellites in neighboring planes are offset from each other is called the **phasing**. Altitude, inclination, number of planes, satellites per plane and phasing together describe a shell; constellation designers call such an arrangement a Walker pattern, and *The Bit's Path* gives the geometry.

The FCC's records give two shells in exactly those terms. In the 2021 order, the core shell of SpaceX's first-generation system is 1,584 satellites at 550 km, inclined 53 degrees, in 72 planes of 22. In its 2017 order granting OneWeb access to the US market, the FCC describes 720 satellites "evenly distributed in 18 near-polar orbital planes, at an approximate altitude of 1200 kilometers", which is 40 to a plane. Both are authorizations, a status field with its instrument and date; neither is a count of satellites in orbit today.

A satellite can serve a user only when it is high enough above the user's horizon. The lowest usable angle is the **minimum elevation**, or elevation mask: below it, the path through the air is long, buildings and trees block it, and the terminal's antenna loses gain. The 2021 order lets SpaceX use user terminal elevations as low as 25 degrees. The mask sets the **footprint**, the area on the ground from which a satellite is above the mask. At 550 km with a 25 degree mask, one satellite's footprint has a radius of about 940 km and covers about 0.54 percent of the Earth's surface. At 1,200 km with the same mask, the radius is about 1,700 km and the share about 1.8 percent, a little over three times the area (calculated on a spherical Earth, R = 6,378 km).

That is the first reason one design needs thousands of satellites and another hundreds: a lower satellite sees less. The second reason has nothing to do with seeing. **Coverage** asks whether some satellite is above the mask for a user at a given place and time. **Capacity** asks how much traffic the satellites over that place can carry at the busy hour. A shell can give continuous coverage with far fewer satellites than it needs to carry a city's evening traffic. The two numbers are different, and a satellite count answers neither on its own.

## Latitude is a calculation

A satellite in an orbit inclined at 53 degrees passes over the ground only between 53 degrees north and 53 degrees south. That is a statement about its ground track, not about who it serves. A user farther north still sees satellites whose footprints reach past the track: with the 550 km shell and a 25 degree mask, the footprint reaches about 8.5 degrees of latitude beyond the track, so users up to about 61.5 degrees can see a satellite at times, with fewer satellites in view and for less of the day as the latitude rises toward that limit. Whether a given high-latitude site is served continuously depends on altitude, inclination, mask and phasing together, and has to be computed for that site.

Satellites also do not spread evenly over the latitudes they cover. A satellite spends more of each orbit near the top and bottom of its track, where it turns, than near the equator, where it crosses quickly. Take the **subsatellite point**, the point on the ground directly below a satellite. Per unit of area, the density of subsatellite points in a shell inclined at 53 degrees is about 1.3 times its equatorial value at 30 degrees of latitude, about 2.2 times at 45 degrees and about 3.5 times at 50 degrees, rising sharply just below 53 (calculated; figure 2.1 gives the formula). For a near-polar shell the crowding moves to the poles: at an inclination of 88 degrees the density is about 1.4 times the equatorial value at 45 degrees and about 2.9 times at 70 degrees.

FIGURE 2.1

### Where two reference shells put their satellites: crowding near the inclination, reach past it

| Latitude | Shell A density | Shell A: a satellite above the mask at times | Shell B density | Shell B: above the mask at times |
|---|---|---|---|---|
| 0 degrees | 1.0 | yes | 1.0 | yes |
| 30 degrees | 1.3 | yes | 1.2 | yes |
| 45 degrees | 2.2 | yes | 1.4 | yes |
| 50 degrees | 3.5 | yes | 1.6 | yes |
| 52 degrees | 6.2 | yes | 1.6 | yes |
| 60 degrees | 0 (above the track) | yes, from footprints only | 2.0 | yes |
| 70 degrees | 0 (above the track) | no | 2.9 | yes |
| 80 degrees | 0 (above the track) | no | 5.9 | yes |

Relative density of satellite ground positions per unit area (equator = 1), rho = sin i / sqrt(sin squared i minus sin squared latitude) below the inclination i, and whether a satellite can be above a 25 degree mask at some times; shell A is 550 km at 53 degrees, shell B 1,200 km at 88 degrees.

*Calculated by the author for two reference shells (spherical Earth, R = 6,378 km; circular orbits; uniform phasing assumed); reach = the inclination (or 180 degrees minus it, for a retrograde shell) plus the footprint's central angle, 8.5 degrees for shell A and 15.3 degrees for shell B at 25 degrees, capped at 90: shell B reaches the poles. Reference shells, not any operator's fleet.*

Three consequences follow, each one a question for a supplier rather than a conclusion. A shell inclined near 50 degrees concentrates satellites over the mid-latitudes and thins out toward its limit. A near-polar shell spends many of its satellites over the high latitudes and the oceans. And a system that wants both can fly both, as SpaceX's 2021 order shows: shells at 53 and 53.2 degrees for the mid-latitudes, and shells at 70 and 97.6 degrees that the FCC notes are "uniquely able to provide improved service to higher latitude regions", with gateway elevation masks as low as five degrees for gateways above 62 degrees latitude. "Inclined" alone therefore says little about the poles: the 550 km shell at 53 degrees reaches no farther than about 61.5 degrees at a 25 degree mask, while a near-polar shell reaches them. A sentence about polar coverage names the shell, the mask and the latitude.

## Capacity is per area

A satellite divides its footprint into **beams**, each a smaller spot on the ground served on a set of frequencies. Beams that are far enough apart, or that use opposite polarizations, can use the same frequencies at the same time; that **frequency reuse** is how one satellite carries more traffic than a single wide beam could with the same spectrum. What a user receives is a share of the capacity of the beam over the user's cell, scheduled among the users active there by the operator's traffic rules, plan priorities and the terminals' signal quality.

So the number that decides a broadband service is capacity per area at the busy hour, and it varies with latitude, with the beams a supplier points at the cell, and with the number of other users there. The density figures above show one reason it can vary: a shell inclined at 53 degrees passes more satellites over a site at 50 degrees latitude than over one at the equator, which gives the operator more satellites it can assign to that area if its design does so. Density is not delivered capacity; beams, gateways, interference limits and demand decide how much of it reaches a user. A rated capacity per satellite, which chapter 3 quotes for one operator's newest satellites, is an operator claim about the link; it is not what a customer in a busy cell receives. Chapter 4 turns that difference into questions on contention and fair use.

## Three reference geometries

Three altitudes cover most of the services in this book. The delays below are from propagation alone, at the speed of light, before any processing, queuing or ground network is added; they are references, not measurements of a service.

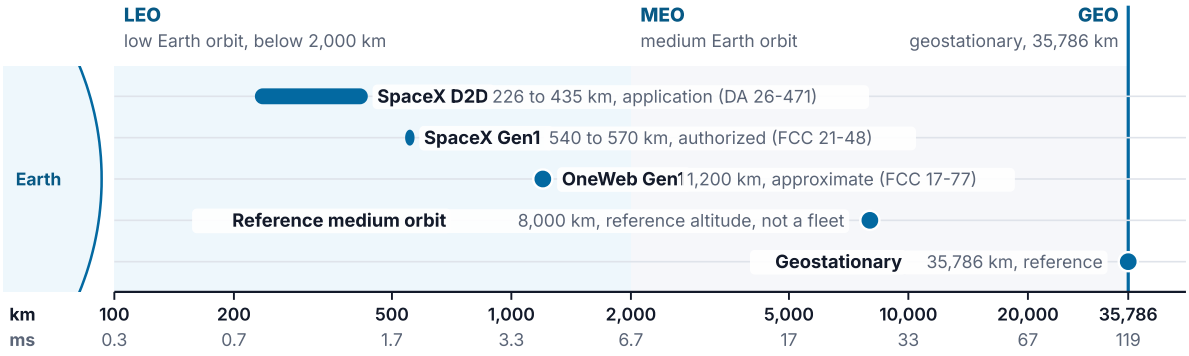
**Three reference geometries (calculated; spherical Earth, R = 6,378 km)**

| Altitude | One leg, satellite overhead | One leg, at the mask | Share of the Earth one satellite sees |
|---|---|---|---|
| 550 km, low orbit | about 1.8 ms | about 3.8 ms at 25 degrees | about 0.54 percent at 25 degrees |
| 8,000 km, medium orbit | about 27 ms | about 39 ms at 10 degrees | about 21 percent at 10 degrees |
| 35,786 km, geostationary | about 119 ms | about 135 ms at 10 degrees | about 42 percent at the horizon; about 34 percent at 10 degrees |

For a geostationary circuit, up and down once, the propagation alone takes about 239 ms when both ends are under the satellite and about 278 ms when both are at the horizon; a reply, which crosses that circuit twice, takes at least about 477 ms before any processing. That is the "about a quarter second one way, half a second for a reply" of *The Bit's Path*. A low orbit leg is two orders of magnitude shorter, but a low orbit path may cross several satellites and a distant gateway before it reaches the internet, so its end-to-end delay depends on routing and on where the traffic lands, which chapters 3 and 4 take up. The medium orbit row is a reference altitude; the altitude of the medium orbit fleet in service is stated in chapter 5 from its operator.

FIGURE 2.2

## The shells of this chapter by altitude: each step up buys area and costs light time




km: altitude above the surface (log scale). ms: light time straight up, one way (altitude divided by the speed of light).

SpaceX's pending direct to device application (D2D, 226 to 435 km) and its authorized first-generation shells (Gen1, 540 to 570 km), OneWeb's market access grant near 1,200 km, and two reference altitudes; the second axis row is the one-way light time straight up, calculated from the altitude.

*FCC 21-48 (released 2021-04-27), paragraph 4; FCC 17-77 (released 2017-06-23), paragraph 2; FCC DA 26-471 (released 2026-05-12). Light time calculated. Checked 2026-11-23.*

Figure 2.2 places the shells of this chapter by altitude on a log scale, with the one-way light time straight up under each. Three geostationary satellites spaced evenly around the equator put one above the horizon from every longitude up to about 72 degrees of latitude; above a 10 degree mask, at the longitudes midway between two satellites, only up to about 50 degrees (calculated). That is the "only three" of this chapter's question, with its limits, and its price is the delay in the table.

### Lower still

The FCC's order of 12 May 2026 on EchoStar's spectrum (DA 26-471) records an application by SpaceX, still pending then, for a direct to device system of "up to 15,000 satellites operating at altitudes as low as 226 kilometers and as high as 435 kilometers". That is an application, a status field below authorized.

What a very low orbit buys can be calculated. At the same frequency, a satellite straight up at 226 km has about 7.7 dB less free space path loss than one at 550 km, because the loss grows with the square of the distance; at a 25 degree mask the difference is about 7.1 dB, because slant ranges shrink less than altitudes (calculated, propagation loss only). For a satellite with the same antenna, a lower orbit also gives a smaller spot on the ground, which helps capacity per area. What it costs follows from the same geometry: at 226 km with a 25 degree mask a

footprint covers about 0.12 percent of the Earth, under a quarter of the area at 550 km, so continuous coverage needs several times as many satellites. Air drag is also stronger at lower altitude, so satellites there must carry more propulsion or be replaced sooner; this book read no operator figure for that lifetime and prints none.

## Replacement and disposal are part of the design

A low orbit fleet is not built once. It is a production line that keeps running, because satellites wear out, are replaced by newer generations, and must be removed. Eutelsat said on 7 August 2026 that it would deploy 229 more satellites, on top of 440 first-generation satellites already procured, to extend the OneWeb constellation through 2034; trade press reported on 30 October 2026 that 669 OneWeb refresh satellites were on order. For a buyer, the order book is a fact of the service: it says whether the operator intends to keep the fleet flying through the term of a contract.

Removal is a rule as well as a cost. Under the FCC's 2022 order on orbital debris (FCC 22-74), effective 9 September 2024 with compliance required from 29 September 2024, a satellite licensed by the FCC or granted US market access that operates below 2,000 km and plans disposal by uncontrolled reentry must be removed as soon as practicable and no later than five years after its mission ends, a rule that also covers satellites passing through that region; satellites already in orbit when the rule was adopted are exempt, and satellites authorized but not yet launched had a two-year transition. That rule shapes how low an operator flies and how it plans a satellite's last months. It is a US rule; the full treatment of debris law is covered in depth later in this series.

THE TRADE-OFF

Two operators answered "how many satellites" in opposite directions, and the records show what each bought. Eutelsat's OneWeb constellation was authorized for the US market in 2017 as 720 satellites in 18 near-polar planes near 1,200 km (FCC 17-77); Eutelsat described its low orbit constellation as "more than 600 satellites" on 7 August 2026 (operator claim). SpaceX's first-generation system was authorized with its core shell at 550 km and 53 degrees (FCC 21-48), and SpaceX's quarterly report for the period to 30 September 2026, filed on 22 October 2026, states over 11,100 broadband and mobile satellites in low orbit, across shells and generations (operator claim). The higher shell sees about three times the area per satellite at the same mask and covers the poles with its near-polar planes; it pays with longer legs (about 4 ms straight up against about 1.8 ms) and a larger area sharing each satellite's capacity. The lower shells see less and need many more satellites for the same coverage, and in return give shorter legs, and capacity concentrated where the satellites crowd. The two counts are not of the same kind: both are the operators' own, made on different dates with different scopes, one a description of a constellation and the other a total across shells, generations and a mobile service, and both can include satellites kept for replacement. Neither number is better on its own, and the two operators sell different services to different buyers (chapter 3 sets out their delivery models). The lesson the records support is narrow: a satellite count follows from an altitude, a mask, a capacity target and a replacement plan, and is read only with them.

SECURITY NOTE

**Who can interfere or command.** Geometry changes who can intercept and who can interfere, under conditions. A small beam from a low satellite illuminates a smaller area than a wide geostationary beam, so fewer places on the ground lie inside it; but the beam moves, and many satellites pass over any site, so a jammer on the ground can find satellites in view at most times. A geostationary satellite sits still, so its receive beam and any uplink into it stay in one geometry, which helps an interferer aim and helps an operator locate one. None of this makes one geometry "more secure"; each condition holds only for the beam sizes, powers and filters of a given system, which operators rarely publish. Command access is held by the operator's control center for every shell, whatever its altitude. **How it is seen.** By the operator's monitoring of each beam; a user sees only lower throughput or an outage. **How it is recovered.** In a large shell, by moving traffic to other satellites and beams where the design allows it; for a geostationary satellite, by the operator's interference procedures and the regulator's enforcement.

**Monday rule:** ask for coverage at your latitude and elevation mask, and for capacity in your cell at your busy hour, not for the number of satellites.

CHAPTER THREE

# Broadband from Low Orbit: Two Reference Patterns and Their Hybrids




On 15 November 2026 a rocket carrying 40 Amazon Leo satellites suffered what Amazon's own progress page calls an anomaly, and the payload was lost. The same page, updated on 23 November 2026, counts "nearly 400" satellites launched across 14 missions and lists the next mission, 36 satellites, as targeted for 24 November. A buyer reading that page learns two things at once: a low orbit broadband system is built one launch at a time, and its service date depends on those launches. This chapter asks what the two reference ways to build broadband from low orbit are, how real systems mix them, and who has built which, so that a buyer can place any offer before comparing prices.

## Pattern one: transparent, with gateways

In the first pattern the satellite repeats. It receives the user terminal's signal, shifts its frequency, amplifies it and sends it down to a gateway, without recovering the bits. The standards body for mobile networks, 3GPP, calls such a payload transparent: the satellite acts like a remote radio head, and the base station functions stay on the ground, reached through the gateway at the end of the feeder link. Chapter 1 gives the full definitions; the first book of this series, *The Bit's Path*, works the radio behind them.

The consequence is geometric. In this pattern, with no links between satellites and nothing stored on board, a satellite can serve a user only while it also sees a gateway, so the user beam and a feeder beam must be in view of the same satellite at the same time, each above its minimum elevation. Service therefore follows the gateway map. Over an ocean, far from any coast that hosts a gateway, a satellite in this pattern carries nothing, however many satellites fly overhead.

The first generation of OneWeb is the case. The FCC's order of June 2017 granting the system access to the US market (FCC 17-77) describes 720 satellites "evenly distributed in 18 near-polar orbital planes" at an approximate altitude of 1,200 km. The order lists the downlink bands, 10.7 to 12.7, 17.8 to 18.6 and 18.8 to 19.3 GHz, and the uplink bands, 14.0 to

14.5, 27.5 to 29.1 and 29.5 to 30.0 GHz, and it describes no links between satellites. The ground was planned to match: the operator anticipated at least four gateway sites in the United States and about 50 or more worldwide, as the order records from its petition, and each gateway needs its own earth station license, which the order does not grant. At 1,200 km the two radio legs take 8.0 ms straight up and 14.7 ms when both legs are at 25 degrees elevation, before any ground network or processing. The elevation limit the operator uses was not in the sources read; 25 degrees is shown so that the figure can be set beside the other pattern's.

The pattern has a clear division of labor. The satellites stay simple, and the work of the network sits on the ground, where it can be upgraded and where the operator can add capacity without launching. The price is a gateway in reach of every satellite that serves users, in every country where the operator needs one, under that country's license.

### Pattern two: crosslinked, with routing in orbit

In the second pattern traffic can cross several satellites before it comes down. A satellite above a user with no gateway in view passes the traffic along links between satellites to one that does see a gateway. The landing point stops being a consequence of geometry and becomes a choice.

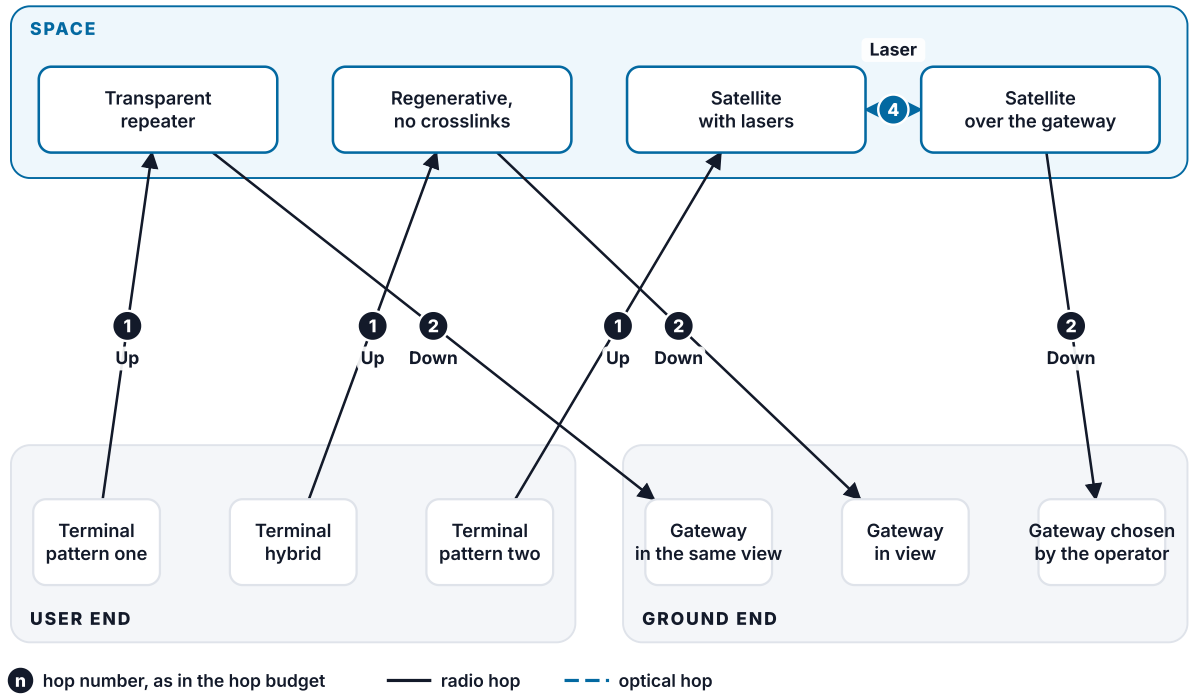
The case is SpaceX's Starlink, because it is the operator in the sources read that states its crosslinks in a primary document. Its registration statement, filed with the SEC on 20 May 2026, says that as of 31 March 2026 the constellation "already incorporated over 23,000 inter-satellite lasers that create a dynamic mesh network in space, enabling traffic to route through orbit rather than relying solely on terrestrial backhaul infrastructure". That is an operator claim; the filing gives no rate per laser link, and this book prints none. A measurement study of the network, published at the ACM Web Conference in 2024, describes the path as an "extended bent-pipe": up from the terminal, possibly across several satellites by laser, down at a ground station that need not be near the user, then to a point of presence where the traffic enters the internet. The same study notes that not all of the operator's satellites carried laser links when it was written, and it observed swings in delay and rate every 15 seconds, which its authors attribute to a reconfiguration of the satellite links across the network. The first-generation shells were authorized at 540 to 570 km in April 2021 (FCC 21-48), the core shell at 550 km; two legs through one satellite at 550 km take 3.7 ms straight up and 7.5 ms at 25 degrees, as *The Bit's Path* computes.

Four things crosslinks do not change by themselves, and a buyer should not read them into the word.

- **Crosslinks are not regeneration.** Routing between satellites needs some processing on board, but whether the user link is regenerated, and how, is the operator's design and is not stated in the sources read.
- **Crosslinks do not remove gateways.** Every bit still lands somewhere. They reduce the number of gateways that coverage requires, especially over water, and move the decision about where traffic lands from the map to the operator.
- **Crosslinks are not sovereignty.** Traffic that can land anywhere lands where the operator routes it, under the law of that place; chapter 4 follows it to the point of presence.
- **Crosslinks are not security.** A path through space avoids some ground sites and adds a routing system that only the operator controls; neither fact makes the traffic private.

FIGURE 3.1

## Two reference patterns and one hybrid: where the satellite repeats, where it routes, and where the traffic lands




Pattern one repeats the terminal's signal to a gateway that the same satellite sees; pattern two carries traffic between satellites by laser to a gateway the operator chooses; the hybrid regenerates on board without crosslinks, so it still needs a gateway in view.

*Author's diagram based on FCC 17-77 (2017) for pattern one as authorized for OneWeb; SpaceX, Form S-1 (2026-05-20), and Mohan and others, ACM Web Conference 2024, for pattern two; 3GPP NTN overview for the payload terms. Checked 2026-11-23.*

Figure 3.1 draws both patterns and one hybrid on the canvas of chapter 1. The hop numbers are the series convention; no hop of this chapter has a published budget, so none has a verdict.

## Hybrids and generations

The two patterns are references, not boxes. A satellite can carry crosslinks; it must recover the bits that cross them in order to route them, but that alone does not show that it demodulates and decodes the user link, whose waveform remains the operator's own design, not described in the sources read. Another satellite can regenerate the user link on board and have no crosslinks, so that it still needs a gateway in view, as the third branch of figure 3.1 shows. Operators also change pattern between generations. The OneWeb order of 2017 describes no links between satellites; Eutelsat's statement of 7 August 2026 about the European IRIS$^2$ program describes optical links between satellites for that future constellation. The pattern is a property of a generation and must be dated like a count.

Capacity is stated per satellite, and the statement is a design rating. SpaceX's registration statement describes its third version of broadband satellites as "designed to offer one Tbps of downlink capacity per satellite"; trade press reported that 26 of them were deployed from Starship on 28 September 2026 and gave an uplink rating of 160 Gbit/s. A rating is the operator's figure for one satellite across all its beams, under conditions the filing does not state. It is not what a customer in one busy cell receives, which chapter 2 explains and chapter 4 turns into questions on contention.

## The systems on the book's date, by status field

Table 3.2 lists the low orbit broadband systems with what each has in orbit and what the sources read say about service, each count with its date and its counter; announcements and authorizations are in the text, and Appendix D repeats each row with its source. Space in this chapter follows service history and architectural difference; a system with only an announcement is a table row.

FIGURE 3.2

## Low orbit broadband systems by status field on 23 November 2026, each count with its date and who counted

| System (state) | Owner | Pattern and delivery | In orbit or launched (date, who counted, what) | Service as the sources read state it (qualifier, scope), or the status reached |
|---|---|---|---|---|
| Starlink (United States) | SpaceX | Crosslinked by laser; sold direct to consumers, and to enterprises and governments | Over 11,100 broadband and mobile satellites (10-Q to 2026-09-30, filed 2026-10-22; operator) | General commercial in 174 countries, territories and other markets (same filing): a fleet-level claim; a given configuration not checked |
| Eutelsat OneWeb (France, United Kingdom) | Eutelsat Group; UK special share | Transparent with gateways in the 2017 authorization; sold through distribution partners (trade press, 2022) | More than 600 (2026-08-07; operator) | Sold through partners, with revenue reported (trade press, 2026-10-30); no country, device or partner record read: not checked |
| Amazon Leo (United States) | Amazon | Pattern not stated in a primary source read; enterprise terminals first | Nearly 400 launched over 14 missions, a launch count (page updated 2026-11-23; operator) | Enterprise preview announced from 2025-12-01 (GSMA, reporting Amazon); no dated general commercial service found |
| Guowang (China) | China Satellite Network Group (state) | Not verified | 222 cataloged (October 2026; independent tracker) | No service record read |

| System (state) | Owner | Pattern and delivery | In orbit or launched (date, who counted, what) | Service as the sources read state it (qualifier, scope), or the status reached |
|---|---|---|---|---|
| Qianfan (China) | Shanghai Spacecom | Not verified | 233 working of 251 objects (October 2026; independent tracker) | No service record read |
| Rassvet (Russia) | Bureau 1440 | Not verified | About 31 (after 2026-07-19; specialist press) | No service record read |
| Telesat Lightspeed (Canada) | Telesat | Not verified | 0 in orbit (2026-10-29; operator) | Announced: high-latitude service around the end of Q1 2028 |
| IRIS2, low orbit part (European Union) | EU program; Eutelsat leads this part | Not verified | None found in the sources read; first launches stated from 2029 (2026-08-07; operator) | Announced: commercial Ku constellation by mid 2032 |

This table shows what each system has in orbit and what the sources read say about service; announced and authorized records are in the text, a count is the counter's, on the counter's date, and Appendix D repeats each row with its source.

*Source: SpaceX, Form 10-Q to 2026-09-30; Eutelsat release, 2026-08-07; FCC 17-77; Via Satellite (trade press), 2022-03-24; Amazon progress page, read 2026-11-23; GSMA, 2025-12-01; KeepTrack, October 2026; RussianSpaceWeb (specialist press), 2026-07; Telesat results, 2026-10-29. Read 2026-11-22 and 2026-11-23.*

- **Selling service, by the operators' own reports.** Starlink: SpaceX's quarterly report for the period to 30 September 2026, filed on 22 October 2026, states over 11,100 broadband and mobile satellites in low orbit and service in 174 countries, territories and other markets; its key business metrics give 13.6 million consumer subscribers on 30 September 2026, by the company's own definition of a subscriber. Eutelsat OneWeb: Eutelsat stated more than 600 satellites in its low orbit constellation on 7 August 2026; the trade press reported low orbit revenue up 30 percent year on year in the quarter to September 2026, and 669 replacement satellites on order. Both counts are the operators'.

They count different things and are not compared here. Neither record names a country, a device and a date for an offer a buyer could order, so the in-service field for a particular configuration still has to be filled from the supplier's own terms.

- **In orbit, before general service.** Amazon Leo, renamed from Project Kuiper on 13 November 2025: "nearly 400" satellites launched by its own page, and an enterprise preview announced to begin on 1 December 2025, as the GSMA reported Amazon's announcement. No dated start of general commercial service was found. Its authorization and the waived milestone are chapter 1's case.
- **In orbit, service not established from a primary record.** China's Guowang and Qianfan, with 222 cataloged and 233 working satellites respectively in October 2026 by the count of one independent tracker, KeepTrack, whose figures differ from other trackers by tens of satellites; and Russia's Rassvet, by Bureau 1440, with about 31 production satellites after a launch on 19 July 2026, as specialist press reported. No operator's or regulator's record of service status was read for any of the three, so their bands, terminals and service dates are not printed.
- **Announced or contracted.** Telesat Lightspeed, with no satellite of the constellation in orbit on 29 October 2026 by the operator's own release, a plan raised from 156 to 225 satellites and high-latitude service expected around the end of the first quarter of 2028; and the low orbit part of IRIS$^2$, which Eutelsat leads, with first launches stated from 2029 and no satellite of it found in the sources read (chapter 7 treats the program).

## Two delivery models

The two operators that report selling service also sell in two different ways, and the difference reaches the buyer before any radio question does.

**Sold direct.** SpaceX's registration statement describes consumer revenue as "monthly subscription fees based on geographic market and download speed", "plus typically a one-time sale of a kit", and enterprise revenue as contracts built from "subscriptions, data consumption, and capacity". The kit, terminal and accessories, comes from the operator. The buyer has one counterparty for the terminal, the service and the support, and accepts that counterparty's standard terms; an enterprise contract may change the terms, which is a question for the contract.

**Sold wholesale through partners.** OneWeb's service reaches its users through distribution partners. In March 2022 the trade press reported that OneWeb had added Eutelsat, Kymeta and Speedcast as distribution partners, for maritime, aviation, enterprise, carrier and government customers among others, with Kymeta bundling the service with its own terminals. The buyer then signs with a partner, which buys capacity from the operator

and often supplies a terminal from a third maker. There are two contracts in the chain, the buyer's with the partner and the partner's with the operator, and only the first is visible to the buyer.

Neither model is better without an objective. Direct sale gives one point of contact and one company's terms. Wholesale gives the buyer a partner that can combine services, carry the support and take the contract into a local jurisdiction, at the price of a second company between the buyer and the satellites. What the buyer must establish in each case is who it can call, who replaces a terminal, and what happens to the service if either contract ends.

## The two worked pages, side by side

The two service pages at the end of this chapter, LL-2026-04 and LL-2026-05, take one route each. The first is the crosslinked route as *The Bit's Path* prints it, dated by its sources from 2018 to 2024: a field office on a consumer-style service, with round trips and rates measured by named researchers across many sites, a historical page rather than a plan a buyer can order today. The second is new to this book: a fixed enterprise site on the transparent pattern, bought through a distribution partner, with every number dated by its source. It is written at the level of the architecture: no partner's offer for a named country was read, so the partner, the country, the terminal model and the plan are left for the buyer to fill. Neither page has a radio budget, because the sources read give, for neither configuration, the waveform, the transmit power and the antenna figures that a budget needs. Fields 4 to 7, the band, the capacity, the owners and the trust, are what chapter 4 fills from the ground up.

## What a buyer can measure

No service in this chapter has been measured for this book. The step that would measure one is simple to state. It requires a terminal on a paid plan at a known site; a server under the buyer's control at a known place on the internet; light probes every second or few seconds for round trip and loss, each kept with its time and summarized each minute (an interruption shorter than the interval can fall between probes, so the interval is stated with the results); short throughput tests both ways at set times, in the busy hour and outside it, kept brief so that they do not load the link or use up an allowance; all of it kept for at least a month; and a record of every outage with its start, its end and what the terminal reported. Before the month starts, the buyer writes down what counts as a failed minute and which limits must hold together; the rate is known only for minutes with a throughput test, and the report says so. The log is then read against field 5 and field 8 of the page: does the sustained rate in the busy hour meet the requirement, and does the round trip stay under its limit? Third-party results, such as the 2024 study cited above, are used only with their date, place, method and authors.

### THE SYSTEM'S FAILURE

The lead case is a launch. Amazon's progress page records that on 15 November 2026 the Vulcan rocket carrying 40 Amazon Leo satellites "experienced an anomaly" and "the payload was lost". The wording follows Amazon's page and its date; no statement by the launch provider is cited. What failed was the delivery to orbit; the record cited assesses nothing about the satellites' design, and the lost satellites had not been commissioned, and no dated start of general commercial service for Amazon Leo was found. What the loss costs a buyer is time. An operator that buys its launches carries a schedule that depends on other companies' rockets; chapter 13 returns to that supply risk.

A shorter case shows a company failure in this market. OneWeb filed for chapter 11 protection on 27 March 2020 in the US Bankruptcy Court for the Southern District of New York, after its attempts to raise new capital were interrupted by the Covid-19 pandemic, as its counsel in the case described it; the plan was confirmed on 2 October 2020, and the business was sold to a consortium led by the UK government and Bharti Global, each of which the UK government said would invest 500 million dollars. The satellites already in orbit kept flying. What failed was the financing, and the system that serves customers today has different owners from the one that was licensed in 2017.

### SECURITY NOTE

**Who can interfere or command.** On the crosslinked consumer service, users are accounts tied to terminals, and the operator alone holds technical command of the satellites, the routing between them and the terminals, which it updates over the air, as its registration statement describes. On the wholesale service, the partner authorizes its own customers and holds the account, while the operator commands the satellites and the gateways; the partner's contractual control sits between the two. Lawful authority adds a layer: when OneWeb's combination with Eutelsat was announced in July 2022, the UK government stated that it would keep its special share and national security rights, including over the security standards of the network. A special share gives a state a shareholder's say over the company. That is a form of control over the owner, separate from the licensing powers this book calls lawful authority, and it is not command access. Who can intercept or jam the user link is not described in the official sources read, so no case is printed here. **How it is seen.** The operator sees its network; the buyer sees only its own terminal and whatever the partner passes on. Keep your own record of loss, round trip and throughput each minute, and ask the operator or partner, in writing, how it notifies an incident. **How it is recovered.** Recovery on both services runs through the operator's own systems, often by software update, which is also a dependency: the party that can repair every terminal at once can also stop them at once. Encrypt end to end, and keep a second path through another operator or the ground network.

**LINK LEDGER · LL-2026-04 · SERVICE LEDGER**

2021 to 2023 (historical)

System: Low orbit broadband: terminal, satellite, ground station, PoP (one operator, many users' sites)

**Status on the book's date: not checked** | **Class: service only**

| | |
|---|---|
| **1 Requirement** | Illustrative: a field office needs 25 Mbit/s down, 3 Mbit/s up and a reply under 100 ms in the busy hour, 99 percent of each month. |
| **2 Ends and path** | A flat phased array terminal at the site; the internet beyond the operator's point of presence (PoP).<br>**Path:** Terminal, satellite, ground station, PoP; laser crosslinks where one satellite does not see both ends. |
| **3 Orbit and time** | Shells at 540 to 570 km; terminals and gateways at 25 degrees elevation or more, polar gateways down to 5 degrees (filed and authorized, 2021).<br>**Time:** 3.7 to 7.5 ms one way over two legs through one satellite at 550 km (calculated); 36 to 48 ms round trip to the PoP, median about 40 ms (measured); the rest (ground, crosslinks, processing, queueing) is not separated in the source. |
| **4 Band and permission** | **User link.** 14.0 to 14.5 GHz up, within 10.7 to 12.7 GHz down; FCC 18-38 (2018), United States<br>**Ground station links.** Ka band ranges in the same grant, not tied to a hop in the text read |
| **5 Capacity** | **Up.** About 4 to 12 Mbit/s (75th percentile of public speed tests, 2021 on; published 2024).<br>**Down.** About 50 to 100 Mbit/s (same).<br>Shared: a test is one user at one moment; under load, round trips grew 2 to 4 times. |
| **6 Who owns each end** | **Space segment.** SpaceX, the licensee<br>**Ground segment.** Its ground stations and PoPs; sites not checked<br>**Customer relationship.** The operator or a reseller<br>**The exit.** Not checked: a contract question |
| **7 Trust** | The operator commands the satellites and updates the terminal; no customer keys are described. Traffic comes down at a ground station and leaves at the PoP, each under its country's law. Link encryption not stated: encrypt end to end. |
| **8 How it fails, and how we would see it** | Obstruction, load, a distant PoP and the 15 second swings the authors attribute to satellite link reconfiguration move delay and rate.<br>**How we would see it:** From your server: probes every few seconds summed each minute, and short throughput tests both ways; a minute fails when any field 1 limit fails. |
| **9 Cost shape** | Monthly fee and terminal; prices not printed. Leaves out installation, power and a second path. |
| **10 Evidence** | Field 1 figures *assumption* To verify: the buyer sets them, 2026-11-23<br>540 to 570 km; 25 degrees, 5 for polar gateways **standard** FCC 21-48 (2021), regulatory document, 2026-11-23<br>3.7 to 7.5 ms one way (two legs) **calculated** 550 km, 25 to 90 degrees, 2026-11-23<br>36 to 48 ms to the PoP; 50 to 100 Mbit/s down, 4 to 12 up; 2 to 4 times under load; 15 s swings **measured** Mohan and others, 2024, 2026-11-23 |

**Service only, no hop budget:** the documents read publish no waveform, transmit power or antenna figure for either radio hop, so no hop is given a verdict.

*Historical: a 2021 to 2023 profile, not today's fleet. Measured numbers are the researchers'.*

**LINK LEDGER · LL-2026-05 · SERVICE LEDGER**

2026-11-23 (sources dated 2017 to 2026)

System: Low orbit broadband, transparent with gateways: enterprise terminal, sold through a partner (Eutelsat OneWeb)

**Status on the book's date: not checked** **Class: service only**

| | |
|---|---|
| **1 Requirement** | Illustrative: 50 Mbit/s down, 10 up, a reply under 150 ms, one contract. |
| **2 Ends and path** | A third-party enterprise terminal at the site; the customer's network beyond the partner's point of presence.<br>**Path:** Transparent: terminal, satellite, gateway in the same footprint. No links between satellites in the 2017 order. |
| **3 Orbit and time** | 720 authorized in 18 near-polar planes near 1,200 km (FCC 17-77); more than 600 in orbit (operator, 2026-08-07).<br>**Time:** One way, two radio legs: 8.0 ms straight up, 14.7 ms at 25 degrees (calculated). |
| **4 Band and permission** | **All links.** Ku and Ka bands in FCC 17-77 (US access, 2017); 17.8 to 18.6 GHz for gateways only; other countries not read |
| **5 Capacity** | **Up.** Not in the sources read.<br>**Down.** Not in the sources read; ask the partner for committed rates both ways at the busy hour. |
| **6 Who owns each end** | **Space segment.** Eutelsat Group; UK special share kept (UK statement, 2022)<br>**Ground segment.** Operator's gateways; about 50 or more sites planned<br>**Customer relationship.** The distribution partner<br>**The exit.** Two contracts; terms not in the sources read |
| **7 Trust** | The operator commands satellites and gateways; the partner holds the account. Link encryption not stated: encrypt end to end. |
| **8 How it fails, and how we would see it** | A gateway down can take its region with it; a partner contract can end service while the satellites work.<br>**How we would see it:** Your own probes: round trip and loss per minute; short scheduled rate tests. Ask which gateway carries your traffic. |
| **9 Cost shape** | Partner's terminal and plan; prices not printed; excludes installation and a second path. |
| **10 Evidence** | 50 down, 10 up, under 150 ms *assumption* Illustrative; the buyer's acceptance test settles it, 2026-11-23<br>720 satellites, 18 planes, 1,200 km **standard** FCC 17-77, para. 2, 2026-11-23<br>More than 600 in orbit operator claim Eutelsat, 2026-08-07, 2026-11-23<br>8.0 to 14.7 ms calculated Chapter 3, 2026-11-23<br>About 50 gateway sites planned operator claim FCC 17-77, note 57, 2026-11-23<br>Sold through partners operator claim Via Satellite (trade press), 2022, 2026-11-23 |

**Service only, no hop budget:** the sources read give no waveform, transmit power or antenna figure for either hop of this configuration.

*Architecture level: partner, country, terminal and plan are left to the buyer.*

**Monday rule:** ask which pattern or hybrid the service is, then where your traffic lands: which gateway, which country, which point of presence.

CHAPTER FOUR

# The Terminal, the Gateway and the Network Service




On 24 February 2022, about an hour before Russia's major invasion of Ukraine, tens of thousands of satellite broadband terminals across Europe were disabled, by the UK government's later account. By the operator's account, the satellite above them was not affected; the attacker had reached the network's management systems on the ground and used them to send commands to the terminals. A buyer who judges a service by its satellites misses where that service failed. This chapter asks what, on the ground and in the network, still decides the service a buyer gets, once the satellites themselves have become cheap to build in volume.

## The user terminal

A low orbit satellite crosses the sky in minutes, so the terminal must follow it and hand over to the next one. One answer is a tracking dish that turns to follow the satellite; the answer the consumer services of chapter 3 use is the flat phased array: a panel of many small antenna elements whose beam is steered electronically, with no moving dish. SpaceX's registration statement describes its own as a "self-aligning antenna" and reports that the average cost of making its kit fell by about 59 percent between 2022 and 31 March 2026. Both are the operator's statements.

A flat array pays for steering with gain, called scan loss. Its effective area is the area it presents to the satellite, and that shrinks as the beam is steered away from the panel's face. For a panel lying flat and facing straight up, the projection alone costs 1.9 dB when the satellite is at 40 degrees elevation and 3.7 dB at 25 degrees, against a satellite overhead. Those two numbers are calculated from the projection alone; a real array loses more, from the pattern of its elements and from mismatch, and its maker's figure is the one to ask for. This is one reason a terminal's performance depends on where in the sky it has to look, and why a mounting tilted toward the satellites a site sees most can matter. *The Bit's Path* works the antenna theory.

Terminals come in classes, and table 4.2 lists them with what each changes. A fixed terminal sees the sky from one place; a terminal in motion on a vehicle, a ship or an aircraft must track while the platform turns, and its installation may need its own approval. Enterprise terminals add rate: Amazon describes its Leo Ultra enterprise terminal as delivering up to 1 Gbit/s down and 400 Mbit/s up, as the GSMA reported on 1 December 2025, an operator claim for a service then in enterprise preview. The supply model differs as well. A service sold direct, like Starlink's, ships the operator's own kit. A service sold through partners, like OneWeb's, is often delivered on terminals from third makers; the trade press reported in 2022 that one distribution partner, Kymeta, would bundle the service with its own fixed and mobility hardware. A third-party terminal can widen the choice of hardware and splits the support between the maker and the operator. Model names and prices change faster than this book; where a chapter needs one, it comes from the dated register in Appendix D.

## The gateway

The gateway is where the satellite's traffic meets the ground. Its feeder link usually runs in a higher band than the user's link, through several large antennas at one site, so that one antenna can follow a satellite while another acquires the next. The site needs fiber, power, a host country and a license. In the United States, the OneWeb order of 2017 (FCC 17-77) states that gateway earth stations need their own applications, which it does not grant, and records the operator's own figure, from its petition, of at least four US gateway sites and about 50 or more worldwide. The SpaceX order of April 2021 (FCC 21-48), which modified the satellites' authorization, lets the system work with user terminals and gateways at elevations of 25 degrees or more, and polar gateways as low as 5 degrees; it is not itself the license of any one earth station. It also records a competitor's argument that lowering the shells would "significantly increase the number of SpaceX gateway sites". Gateways are not an afterthought to a constellation; they are a large part of it, and each one is licensed by the state that hosts it.

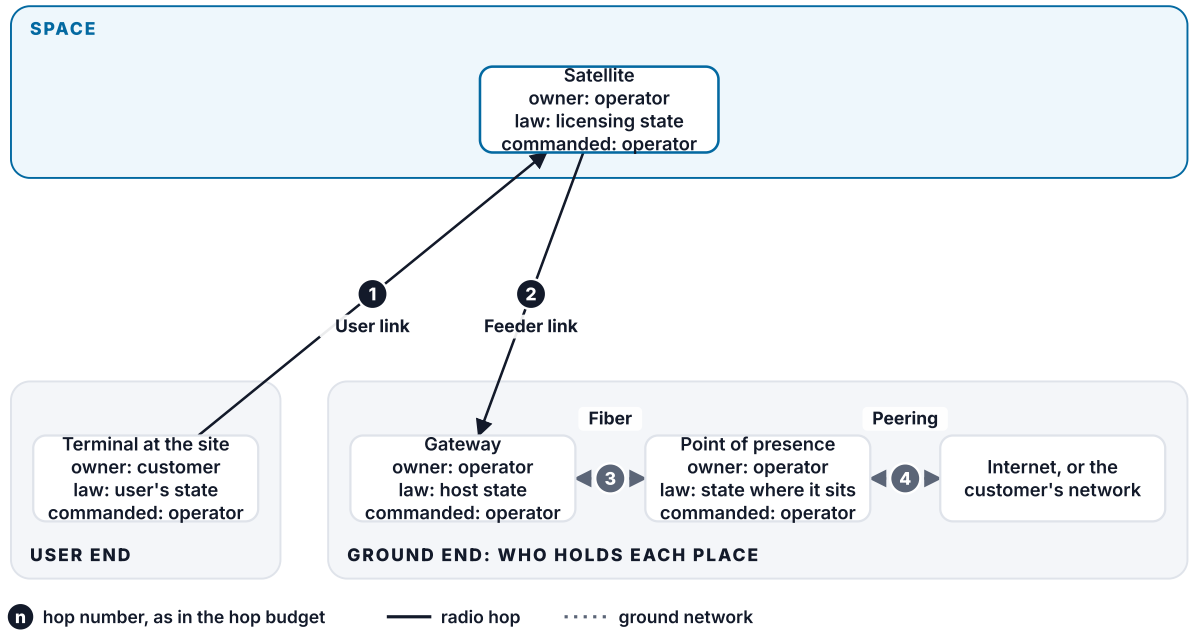
A gateway also fails in its own ways. Heavy rain at the feeder band can fade the link, which is why operators can pair sites far enough apart that heavy rain rarely fades both at once, so that one takes the other's traffic, a technique called site diversity. A site can lose fiber or power. What happens to a buyer's service when one site is down is the operator's design and is rarely published. On the transparent pattern, a user served only by satellites that see that one gateway may lose service; on the crosslinked pattern, traffic can be routed to another gateway, which may change the delay. The buyer's question is simple and should be asked in writing: which gateway carries my traffic, and what happens to my service when that site is down?

## The point of presence and the core

The traffic lands twice. It comes down at a gateway and then travels by fiber to a point of presence, where the operator hands it to the internet or to the customer's private network and where the user's address appears to the rest of the internet. The point of presence decides much of the delay to the servers a user reaches and much of what the user experiences as "local". Figure 4.1 draws the path with the three names chapter 1 asks for at each place: the owner, the state with lawful authority, and the holder of command access.

FIGURE 4.1

### The bit lands twice on the ground, at a gateway and at a point of presence, each under some state's law




Each place on the path has an owner, a state with lawful authority and a holder of command access, shown here in the typical case of chapter 1; a real service fills them from its own documents, and the operator's command of the terminal through its management network is the path this chapter's incident used.

*Author's diagram on the canvas of chapter 1, based on 3GPP NTN overview (service and feeder link); Mohan and others, ACM Web Conference 2024 (point of presence); FCC 17-77, paragraph 8 (gateways licensed separately). Checked 2026-11-23.*

The 2024 measurement study of SpaceX's network gives the clearest case in the sources read. Its authors found that the round trip from the terminal to the point of presence was 36 to 48 ms in almost all countries, with a median of about 40 ms; a measured round trip includes processing and queuing as well as propagation. Users in the Philippines reached servers in their own country through a point of presence in Japan until a local one was

deployed in May 2023; by the authors' account the detour added 50 to 70 ms to the round trip to in-country servers, and the delay to those servers fell sharply once the local site opened. What changed was on the ground: a new point of presence, closer to the servers.

The point of presence also sets jurisdiction, but not alone. Where traffic enters the internet is one factor in which state's law reaches it; others are where the provider is established, where the user is, which licenses the service holds and where its gateways sit. This book treats the point of presence as jurisdictional exposure that a buyer should know, not as a legal conclusion. The law itself is covered in depth later in this series.

## Capacity and contention

A satellite's rated capacity is spread over its beams, and a beam's capacity is shared by every terminal in its cell. The rate one terminal gets therefore depends on how many others are active in the same cell at the same time. The 2024 study found round trips two to four times higher during active downloads than when the link was idle, which is what queueing under load looks like from one terminal; other users active in the same cell add to it.

Offers express this in their terms. SpaceX's registration statement describes consumer fees based on "geographic market and download speed" and enterprise contracts built from "subscriptions, data consumption, and capacity". A buyer should separate four things on any offer: the peak rate, the sustained rate in the busy hour, whether any rate is committed or only best effort, and the fair use terms that apply when a plan's allowance runs out. Field 5 of the service page asks for the first three in each direction, and the second is the one that matters.

## The network service a buyer actually gets

An internet connection is more than a rate and a delay. The items below decide whether an enterprise's applications work, and each one is a question for the supplier, answered in writing with a date. A value printed in this book would come only from a dated operator document or a dated third-party measurement with its method. The operators' own addressing terms are not among the sources cited (Appendix B lists them as sought), so this chapter prints no values for them.

- **Handover.** A terminal moves from satellite to satellite, and the network reconfigures its routes. The 2024 study observed regular swings in delay and rate every 15 seconds. Ask how long an interruption lasts, how often it happens, and whether the operator publishes either with a method.
- **Loss, delay and jitter.** Voice, video and control traffic can fail on loss, on delay itself and on its variation, and a buffer that smooths variation adds delay; the application sets a limit for each. Ask for all three, at the busy hour, measured the way the buyer will

measure them.

- **Routing changes.** The landing point and the point of presence can change during a session. Ask whether a session can move, and what the address does when it does.
- **Shared addresses.** Many broadband services place customers behind carrier-grade network address translation, in which many users share one public address. Unsolicited inbound IPv4 connections then usually cannot reach the site unless the provider offers a mapping or another supported way in. Ask whether a public address is available, on which plan.
- **IPv6.** Native IPv6 removes the shared-address obstacle, but a provider's or a router's firewall can still block inbound sessions, and a prefix that changes breaks hosted services. Ask whether IPv6 is native, which prefix is delegated, whether it is stable, and whether inbound traffic is filtered.
- **VPN behavior and traffic priority.** Ask which tunnels are supported, whether any traffic is ranked, limited or inspected, and what the enterprise terms say about it.

FIGURE 4.2

## What the ground and the network decide, and the question each item puts to the supplier

| Item | What it changes | Question to the supplier |
|---|---|---|
| Fixed terminal | Sees the sky from one place; obstruction and low elevation decide its margin | Which mounting and field of view does the service assume at my site? |
| Terminal in motion (vehicle, ship, aircraft) | Must track while the platform moves; installation may need approval | Which terminal is approved for my platform, and who installs it? |
| Enterprise or third-party terminal | Hardware from more than one maker; support splits between maker and operator | Who replaces a failed terminal, and how fast? |
| Gateway and point of presence | Where traffic first lands and where it enters the internet; delay to my servers | Which gateway and point of presence carry my traffic, in which country? |
| Capacity and contention | Peak against sustained rate; fair use terms | What is committed, in each direction, at the busy hour? |
| Handover between satellites | Short interruptions, loss and jitter | How long, how often, and is it published with a method? |
| Shared addresses (carrier-grade NAT) | Inbound connections may not reach the site | Is a public address available, and on which plan? |
| IPv6 | Addressing for inbound services and for tunnels | Is IPv6 native, and which prefix is delegated? |
| VPN and traffic priority | Tunnels may slow or break; some traffic may be ranked | Which VPN types are supported, and is any traffic prioritized or limited? |

Values come only from a dated supplier document or a dated third-party measurement with its method; the last column is what to ask for in writing.

*Author's table based on the sources of chapter 4: Mohan and others, ACM Web Conference 2024; SpaceX, Form S-1 (2026-05-20); FCC 17-77. Checked 2026-11-23.*

## Four fields, filled from the ground up

The two service pages at the end of chapter 3 carry fields that only the ground can fill. Field 4, the band and the permission: each hop's band is licensed by a state, and the user's state, the gateway's host state and the satellite's licensing state can be three different states. Field 5, capacity: the committed rate in the busy hour, both ways, which the sources read do not give for either configuration. Field 6, the owners: the space segment, the ground segment, the customer relationship and the exit, which on the wholesale page are held by three different companies. Field 7, trust: who commands the terminal and the gateway, and where the traffic is readable. On both pages that last field ends the same way: encrypt end to end, because no source read states how the radio links are protected.

## Landing rights, installation and power

A service that a satellite can reach is not a service a buyer can use until the state where the buyer sits allows it. "Landing rights" is a loose name for several permissions that differ by country and may sit with different companies: access to the market for the satellite system, licenses for its gateways and for the terminals, approval of the terminal as a radio, and authorization to sell a telecommunications service. They are granted country by country, and a coverage map does not show them; they are covered in depth later in this series. At the site, three ordinary things decide the rest: a clear view of the sky in the directions the satellites pass, which trees and buildings can block; an installation that holds its mounting in wind and weather; and power for the terminal, which a phased array draws continuously. A buyer who confirms these before signing avoids common causes of a poor service that have nothing to do with orbit.

### THE SYSTEM'S FAILURE

The incident of 24 February 2022 shows that the terminal fleet and its management network are part of the service. The UK government stated on 10 May 2022 that its National Cyber Security Centre assessed it "almost certain" that Russia was responsible for a cyber attack on Viasat's KA-SAT network, that wind farms and internet users in central Europe were disrupted, and that, according to Viasat, "tens of thousands of terminals have been damaged, made inoperable and cannot be repaired". Viasat published its own overview of the attack on 30 March 2022; it is cited here as the trade press reported it the same day. By that report, the attacker used a misconfigured VPN appliance to reach the "trusted management section" of the network and pushed "legitimate, yet malicious, commands" to residential modems, which overwrote key data in their flash memory and left them unable to reach the network; Viasat said, in its overview as trade press reported it, that it had found no evidence of hardware damage to the modems and no sign that the satellite or its supporting ground infrastructure was affected, while the ground management network the attackers entered was compromised, and that 30,000 modems had been sent to distributors. A peer-reviewed survey of satellite security, published in *Sensors* in 2024, adds that the effect reached the remote monitoring of thousands of wind turbines.

What failed was the ground management path, and through it the terminals of one consumer service: the most numerous end of the system, reached in large numbers at once. Recovery meant shipping hardware, not repairing a satellite. The second book of this series, *From Telstar to the Phone in Your Pocket*, tells the case as history and *The Bit's Path* treats it as link security; this chapter keeps only its lesson for a buyer. US agencies drew the same lesson in their guidance: in March 2022 the US Cybersecurity and Infrastructure Security Agency and the FBI advised satellite network customers to review their trust relationships with providers and to "implement independent encryption across all communications links leased from, or provided by, your SATCOM provider".

**SECURITY NOTE**

**Who can interfere or command.** The terminal is two things at once: an authenticated account, which the operator or partner can suspend, and a radio that transmits from a known site, fixed or moving, which an adversary with the right equipment may be able to locate. The operator holds technical command of the terminal through its management network and its software updates; the customer usually holds no command or signing keys. That management network is a path to many terminals at once, as far as its segmentation allows, which is what the 2022 incident used. **How it is seen.** A fleet that stops together points to the management path or the operator's network, though regional jamming or a fault in space can look the same until the operator's telemetry separates them. A customer sees only that its own terminal is gone; logs kept on the customer's own servers, and the supplier's written incident notice, are what it has. **How it is recovered.** Ask before buying how terminals are recovered after a fleet-wide fault: remotely, by an update the operator can push, or by hand, with replacement hardware shipped to every site. Encrypt end to end, independent of the provider, and keep a second path whose management does not run through the same place.

**Monday rule:** before buying, find the gateway and point of presence your traffic will use and ask what happens to your service when that site is down.

CHAPTER FIVE

# Geostationary and Medium Orbit Broadband: What the High Orbits Sell

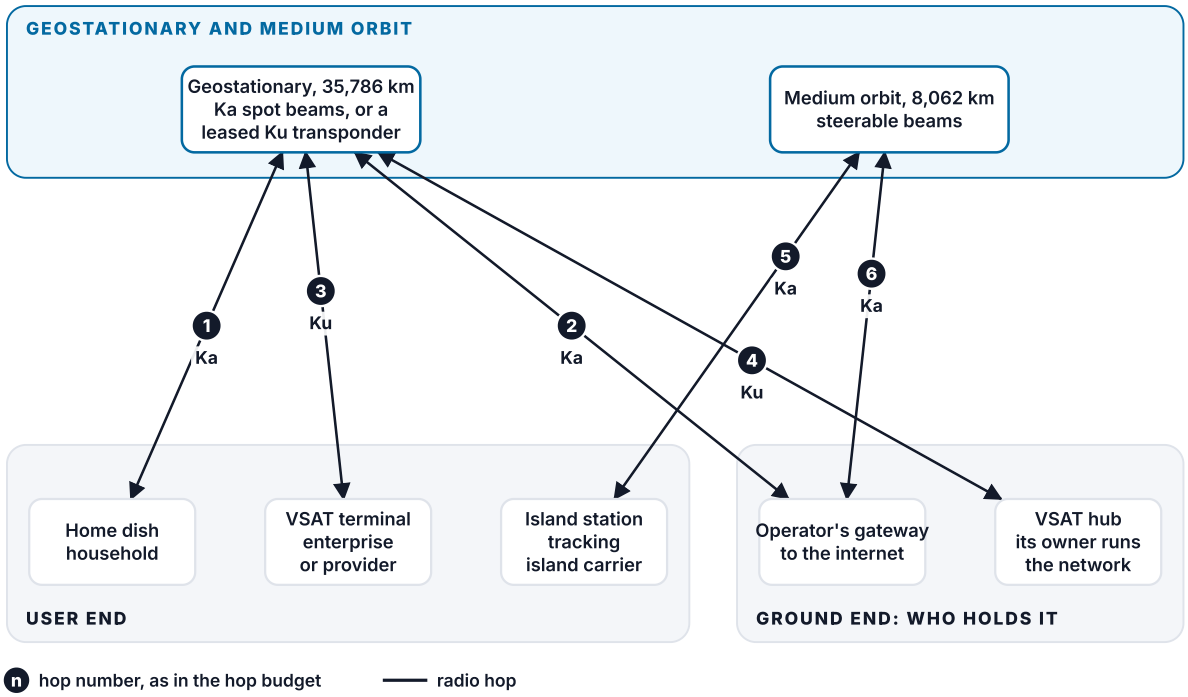



On 13 September 2026 a rocket carried the last three O3b mPOWER satellites toward medium orbit, 8,062 km up, and their builder stated that the launch completed the thirteen-satellite constellation, with the new three forecast to enter service in mid 2027 (Boeing). Eight days later the same builder reported that all three ViaSat-3 satellites, each in geostationary orbit at 35,786 km, were in service. By then thousands of satellites flew in low orbit (chapter 3 gives the dated counts). This chapter asks why customers still buy from the two high orbits, what they get, and what they give up. The decision it changes is how a buyer weighs delay against the other fields of a requirement: a reply time written in milliseconds comes first, and the orbit follows from it.

The chapter has three parts: the geostationary services sold to homes and businesses, the enterprise networks built on leased geostationary capacity, and the medium orbit fleet. The history of each, from the first spot beam satellites to the first medium orbit system, is told in the second book of this series, *From Telstar to the Phone in Your Pocket*; this chapter starts with the service as a buyer finds it on 23 November 2026. Figure 5.1 places the three services on one path.

FIGURE 5.1

## Three services bought from the high orbits: a home dish, an enterprise VSAT through a hub, and a medium orbit trunk to an island




Hops 1 and 2 are the home service, 3 and 4 the enterprise VSAT network (its forward and return formats are the DVB standards in the text), 5 and 6 the island trunk. Each service has its own holder of the ground end: the operator's gateway for the home, the hub owner for the VSAT network, and the operator's gateway with the island carrier for the trunk.

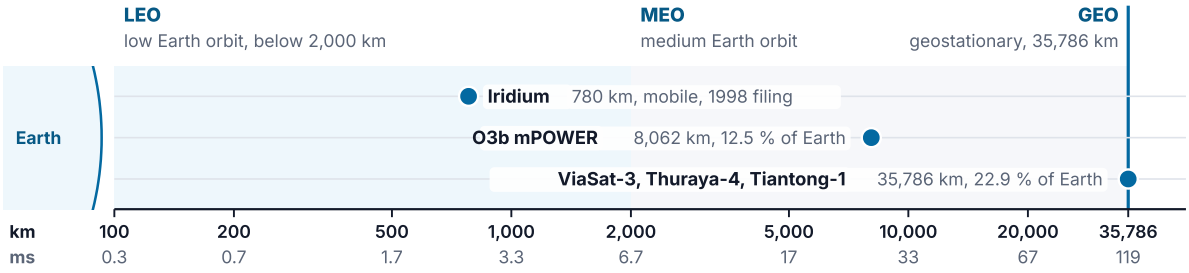
*Author's diagram based on this chapter's sources: Viasat Form 10-K for fiscal 2026; ETSI EN 302 307-1 and EN 301 545-2; FCC 18-70 for the 8,062 km altitude; SES release on CNT Ecuador, 2023-04-26. Checked 2026-11-23.*

## What geostationary orbit is chosen for in 2026

A geostationary satellite stays over one point of the equator, so a fixed dish pointed at it does not need to follow it. That single fact explains most of what this orbit still sells. One satellite sees a large part of the Earth: about 42.4 percent of the surface lies above its geometric horizon, 34.1 percent sees it more than 10 degrees above the horizon, and 22.9 percent more than 25 degrees (calculated for a spherical Earth). A wide region can therefore be served from one spacecraft, with capacity placed where the operator's beams put it. Television contribution, cellular backhaul, fixed service to homes and offices beyond the cables, and ships and aircraft all ride on this geometry. Figure 5.2 sets the two high orbits beside the low orbit mobile network of chapter 6.

FIGURE 5.2

## Where the high orbit services sit, and how much of the Earth one satellite sees above 25 degrees




km: altitude above the surface (log scale). ms: light time straight up, one way (altitude divided by the speed of light).

Above a 25 degree elevation mask one geostationary satellite sees about 22.9 percent of the Earth and one satellite at 8,062 km about 12.5 percent (calculated, spherical Earth).

*Source: altitudes from Iridium Form 10-K405 for 1998, FCC 18-70 (2018) and the nominal geostationary altitude of 35,786 km; coverage shares calculated for a 25 degree elevation mask. Checked 2026-11-23.*

The price is time and the look angle. One leg, straight up, is 119.4 ms; at 25 degrees elevation it is 130.3 ms. A path up to the satellite and down to the gateway takes at least 238.7 ms, and a reply, which crosses the satellite twice, at least 477.5 ms, or 521.3 ms with every end at 25 degrees (calculated, propagation only, before any processing or network delay). In plain words: about a quarter second one way, half a second for a reply. Far north or south the satellite also sits low in the sky. A site on the same meridian as the satellite sees it below 25 degrees beyond about 57 degrees of latitude and not at all beyond about 81 degrees (calculated); at other longitudes the limits come sooner. Terrain, buildings and rain then cost more of the signal. The radio side of these numbers, and why a lower elevation costs margin, is in the first book of this series, *The Bit's Path*.

Neither fact makes the orbit better or worse. For a television feed or a sensor upload the half second does not matter; for a voice call or an interactive session it does, and the buyer measures it against the requirement, not against another orbit.

### Very high throughput satellites

The geostationary answer to the demand for data has been to put more capacity on each satellite: many narrow spot beams that reuse the same frequencies, each beam landing its traffic at a gateway. Viasat's ViaSat-3 class is the dated example this chapter uses. The operator's page gives the launches as 1 May 2023 for the first satellite (F1), 13 November 2025 for F2 and 29 April 2026 for F3, all in Ka band, and states that F2 and F3 are each rated above 1 Tbit/s. Its annual report for the year to 31 March 2026 confirms the November

2025 and April 2026 launches and expected F3's commercial service "by late summer 2026". Boeing, which built F2 and F3, reported on 21 September 2026 that both had entered service and that the three-satellite constellation was complete. These are the operator's and the builder's statements; no independent check of the capacity was read.

A rating is not a service. A terabit per second is the sum over all beams of one satellite under the operator's assumptions; what one household receives depends on its beam, the number of users sharing it at the busy hour, the plan's priority rules and the weather. On 31 March 2026 Viasat reported a fleet of 23 satellites in service or operational: 13 in Ka band, eight in L band (three of them held as contingency), one S band satellite serving European aviation and one hybrid Ka and L band satellite. It reported about 130,000 subscribers to its US fixed broadband service, with a reported average monthly revenue per user of 113 dollars for its fiscal year (Viasat Form 10-K for fiscal 2026); that is an accounting average, not a plan price. Subscriber counts are defined differently by each operator, so the book compares none of them. The service page below describes the home service as one configuration; its status on the book's date was not checked against a newer source than that report.

The annual report section read does not describe the first satellite's antenna problem or its effect on capacity, so the book gives no figure for it. Another geostationary consumer broadband business, whose parent's spectrum was worth more than its network, is told once, in chapter 9.

**LINK LEDGER · LL-2026-07 · SERVICE LEDGER**

2026-11-23

System: Geostationary Ka band broadband to a home terminal: Viasat residential service, United States (operator claims, calculated delay)

Status on the book's date: not checked | Class: service only

| | |
|---|---|
| **1 Requirement** | Home internet where cable or fiber is not offered. Viasat reported about 130,000 US fixed broadband subscribers on 2026-03-31. Plan speeds and data rules were not read. |
| **2 Ends and path** | A fixed dish and modem at the home; a Viasat gateway connected to the internet, sites not named.<br>**Path:** Transparent spot beams on Viasat's earlier Ka satellites (second book of this series); the ViaSat-3 payload type is not stated in the sources read. No crosslinks. |
| **3 Orbit and time** | Geostationary, 35,786 km; 13 Ka band satellites in the fleet in service or operational on 2026-03-31, including ViaSat-3 F2. F3 launched in April 2026; all three in service by 2026-09-21 (builder).<br>**Time:** One leg 119.4 ms straight up, 130.3 ms at 25 degrees; a reply 477.5 to 521.3 ms (calculated, propagation only). |
| **4 Band and permission** | **Both hops.** Ka band; frequencies and the licensing state of the satellite serving US homes not in the sources read |
| **5 Capacity** | **Up.** Not read.<br>**Down.** Not read. A satellite's 1 Tbit/s is a rating, not a household's rate. |
| **6 Who owns each end** | **Space segment.** Viasat Inc., United States<br>**Ground segment.** Viasat gateways and network management<br>**Customer relationship.** Viasat: website, call centers, dealers<br>**The exit.** Not in the sources read |
| **7 Trust** | The modem authenticates to the provider's network; the management system can reach the modem fleet, the path used in the 2022 attack on another Ka network (chapter 4). |
| **8 How it fails, and how we would see it** | Heavy rain at home or gateway; a dish knocked off its satellite; a gateway outage; a busy beam at peak hour.<br>**How we would see it:** Home: modem status. Provider monitoring: not in the sources read. |
| **9 Cost shape** | Per month per household; reported average revenue per user 113 dollars a month, fiscal 2026 (operator): an average, not a price. |
| **10 Evidence** | About 130,000 US subscribers; 113 dollars a month operator claim Viasat Form 10-K, fiscal 2026, 2026-11-23<br>23 in service or operational, 13 in Ka band operator claim Viasat Form 10-K, fiscal 2026, 2026-11-23<br>Above 1 Tbit/s each (F2, F3) operator claim Viasat ViaSat-3 page; Boeing, 2026-09-21, 2026-11-22<br>477.5 to 521.3 ms reply calculated Slant range over the speed of light, 2026-11-23 |

**Service only, no hop budget:** beam, terminal and gateway figures are not in the sources read.

## Software defined geostationary satellites

A conventional communications satellite is largely fixed at the factory: its beam shapes and frequency plan are set by its antennas and filters, with limited switching by command. A software defined satellite moves those choices to the ground. Digital processors and active antennas let the operator change coverage, frequencies and power after launch, by command. ESA described Eutelsat Quantum, launched on 30 July 2021, as a telecommunications satellite that "can be completely repurposed while in space". Thales Alenia Space's Space INSPIRE product line, supported by ESA, is described as a fully software defined payload, with SES, Arabsat, Intelsat, Eutelsat and SKY Perfect JSAT named as customers; ESA wrote in May 2025 that the first satellite, ASTRA 1Q, was scheduled for launch in 2026. No record of that launch was read, so the book states none.

For a buyer the change is contractual as much as technical. If capacity can be moved from one region to another in orbit, the question is who decides when it moves, how quickly, and whether a written commitment protects the capacity a customer has bought. A satellite that can follow demand can also follow a larger customer's demand.

## Enterprise VSAT on leased capacity

A very small aperture terminal network, a VSAT network, has this shape: a central hub, many small terminals at branches, wells, mines or shops, and transponder capacity leased on a geostationary satellite in Ku band or, where heavy rain makes Ku band costly, in C band (the rain physics is in *The Bit's Path*). The satellite is usually a transparent repeater owned by one company; the hub, the terminals and the network management are often owned by another, a service provider or the enterprise itself. Who owns the hub decides who can change the service: add a site, raise a priority, update the terminals' software, or shut a terminal off. The hub may be the satellite operator's, a service provider's that leases the capacity, or the enterprise's own; the service description should name it.

The radio formats are standards. The forward link, from hub to terminals, is usually DVB-S2, defined in ETSI EN 302 307-1 (version 1.4.1, November 2014): it maps data into one of four modulation formats, QPSK, 8PSK, 16APSK or 32APSK (a format with more signal points carries more bits per symbol and needs a stronger signal), and in adaptive coding and modulation the format may change from one frame to the next, so a terminal in clear sky gets a denser format than one in rain. Its extension, DVB-S2X (EN 302 307-2, version 1.4.1, August 2024), adds finer steps, sharper filters, beam hopping and operation at very low signal to noise ratios. The return link, from terminals to hub, is either DVB-RCS2, whose lower layers are ETSI EN 301 545-2 (version 1.5.1, April 2026), or a vendor's proprietary

design. A standard fixes the waveform, not the service: two networks on the same standard can still differ in contention, priority and support, and a terminal from one provider's network does not join another's by default.

This book prints no service page for an enterprise VSAT. No operator's published service description, with its terminal class, its forward and return formats and its terms, could be read on the book's date; Appendix B records the search. A buyer can fill the page from the provider's own answers, field by field, starting with the owner of the hub.

## Regional and national operators

Much geostationary capacity is sold by operators whose home market is one country or one region: domestic access, wholesale capacity to carriers, and capacity a state keeps under its own control. Figure 5.3 lists what the sources read state for the operators whose own pages or filings could be opened. India's NSIL, a Government of India company, states that it is mandated to provide transponder capacity in C, Ku, Ka and S band on the INSAT and GSAT fleet, for direct-to-home television, news gathering and VSAT (NSIL site, updated 29 October 2026). The two regional mobile satellite operators in the table, in the United Arab Emirates and China, are described in chapter 6. Operators in Japan, Indonesia, Brazil, the Gulf, Türkiye, Thailand, Spain and Africa were sought; their fleets are not printed because no page or filing of theirs could be read on the book's date, and Appendix B lists each.

FIGURE 5.3

## The high orbit fleets and regional operators, as the sources read state them on 2026-11-23

| Operator | Country | Orbit | Bands | Satellites (date, who counted) | Services sold | Source |
|---|---|---|---|---|---|---|
| SES (owns Intelsat since 2025-07-17) | Luxembourg | GEO and MEO | C, Ku, Ka | About 120: about 90 GEO, nearly 30 MEO (2025-07-17, operator); 120 across GEO and MEO (operator page, read 2026-11-23) | Trunks, mobility, enterprise, government, media | SES release, 2025-07-17; SES site |
| SES, O3b mPOWER | Luxembourg | MEO, 8,062 km (FCC, added satellites) | Ka | 10 launched by 2026-03-05, the latest pair in commercial service (operator); last 3 launched 2026-09-13, service forecast mid 2027 (builder) | Trunks to carriers, cruise lines, airlines, government | SES, 2026-03-05; Boeing, 2026-09; FCC 18-70 |
| Viasat (with the former Inmarsat fleet) | United States | GEO | Ka, L, S | 23 in service or operational: 13 Ka, 8 L (3 contingency), 1 S, 1 Ka and L (2026-03-31, operator) | US home broadband, aviation, maritime, government, L band mobile | Viasat Form 10-K, fiscal 2026 |
| Viasat, ViaSat-3 class | United States | GEO | Ka | 3 launched: 2023-05-01, 2025-11-13, 2026-04-29; all in service by 2026-09-21 (builder) | Broadband; F2 and F3 each rated above 1 Tbit/s | Viasat ViaSat-3 page; Boeing, 2026-09-21 |
| NSIL (Government of India company) | India | GEO | C, Ku, Ka, S | - | Transponder capacity on the INSAT and GSAT fleet for DTH, TV, news gathering, VSAT | NSIL site, updated 2026-10-29 |
| Space42, Thuraya | United Arab Emirates | GEO | L | Thuraya-4 commercial from November 2025 (operator); fleet count - | Mobile satellite service (chapter 6) | Space42 release, 2025-11-05 |
| China Telecom, Tiantong | China | GEO | - | Tiantong-1, launched 2016 (state press); later satellites - | Mobile satellite service in China (chapter 6) | China Daily, 2020-01-13 |

Counts are each operator's own, with their date; a dash means the source read does not state it; operators sought without a readable source are listed in Appendix B.

*Source: each row's source, read on 2026-11-22 or 2026-11-23; the dated register (Appendix D) carries the counts.*

## The medium orbit fleet

The medium orbit broadband fleet in the sources read is SES's. SES describes O3b mPOWER as its "software defined Medium Earth Orbit (MEO) system", with steerable beams and capacity it can shift as demand moves. On 5 March 2026 SES stated that it had launched 10 of 13 O3b mPOWER satellites and that the pair launched in July 2025 had

entered commercial service. The final three were launched on 13 September 2026; Boeing, the builder, forecasts their entry into service in mid 2027, after orbit raising (Boeing feature, September 2026). The count of 13 is stated in both the SES and the Boeing texts.

The FCC's 2018 order on the system's added satellites gives their altitude as 8,062 km: twelve in a circular equatorial orbit and ten in two inclined planes (FCC 18-70, paragraph 18). The order does not use the name mPOWER, so the book uses 8,062 km as the system's authorized altitude, not as a measured orbit of each satellite. At that height one leg, ground to satellite, is 26.9 ms straight up and 35.1 ms at 25 degrees; ground to ground through the satellite takes 53.8 to 70.3 ms, and a reply 107.6 to 140.6 ms (calculated, propagation only). SES's page states "150 milliseconds of predictable satellite latency across large regions" without saying what the figure includes; it is an operator claim. Before comparing it with the propagation floor a buyer asks what it measures (one way or a reply, which end points, which elevations), because processing, routing and geometry other than the best case can all sit in the gap.

The orbit moves cost to the ground. A satellite at 8,062 km circles the Earth in about 4.8 hours (calculated), so every earth station tracks it and hands over to the next; a peer-reviewed survey states that mPOWER terminals use two tracking antennas to make the handover without a break ("Multibeam High Throughput Satellite: Hardware Foundation, Resource Allocation, and Precoding", IEEE Communications Surveys and Tutorials, 2026); the operator's own terminal documents were not read. An equatorial orbit at this height also stops short of high latitudes: a site under the satellite's longitude sees it above 25 degrees only up to about 41 degrees of latitude, and above the horizon up to about 64 degrees (calculated). The inclined planes in the FCC order reach further; their use for service was not stated in the sources read.

The customers SES and Boeing name are the ones a cable does not reach or cannot follow: cruise lines, airlines, mobile operators and governments. Ecuador's CNT stated in April 2023 that it had raised its medium orbit capacity to the Galapagos from 1.5 to 2.5 Gbit/s on O3b and planned to move to O3b mPOWER (SES release, 26 April 2023); SES's product page still names CNT among its customers on the book's date. The service page below describes such an island trunk.

**LINK LEDGER · LL-2026-06 · SERVICE LEDGER**

2026-11-23

System: Medium orbit trunk to an island operator: SES O3b mPOWER, for example CNT in the Galapagos (operator claims, calculated delay)

Status on the book's date: not checked | Class: service only

| | |
|---|---|
| **1 Requirement** | Carry an island operator's traffic to the mainland with less delay than geostationary. CNT stated 2.5 Gbit/s on O3b in April 2023 and a planned move to mPOWER (SES). |
| **2 Ends and path** | A tracking earth station at the island operator; an SES gateway on the mainland side, site not named.<br>**Path:** Ground to a medium orbit satellite to ground. SES calls mPOWER software defined: beams, power and bandwidth set from the ground. No crosslinks named. |
| **3 Orbit and time** | Medium orbit: added satellites authorized at 8,062 km, equatorial and inclined (FCC 18-70); which planes carry this route is not stated.<br>**Time:** One leg 26.9 ms straight up, 35.1 ms at 25 degrees; a reply 107.6 to 140.6 ms (calculated, propagation only). SES states about 150 ms, method not stated. |
| **4 Band and permission** | **Both hops.** Ka band; FCC 18-70 lists the US access frequencies; those used in Ecuador and the gateway's license are not in the sources read |
| **5 Capacity** | **Up.** Per link: not in the sources read; SES states return speeds that can match forward speeds.<br>**Down.** CNT: 2.5 Gbit/s on O3b, April 2023 (operator claim); the mPOWER figure is not in the sources read. |
| **6 Who owns each end** | **Space segment.** SES S.A., Luxembourg; United Kingdom authority (FCC 18-70; FCC 20-13)<br>**Ground segment.** SES gateways; the island station's owner not stated<br>**Customer relationship.** The island operator holds the subscribers<br>**The exit.** Not in the sources read |
| **7 Trust** | SES commands the satellites and can move beams and capacity; the customer does not hold that control. Command authentication is not in the sources read. |
| **8 How it fails, and how we would see it** | Rain fade at either end; a failed handover drops the trunk until the antenna reacquires; gateway backup arrangements are not in the sources read.<br>**How we would see it:** Island: carrier loss and handover alarms. Operator monitoring: not in the sources read. |
| **9 Cost shape** | Capacity contract per route; terms and price not in the sources read. |
| **10 Evidence** | 2.5 Gbit/s on O3b; move to mPOWER planned (operator claim) SES release, 2023-04-26, 2026-11-23<br>8,062 km; 22 authorized (12 equatorial, 10 inclined), not the fleet (standard) FCC 18-70, para. 18, 2026-11-23<br>10 of 13 launched, latest pair in service (2026-03-05); last 3 launched, service from mid 2027 (operator claim) SES, 2026-03-05; Boeing, 2026-09, 2026-11-23<br>107.6 to 140.6 ms reply (calculated) Slant range over the speed of light, 2026-11-23 |

**Service only, no hop budget:** no source read gives the terminal, satellite or gateway figures.

*Not checked: CNT's move from O3b to mPOWER is planned in the 2023 release; no later record of it was read.*

## The merged operator

The two high orbits are now sold by one company as well as separately. SES completed its acquisition of Intelsat on 17 July 2025 and stated a fleet of about 120 satellites, about 90 geostationary and nearly 30 in medium orbit; its site on the book's date gives "120 satellites across GEO and MEO". Its results for the first nine months of 2026 name the next generation of its medium orbit system, meoSphere, without a design the book can describe. A buyer may now get a geostationary and a medium orbit service under one contract, which does not by itself make them one integrated service; chapter 7 asks what such a combination still shares, and chapter 13 asks what a change of control does to a service. Intelsat's and O3b's histories belong to the second book of this series.

THE SYSTEM'S FAILURE

**What failed: four satellites, to an extent the record does not state.** In its results for the first nine months of 2026, SES stated that it had collected 229 million dollars of insurance on O3b mPOWER satellites 1 to 4. The record shows an insured loss on four satellites of the first batch. It does not quantify lost service to customers, and SES's own statement of the technical cause was not among the sources read, so the book names no cause. What the record does show: a constellation that is sold as capacity carries the health of each satellite into the contract, and a buyer of a route served by a partly impaired satellite needs to know which satellites carry it and what the operator commits to when one degrades.

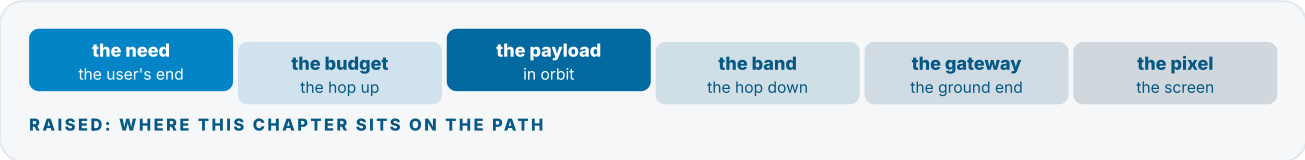
**SECURITY NOTE**

**Who can interfere or command.** Technical command of each satellite sits with its operator; on a software defined satellite the same commands also move beams and capacity, so the operator's control center decides where service exists. A wide geostationary beam on a transparent satellite can be received by anyone inside it who has the right equipment, and anyone inside the uplink footprint with enough power can interfere with it; that is a condition of the design, not a rating of risk. In a VSAT network the hub owner holds contractual and technical control of the terminals, which may be a different company from the satellite operator. Lawful authority rests with the satellite's licensing state, the gateway's or hub's host state and the user's state, each for its part. **How it is seen.** Authentication sits in the modem and the hub, not in the satellite: a terminal that leaves the network shows at the hub, and interference shows as a loss of signal quality in a beam or on a carrier. How operators locate an interferer is not described in the sources read. **How it is recovered.** The operator can move a carrier or, on a software defined satellite, a beam; a lost gateway is replaced only where another gateway serves the same beams; terminals managed from one hub recover through that hub, and the attack on another operator's modems in 2022 (chapter 4) shows the cost when the management path itself is the problem.

**Monday rule:** write the reply time your application needs in milliseconds before comparing orbits, then ask where the hub or gateway is and who owns it.

CHAPTER SIX

# Mobile Satellite Services as Sold Today: Handhelds, Small Terminals and Safety



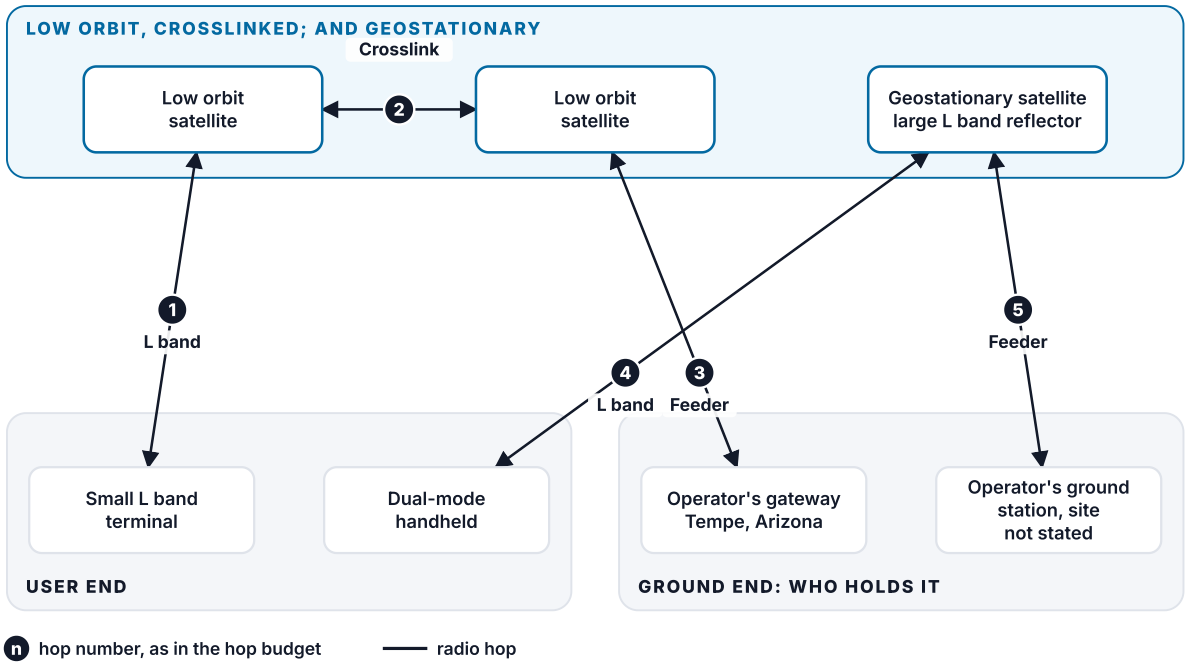

On 24 September 2026 the stockholders of Iridium, the low orbit mobile satellite operator, approved its sale to Rocket Lab with about 99.6 percent of the votes cast; the company expects the deal to complete by mid 2027, once the remaining regulatory approvals arrive (Iridium, Form 8-K). Ten months earlier, in November 2025, a new geostationary satellite, Thuraya-4, had opened commercial service for handhelds and small terminals across Europe, Africa, Central Asia and the Middle East (Space42). Long before phones talked to satellites, ships, aircraft and field teams bought this kind of service, and they still do. This chapter asks what is sold today, on which terminals, and which of it is a recognized safety service. The decision it changes is how a buyer weighs a dedicated satellite terminal against the phone already in the pocket.

## The architecture

The mobile satellite services of this chapter work in L band or S band, between about 1 and 4 GHz, where a small antenna can still reach a satellite: on a handheld, one that need not be pointed, while some larger portable terminals must be pointed and many on ships and aircraft track the satellite. The rates are low by broadband standards because the user's antenna is small and its power is limited; the satellite and the ground make up the rest. Two designs from the 1990s are still sold. The first is a crosslinked low orbit network: satellites pass traffic to each other by radio and land it at a few gateways, so one company covers oceans and poles with little ground. The second is a geostationary satellite with a very large reflector that forms many beams over one region, so a handheld can reach a satellite 35,786 km away. The second book of this series, *From Telstar to the Phone in Your Pocket*, tells how both designs came to be; this chapter takes them as a buyer finds them on 23 November 2026. Figure 6.1 shows the two paths.

FIGURE 6.1

## Two designs still sold for mobile satellite service: a crosslinked low orbit network and a geostationary satellite with a large reflector




In the low orbit design traffic can cross several satellites before it lands at the operator's gateway; in the geostationary design one satellite serves a region and lands traffic at the operator's ground station.

*Author's diagram based on Iridium Form 10-K for 2025 (crosslinks, gateways) and the Space42 releases of 2025 (Thuraya-4, Thuraya One). Checked 2026-11-23.*

## Low orbit mobile satellite service today

Iridium's annual report for 2025 describes a network of 66 operational satellites with in-orbit spares, linked to each other by radio crosslinks. Its commercial gateway is in Tempe, Arizona; a second commercial gateway in Russia serves only traffic within Russia, and the US government owns and operates its own gateway, which works only with Iridium's satellites. The company states that it holds licenses for up to 8.725 MHz of contiguous L band spectrum near 1.62 GHz; the band edges the filing prints span a different width, so the book gives the amount and not the edges. Its US space station license runs to 23 February 2032 (Iridium Form 10-K for 2025).

Three families of service ride on that network. Voice runs on handsets; the report describes one model as capable of Type 1 encryption, a US government grade. Iridium Certus is the data service, sold in classes named Certus 100, 200 and 700 on terminals made by partner

companies, with data speeds "up to 704 Kbps" (704 kbit/s); the report read gives neither the direction of that figure nor the rate of each class. Short burst data carries small messages for tracking and machine to machine use. On 30 September 2026 Iridium reported 2,696,000 billable subscribers: 396,000 commercial voice and data, 2,163,000 commercial IoT, 16,000 broadband and 121,000 government (Iridium results, 20 October 2026). These are the operator's figures and its own definitions. The service page below describes a Certus terminal as one configuration. Iridium's newer service for standard IoT modules is part of the direct to device story of chapter 10.

**LINK LEDGER · LL-2026-14 · SERVICE LEDGER**

2026-11-23

System: Low orbit mobile satellite data to a small L band terminal on a crosslinked network: the Iridium Certus family (operator claims; per-class figures not in the filing read)

**Status on the book's date: not checked** **Class: service only**

| | |
|---|---|
| **1 Requirement** | IP data and voice to a small terminal on land, at sea or in the air (Certus 100, 200, 700). The operator reports subscribers to 2026-09-30 on a global network under a US license; no country, terminal or plan record was read. |
| **2 Ends and path** | A Certus terminal from a partner maker; Iridium's commercial gateway in Tempe, Arizona, then the internet or a customer network.<br>**Path:** Crosslinked: up, radio crosslinks between satellites, down to the gateway. A US government gateway and a Russian gateway for traffic inside Russia also exist. |
| **3 Orbit and time** | Low orbit, 66 operational satellites with spares (operator). Per leg 2.6 ms straight up, 5.1 ms at 25 degrees at 780 km, the altitude of the 1998 filing (calculated).<br>**Time:** End to end delay through the crosslinks to Tempe: not in the sources read. |
| **4 Band and permission** | **User link.** L band, up to 8.725 MHz of contiguous spectrum near 1.62 GHz; US license to 2032-02-23 (operator)<br>**Feeder and crosslinks.** Ka and K band in the 1998 filing; not restated in 2025 |
| **5 Capacity** | **Up.** Not stated by direction or class in the filing read.<br>**Down.** Not stated by direction or class in the filing read.<br>Up to 704 kbit/s for the service, direction and class not stated; 16,000 broadband subscribers (OpenPort and Certus) on 2026-09-30 (operator). |
| **6 Who owns each end** | **Space segment.** Iridium; sale to Rocket Lab agreed 2026-06-28, completion expected by mid 2027<br>**Ground segment.** Iridium (Tempe); the US government's own gateway<br>**Customer relationship.** Resellers and service providers<br>**The exit.** Not in the sources read |
| **7 Trust** | Iridium commands the satellites and its core authenticates each terminal; resellers hold the customer. A change of owner awaits regulators. |
| **8 How it fails, and how we would see it** | A blocked sky; a gateway outage, which crosslinks do not remove for traffic that lands in Tempe; satellites have a limited life and no in-orbit insurance (operator).<br>**How we would see it:** Terminal: registration and signal. Operator monitoring: not in the sources read. |
| **9 Cost shape** | Monthly access fee plus usage (operator); amounts not in the filing read. |
| **10 Evidence** | 66 satellites; crosslinks; up to 704 kbit/s operator claim Iridium Form 10-K for 2025, 2026-11-23<br>Up to 8.725 MHz in L band; license to 2032 operator claim Iridium Form 10-K for 2025, 2026-11-23<br>16,000 broadband (OpenPort and Certus), 2026-09-30 operator claim Iridium Form 8-K, 2026-10-20, 2026-11-23<br>2.6 to 5.1 ms per leg at 780 km calculated Slant range; altitude from the 1998 Form 10-K405, 2026-11-23 |

**Service only, no hop budget:** terminal power and gain, satellite G/T and required Eb/N0 are not in the sources read for Certus.

Globalstar, the other low orbit mobile satellite operator of the 1990s, also sells its own phones and asset trackers beside its partnership with a phone maker (chapter 10). No current Globalstar service page or filing could be opened on the book's date, so this chapter gives its own services no rates or terminal classes; Appendix B records the search.

## Geostationary mobile satellite service today

**The former Inmarsat fleet.** Viasat completed its acquisition of Inmarsat on 30 May 2023 (Viasat Form 10-K for fiscal 2026). On 31 March 2026 its fleet included eight L band satellites, three of them held as contingency, and one hybrid Ka and L band satellite; it sells L band services for maritime, aviation, land and government users, including machine to machine tracking and safety services. The Inmarsat maritime safety page, read on the book's date, states that its L band network supports ships that must carry safety equipment under the SOLAS convention and those that need not, serving about 1.89 million seafarers (operator claim), and that Inmarsat C, its narrowband message service, has met the requirements of the safety system described below since its release.

**Thuraya.** Space42, an Abu Dhabi company listed on the Abu Dhabi Securities Exchange, now holds the Thuraya business. Its Thuraya-4 satellite, which Space42 calls its sixth geostationary satellite, was launched on a Falcon 9 from Cape Canaveral in early January 2025 (Space42; reported by The National on 4 January 2025), and on 5 November 2025 Space42 announced commercial availability in over 100 countries across Europe, Africa, Central Asia and the Middle East, with new markets in southern Africa. It names sixteen new products, among them land, maritime and airborne terminals, with data speeds above 1 Mbit/s on the terminals, and states that the satellite supports existing services. Its Thuraya One phone, shown in March 2025, is a dual SIM, dual-mode handset that switches between cellular networks and Thuraya's satellite network, including Thuraya-4, and is sold through more than 140 service partners and distributors. The service page below describes a call from that phone. Thuraya's first satellite of 2000 is history, in the second book.

**LINK LEDGER · LL-2026-08 · SERVICE LEDGER**

2026-11-23

System: Regional geostationary mobile satellite service to an L band handheld: Thuraya One through Thuraya-4, Space42, UAE (operator claims)

Status on the book's date: not checked | Class: service only

| | |
|---|---|
| **1 Requirement** | Calls and messages from one handset inside and beyond cellular coverage. Space42 states service in over 100 countries across Europe, Africa, Central Asia and the Middle East (2025-11-05). |
| **2 Ends and path** | A dual SIM, dual-mode phone; the operator's ground network and the public telephone network.<br>**Path:** Phone to one geostationary satellite to the operator's ground station, whose site is not stated. No crosslinks. |
| **3 Orbit and time** | Geostationary; Thuraya-4 launched in early January 2025, commercial from November 2025 (operator). Slot not stated in the releases read.<br>**Time:** Phone to ground station at least 238.7 ms, 260.6 ms at 25 degrees; a reply at least 477.5 ms (calculated). |
| **4 Band and permission** | **Phone link.** L band mobile satellite service; frequencies and national licenses not in the sources read<br>**Feeder link.** Not stated |
| **5 Capacity** | **Up.** Calls and messages; handset rate not in the sources read.<br>**Down.** As up; above 1 Mbit/s is stated for data terminals, not the phone. |
| **6 Who owns each end** | **Space segment.** Space42 PLC, Abu Dhabi, which holds Thuraya<br>**Ground segment.** Space42<br>**Customer relationship.** Over 140 service partners and distributors<br>**The exit.** Not in the sources read |
| **7 Trust** | The operator's core authenticates the satellite SIM. The cipher used on Thuraya-4 is not stated; an older cipher of this network family has published weaknesses (second book). |
| **8 How it fails, and how we would see it** | No service outside the region; buildings, terrain or a low look angle block the path; one satellite serves the region.<br>**How we would see it:** Phone: signal and registration. Operator monitoring: not in the sources read. |
| **9 Cost shape** | Airtime through service partners; amounts not read. |
| **10 Evidence** | Over 100 countries; commercial from November 2025 operator claim Space42 release, 2025-11-05, 2026-11-23<br>Dual-mode phone on Thuraya-4 operator claim Space42 release on Thuraya One, 2025-03, 2026-11-23<br>Launch in early January 2025, Falcon 9 operator claim Space42 launch release; The National, 2025-01-04, 2026-11-23<br>238.7 to 260.6 ms one way calculated Slant range over the speed of light, 2026-11-23 |

**Service only, no hop budget:** handset power, satellite G/T and the waveform's required Eb/N0 are not in the sources read.

**Tiantong.** China Telecom sells the Tiantong service. According to the state press (CGTN, published by China Daily on 13 January 2020), which describes the system as owned by China Telecom, its first satellite, Tiantong-1, was launched in 2016 into geostationary orbit; the system serves China and parts of the Middle East, Africa and the Pacific and Indian

Oceans; it began service to domestic users in January 2020 after a pre-commercial phase from 2018, with about 30,000 satellite phone users by then. Later satellites are not described in the sources read. A phone maker's support page, read on the book's date, describes Tiantong satellite calling as a carrier service that must be activated with a China Telecom package, also offered by China Unicom and China Mobile in some provinces and by carriers in Hong Kong and Laos. Phones with this function belong to the direct to device chapters; here Tiantong is a mobile satellite service sold in China, on that operator's terms. Figure 6.2 sets the services side by side.

FIGURE 6.2

### Mobile satellite services a buyer can name on 2026-11-23, and what the sources read state about each

| Operator | Orbit | Band | Terminals | Services | Safety recognition | Status (date) | Source |
|---|---|---|---|---|---|---|---|
| Iridium, United States (sale to Rocket Lab agreed 2026-06-28) | Low, crosslinked, 66 satellites | L | Handsets; Certus terminals from partner makers; IoT modules | Voice; Certus data up to 704 kbit/s; short burst data | GMDSS provider (IMO 2018; IMSO letter of compliance 2019-12-19) | 2,696,000 billable subscribers (2026-09-30 ) | Iridium Form 10-K for 2025; Forms 8-K, 2026; Iridium releases |
| Viasat, former Inmarsat L band fleet, United States | GEO; 8 L band satellites, 3 of them contingency | L | Maritime, land and aviation terminals | Maritime narrowband and broadband; Inmarsat C | GMDSS provider (IMSO) | Fleet as of 2026-03-31 | Viasat Form 10-K, fiscal 2026; Inmarsat safety page; IMSO |
| Space42, Thuraya, United Arab Emirates | GEO, Thuraya-4 | L | Thuraya One phone; land, maritime and airborne terminals | Calls and messages; data above 1 Mbit/s on terminals | - | Commercial from November 2025 | Space42 releases, 2025 |
| China Telecom, Tiantong, China | GEO, Tiantong-1 (2016) | - | Satellite phones; phones with built-in satellite calling | Calls, texts and data in service areas | - | Commercial for domestic users from January 2020 | China Daily, 2020-01-13; Huawei support page |
| Globalstar, United States (Amazon agreed to acquire it, announced 2026-04-14; closing expected 2027) | Low, transparent | - | - | - | - | - | Amazon Form 8-K, 2026-04; no Globalstar service source read (Appendix B) |

Status is each operator's own statement with its date; a dash means the sources read do not state it; where no service source could be read, the service cells are dashes and Appendix B records the search.

*Source: each row's source, read on 2026-11-23; Appendix D carries the dated counts.*

## What these services carry, and the shape of their price

The services carry voice, short messages, narrowband data for tracking, and data at hundreds of kilobits per second, or above a megabit per second on some terminals, by the operators' own statements. Iridium's report describes the shape of its prices without the amounts: postpaid voice and data carry a monthly access fee per subscriber plus usage; prepaid voice is sold as blocks of minutes that expire after 30 days to two years; IoT service carries a monthly fee plus data usage. The other operators' tariffs were not read. Amounts, where a buyer needs them, are entered in the register with their date, country and what they leave out (Appendix D).

## Ownership in motion

Iridium agreed on 28 June 2026 to be acquired by Rocket Lab for 27 dollars in cash plus Rocket Lab shares per Iridium share, a notional 54 dollars per share and an enterprise value of about 8.0 billion dollars, with completion expected by mid 2027 (Iridium, Form 8-K exhibits of 29 June and 24 September 2026). Viasat has owned the Inmarsat fleet since 2023, Thuraya is part of Space42, and Amazon has agreed to acquire Globalstar, announced on 14 April 2026 with closing expected in 2027 (Amazon; chapter 10). A buyer of any of these services is buying from an owner that changed recently or is about to; chapter 13 treats what that means.

## Safety services

The Global Maritime Distress and Safety System, GMDSS, is the international system through which ships send distress alerts and receive safety information. Satellite providers in it are recognized by the International Maritime Organization and overseen by the International Mobile Satellite Organization, IMSO, which has 112 member states and states that the satellite elements of the system are "currently provided by Inmarsat Ltd and Iridium Ltd" (IMSO, read on the book's date). By Iridium's own account (operator claims), the IMO's Maritime Safety Committee agreed in May 2018 to recognize its network as meeting the criteria for GMDSS service; IMSO issued its letter of compliance on 19 December 2019, presented on 13 January 2020, which Iridium described as the formal authorization to provide the service (Iridium releases, 21 May 2018 and 13 January 2020).

Three things are kept apart in this book. A recognized safety service has a regulator's recognition, a supervising body and distress routing to rescue centers. Distress routing is the operational path from the terminal to a rescue coordination center. Consumer emergency messaging from a phone, told in chapter 10, may carry a message toward rescue services, but it is not a recognized GMDSS service and IMSO does not oversee it. Aviation safety services

are approved by aviation authorities; their documents were not read for this book, so it names none, and the safety guidance of this chapter is for ships; for an aircraft, the aviation authority's approval of the exact installation decides.

## The trade-off: a dedicated terminal or a phone

The established services buy their margin with what a phone cannot carry: a terminal with a larger antenna, more power, sometimes a mast or a dome, and a subscription of its own. In return the buyer gets data rates of hundreds of kilobits per second, voice where the network carries it, and on some networks a recognized safety service. A phone that reaches a satellite on its own (chapters 8 to 10) may need no second device, though it may need an eligible plan or an activated package; in the phone text services of chapters 8 to 10 it carries less, messages and limited data rather than hundreds of kilobits per second, under conditions its operator sets; a phone with built-in geostationary satellite calling, such as the Tiantong phones above, also carries voice, in that operator's service area. The two service pages of this chapter and the phone text service of chapter 10 (LL-2026-02) show the difference field by field: the requirement each meets, the path, and the owners. No new fact is needed to see it.

THE SYSTEM'S FAILURE: NONE ON RECORD, A TRADE-OFF INSTEAD

**A trade-off, not a failure.** No service in this chapter has a failure on record in the documents read, so none is told; Iridium's bankruptcy of 1999 and Globalstar's of 2002 belong to the second book. The documented trade-off is this: the services in Figure 6.2 that carry data at hundreds of kilobits per second or more do so on dedicated terminals, by their operators' statements. Safety recognition is a further step: it belongs to a particular service and an approved terminal installation, with its distress routing and oversight, not to link margin alone. A buyer who replaces a recognized installation with a phone or an unapproved terminal loses the recognized safety service, whatever the link can carry.

**SECURITY NOTE**

**Who can interfere or command.** Each network in this chapter has its own core: the operator commands the satellites and authenticates the subscriber's SIM or terminal, and resellers hold the customer contract. Iridium's own report shows how state authority divides the ground: a gateway in Russia serves only Russian traffic, and the US government owns a separate gateway; the operator's licensing state and the state where the user stands each keep their own authority. A transmitter near the user can overwhelm the terminal's weak received signal, and one inside the satellite's receive beam can interfere with the uplink. Safety traffic carries routing obligations of its own under IMSO's oversight. **How it is seen.** The terminal shows registration and signal; outages and interference are seen in the operator's network monitoring, which is not in the sources read. **How it is recovered.** A link lost to a blocked sky returns with a clear view; a terminal lost at sea is a procedure, not a link: the ship falls back on its other GMDSS equipment, and the rescue center on its own channels.

**Monday rule:** if lives depend on the link, ask whether the service is a recognized safety service for your vessel or aircraft, and get the answer in writing.

CHAPTER SEVEN

# More Than One Orbit: Ships, Aircraft, Enterprises and Governments




On 1 December 2025 the GSMA, the mobile industry's association, reported that Amazon Leo had begun an enterprise preview of its Ultra terminal, and named an airline, JetBlue, among the preview customers. An airline that adds a low orbit service to aircraft does not usually throw away what it already flies with, and a shipping line or a government that buys a second network rarely buys it for speed alone. Buyers who cannot accept one network's failure modes often add a second network, and some add a second orbit. This chapter asks how orbits are combined, who does the combining, and what the combined links still share. The decision it changes is how a reader judges a claim that two links are "resilient".

## Why combine

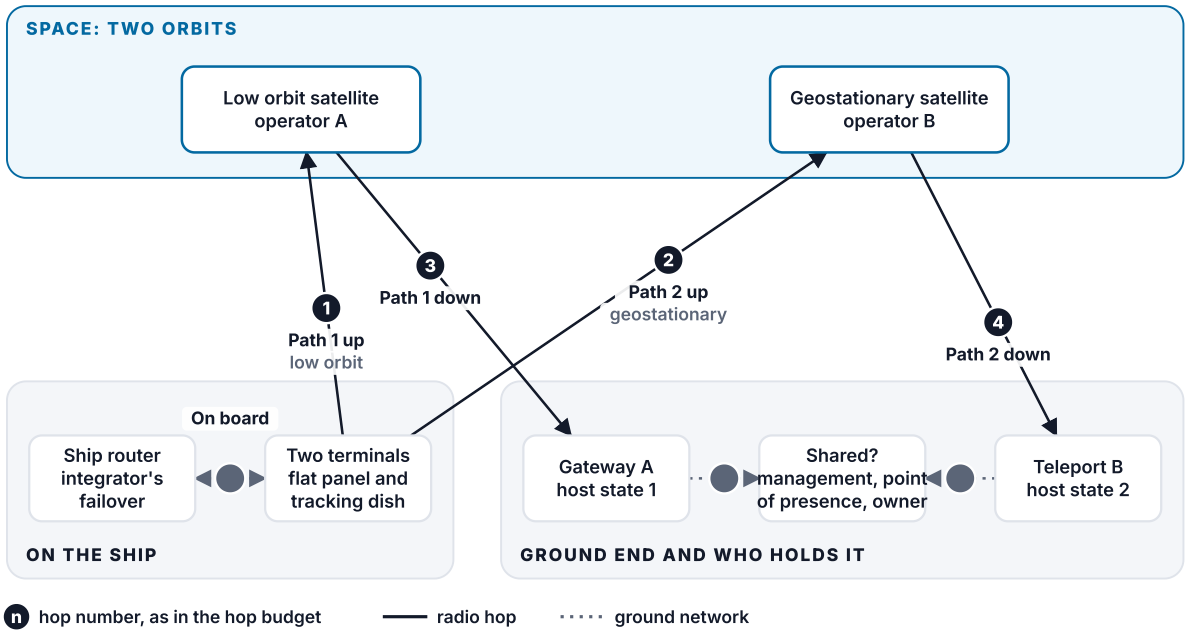
This chapter considers four reasons a buyer may combine networks, and they are different reasons. The first is delay. A low orbit satellite at 550 km is 1.8 ms away straight up; a geostationary satellite is 119.4 ms away straight up, and a path up and down through it is about a quarter second one way, half a second for a reply (propagation only, calculated; chapter 2 gives the geometry). An application that waits on each reply, such as an interactive session or a voice call, feels the difference. The second is coverage. A geostationary satellite sees a fixed region and stays nearly fixed in the sky of a site that does not move, although a terminal on a ship or an aircraft must still keep pointing as the platform moves; a low orbit shell serves the latitudes and the countries its operator covers, with the gateways and landing rights it holds (chapters 2 to 4). The third is capacity: a busy cell in one network can be relieved by another network's beam over the same place. The fourth is a second supplier: a buyer who has seen one network stop for reasons outside the radio path wants another company's network beside it.

The four reasons lead to different designs. A buyer who wants low delay most of the time and coverage the rest of the time uses one link first and the other as a fallback. A buyer who wants capacity spreads traffic over both at once. A buyer who wants a second supplier needs

the second link to fail for different reasons than the first; in the author's practice, that independence is the hardest of the four to show. This chapter does not rank the combinations. Each is judged against the buyer's own requirement, written down first (chapter 12 explains how). Figure 7.1 shows the simplest combination, a ship with one terminal for each orbit.

FIGURE 7.1

**Two orbits, two paths, and the places where they meet again**




A ship with a low orbit terminal and a geostationary terminal: the radio paths are separate (hops 1 to 4), but both can depend on one router, one management network, one point of presence, one owner or one licensing state, shown in the node marked Shared? between the two ground stations; this is an architecture, not a named service.

*Author's diagram based on this chapter's dependency list; FCC 26-47 (2026), paragraph 62, for the multi-orbit system as a licensing category. Read 2026-11-23.*

## Who does the combining

Three parties can combine orbits, and the buyer must know which one holds the switch.

**An operator that owns several orbits.** SES completed its acquisition of Intelsat on 17 July 2025 and stated a fleet of about 120 satellites, about 90 geostationary and nearly 30 in medium orbit (SES; chapter 5 gives the fleets). Eutelsat flies a geostationary fleet and the OneWeb low orbit constellation, which it describes as "more than 600" satellites on 7 August 2026 (chapter 3). Common ownership can also span bands without spanning orbits: the ViaSat-3 Ka band satellites and the former Inmarsat L band fleet are both geostationary

(chapters 5 and 6). Owning several orbits can support one contract over them, but whether the orbits are integrated into one service is shown only by the service offered. It does not by itself make them independent: one company also means one owner, one management organization and one set of corporate risks (chapter 13).

Regulators have started to name the pattern. The FCC's order of 22 July 2026 that adopts a new Part 100 of its rules (FCC 26-47) defines a multi-orbit satellite system as "a system of two or more types of satellite system(s) operating together under one call sign". The same order says that each system inside such a license keeps its own rules: a geostationary part and a low orbit part each meet their own deployment milestones and bonds. A single license is an administrative convenience, not an engineering merger. This is a United States case: Part 25 governs until Part 100 takes effect, and Part 100 was adopted on 22 July 2026 with its effective date not set when checked.

**A reseller or integrator.** A service company buys capacity on two or more networks, installs the terminals, and sells the result with its own router, its own network operations center and its own support line. The integrator decides when traffic moves from one link to the other, how a session survives the move, and which link carries the integrator's own management traffic. Each of those is the integrator's design, and a buyer should get it from the integrator's document, not from a brochure.

**The customer's own router.** The buyer contracts with each network separately and puts a router on site that chooses between them. The buyer then holds the switch and the support burden. When a link fails, the buyer must tell which network failed and call that operator, unless the buyer has also bought monitoring or managed support from someone else.

FIGURE 7.2

### Who integrates two orbits decides who controls failover and whom the buyer calls

| Who integrates | Who controls failover | Whom the buyer calls | What the buyer asks in writing |
|---|---|---|---|
| An operator that owns several orbits | The operator's network and its own terminal or router | One operator | Which parts of the two networks are common: management, gateways, points of presence, owner; how a session survives a change of orbit |
| A reseller or integrator | The integrator's router and network operations center | The integrator, who calls each operator | Which link carries the integrator's management traffic; what happens when both links meet the terms and the combination fails |
| The customer's own router | The customer | Each operator separately | Each operator's authorized service area along the route, dated; per-link monitoring; who on site can reach the router when both links are down |

Three ways to combine networks, each with the question the buyer asks in writing; no operator or integrator is rated.

*Author's table based on this chapter. Read 2026-11-23.*

Three things move when traffic fails over, and a buyer should ask about each. The address: the two networks give the site different addresses, often from different address spaces and sometimes behind carrier-grade NAT, so the address the far end sees can change at failover and a connection opened on one link can break when traffic moves unless the design keeps it alive, for example with a tunnel that ends somewhere both links can reach, or with applications that reconnect. The delay: an application tuned for the delay of one link may behave differently at the other's. The policy: the two networks may treat the same traffic differently, under different service terms and different states' laws (chapter 4). None of this is a radio question, and none of it appears on a coverage map.

## Ships and aircraft

On a ship or an aircraft the terminal is the constraint. A tracking dish or a flat panel must hold a satellite while the platform rolls, pitches and turns, survive salt or vibration, and fit where the hull or the fuselage allows (chapter 4 describes the terminal classes). A second

network usually means a second terminal, a second installation and, on an aircraft, a second certification of that installation. Combining orbits on a moving platform is therefore an engineering project as well as a contract.

The route adds a second constraint. A ship or an aircraft crosses the waters or the airspace of several states, and each can have its own rules on the use of terminals and the landing of traffic. A network that may serve a vessel in one ocean region may not be authorized near another state's coast. Which state's rules apply where is a legal question (covered in depth later in this series); here it is enough that a buyer asks each network for its authorized service area along the route, dated, and does not assume that the two networks' maps agree.

For an aircraft cabin the arithmetic of the ledger does not change, but its configuration does: a moving terminal, a cabin full of users who share one link, and a route that crosses beams and countries. The geostationary home service of chapter 5 (LL-2026-07) is one configuration; a cabin service on the same kind of satellite is another, and a ledger for it is filled as a separate configuration with its own terminal, its own operating point and its own owners, not as a footnote to the home service.

## Governments

Governments do two different things with satellite capacity, and they are often mixed up. They buy commercial capacity, under contracts with the same operators that sell to enterprises, sometimes with priority terms or dedicated beams. And they build or commission capacity whose aim is control: who owns the satellites, who commands them and under which state's law they operate. No government procurement record was read for this chapter, so no government purchase of commercial capacity is named here; the chapter states only the architecture.

The European Union's IRIS$^2$ program is the clearest public example of the second kind in the sources read. Eutelsat stated on 7 August 2026, after the program passed a milestone it calls the First Rendez-Vous, that it leads the low orbit part: 264 satellites carrying both military Ka band and Ku band payloads plus 66 military Ka band satellites, 330 in all, with first launches from 2029 and the commercial Ku band constellation stated to be fully operational by mid 2032. The sources read for this chapter show no IRIS$^2$ satellite in orbit and no IRIS$^2$ service on the book's date. SES also signed the program's implementation agreement, according to its results for the first nine months of 2026. In this book's status fields, IRIS$^2$ is announced and contracted; its authorization was not read, and nothing in orbit or in service was found; it is a table row, not a service a reader can buy (chapter 3). Whether it meets its aim is a question for after 2029; this chapter states the aim and the dates as the operator gives them, without judgment.

The three kinds of control (chapter 1) separate the two. Lawful authority over a commercial network sits with the states that license its parts; contractual control sits with whoever signed the contract; technical command access sits with the operator. A sovereign program tries to bring all three under one state or one union. A buyer who combines a commercial network with a sovereign one should write the three kinds of control for each, side by side (chapter 13).

## What a service agreement usually promises

A satellite service agreement can promise many things or almost nothing, and the difference is in the definitions. An availability figure means little until the agreement says what counts as an outage, where it is measured (at the terminal, at the gateway, at the point of presence), over what period, and what is excluded: weather beyond a stated rain rate, obstruction at the site, maintenance windows, events the operator calls force majeure. A restoration time means little until it says when the clock starts. A priority term means little until it says priority over whom, in which cell, at which hour. No terms are quoted here, because no agreement was read for this chapter; chapter 12 turns these into questions a buyer asks in writing. Where two links are combined, ask also how quickly a failed or degraded link is detected, how long traffic stops while it switches, and whether sessions survive the switch, and test it with the preferred link degraded, not only cut.

For two combined links the agreement has one more job: it should say who is responsible when the combination fails while each link, measured alone, met its own terms. If the integrator's router chose the wrong link, or the shared management server stopped, both operators can be in compliance and the buyer can still be without service.

**THE SYSTEM'S FAILURE: TWO ORBITS THAT SHARE ONE FAILURE**

The trade-off this chapter is built on needs no new case. Two orbits are not two independent suppliers when both paths depend on the same thing. Figure 7.1 shows the places where two paths through two orbits can meet again: the integrator's router and its software; the management network that configures both terminals; a gateway or teleport site, or the fiber and power that feed it; a point of presence in one city; one reseller's billing and support; one licensing state that can order both services to stop in its territory; one corporate owner of both networks. Chapter 4 tells the case of 2022 in which the terminals of a geostationary network were disabled through its management network while the satellite itself was untouched; a second link that shared the compromised management mechanism could have been exposed to the same failure. The test is not to claim that the second network "shares nothing", which a supplier can rarely show for every way a service fails. It is to list the common dependencies, document each one from the suppliers' written answers, reduce what can be reduced, and state the risk that remains.

**SECURITY NOTE**

**Who can interfere or command.** Combining orbits adds a party. The integrator, whether an operator, a reseller or the customer's own team, holds technical command access to the combined service: it controls the router that chooses the link and usually the management plane that configures both terminals. A single management plane over several networks is one point to compromise, and an attacker who reaches it can move or stop traffic on every link at once. Each network operator still commands its own satellites and its own gateways; the states that license each operator and gateway keep lawful authority over what they license, each state over the stations and users on its territory, and a state with that authority can compel the party that holds command access without holding it itself. **How it is seen.** Per-link monitoring is the first tool for telling which network failed, with operator telemetry and terminal events beside it: delay, loss and availability logged separately for each path, with the router's own decisions logged beside them. A combined dashboard that shows only "up" hides the case in which the second link has been down for weeks and nobody noticed. **How it is recovered.** The recovery plan names which network carries the management traffic, so that the management of one link does not depend on the other link being up, and it says how the site is reached when both are down. Recovery after a compromise of the shared management plane may mean work on site at each affected terminal (chapter 4).

**Monday rule:** when two links are sold as resilient, write what they share (site, vendor, reseller, management network, spectrum, licensing state, owner) and ask in writing who controls failover and which link carries management traffic.

CHAPTER EIGHT

# Direct to Device, Part 1: The Phone's Budget and the Standard



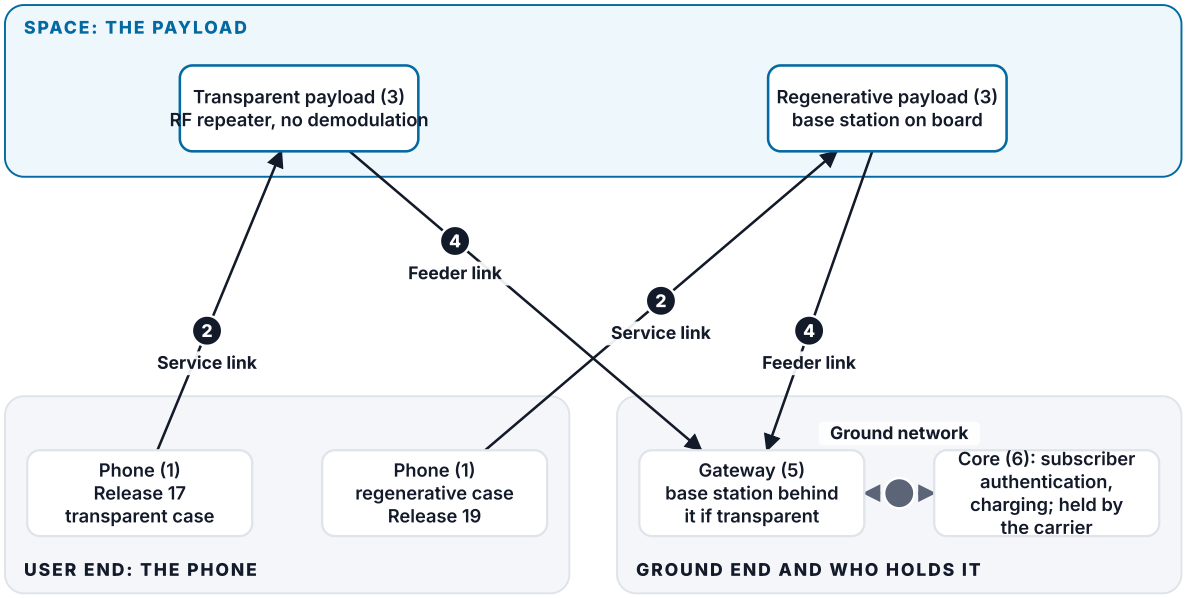

On 9 November 2026 AST SpaceMobile told its investors, in a business update filed with the SEC, that its second generation satellites carry an array of about 2,400 square feet, about 223 $m^2$, against about 700 square feet for the first generation. A satellite the size of a small house points that array at a phone that transmits about a fifth of a watt through an antenna inside its case. The phone cannot grow, so everything else must give. This chapter asks what the rest of the system must do for an ordinary handheld to reach a satellite, and what the 3GPP standard fixed and did not fix. The decision it changes is how a reader separates four questions that brochures merge: the standard, the spectrum, the device and the operator's design.

## Where this starts

Satellite service to a handheld is not new. Low orbit handsets were sold from 1998, and geostationary handheld services followed; the second book of this series, *From Telstar to the Phone in Your Pocket*, tells how each was built, and chapter 6 describes the mobile satellite services on dedicated terminals still sold today; this chapter and the next two are about services that reach an ordinary phone. What changed after 2022 is where the satellite function lives: inside a mass-market phone, or in a satellite that speaks to phones already in people's pockets. Neither means the phone is unchanged. A phone needs the right radio, the right software and the right carrier settings for each service, and chapter 10 treats device support as its own question. This chapter is about the link and the standard. Figure 8.1 names the six elements of a direct to device path with 3GPP's terms, from the phone (the user equipment) through the service link, the satellite payload, the feeder link and the gateway to the core network, for the two places a base station can sit; the last section of this chapter returns to that choice.

FIGURE 8.1

## Six elements from phone to core: the base station behind a transparent satellite, or on a regenerative one




Elements follow 3GPP's terms: 1 the phone (user equipment), 2 the service link, 3 the payload, 4 the feeder link, 5 the gateway, 6 the core; the numbered badges are these element numbers, not hops of a budget. Left, a transparent payload with the base station on the ground; right, a regenerative payload with base station functions on board; the node on the far right names who holds each part.

*Author's diagram based on 3GPP, Non-Terrestrial Networks (NTN) overview (payload definitions; Releases 17 and 19). The satellite operator holds the satellites and the gateway; in the carrier arrangement drawn, the carrier holds the core and the subscriber (a satellite operator may run its own core instead); the states that license the operator, the gateway and the carrier keep lawful authority over each, and a state has authority over the stations and users on its territory. Read 2026-11-22 and 2026-11-23.*

### The budget in words

A handheld of 3GPP power class 3 transmits at a nominal maximum of 23 dBm, with a tolerance of plus or minus 2 dB, in the satellite bands n255 and n256 (3GPP TS 38.101-5, Table 6.2.1-1). That is about 0.2 W. The standard assumes a 0 dBi reference antenna for its requirements (TS 38.101-5, clause 6.1); a real phone in a hand does worse, and the first book of this series, *The Bit's Path*, carries that loss as a stated assumption of 3 dB on its model phone uplink (LL-2026-01, chapter 4 of that book).

Distance is the first thing the rest of the system pays for. At 2 GHz, a path of 550 km straight up loses 153.3 dB in free space; a path of 5 km, chosen as a stand-in for a phone's distance to a cell tower, loses 112.4 dB. The satellite path starts 40.8 dB behind in free space, a factor of about 12,000 in power. Both numbers are free space and both are calculated; the 5 km path

is a reference for scale, not a measurement of any tower, and a real terrestrial path loses more than free space near the ground. The same comparison appears in *The Bit's Path* and in *From Telstar to the Phone in Your Pocket*; it is repeated here only because the rest of this chapter is about where the 40.8 dB is recovered.

*The Bit's Path* worked the consequence on one hypothetical uplink. A phone at 23 dBm sending 64 kbit/s to a satellite at 600 km, 30 degrees above the horizon, in open sky, reaches a 3 dB design margin only if the satellite's receive figure of merit toward the phone, its G/T, is at least 3.6 dB/K. G/T is the receive antenna's gain divided by the receiver's system noise temperature in kelvin, so a higher G/T hears a weaker signal. At 10 Mbit/s the rate costs 21.9 dB more (10 log10 of 10,000/64), which spends the 3 dB design margin and leaves the hop 18.9 dB short of zero margin. That ledger is an illustrative model with stated assumptions, not the budget of any operator, and this book does not reprint it.

## Where the missing gain goes

Four places can recover what the phone cannot supply (figure 8.2). Each has a price.

**A very large array on the satellite.** Gain on the receive side of the satellite raises its G/T toward the phone, and a larger array also makes narrower beams, so the same spectrum can be reused in more places. AST SpaceMobile's second generation array is about 2,400 square feet against about 700 for its first generation; if the two had the same efficiency at the same frequency, the larger area would be worth 5.4 dB. Area is not effective aperture, and the operator's filings read for this book publish neither antenna gain nor noise temperature, so 5.4 dB is an area ratio and nothing more. The price is mass, folded volume at launch and a satellite whose loss is a visible share of the fleet (the failure below).

**A lower orbit.** Free-space loss falls with distance squared. Moving from 550 km to 350 km saves 3.9 dB straight up; moving to 226 km, the bottom of the range in SpaceX's pending application for a direct to device system of up to 15,000 satellites at 226 to 435 km (described in the FCC's order DA 26-471 of 12 May 2026), saves 7.7 dB. Both are calculated. A lower orbit costs drag, a shorter life, smaller footprints and so more satellites for the same coverage (chapter 2).

**A lower rate.** Eb/N0 is the energy of one information bit against the noise in one hertz; the value a receiver needs is set by the waveform, its coding and the error rate wanted. At a fixed required Eb/N0 and otherwise unchanged assumptions, the required received power rises in proportion to the information rate. Sending 16 kbit/s instead of 1 Mbit/s needs 18.0 dB less. Low rates make messaging an obvious first service for a phone; the order in which any operator adds services also depends on its architecture, devices, spectrum and commercial choices.

**The user's help.** Open sky, no body or roof in the path, and a phone held where its antenna can see the satellite. *The Bit's Path* shows that a stated 10 dB obstruction leaves its model uplink 7.0 dB short: indoors, the budget that closes outdoors does not close. This is the one place the user pays, and the reason "works indoors" is not a claim this book prints.

FIGURE 8.2

### The 40.8 dB the phone cannot supply, and where it is recovered: arithmetic, not a verdict

| Step (2 GHz, free space, straight up) | Change, dB | Level against the reference, dB | How it is obtained |
|---|---|---|---|
| Reference: a 5 km path at 1 Mbit/s | | 0.0 | A stand-in for a phone's distance to a tower, for scale only |
| Free-space gap: 550 km against 5 km | -40.8 | -40.8 | 20 log10 (550 / 5), calculated (ITU-R P.525) |
| Lower rate: 16 kbit/s instead of 1 Mbit/s | +18.0 | -22.8 | 10 log10 (1,000 / 16) at a fixed required Eb/N0, calculated |
| Lower orbit: 350 km instead of 550 km | +3.9 | -18.9 | 20 log10 (550 / 350), calculated |
| Remainder: satellite G/T beyond a tower's | +18.9 | 0.0 | Solved so the level returns to the reference with every other term equal; not any operator's value |

Arithmetic from a terrestrial reference, not a hop budget of any service: no operating point and no verdict; the user's open sky is a fourth place, not in the table.

*Calculated by the series budget script from the free-space formula (ITU-R P.525) and the rate rule; the 350 km altitude is from Garcia-Cabeza and others, arXiv 2506.00283 (2025; the preprint version was read, journal status not confirmed), and the 226 to 435 km range in the text from FCC DA 26-471. The remainder is solved, not any operator's value. Computed 2026-11-23.*

Figure 8.2 is arithmetic, not a design, and it gives no verdict. It starts from the terrestrial reference, subtracts the 40.8 dB path gap, adds back the lower rate and the lower orbit, and shows what is left, 18.9 dB. (That this equals the shortfall of *The Bit's Path*'s 10 Mbit/s case above is a coincidence of the two calculations.) If the phone's power, the required Eb/N0, the margins and every other loss were the same on both paths, that is how much more G/T

the satellite's receiver would need than the reference tower's. The comparison establishes no absolute G/T and no service. How each operator splits that remainder between array size, beam count, orbit and rate is its own design, and is stated in chapter 10 only from its own filings.

## Time and frequency: what the phone must correct

A satellite at 550 km moves at about 7.6 km/s. Seen from the ground near the horizon, that motion shifts a 2 GHz carrier by up to 46.6 kHz, 23.3 parts per million (calculated for a non-rotating Earth; chapter 6 of *The Bit's Path* works the formula). A one-way trip straight up takes 1.8 ms, and a slant path at low elevation takes longer. A terrestrial network already corrects small delays (timing advance) and frequency errors, sized for cells a few kilometers across; a satellite's are far larger and change by the second, so the phone pre-corrects both before it speaks.

In 3GPP Release 17 the network broadcasts the satellite's orbit data through the satellite, and the phone uses its own position from its navigation receiver to compute its distance and speed relative to the satellite. It pre-compensates the frequency shift and the timing of its first transmission. The network signals a common timing advance component, referred to a point of its own choosing and covering the feeder link, the satellite's leg to the gateway; the phone computes its own component for the service link, the leg between itself and the satellite, and sets its uplink timing from both (the 3GPP specifications define the exact relationship). A phone without valid position and orbit data may not transmit at all. Long round trips also stall the fast retransmissions of a cellular link, its hybrid automatic repeat request (HARQ), which waits for acknowledgments: the standard raises the number of parallel HARQ processes from 16 to 32, or lets the network switch HARQ feedback off; recovery by the layers above HARQ is a separate mechanism (3GPP's overview; Lin and others, Ericsson, labeled scholarship).

These are the standard's answers. A service that does not use the standard handles Doppler and delay its own way, often on the network side so that an ordinary phone can be served. How each such design does it is stated only from that operator's filing, and none of the filings read for this book describes it.

## The standard: two tracks across three releases

3GPP, the body that writes the mobile standards, calls satellite access "non-terrestrial networks" (NTN). Its work runs on two tracks. NR-NTN brings 5G New Radio to satellites for phones and broadband devices. IoT-NTN brings the narrowband Internet of Things radios, NB-IoT and eMTC, to satellites for small, low power devices (chapter 11). Both arrived in Release 17 and grew in Releases 18 and 19 (figure 8.3).

FIGURE 8.3

## 3GPP satellite access by release: two tracks, more bands, then the base station in orbit

| Release | NR-NTN (phones and broadband devices) | IoT-NTN (NB-IoT and eMTC) | What the label does not prove |
|---|---|---|---|
| 17, frozen June 2022 | Transparent payloads only; FDD in the lower range; n255 L band (1626.5 to 1660.5 MHz up, 1525 to 1559 MHz down) and n256 S band (1980 to 2010 MHz up, 2170 to 2200 MHz down); power class 3 handhelds that know their position (TS 38.101-5) | Introduced: NB-IoT and eMTC over satellite | That a chip implements it, that vendors interoperate, or that an operator runs it in a country |
| 18 | n254 (1610 to 1626.5 MHz up, 2483.5 to 2500 MHz down); Ka bands n510 to n512; 30 MHz channels in n255 and n256; mobility with ground networks; network verification of the phone's location to about 5 to 10 km | An L plus S band added for IoT-NTN (a Release 18 work item named in the overview) | That the band is licensed to anyone for this use |
| 19, stated complete, end 2025 | Regenerative payloads with base station functions on the satellite; uplink capacity and downlink coverage enhancements; reduced capability devices. 3GPP states implementable specifications were available at the end of December 2025 | Store and forward, with a full base station on board | That any satellite in orbit carries it |

What each release adds for satellites, from 3GPP's own overview and the band table of TS 38.101-5; the last column is what a release label does not show.

*Source: 3GPP, Non-Terrestrial Networks (NTN) overview, https://www.3gpp.org/technologies/deep-dive/ntn-overview; 3GPP, Release 19 page, https://www.3gpp.org/specifications-technologies/releases/release-19; 3GPP TS 38.101-5 V17.8.0 (ETSI TS 138 101-5, 2024-08), Tables 5.2.2-1 and 6.2.1-1. Read 2026-11-22 and 2026-11-23.*

Release 17, whose protocol definitions were frozen in June 2022, supports transparent payloads only, frequency division duplex (separate frequencies up and down) in the lower frequency range, and two satellite bands: n255 in L band, 1626.5 to 1660.5 MHz up and 1525 to 1559 MHz down, and n256 in S band, 1980 to 2010 MHz up and 2170 to 2200 MHz down (TS 38.101-5, Table 5.2.2-1). Release 18 added band n254, with the phone transmitting at 1610 to 1626.5 MHz and the satellite at 2483.5 to 2500 MHz, three Ka bands numbered n510 to n512, 30 MHz channels in n255 and n256, mobility between satellite and ground networks, and a way for the network to verify a phone's reported location to within about 5 to 10 km. 3GPP's overview also lists a Release 18 item that adds an L plus S band for IoT-NTN. Release 19 adds regenerative payloads, which carry base station functions on the satellite; better uplink capacity; reduced capability devices; and store and forward for IoT-NTN with a full base station on board. 3GPP states that Release 19 is complete, with fully implementable specifications available at the end of December 2025.

Band names need care. A band whose name starts with "n" is a 5G New Radio band; the narrowband IoT bands are listed separately, in their own specification (TS 36.102), and a module's support for one does not imply the other. More important, a release label proves only that a feature is written down. It proves neither that a chip implements it, that two vendors' equipment interoperate, nor that any operator runs it commercially in any country.

## What the standard does not give

The standard gives a common language. It does not give spectrum: a band number says where the standard can work, not who may transmit there in which country (chapter 9). It does not give a device: a phone must implement the release and the band, and its maker and the carrier must enable it (chapter 10). It does not give a network: someone must fly satellites, build gateways and connect a core (chapters 1 and 10).

Several services launched between 2022 and 2026 do not use the satellite standard at all, or use it only in part; their status on the book's date is in chapter 10. Apple's service of 2022 needs custom components and software in the iPhone 14 line and later, per Apple, and runs on Globalstar's licensed mobile satellite spectrum; Apple does not describe it as an implementation of the 3GPP satellite releases in the sources read, which does not show that it uses no standardized parts. T-Mobile's service with SpaceX serves ordinary LTE phones on the carrier's own band: the phone sees a cell like any other, and the adaptations are on the network side, with conventional LTE base station payloads on the satellites, according to a measurement study read in its preprint version, and a design that SpaceX itself calls "cell towers in space", as the FCC's 2026 order quotes it. Iridium's NTN Direct, activated on 17 November 2026, is described by Iridium as a standards-based NB-IoT service in its own L band spectrum. Standards-based and proprietary services coexist, and "standards-based" does not mean "works with my phone".

## Where the base station sits

The six elements of figure 8.1 are the same in both designs. The design choice is where the base station sits.

With a **transparent** payload, which 3GPP defines as an analog radio frequency repeater with no on-board processing (it filters, shifts in frequency and amplifies, but does not demodulate), the satellite sends the phone's signal down the feeder link to a gateway. The base station sits at or behind the gateway. Every message crosses both legs before any base station processing, so the feeder link's delay is inside every exchange, and the satellite must have a gateway in view while it serves the phone. The carrier's core can stay where it always was.

With a **regenerative** payload, which demodulates, switches and modulates on board, base station functions fly. Where the relevant functions are on board, signaling they handle need not cross the feeder link before the phone gets an answer, and regenerative platforms can be linked by intersatellite links, so traffic can travel through space before it lands (Araniti and others, IEEE Network, labeled scholarship). The price is power, mass and software in orbit, and a base station that is updated over a radio link. Neither choice moves the core: the carrier's core, or the satellite operator's own, still authenticates the phone and routes its traffic (chapter 10). Payload types are treated in depth in chapter 8 of *The Bit's Path*.

**THE SYSTEM'S FAILURE: A LAUNCH THAT LEFT A LARGE SATELLITE TOO LOW**

AST SpaceMobile wrote off one of its satellites, BlueBird 7, according to its business update filed with the SEC on 9 November 2026; trade press reported that a New Glenn upper stage left it in an orbit that was too low in April 2026. The trade press attributes the loss to the launch; the operator's filing establishes the write-off; no launch failure investigation was read for this book. *From Telstar to the Phone in Your Pocket* records the event as history. Its lesson for this chapter is the design trade above: a system that recovers the phone's missing gain with a few very large satellites concentrates capacity and coverage in each one, so a single lost satellite is a large share of the fleet. The company reported BlueBirds 1 to 6 and 8 to 13 unfolded and operating on 9 November 2026 and kept its target of about 45 in orbit by mid 2027. The source shows a lost satellite and a revised fleet; it does not quantify lost service.

**SECURITY NOTE**

**Who can interfere or command.** For a standards-based phone served through its own carrier, the subscriber's credentials stay in the SIM and the carrier's core authenticates them, as on the ground; where a satellite operator runs its own core, who authenticates is that service's design, which the sources read for chapter 10 do not describe. The satellite operator commands the satellites and, with a regenerative payload, the base station software in orbit; the carrier holds the subscriber's account; the states that license the satellite, the gateway and the carrier keep lawful authority over each, which is not the same as holding command credentials. A satellite beam covers a wide area, so the network must know where a phone is to apply the right country's rules: Release 18 adds network verification of the phone's reported location, to within about 5 to 10 km according to 3GPP. A phone that must know its position from navigation signals before it may transmit inherits the weaknesses of those signals: if they are jammed or spoofed, the satellite link may not start (navigation is covered in depth later in this series). Anyone with a transmitter in the beam can raise the noise against a very weak uplink. **How it is seen.** The carrier sees registrations and delivery records in its core; the satellite operator sees uplink quality per beam. The user sees only whether the phone found the satellite network. **How it is recovered.** For a link problem, open sky or the next pass; for a fault in the core or a revoked entitlement, neither helps, and the user must know which party to call (chapter 10 treats each design's trust boundary).

**Monday rule:** for any direct to device claim, write four answers with a source each: which standard and release, which spectrum and whose license, which devices, and which operator's design.

CHAPTER NINE

# Direct to Device, Part 2: The Two Spectrum Roads



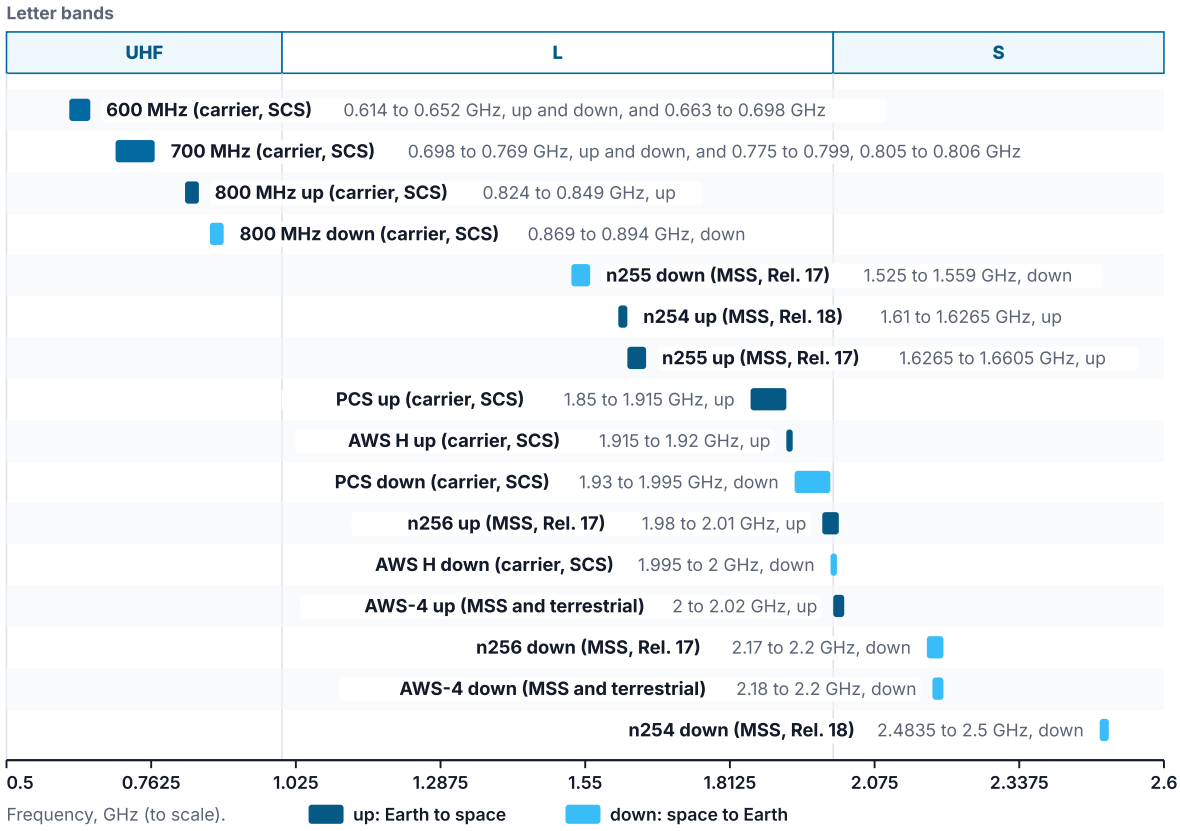

On 12 May 2026 the FCC consented to the assignment of a satellite company's spectrum licenses to another satellite company. EchoStar's AWS-4 band, its H block and its unpaired AWS-3 licenses were to pass to SpaceX through a trust, with final closing expected about 30 November 2027 (FCC order DA 26-471). The same day the FCC approved the sale of other EchoStar spectrum to AT&T, a ground carrier. Bands held by a satellite company were assigned to an operator that until then had served phones on a carrier's leased terrestrial band. This chapter asks whose spectrum carries a phone's signal to a satellite, and what follows from that choice. The decision it changes is what a buyer writes down about a direct to device service before depending on it: the band, the license holder, the status of the satellite's use, the jurisdiction and the date the right ends.

## Two roads

A phone can reach a satellite on one of two kinds of spectrum, and this book calls them the two roads (figure 9.1). On **road one**, the satellite uses a ground carrier's own terrestrial mobile band, under an arrangement with the carrier; the phone can be an ordinary phone that already works in that band. On **road two**, the satellite uses a band allocated to the mobile satellite service, in L band or S band; the satellite operator holds the right, and the phone needs a radio and software for that band. The standard of chapter 8 is not a road: 3GPP's satellite bands n254, n255 and n256 sit inside mobile satellite allocations, but a band number says where the standard can work, not who may transmit there.

FIGURE 9.1

## Two spectrum roads on one axis: a carrier's own bands used from space, or bands allocated to mobile satellite service




Dark: phone to satellite; light: satellite to phone; the carrier bands are those the FCC lists for supplemental coverage from space (road one, a United States case); the 3GPP satellite bands and AWS-4 are road two; the Resolution 253 study range of WRC-23 spans 694 or 698 MHz to 2.7 GHz. The 600 and 700 MHz rows draw the first listed range, the others are in their notes, and "both" marks a carrier band used in either direction under the carrier's own band plan. A band on this axis is an allocation or a band plan, not a permission.

*Source: Federal Register 89 FR 34148 (2024-04-30), Supplemental Coverage From Space, band list; 3GPP TS 38.101-5 V17.8.0, Table 5.2.2-1 (n255, n256); 3GPP NTN overview (n254); FCC DA 26-471 (2026-05-12) (AWS-4); ITU Resolution 253 (WRC-23). Read 2026-11-22 and 2026-11-23.*

## Road one in the United States: supplemental coverage from space

The United States framework is the worked case here, and it is a United States case: other countries' rules follow in the next section. The FCC calls it supplemental coverage from space (SCS). Its Report and Order, FCC 24-28 in GN Docket 23-65, was adopted on 14 March 2024 and released on 15 March 2024; its summary was published in the Federal Register on 30 April 2024 (89 FR 34148). The rules took effect on 30 May 2024, except for a few sections whose effective dates were delayed indefinitely and are announced separately.

The framework has five parts that a buyer should be able to name.

- **Who may lease.** One or more terrestrial licensees that together hold all the licenses on the relevant channel throughout a defined geographically independent area may lease access to a satellite operator. A carrier with a license in only part of an area cannot open it alone.
- **The status of the satellite's use.** The rules authorize bi-directional, secondary mobile satellite operations in the listed bands. The satellite may not cause harmful interference to stations operating under the international rules and may not claim protection from them.
- **The phone.** Phones that use the service are licensed by rule, so the user files nothing.
- **Emergency calls.** The carrier must deliver all 911 voice calls and texts carried over the service to a public safety answering point, by location-based routing or through an emergency call center, under interim rules.
- **The bands and a limit.** The listed bands are 600 MHz (614 to 652 and 663 to 698 MHz), 700 MHz (698 to 769, 775 to 799 and 805 to 806 MHz), 800 MHz (824 to 849 and 869 to 894 MHz), Broadband PCS (1850 to 1915 and 1930 to 1995 MHz) and the AWS H block (1915 to 1920 and 1995 to 2000 MHz). Under the rule, the aggregate of all the satellites' downlink emissions outside the licensee's SCS bands (out-of-band emissions, in short) may not exceed a power flux density of minus 120 dBW per square meter per MHz at 1.5 m above the ground (47 CFR 25.202(k), as adopted in FCC 24-28).

Two things follow. The satellite's use is only as long as the lease and only as wide as the carrier's channel; and it is secondary, so the satellite yields when it interferes. The rules also sit inside the FCC's satellite licensing rules, which are changing: Part 25 governs until Part 100 takes effect, and Part 100 was adopted on 22 July 2026 with its effective date not set when checked. The Part 100 order carries the SCS definition into the new part. Licensing as a whole is covered in depth later in this series.

Leased spectrum is narrow. A carrier may hold only a few MHz of a band in an area, and the service shares it with the carrier's own towers nearby. Chapter 10 records which carrier and which operator use this road on the book's date; this chapter records only the rule.

## Road one outside the United States

Other regulators have opened the same road by other instruments. For each, the fields that matter are the same: the instrument, the band, primary or secondary status, who holds the license, how phones are authorized, and how emergency calls are routed. A field this book could not read in the regulator's own document is marked so, and is not filled from press reports.

**Canada.** The Government of Canada announced on 20 February 2025 a "Decision on a Policy, Licensing and Technical Framework for Supplemental Mobile Coverage by Satellite", naming improved access to emergency services and 9-1-1 among its aims. The regulator's decision itself, which would give the bands, the status of satellite use and the license holder, is not cited here, so those fields stay blank.

**Japan.** The Kanto Bureau of Telecommunications of the Ministry of Internal Affairs and Communications announced on 25 December 2024 that it had licensed KDDI, a mobile carrier, for radio stations of a "2 GHz band non-geostationary satellite communication system for mobile phones" using a satellite constellation. The related ordinances had taken effect on 20 December 2024; the mobile earth station licenses are dated 20 and 23 December 2024 and the base station license 23 December 2024. The carrier holds the licenses in its own 2 GHz mobile band. The press release does not state primary or secondary status or the emergency call rules.

**The United Kingdom, Australia and New Zealand.** Framework documents were sought from each regulator and not read; Appendix B lists them, with the Canadian decision. This chapter makes no claim about their provisions or status.

The two read instruments already differ from the United States case. Japan licenses the carrier for the stations of the system; the United States leases the carrier's spectrum to the satellite operator, whose use is secondary. A buyer outside the United States reads that country's instrument, not the FCC's.

## The layers under every satellite right

Whichever road a service uses, its right to transmit sits on layers, and each layer can fail on its own (figure 9.2).

- **International allocation.** The ITU Radio Regulations allocate bands to services, such as the mobile service and the mobile satellite service, region by region.
- **International filing and coordination.** A state files the satellite network's frequency assignments with the ITU, coordinates them with other states' networks (technical studies and agreement, so that the networks do not cause each other harmful interference), and notifies them for recording in the Master International Frequency Register, which gives them international recognition under the conditions of the Radio Regulations; recording is not a worldwide authorization.
- **National authorization.** Each state where the satellite transmits to users decides whether it may, in which band, under which conditions; a license in one state is not a license in its neighbor.

- **Coordination with other operators**, satellite and terrestrial, in the same and adjacent bands.
- **Equipment approval** for the phone or terminal in each market.
- **The operator's agreements**: a lease from a carrier on road one, a wholesale or roaming agreement on road two, and the landing of traffic.

The international layer is moving. The World Radiocommunication Conference of 2023 (WRC-23), held in Dubai from 20 November to 15 December 2023, revised the milestone rules for non-geostationary systems (Resolution 35) and the aggregate limits that protect geostationary networks (Resolution 76), according to the ITU. It also adopted Resolution 253 (WRC-23), "Studies on possible new allocations to the mobile-satellite service for direct connectivity between space stations and International Mobile Telecommunications (IMT) user equipment to complement terrestrial IMT network coverage". The resolution asks for studies in the range from 694 or 698 MHz to 2.7 GHz, and for measures so that mobile satellite stations "do not cause harmful interference to, or claim protection from, stations operating in the mobile service", and invites the next conference to consider new allocations based on the results. That next conference, WRC-27, is to meet in Shanghai in 2027, according to the ITU. Road one today runs through national instruments such as the FCC's; whether it gets an international allocation is a question that conference is asked to consider, and its outcome is not known on the book's date.

FIGURE 9.2

### Road one against road two, layer by layer and country by country

| Layer or jurisdiction | Road one: a carrier's terrestrial band | Road two: mobile satellite spectrum | Source |
|---|---|---|---|
| International allocation | Mobile service; satellite use of these bands studied under Resolution 253 (WRC-23) for WRC-27 | Mobile satellite service in L and S band | ITU Res. 253 |
| International filing | The satellite network is still filed, coordinated and recorded by a state | Filed, coordinated and recorded in the Master Register | ITU backgrounder |
| National authorization | Per country: a lease to the satellite operator (United States) or a license to the carrier (Japan) | Per country, for the satellite operator or its partner | Below |

| Layer or jurisdiction | Road one: a carrier's terrestrial band | Road two: mobile satellite spectrum | Source |
|---|---|---|---|
| Priority and sharing | Secondary in the United States | Set by the allocation, the national authorization and coordination, band by band | 89 FR 34148 |
| Equipment | Ordinary phones in the band; licensed by rule in the United States | A phone or module with the band's radio | 89 FR 34148; ch. 10 |
| Agreement | A lease from the carrier, as wide as its channel and as long as the lease | Wholesale or roaming agreements; landing rights | This chapter |
| United States | SCS, FCC 24-28, effective 2024-05-30 (most sections); 600, 700, 800 MHz, PCS, AWS H; secondary; 911 to a public safety answering point | AWS-4: terrestrial and satellite allocations. H block: terrestrial and satellite allocations, and also a road-one SCS band. Unpaired AWS-3: SCS use requested, pending, not granted by the order. Assignment of all three to SpaceX consented 2026-05-12, final closing about 2027-11-30 | 89 FR 34148; DA 26-471 |
| Canada | Framework decision announced 2025-02-20; bands, status and holder not read | Not read | Government of Canada |
| Japan | KDDI licensed for a 2 GHz band constellation system for phones; ordinances 2024-12-20; status and emergency rules not stated | Not read | MIC Kanto Bureau, 2024-12-25 |
| European Union | Not read | 2 GHz band: Commission proposal 2026-05-27 for an EU-level selection beyond 2027, when current licenses expire | European Commission |

| Layer or jurisdiction | Road one: a carrier's terrestrial band | Road two: mobile satellite spectrum | Source |
|---|---|---|---|
| United Kingdom, Australia, New Zealand | Sought, not read | Sought, not read | Appendix B |

Each layer of a satellite right on each road, then the jurisdictions read for this book; a blank field means the regulator's own document was not read, not that the field is empty.

*Source: ITU Resolution 253 (WRC-23); ITU, Backgrounder: Regulation of satellite systems; Federal Register 89 FR 34148; FCC DA 26-471; Government of Canada news release (2025-02-20); MIC Kanto Bureau of Telecommunications press release (2024-12-25); European Commission news (2026-05-27). Read 2026-11-22 and 2026-11-23.*

## Road two: mobile satellite spectrum

Road two uses bands that were allocated for satellites to talk to mobile users. In the 3GPP band plan they are n255 in L band (1626.5 to 1660.5 MHz up, 1525 to 1559 MHz down), n256 in S band (1980 to 2010 MHz up, 2170 to 2200 MHz down), and, from Release 18, n254 (1610 to 1626.5 MHz up, 2483.5 to 2500 MHz down). The right comes from the band's allocation and from a national authorization held by the satellite operator or its partner, so no lease from a ground carrier is needed; the holder, priority and sharing conditions are checked band by band and country by country. The price is that a phone without support for these bands does not transmit in them: the phone needs a radio and software for the band (chapter 10), or a module built for it (chapter 11).

The amounts are small. One merged company, Elveo Mobile, formed from Lynk Global and Omnispace on 14 August 2026, holds 60 MHz of S band mobile satellite rights internationally, according to the trade press. Small as they are, these bands are contested, and a mobile satellite right is not one worldwide license either: the band must be allocated, the satellite network filed and coordinated, and the service authorized in each country where users are, with landing rights where a country requires them.

The European Union shows how such a right can end and be reassigned. The European Commission adopted on 27 May 2026 a proposal for an EU-level procedure to select mobile satellite providers in the harmonized 2 GHz band for use beyond 2027, "when the current licenses expire", and describes the band as well suited to direct to device services. The proposal must pass the European Parliament and the Council; on the book's date the holders after 2027 are not known.

Operators on this road have organized. The Mobile Satellite Services Association was introduced on 9 February 2024 by five operators (Viasat, Terrestar Solutions, Ligado Networks, Omnispace and Yahsat) to build a direct to device ecosystem on L and S band mobile satellite spectrum aligned with 3GPP, according to the trade press.

## Where the roads cross

The two roads are not fixed camps. The FCC's order of 12 May 2026 consented to the assignment to SpaceX, through a trust, of EchoStar's AWS-4 band (2000 to 2020 MHz and 2180 to 2200 MHz), its H block, and unpaired AWS-3 spectrum at 1695 to 1710 MHz, with final closing expected about 30 November 2027 (DA 26-471). The FCC's news release counts about 65 MHz in all for SpaceX: 15 MHz of unpaired AWS-3, 40 MHz of AWS-4 and 10 MHz of H block, with waivers that allow terrestrial, satellite or hybrid use, subject to performance obligations. The order itself notes that AWS-4 and the H block have both terrestrial and satellite allocations, and that SpaceX's request to use unpaired AWS-3 for supplemental coverage from space remained pending in its separate application. The order describes an interim trust and an expected final closing; consent to an assignment does not by itself show that a satellite service is authorized or operating in each band. Once closed, an operator that served phones on a carrier's leased band on road one will also hold bands of its own. AWS-4's 2180 to 2200 MHz lies inside the n256 downlink, 2170 to 2200 MHz, and its 2000 to 2020 MHz overlaps the upper 10 MHz of the n256 uplink: on the frequency axis of figure 9.1 the two roads meet.

Another operator plans to drive on both roads. AST SpaceMobile states a target of about 100 MHz of shared carrier and controlled mobile satellite spectrum in the United States, and more than 60 MHz globally (its business update of 9 November 2026). That is a target, not a holding, and the filings read for this book do not list the frequencies (its results release of the same date).

### THE SYSTEM'S FAILURE: LICENSES SOLD, NETWORK COMPANIES IN BANKRUPTCY

EchoStar's units ran networks: Dish DBS, Dish Wireless and the Hughes satellite broadband service. In 2026 its licenses were sold. On 12 May 2026 the FCC approved EchoStar's sale of about 65 MHz to SpaceX and about 50 MHz to AT&T (30 MHz at 3.45 GHz and 20 MHz at 600 MHz), with a 2.4 billion dollar escrow (FCC news release). The AT&T sale closed on 28 July 2026 for a reported 23 billion dollars, according to the trade press. In the same months the network companies entered bankruptcy. DISH DBS and DISH Wireless filed prepackaged chapter 11 cases on 30 June 2026, according to EchoStar's quarterly report. Hughes Satellite Systems and its US subsidiaries filed chapter 11 petitions on 2 August 2026 in the Southern District of Texas, and stated that customers would be served during the case (EchoStar's Form 8-K); the trade press reports a missed 1.5 billion dollar debt payment and 622,000 broadband subscribers at the end of the second quarter of 2026. What failed was the companies, not a satellite or a link, and the sources read do not show any network stopping. In this dated case, the spectrum licenses and the network companies followed different corporate paths: the licenses were sold for large sums while the companies that ran the networks entered bankruptcy. That is the whole lesson the sources support. It is not a law that spectrum is worth more than satellites, and the case says nothing about the quality of any of the services. Chapter 13 returns to it in one line as a supplier risk.

**SECURITY NOTE**

**Who can interfere or command.** On road one in the United States the satellite is a secondary user of the carrier's band: it may not cause harmful interference and may not claim protection, so in practice it must change or stop transmissions that interfere, on the terms of its authorization (how fast was not stated in the documents read). On road two the satellite operator holds the band and must coordinate with its neighbors. On either road, a transmitter on the same frequency, strong enough at the satellite's receiver, can degrade an uplink that starts from a 0.2 W phone, and one near the phone can degrade its downlink. Lawful interception and emergency routing are questions of jurisdiction: where the core sits, where the user is, and which licenses apply. In the United States the FCC requires 911 calls and texts over SCS to reach a public safety answering point; for Canada and Japan the routing rules were not in the documents read. A state's lawful authority over a carrier or a satellite operator is not command access, but it can compel the party that holds it. **How it is seen.** Interference is seen by the party whose service degrades: the carrier's towers, a neighboring satellite operator, or the users, and the regulator resolves the complaint. **How it is recovered.** On road one, the right ends with the lease or the license; on road two, with the authorization, as the European Union's 2027 expiry shows. A buyer recovers from a lost right only through another service with a valid authorization, on either road or on the ground.

**Monday rule:** for a direct to device service, write the band, the license holder, whether the satellite's use is primary or secondary, the jurisdiction, and the date the right ends, each from the regulator's own document.

CHAPTER TEN

# Direct to Device, Part 3: Devices, Operators and the Meaning of "In Service"




Eight days apart in November 2026, two satellite companies told investors about service to small devices. On 9 November AST SpaceMobile reported twelve satellites in operation and said it expected to activate intermittent nationwide service in the United States before the end of the year. On 17 November Iridium announced the activation of Iridium NTN Direct, a standards-based narrowband service, and added that "initial availability, however, will vary". Neither statement says that a person can buy the service today, in a named country, on a named phone. This chapter asks, for the book's date of 23 November 2026, which phone can do what, through whom, where, and with which qualifier. The decision it changes is how a reader turns a press release into a row of facts that can be checked.

## Device support is its own question

Chapter 8 covered the standard and chapter 9 the spectrum. The third separate thing is the device. A phone that "supports satellite" belongs to one of three classes, and each needs something different from its maker, its software and its carrier.

- **A phone built for mobile satellite spectrum, with a proprietary link.** The phone carries radio hardware and software for a band allocated to satellites, and the satellite operator holds that band. Apple's satellite features on the iPhone 14 and later, carried by Globalstar, are the case. No carrier is on the satellite radio link, though the phone maker states that SMS by satellite needs the carrier's support.
- **A phone that implements the satellite standard in a satellite band.** The modem implements a 3GPP satellite variant (NR-NTN or IoT-NTN, chapter 8) in mobile satellite spectrum that a satellite operator holds; supporting one does not mean supporting the other. Skylo's service for Verizon on named Android phones is the case; researchers who measured Skylo's network in 2026 describe it as NB-IoT over geostationary satellites.

- **A compatible phone served on its carrier's own band.** The service needs no satellite band in the phone; the satellite transmits in the carrier's terrestrial spectrum, and the same phone may also support another class. Even so the phone is not simply any phone: both carriers outside the United States whose pages were read publish a list of the phone models that support it. SpaceX's service with T-Mobile, and the same company's service with carriers in Japan and Australia, are the cases.

Each class needs a different party to say yes. In the first class the phone maker decides which phones get the feature. In the second the modem maker, the phone maker and the carrier must all enable it. In the third the carrier lists the phones, and a listed phone may still need a software update or a carrier setting before it uses the service; which phones need what is stated service by service. A supported phone list is a dated document; this book prints none as complete.

## Operator designs on the book's date

Figure 10.1 sets out each design as one row: the country, the retail operator, the satellite operator, the device class, what it carries, the qualifier with its start date, and the newest source read for its status. The status column matters most. A launch release proves a start date; it does not prove that the service still runs on the book's date. Where no source newer than the launch was read, the row says so.

FIGURE 10.1

## Direct to device on 23 November 2026: what each service carries, on which phone, where, and how recent its status is

| Country | Retail operator | Satellite operator | Device class | Carries | Qualifier, since | Newest status source read |
|---|---|---|---|---|---|---|
| United States | T-Mobile (T-Satellite) | SpaceX | Compatible phone on the carrier's list (list not read), carrier's band | Messaging; app capabilities announced for October 2025 (carrier's release) | General commercial from 2025-07-23 (carrier's release, operator claim); not checked on the book's date | FCC DA 26-471, 2026-05-12: service has brought connectivity |
| United States, Canada and others (LL-2022-01) | None on the satellite link: the phone maker (SMS needs carrier support) | Globalstar | Phone built for satellite spectrum, proprietary link (iPhone 14 or later) | Emergency messages from 2022-11-15 in the US and Canada (Apple); messages, location and roadside help, each with its own countries and dates, not itemized here | General commercial for emergency messages from 2022-11-15 (Apple); the Apple Support page read 2026-11-23 describes Messages via satellite; other features not rechecked | Apple Support page on Messages via satellite, read 2026-11-23; Amazon Form 8-K, 2026-04-14 |
| United States | Verizon | Skylo with partner geostationary operators | Phone with the satellite standard in a satellite band (select Galaxy S25, Pixel 9) | Text to any device; emergency messages from 2024 | From 2025-03-19 | Skylo, 2025-03-19; not rechecked |
| United States | Partner carriers | AST SpaceMobile | Compatible phone, carrier's band | Voice and data as a target | Intermittent nationwide activation expected before end of 2026 (company); no general commercial date read | AST Form 8-K, 2026-11-09 |
| Where authorized | Iridium and partners | Iridium | Module (nRF9151), not phones | Low power data | Activated 2026-11-17; availability "will vary" | Iridium release, 2026-11-17 |
| Japan | KDDI, Okinawa Cellular (au Starlink Direct) | SpaceX | Compatible phone, 50 models at start | Text, location sharing, alerts; Gemini on Android | From 2025-04-10; free for the time being | KDDI, 2025-04-10; not rechecked |
| Australia | Telstra (Satellite Messaging) | SpaceX | Listed iPhone and Samsung models | Text only; not an emergency service | Intermittent, from 2025-06-07 | Telstra, 2025-06-07; not rechecked |
| Announced | Elveo Mobile (Lynk and Omnispace) | Elveo Mobile | Not stated | Not stated | Services targeted early 2028 (trade press) | Light Reading (trade press), 2026-08 |

| Country | Retail operator | Satellite operator | Device class | Carries | Qualifier, since | Newest status source read |
|---|---|---|---|---|---|---|
| Announced | Amazon | Amazon Leo | Not stated | Not stated | Own direct to device system from 2028 | Amazon Form 8-K, 2026-04-14 |

Each row is one service as its source describes it; a start date proves a start, and the last column names the newest source read for the status on the book's date.

*Source: Amazon Form 8-K exhibit 99.1 (2026-04-14); Globalstar Form 8-K (2024-10-29); Broadband Breakfast, trade press (2025); FCC DA 26-471 (2026-05-12); Skylo release (2025-03-19); Verizon release (2024-08-28); AST SpaceMobile Form 8-K exhibits 99.1 and 99.2 (2026-11-09); Iridium release (2026-11-17); KDDI release (2025-04-10); Telstra release (2025-06-07); Light Reading, trade press (2026); Lynk release (2022). Read 2026-11-22 and 2026-11-23.*

**A phone maker with a low orbit mobile satellite operator.** Emergency messaging on the iPhone 14 line began on 15 November 2022 in the United States and Canada; the second book of this series, *From Telstar to the Phone in Your Pocket*, tells how it came about and prints its service page as LL-2022-01. What it means today rests on two filings. Globalstar's agreement of 2024 allocates 85 percent of its current and future network capacity to that one customer. On 14 April 2026 Amazon and Globalstar announced that Amazon would acquire Globalstar, closing expected in 2027, and Amazon states that its own network will power the phone maker's satellite features (Emergency SOS, Messages, Find My and Roadside Assistance) for the iPhone 14 or later, and will add its own direct to device system from 2028. Chapter 13 takes up what that change of owner means for a buyer.

**A broadband constellation with a carrier, on leased spectrum.** T-Mobile's release of 23 July 2025 says that T-Satellite, on SpaceX's satellites, was available in the United States from that day "for everyone", customers of other carriers included, with app capabilities such as maps and weather to be added in October. Trade press had reported the date in advance from the carrier's June event, with more than 657 direct to cell satellites in orbit by the carrier's count. The release is the carrier's own claim and speaks for July 2025, not for the book's date, and the carrier's current service page, with plans, phones and coverage, was not read. This book therefore uses T-Satellite as a worked example of the status fields, not as a recommendation: a buyer reads that page before treating it as a candidate; the newest primary record read is the FCC's order of 12 May 2026, which describes supplemental coverage from space as having "brought" connectivity to consumers in dead zones, so far for text-based services. Page 1 of this service, as it stands, follows below as LL-2026-02. It is copied unchanged from the second book, whose evidence row now gives the launch date as the carrier's own claim, from the same release. Its illustrative uplink model is *From Telstar to the Phone in Your Pocket*'s and is not reprinted.

**LINK LEDGER · LL-2026-02 · SERVICE LEDGER**

2026-11-23

System: A text from a compatible phone over a carrier's terrestrial spectrum: T-Mobile's T-Satellite on Starlink direct to cell satellites, United States (page 2: an illustrative model)

**Status on the book's date: not checked** | **Class: full** | **Budget: page 2 not printed in this book**

| | |
|---|---|
| **1 Requirement** | A listed phone, outdoors with open sky and no tower in reach, sends a short text. The rate is not published; page 2 assumes one. |
| **2 Ends and path** | A listed phone that needs no satellite-band hardware; the carrier's core network, which delivers the text.<br>**Path:** Regenerative: an LTE base station on each satellite; to a ground station, or across satellites by laser, then to the carrier's core (researchers, 2025; SpaceX's filing as quoted by the FCC, 2026). |
| **3 Orbit and time** | Low orbit, mainly about 550 km, some about 350 km (researchers, 2025); each satellite is in view for minutes.<br>**Time:** Phone to satellite: 1.8 ms straight up, 3.7 ms at 25 degrees (calculated). Delivery time of a text is not published. |
| **4 Band and permission** | **Phone to satellite.** 1910 to 1915 MHz, PCS G block, T-Mobile's license; FCC 24-28 framework, the service's own grant not read; United States<br>**Satellite to phone.** 1990 to 1995 MHz, the same block<br>**Satellite to gateway.** Not read |
| **5 Capacity** | **Up.** A short text; rate not published.<br>**Down.** About 3.1 Mbit/s per beam, shared by every phone in it (researchers' estimate, 2025).<br>Beta median reference signal received power (RSRP, a signal level, not throughput): -121 dBm via satellite, -97 dBm via towers, 2024-10 to 2025-07. |
| **6 Who owns each end** | **Space segment.** SpaceX<br>**Ground segment.** SpaceX's gateways; the carrier's core<br>**Customer relationship.** T-Mobile<br>**The exit.** Not checked: a contract question |
| **7 Trust** | The carrier authenticates the SIM in its own core. Satellite command and protection of traffic in space are not described. |
| **8 How it fails, and how we would see it** | No open sky, an unlisted phone or no satellite in view: the text waits or fails.<br>**How we would see it:** Phone: shows the satellite network. Carrier: delivery records. Operator monitoring: not published. |
| **9 Cost shape** | Included in some plans, a monthly fee for others (trade press, 2025). |
| **10 Evidence** | Status: not checked *assumption* Newest record read: FCC DA 26-471 (2026-05-12); the carrier's page would settle it, 2026-11-23<br>Available from 2025-07-23 operator claim T-Mobile, "T-Satellite Now Available", newsroom release, 2025-07-23, 2026-11-23<br>PCS G block, 1910 to 1915 MHz up, 1990 to 1995 down **measured** Garcia-Cabeza and others, "Direct-to-Cell: A First Look into Starlink's Direct Satellite-to-Device Radio Access Network through Crowdsourced Measurements", arXiv 2506.00283v8 (preprint), 2026-11-23<br>RSRP -121 vs -97 dBm (550 km and some 350 km satellites) **measured** Same study, 2026-11-23<br>3.1 Mbit/s per beam (estimate) calculated Same study, 2026-11-23<br>1.8 ms up, 3.7 ms at 25 degrees calculated At 550 km, 2026-11-23 |

*Page 2 is an illustrative uplink model, not a qualification of the service and not a property of Starlink.*

**Very large arrays.** AST SpaceMobile flies the large arrays chapter 8 describes. On 9 November 2026 it reported twelve satellites unfolded and operating, a target of about 45 in orbit by mid 2027, a potential ecosystem of over 60 mobile operators, and an expected activation of intermittent nationwide service in the United States and other markets before the end of 2026. Every one of those is the company's own statement, filed with the SEC. On the book's date the company's own words describe a target, and no general commercial date appears in the sources read, so its page below is marked Planned with the qualifier in its header.

**LINK LEDGER · LL-2026-10 · SERVICE LEDGER**

2026-11-23

System: Voice or data from a compatible phone through very large arrays in low orbit: AST SpaceMobile, United States. Planned: intermittent service expected before the end of 2026; activation not verified on the book's date (service ledger; every number an operator claim)

**Planned** | **Class: service only**

| | |
|---|---|
| **1 Requirement** | An ordinary compatible phone, outdoors with no tower in reach, makes calls and uses data. The company expects to activate intermittent nationwide US service before the end of 2026; no general commercial date appears in the sources read. |
| **2 Ends and path** | A compatible phone on a partner carrier's network; at the ground end, the company's gateways and the partner's core. The company cites a potential ecosystem of over 60 mobile operators.<br>**Path:** Phone to satellite on the partner's band, satellite to a gateway, then the partner's core. Transparent or regenerative: not stated in the documents read. |
| **3 Orbit and time** | Low orbit; 12 satellites unfolded and operating on 2026-11-09; a target of about 45 in orbit by mid 2027 (company). Altitude not read in the company's filings.<br>**Time:** Coverage is intermittent by the company's own word while the fleet is small. Call delay: not in the sources read. |
| **4 Band and permission** | **Phone to satellite.** Partner carriers' terrestrial bands; the company targets about 100 MHz of shared carrier and its own satellite spectrum in the US. License instrument for commercial service not read<br>**Satellite to gateway.** Not read |
| **5 Capacity** | **Up.** Not in the sources read.<br>**Down.** Not in the sources read.<br>Array area (chapter 8) is not capacity; no per-beam or per-user rate is filed. |
| **6 Who owns each end** | **Space segment.** AST SpaceMobile<br>**Ground segment.** AST SpaceMobile's gateways; the partner's core<br>**Customer relationship.** The partner carrier<br>**The exit.** Not checked: a contract question |
| **7 Trust** | The partner's core authenticates the SIM, as on the ground; the company commands the satellites. Protection of traffic in space and on the feeder link is not described in the documents read. |
| **8 How it fails, and how we would see it** | A small fleet means gaps in time: the company itself says intermittent. One launch failure removed a satellite in 2026 (chapter 8).<br>**How we would see it:** Phone: whether the satellite network appears. Partner: core records. Public: the company's SEC filings. |
| **9 Cost shape** | No user price in the sources read. |
| **10 Evidence** | 12 satellites operating on 2026-11-09 (operator claim) AST SpaceMobile, Form 8-K exhibit 99.2 (business update), 2026-11-22<br>Intermittent nationwide US service activation expected before the end of 2026; about 45 satellites by mid 2027 (operator claim) AST SpaceMobile, Form 8-K exhibit 99.1, 2026-11-09, 2026-11-22<br>About 100 MHz US spectrum target; over 60 operators as a potential ecosystem (operator claim) Same exhibit 99.1, 2026-11-22 |

**Service only, no hop budget:** the array gain, the noise temperature and the waveform are not published in the documents read; an illustrative phone uplink is worked in the first book of this series, The Bit's Path.

**Standards-based narrowband through partner geostationary satellites.** Skylo owns no satellites. It uses the mobile satellite spectrum and satellites of partner operators, and runs a core network between their ground stations and the carriers. Verizon and Skylo announced emergency messaging and location sharing from autumn 2024, and on 19 March 2025 Skylo stated that select Galaxy S25 and Pixel 9 phones on Verizon could text any other device by satellite. Skylo's own footnote reads that coverage "is not complete, uniform, or comprehensive worldwide". An independent view exists only of Skylo's IoT service, not of its texting for phones. Researchers at universities in China and Luxembourg measured Skylo's narrowband service for more than six months and reported in September 2026 (a preprint, not yet peer reviewed) that their test used the Inmarsat-4 F1 satellite, a ground station in Hong Kong and a core network in the United States, with a median end-to-end time of about 9 seconds for packets under 32 bytes. Most of those seconds were access signaling, not propagation: each request and its reply cross the geostationary path four times, about 119 ms per crossing straight up, and a connection needs several such exchanges. That measurement is of modules sending data, not of phones sending texts, and it says nothing about Verizon's service on the book's date, which this book did not check.

**LINK LEDGER · LL-2026-09 · SERVICE LEDGER**

2026-11-23

System: Satellite texting from a listed phone through partner geostationary satellites in mobile satellite spectrum: Verizon with Skylo, United States (service ledger)

Status on the book's date: not checked | Class: service only

| | |
|---|---|
| **1 Requirement** | Outside terrestrial coverage, a listed phone sends a text to any other device. Skylo names select Galaxy S25 and Pixel 9 models. No rate, delivery time or availability is published in the sources read. |
| **2 Ends and path** | A listed phone whose modem supports Skylo's service; at the far end, the carrier's messaging network and the recipient's phone.<br>**Path:** Phone to a partner's geostationary satellite, a ground station, Skylo's core, then the carrier. Researchers who tested Skylo's IoT service used Inmarsat-4 F1, a ground station in Hong Kong and a core in the United States (2026). |
| **3 Orbit and time** | Geostationary. The partner satellites that carry US texting are not named in the sources read.<br>**Time:** One leg straight up about 119 ms (calculated). On Skylo's IoT service researchers measured a median of about 9 s end to end for packets under 32 bytes (2026). Text delivery time: not in the sources read. |
| **4 Band and permission** | **Phone to satellite.** Mobile satellite spectrum of Skylo's partner operators (Verizon, 2024); bands and licenses by country not read<br>**Satellite to ground.** Not read |
| **5 Capacity** | **Up.** Short texts; rate not in the sources read.<br>**Down.** Short texts; rate not in the sources read.<br>Skylo: coverage comes from its partners and is not complete, uniform or comprehensive worldwide. |
| **6 Who owns each end** | **Space segment.** Partner satellite operators; Skylo owns no satellites<br>**Ground segment.** Partner ground stations; Skylo's core; the carrier's network<br>**Customer relationship.** Verizon<br>**The exit.** Not checked: a contract question |
| **7 Trust** | Three parties touch each message: the satellite operator, Skylo's core and the carrier. Who holds which keys, and what Skylo's core can read, is not described in the sources read. |
| **8 How it fails, and how we would see it** | No partner satellite in view, a blocked sky or an unlisted phone: the text waits or fails. Each access exchange crosses the long geostationary path, so setup adds seconds in the measured IoT case; for a phone text, not in the sources read.<br>**How we would see it:** Phone: satellite mode and delivery status. Carrier and Skylo: network records, not in the sources read. |
| **9 Cost shape** | Verizon's terms for the feature on the book's date: not read. |
| **10 Evidence** | Texting to any device on select Galaxy S25 and Pixel 9 phones operator claim Skylo newsroom release, 2025-03-19, 2026-11-23<br>Licensed mobile satellite spectrum; emergency messaging from autumn 2024 operator claim Verizon release, 2024-08-28, 2026-11-22<br>Median about 9 s end to end, packets under 32 bytes, Skylo IoT service measured Wang and others, arXiv 2609.06280v1, preprint, not peer reviewed, 2026-09-05, section 3.1, 2026-11-23 |

**Service only, no hop budget:** the partner satellites, their antenna and receiver figures and the waveform settings of this service are not in the sources read.

**A low orbit mobile satellite operator adding the standard in its own band.** Iridium activated Iridium NTN Direct on 17 November 2026, a 3GPP narrowband IoT and direct to device service in its own L band spectrum. Its release certifies one module, Nordic Semiconductor's nRF9151, and says the module maker plans a public firmware update in January 2027. Phones are not mentioned. On the book's date it is a service for modules whose qualifier the operator itself leaves open; chapter 11 places it among the sensor networks.

**Announced, table rows only.** Lynk and Omnispace completed their merger as Elveo Mobile on 14 August 2026, with nine satellites and services targeted for early 2028 (trade press). Lynk states that the FCC granted it a commercial license for satellite service to standard phones on 16 September 2022; a license is not a service. Amazon's own direct to device system is stated for 2028. Both stay rows until a service has a country, a device and a date.

## Outside the United States

Two carriers outside the United States published dated primary records that this book could read. In Japan, KDDI and Okinawa Cellular started au Starlink Direct on 10 April 2025 on SpaceX's satellites: text messages, location sharing through a message app, Google's Gemini on Android phones, and earthquake, tsunami and national alerts, on 50 Android and iPhone models at the start, free "for the time being" with no application needed. In Australia, Telstra began rolling out Telstra Satellite Messaging on 7 June 2025, also on SpaceX's direct to cell satellites. Telstra limits it to text messages, calls it "an intermittent service", and states that it is "not designed to be an emergency service": a user "cannot text Triple Zero directly". Both releases date a start; neither speaks for 23 November 2026, and both rows carry "not rechecked".

Carrier pages for New Zealand and Canada, where trade press reports similar services on the same satellites, were sought and not read, so those countries are not rows; Appendix B lists them. In China, a phone service on the Tiantong geostationary system is reported but no operator page was read. The same preprint that measured Skylo also measured a Tiantong narrowband IoT network, with its ground station in Xi'an and its core in Beijing, and judged that network to be at an early stage. That is a measurement of an IoT test network, not evidence of a phone service.

## What each service carries, and the meaning of "in service"

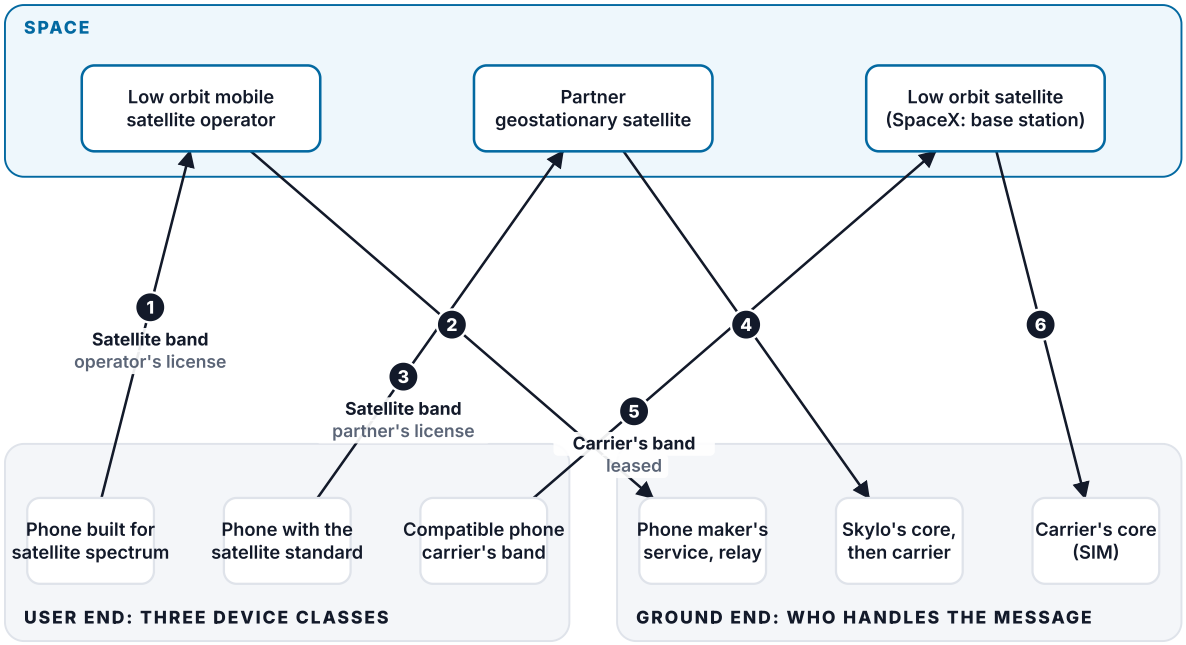
The rows differ most in what they carry. Read across figure 10.1 by the range of uses they support, the services carry: emergency messages only; text to emergency services and to anyone; text with some apps and limited data; voice and data as a stated target. For a safety

requirement, the narrowest row may be the one that matters. A single service also changes over time: T-Satellite was launched with messaging first and app capabilities announced for three months later. A buyer who needs data on 23 November 2026 cannot use a row that carries text, however many satellites stand behind it.

"In service" therefore needs five fields and two more facts. The five fields are the country, the retail operator, the device, the date and the qualifier: trial, preview, limited commercial, general commercial, intermittent, suspended or retired. Intermittent is the operators' word for service with gaps in time while a fleet is small; it describes coverage over time and can sit beside a commercial qualifier. The two facts are what it carries, and whether the sky must be open. Every service in figure 10.1 needs a view of the sky; none of the sources read promises indoor use, and Telstra and KDDI both say so. All three service pages in this chapter print "not checked" or "Planned" in the status field. That is not a gap in the pages; it is what the sources read allow this book to record on its date.

FIGURE 10.2

## Three device classes hand the message to three different sets of parties




From left: a phone built for satellite spectrum reaches the phone maker's service through the satellite operator, with no carrier on the satellite link (the phone maker states that SMS by satellite needs carrier support); a phone with the satellite standard reaches the carrier through a partner's geostationary satellite and Skylo's core, three parties in all; a compatible phone on its carrier's band reaches the carrier's core, which authenticates the SIM as on the ground. The figure shows who handles the message, not who authenticates it in the first two designs or who can read it: the sources read describe neither.

*Author's diagram based on Globalstar Form 8-K (2024-10-29) and Amazon Form 8-K exhibit 99.1 (2026-04-14); Skylo release (2025-03-19) and Wang and others, arXiv 2609.06280v1 (2026; preprint, not peer reviewed); FCC 24-28 and the second book of this series for the carrier design. Read 2026-11-22 and 2026-11-23.*

Figure 10.2 draws the three device classes on one canvas. The difference that matters for the next section is which parties handle the message between the phone and the person who receives it. Who authenticates the user is stated only for the carrier design, and who can read the message is stated for none.

**RECONSTRUCTION · 2026 · THE REPORT FROM OUT OF REACH**

| | |
|---|---|
| **The message** | The adjuster's own phone, no tower in reach. |
| **The link** | Direct to device |
| **Note** | Assumes the service runs as its newest primary record (FCC, May 2026) describes; its status on the book's date was not checked. Appendix D dates each status. |

*A reconstruction: the insurer is invented and illustrative. The link is the documented service of that year.*

The scene is set in the United States on the book's date, on a compatible phone and T-Mobile's T-Satellite, the US service of figure 10.1 with the most recent primary record read, the FCC's order of May 2026. That order describes the service as having brought text connectivity; no source read speaks for 23 November 2026 itself, so its ledger status is "not checked" and the scene assumes the service still runs as the order describes it. What it carried was text, with app capabilities announced for October 2025 in the carrier's release. It did not promise a voice call, and it needed the adjuster outdoors with open sky. No published source read for this book states how long a text takes on this service: the time depends on when a satellite is in view and on the network behind it.

## What a reader can test

A buyer does not need to take a row on trust. A test of a direct to device service requires four things, written before the first message is sent: the phone model and its software version; the plan and the carrier's written confirmation that the feature is enabled; a place with no terrestrial coverage, with its latitude and the sky view recorded; and a log of every attempt, with the time sent, the time delivered and the result. Wi-Fi is off, roaming is set as the service requires, and the place has no terrestrial coverage, so that an attempt can only go by satellite; the phone's satellite indicator is noted for each attempt; the delivered time is read at the receiving end on the same clock; and failed and abandoned attempts are counted, not dropped. Run it at several times of day, because a low orbit service depends on which satellites are overhead. The output is a delivery distribution for that phone, that place and those dates. Attempts within one pass tend to succeed or fail together, so they are spread over many passes and days; with no failure in about 300 independent attempts, the failure rate is below 1 percent at about 95 percent confidence (calculated), so a few dozen attempts cannot show a rate near 99 percent. It says nothing about another country, and one test is not a qualification of the whole service.

THE SYSTEM'S FAILURE

Iridium and Qualcomm had announced agreements to bring satellite messaging and emergency service to phones built on Qualcomm's Snapdragon platforms over Iridium's network. Iridium's Form 8-K of 9 November 2023 records the end: the companies "successfully developed and demonstrated the technology", but "smartphone manufacturers have not included the technology in their devices", and on 3 November 2023 Qualcomm gave notice that it would terminate the agreements, effective 3 December 2023. By the companies' account the technology worked in demonstration; one route to device support did not, because phone makers did not put the technology in their phones. Iridium stated that it was free to work again with phone makers, other chip makers and operating system developers, and three years later it activated a standards-based service for modules. The case shows that a working technical demonstration did not, on its own, put the feature in phones; it does not show who in general decides device support.

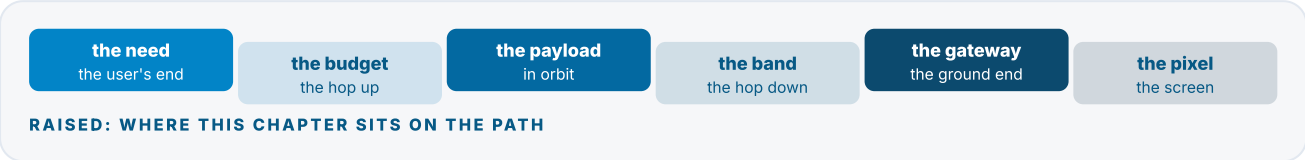
SECURITY NOTE

**Who can interfere or command.** Each design hands the message to a different set of parties (figure 10.2). In the carrier designs the carrier's core authenticates the SIM, as on the ground, and the satellite operator commands the satellites. In Skylo's design three parties handle each message: the satellite operator, Skylo's core and the carrier. In the phone maker's design the phone maker's service and the satellite operator carry the message; a carrier joins only for features such as SMS. What the satellite operator can see depends on the payload, the protocols and the encryption; none of the sources read describes it, so this book marks it not in the sources read. Technical command, contractual control and lawful authority sit with different parties in each row. **How it is seen.** The user sees only whether the phone shows the satellite network and whether a message was delivered; the user cannot tell whether a failure was the sky, the satellite, a core network or an entitlement. **How it is recovered.** Open sky or the next pass helps only when the radio link is the problem. It does not help when a core network fails or when an operator withdraws the feature from a plan or a phone; then recovery is a contract question.

**Monday rule:** before you rely on a phone service by satellite, write five fields for it, the country, the operator, the device, the date and the qualifier, and add what it carries; if one is missing, you do not yet know that it is in service.

CHAPTER ELEVEN

# Narrowband Satellite IoT: Small Messages from Anywhere




In September 2026 eight researchers published six months of measurements of a standard narrowband IoT module talking to geostationary satellites. Their power traces show where a battery's energy went when the module sent one small packet from idle: 5 percent to the data itself, and the rest to finding the network, repeating access messages across the long path, and the signaling that sets up and closes a connection. A sensor that sends forty bytes twice a day is not limited by its data rate. It is limited by how much energy it spends to get each message delivered, and by how sure it can be that the message arrived. This chapter asks, for that sensor, what the right network is, what delivery really means, and what the battery pays. The decision it changes is the question a buyer asks first: not "how fast", but "how much energy per delivered message, and with what probability".

## The requirement comes first

A satellite IoT requirement has four numbers that a broadband requirement does not. Take this chapter's worked case, a sensor that sends forty bytes twice a day. Bytes per day: here eighty. Years of battery, with no visit to the site: the buyer sets it, say five. A price per message or per device that fits a sensor that may cost less than its installation. And the longest acceptable delay, which may be minutes or hours: a water level read twice a day does not need an answer in a second. A fifth number matters as much: the probability that a message is delivered at all within that delay. Write all five before reading a product sheet. The product sheet will lead with the rate, and for a sensor like this one the rate is rarely the number that decides.

Two other facts belong in the requirement. Who must receive the message (a server the customer owns, a platform the operator owns, or a mobile operator's network), and whether the device must hear back: an acknowledgment, a command, a new setting, a firmware

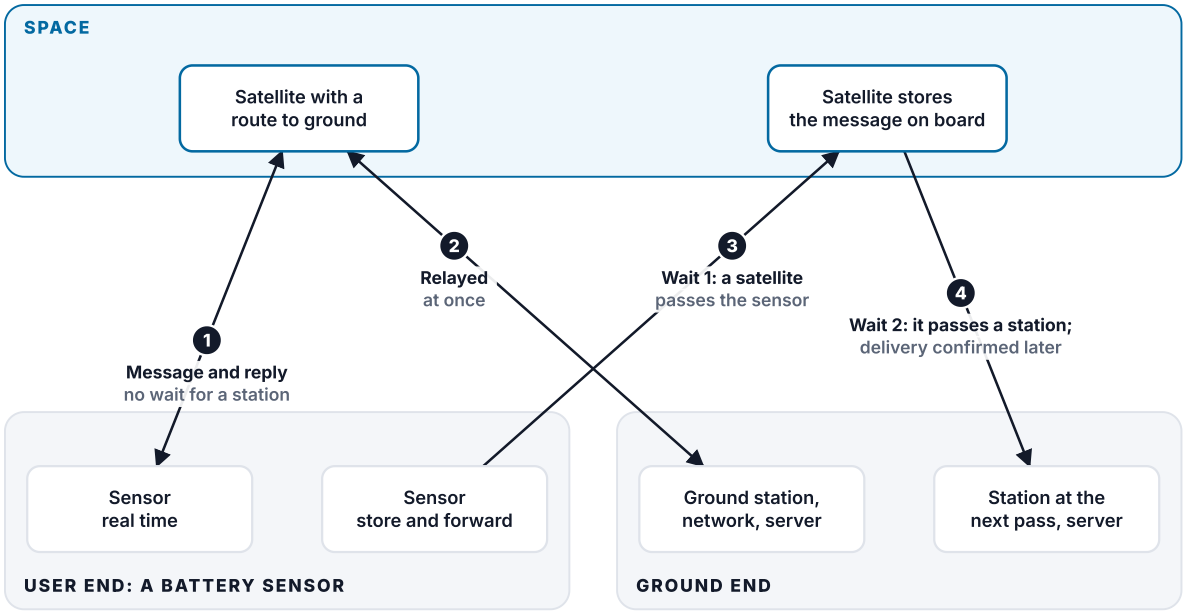
update. A device that only transmits can be very simple. A device that must listen for an answer spends energy listening.

## Real time, or store and forward

There are two ways to carry a small message by satellite, and figure 11.1 draws both. In **real time**, the satellite that hears the device has a route to a ground station at the same moment, directly or through crosslinks, so the message reaches the network without waiting for a ground station and an acknowledgment can come straight back; access and queues still take time, about 9 seconds in the measurements of chapter 10. Geostationary networks work this way, and so do low orbit networks with enough ground stations or crosslinks. In **store and forward**, the satellite that hears the device has no route to a ground station at that moment. It keeps the message on board and delivers it when it passes over a ground station. The second book of this series, *From Telstar to the Phone in Your Pocket*, tells how old this idea is; here it matters as a design a buyer can choose today.

FIGURE 11.1

## Real time or store and forward: the same small message, and where its acknowledgment waits




Left: in real time the satellite that hears the sensor has a route to a ground station, directly or through crosslinks, so the message reaches the network without waiting for one, and a reply can come straight back. Right: in store and forward the satellite can confirm receipt at once, holds the message until a ground station is in view, and confirmation of delivery to the server returns only on a later pass; the wait for a satellite over the sensor applies to any low orbit network with gaps, real time or not; the wait for a station is the one store and forward adds, and both add to the access time.

*Author's diagram based on 3GPP, Non-Terrestrial Networks (NTN) overview (store and forward in Release 19), read 2026-11-22; a pattern, not one operator's design.*

In a low orbit network with gaps, either design can make the device wait for a satellite to pass over it. Store and forward adds a second wait, for that satellite to pass over a ground station. Both depend on the number of satellites, their orbits, the device's latitude and the number and placement of ground stations, so the delay is a distribution, not a number. Delivery is also a probability. It depends on how often the device and a satellite meet, how many messages a satellite can hold, how long a message may wait before it is dropped, whether the device asks for an acknowledgment, and what it does when none comes. Two acknowledgments must be kept apart. The satellite can confirm at once that it received the message; confirmation that the customer's server received it makes the trip in reverse and can arrive one or more passes later. A device that keeps its radio on waiting for the second pays for every minute.

Store and forward does not guarantee eventual delivery. A message can wait in a full queue, expire before the satellite reaches a station, or be lost with a satellite. A buyer learns how often that happens from the operator's delivery statistics, measured per message, from an independent study, or from a trial that logs every message sent against every message received.

## Proprietary networks

A proprietary network designs its own radio link and its own device module, and owns the subscription. Four cases show different choices.

**Kinéis** (France) completed a constellation of 25 nanosatellites with its fifth launch on 18 March 2025: five sun-synchronous planes of five, a ground segment with mission, control and service centers, and 20 ground stations around the world, according to the French space agency CNES, which ran the deployment and the control center with the company. The system descends from Argos, the long-running satellite location and data collection system, and every satellite carries a new generation Argos payload; two satellites per plane also carry a receiver for ships' identification signals. CNES set the transfer of operations to Kinéis for 1 January 2026, with a design life of eight years. CNES describes the service as near real time and low rate, with low energy use; the band and delivery statistics were not published in the source read, and a 2023 review by European radio astronomers lists the system under the European decision for satellite personal communications below 1 GHz.

**LINK LEDGER · LL-2026-12 · SERVICE LEDGER**

2026-11-23

System: Sensor message on a proprietary IoT network of 25 nanosatellites and 20 ground stations, Argos heritage: Kinéis, France (service ledger)

**Status on the book's date: not checked** **Class: service only**

| | |
|---|---|
| **1 Requirement** | Connect and locate any object anywhere, with near real-time, low-rate delivery and low energy use, in the words of the space agency that built it with the operator (CNES, 2025). A buyer adds bytes per day, delay and battery life. |
| **2 Ends and path** | A device with the network's own proprietary radio; at the far end, the service center and the customer's platform.<br>**Path:** Device to satellite to one of 20 ground stations, then the mission and service centers. Whether a message waits on board for a station: not stated in the source read. |
| **3 Orbit and time** | Sun-synchronous low orbit, five planes of five; constellation completed 2025-03-18; design life 8 years (CNES). Contact comes in passes.<br>**Time:** Near real time, per CNES; no delay distribution is published in the source read. |
| **4 Band and permission** | **Device to satellite.** Below 1 GHz: listed under the CEPT decision for satellite personal communications below 1 GHz (a 2023 review); exact band not read<br>**Satellite to ground.** Not read |
| **5 Capacity** | **Up.** Low rate, per CNES; numbers not published in the source read.<br>**Down.** Two-way service: not stated in the source read. |
| **6 Who owns each end** | **Space segment.** Kinéis (created by CLS with CNES support)<br>**Ground segment.** Kinéis: mission center, service center, 20 stations; CNES ran control until the planned transfer<br>**Customer relationship.** Kinéis and its partners<br>**The exit.** Not checked; moving needs another network that supports the same radio, new credentials and a contract, none found in the sources read |
| **7 Trust** | CNES ran the control center; transfer to Kinéis was set for 2026-01-01, and whether it took place was not read. After it, one company would hold command and service. Message protection: not described. |
| **8 How it fails, and how we would see it** | A proprietary device is tied to its network: unless another network supports the radio, devices are replaced when the service ends. Losing a satellite thins a plane of five.<br>**How we would see it:** The service center's delivery records; the customer's own received-message log against the device's schedule. |
| **9 Cost shape** | Not read. |
| **10 Evidence** | 25 nanosatellites, five planes of five, sun-synchronous; complete 2025-03-18; 20 stations; 8 years operator claim CNES, Dernier lancement reussi pour Kineis, 2025-03-18 (CNES is a founding partner), 2026-11-22<br>Operations to transfer to Kinéis on 2026-01-01 operator claim Same page, 2026-11-23<br>Listed under ECC/DEC/(99)06, satellite personal communications below 1 GHz published history ESF-CRAF Periodic Review 2011 to 2021, page 55 (labeled scholarship; the decision itself not read), 2026-11-23 |

**Service only, no hop budget:** the proprietary waveform and the satellites' receiver figures are not published in the source read.

*Status on the book's date not checked: the newest source read is the agency's page of 2025-03-18.*

**Myriota** (Australia) shows a different ownership model: its network software runs on satellites built and launched by another company. On 12 January 2026 Spire launched nine satellites, eight of them for Myriota, by Spire's own account. The buyer's question changes with this model: whose satellite, whose license and whose decision decide whether the network keeps running.

**ORBCOMM** (United States) announced on 18 June 2024 the commercial start of its OGx service, which succeeds its earlier IsatData Pro service on existing satellite network infrastructure and, by the company's account, cuts terminal power use. The release does not name the satellites, and this book did not read which fleet carries it.

The established low orbit mobile satellite operators of chapter 6 also sell short message services to modules. They are rows in figure 11.2, not new cases.

## Standards-based networks

3GPP's Release 17 added narrowband IoT (NB-IoT) and LTE-M, the two cellular standards for small, low-power devices, over satellite, for transparent payloads, and Release 19 adds store and forward for IoT over satellite with a full base station on board (chapter 8). A standards-based network lets a buyer use a module from more than one maker and a SIM from a mobile operator. It does not, by itself, mean that a given module supports a given satellite band, or that a given operator has roaming in place.

**Sateliot** (Spain) launched five six-unit CubeSats (small satellites built from six 10 cm cubes) on 2 October 2026, bringing the number it has launched to eleven, by trade press reporting the company. By the same account, the satellites serve standard Release 17 NB-IoT devices with a store and forward payload. Store and forward on the network side was standardized only in Release 19, and how the satellite admits and authenticates a device while it has no ground station in view is not published in the sources read. Its page follows. The configuration is one sensor with a standard module whose message enters a mobile operator's network; how many of the eleven satellites operate, the bands, and whether the service is in general commercial use on the book's date were not found in a primary source, so the status field reads "not checked".

**LINK LEDGER · LL-2026-11 · SERVICE LEDGER**

2026-11-23

System: Sensor message from a standard NB-IoT device, store and forward through low orbit CubeSats, delivered into a mobile operator's network: Sateliot, Spain (service ledger)

**Status on the book's date: not checked** **Class: service only**

| | |
|---|---|
| **1 Requirement** | A battery sensor with a Release 17 NB-IoT module (company's claim) sends a few small messages a day from outside terrestrial coverage and accepts delays of minutes to hours (this ledger's requirement). |
| **2 Ends and path** | A standard NB-IoT module and its SIM; at the far end, the customer's server, reached through a mobile operator's network.<br>**Path:** Store and forward: the satellite receives the message and holds it until it passes a ground station (trade press, 2026). Entry into a mobile operator's core by roaming: assumption, to verify. |
| **3 Orbit and time** | Low orbit, 6U CubeSats: 11 launched in total after five on 2026-10-02 (trade press); how many operate is not in the sources read. Contact comes in passes.<br>**Time:** Two waits add: a satellite over the device, then over a ground station. Neither is in the sources read; ask for the distribution. |
| **4 Band and permission** | **Device to satellite.** Not read in a primary source<br>**Satellite to ground.** Not read |
| **5 Capacity** | **Up.** A few small messages a day per device (the requirement); network capacity not in the sources read.<br>**Down.** Acknowledgments and commands: whether and when they return is not in the sources read. |
| **6 Who owns each end** | **Space segment.** Sateliot<br>**Ground segment.** Sateliot's ground stations (count not read); a mobile operator's core<br>**Customer relationship.** Not read: a partner operator or Sateliot<br>**The exit.** The module can still use terrestrial networks; contract exit not read |
| **7 Trust** | The standard has the SIM and the operator's core authenticate the device; how that works with no ground station in view, and who can read a message waiting in orbit, are not in the sources read. |
| **8 How it fails, and how we would see it** | Silently: a message waits or expires before a ground pass, and the device learns nothing unless an acknowledgment is required. Each satellite lost lengthens the waits.<br>**How we would see it:** Delivery receipts at the customer's server against the device's send log; per-message delay statistics, if the operator provides them. |
| **9 Cost shape** | Per device or per message; amounts not read. |
| **10 Evidence** | 11 satellites launched in total, five on 2026-10-02 (operator claim) SatNews (trade press) reporting the company, 2026-10-03, 2026-11-22<br>Serves standard Release 17 NB-IoT devices with a store and forward payload (operator claim) Same article, 2026-11-22<br>Store and forward for IoT-NTN standardized in Release 19, not Release 17 (standard) 3GPP's release summary, Non-Terrestrial Networks (NTN) overview, Release 19 section (specification clause not read), 2026-11-22 |

**Service only, no hop budget:** the satellites' antenna and receiver figures and the waveform settings are not in the sources read.

*Status on the book's date not checked: no primary source for commercial service was read.*

**OQ Technology** (Luxembourg) deployed two satellites under Greece's ERMIS program (its total fleet was not read), reported on 13 April 2026 by the mobile industry's association, for narrowband IoT and emergency messaging. **Skylo**, chapter 10's partner model, carries the same standard through other operators' geostationary satellites, with no satellites of its own. **Iridium** activated a standards-based NB-IoT service in its own L band spectrum on 17 November 2026, with one module certified and a public firmware update for it planned for January 2027 (chapter 10).

FIGURE 11.2

## Satellite IoT networks on 23 November 2026: who flies what, how a message reaches the customer, and what the sources read do not state

| Network | Country | Orbit | Radio | Satellites, date, who counted | Ground stations | Delivery path | Band |
|---|---|---|---|---|---|---|---|
| Kinéis | France | Low, sun-synchronous, 5 planes | Proprietary, Argos heritage | 25, complete 2025-03-18 (CNES) | 20 (CNES) | To a station, then the service center | Below 1 GHz (review); exact band not read |
| Myriota | Australia | Low | Proprietary; software on another company's satellites | 8 launched for it 2026-01-12 (Spire); total not read | Not read | Not read | Not read |
| ORBCOMM OGx | United States | Not read: existing partner infrastructure | Proprietary | No own count for this service | Not read | To the operator's platform | Not read |
| Sateliot | Spain | Low, 6U CubeSats | 3GPP NB-IoT, Release 17 | 11 launched by 2026-10-02 (trade press); how many operate is not in the sources read | Not read | Store and forward, then a mobile operator's network | Not read |
| OQ Technology | Luxembourg | Low | 3GPP NB-IoT | 2 deployed under Greece's ERMIS program, reported 2026-04-13 (GSMA); total fleet not read | Not read | Not read | Not read |
| Skylo | United States | Geostationary, partners' satellites | 3GPP NB-IoT | None of its own | Partners' (one in Hong Kong in a 2026 test) | Real time, through Skylo's core | Partners' mobile satellite spectrum |
| Iridium NTN Direct | United States | Low, crosslinked fleet | 3GPP NB-IoT | Existing fleet; activated 2026-11-17, availability "will vary" (Iridium) | Not read | Not read | L band (Iridium) |
| Established mobile satellite services | Chapter 6 | Low and geostationary | Proprietary short messages | Chapter 6 | Chapter 6 | Real time | Chapter 6 |

Counts carry their date and who counted; "not read" means no primary source for that cell was read, not that the value is zero.

*Source: CNES (2025-03-18); ESF-CRAF Periodic Review 2011 to 2021 (2023); Spire launch release, reprinted (2026-01-12); ORBCOMM release (2024-06-18); SatNews, trade press (2026-10-03); GSMA news page (2026-04-13); Skylo release (2025-03-19); Wang and others, arXiv 2609.06280v1 (2026; preprint, not peer reviewed); Iridium release (2026-11-17); 3GPP NTN overview. Read 2026-11-22 and 2026-11-23.*

## Proprietary or standard: what changes for the buyer

The difference is less about the radio than about who the buyer depends on. With a proprietary network, the module, the network and the subscription come from one operator or its partners. The operator can optimize the whole chain for low energy, and the buyer has one party to call. When that operator ends the service, the devices usually end with it: unless another network supports the same radio, they are replaced, not repointed. With a standards-based network, a module from more than one maker can work, and the same module may also use terrestrial cellular coverage where it exists. The subscription is often a mobile operator's, and the satellite operator is a roaming partner behind it. The buyer then depends on two parties, and on a roaming agreement between them that the buyer does not sign. Neither model is safer in general. The test is what happens to devices already in the field when one party stops; this chapter's failure shows one answer.

Two checks apply to every family. The service must be authorized in the country where the device sits, and a device that moves, such as a container tracker, carries that question across borders (the layers of chapter 9). And a module that supports NB-IoT on terrestrial bands does not by that alone support a satellite band: its data sheet must list the satellite band the operator uses there.

A third family has been tried from space: the low power radios of the chirp type used by terrestrial IoT networks. A 2021 peer-reviewed survey described one company's LoRa-based satellite IoT system, an uplink-only design at the time. No operator's primary record of such a service on the book's date was read for this chapter.

## The energy per delivered message

Transmit energy is only part of what a battery pays. The study in this chapter's opening shows the rest, on one standard module and one geostationary network, measured by the authors with a USB power meter on their test board (figure 11.3). For one uplink packet sent from idle, the random access messages took 62 percent of the energy (the initial access burst 6 percent, and the connection request, repeated many times, in the authors' words blindly, to overcome the path loss, 56 percent). The signaling that attaches and authenticates the device took 28 percent. The data took 5 percent and its acknowledgment 5 percent. The long path makes it worse: each exchange, a request and its reply, crosses the path between ground and satellite four times, about half a second in the authors' measurement, and the module, by the authors' account, cannot enter its deep sleep while it waits. The authors put the energy per connection at about three to five times that of terrestrial NB-IoT.

FIGURE 11.3

## Five percent moves the data: where one measured NB-IoT connection over a geostationary network spent its energy

| Step of one connection | What the module is doing | Share of energy | Class |
|---|---|---|---|
| Initial access burst | Announces itself to the satellite and waits about half a second for the answer | 6 percent | measured |
| Connection request, repeated | Sends the request many times over, blindly in the authors' words, to overcome the path loss | 56 percent | measured |
| Attach and authentication signaling | Exchanges with the core network to admit the device and set up the connection | 28 percent | measured |
| The data | Sends the payload itself | 5 percent | measured |
| Acknowledgment | Receives confirmation | 5 percent | measured |
| Ten packets, 2 s apart | Stays connected: 0.0101 Wh, about 3.6 J per packet | | measured; per packet calculated |
| Ten packets, 10 s apart | Wakes and repeats access each time: 0.0262 Wh, about 9.4 J per packet | | measured; per packet calculated |
| Not in the measurement | Searching with no satellite in view, failed attempts and retries, sleep current, cold, antenna installation | | not measured |

Measured by researchers on one module and one network, for one packet sent from idle; a representative case, labeled so, and not a property of any other module or service.

*Source: Wang and others, Exploring the Initial Performance of NB-IoT NTN over GEO: Measurement and Analysis, arXiv 2609.06280v1 (preprint, not peer reviewed, 2026-09-05), section 4.1 and figure 10 (scheme without retained context), section 4.2 and figure 11; per-packet values calculated in this book. Read 2026-11-23.*

The same paper shows how the interval between messages changes the bill. Ten packets sent 2 seconds apart cost 0.0101 Wh, because the module stayed connected; ten packets 10 seconds apart cost 0.0262 Wh, because each one had to wake the module and repeat the

whole access exchange. That is 3.6 J against 9.4 J per packet, a factor of 2.6. A sensor that sends twice a day is like the 10 second case, assuming the same module, network and procedure: every message starts from idle. At 9.4 J a message, two messages a day for a year come to about 1.9 Wh of radio energy, and five years to about 9.6 Wh, before any sleep current, failed attempt, retry or cold weather is counted. That last figure is this chapter's arithmetic from the authors' measurement, an illustration for one module on one network, not a property of any other. It is the energy of successful procedures only. The energy per delivered message is all the energy the device spends (searching, every attempt and retry, listening for answers, sleeping between messages) divided by the messages that arrive within the buyer's deadline.

What the measurement does not cover matters as much. It does not count the energy spent searching for a satellite when none is in view, attempts that fail and are retried, the current drawn while the device sleeps between messages, the effect of cold on the battery, or an antenna installed under a metal lid. Each of these can exceed the cost of sending. A buyer who is given one transmit current from a data sheet has been given one line of a longer list. The module data sheets named for these services were not read for this book; the numbers above are the only measured ones read. A trial closes the gap: log every attempt and delivery, count only what arrives within the deadline, measure total device energy over representative weeks, and compare it with usable battery capacity, less a reserve, over the years required.

**THE SYSTEM'S FAILURE**

Swarm Technologies flew very small satellites for IoT messaging and had about 160 in orbit in 2022. SpaceX acquired it in 2021. In July 2023 Swarm stopped selling new devices, its M138 modem among them, and pointed customers to a future product for SpaceX's direct to cell network, according to the trade press. The record shows an owner's decision to stop selling devices, not a failure of the satellites. For a buyer with sensors in the field the lesson is narrow and practical: a device that speaks one operator's proprietary radio has a service life that the operator decides, not the battery. Whether and when service to installed devices ended is reported differently in secondary sources, and the operator's own notice was not read, so this book prints no date for it.

**SECURITY NOTE**

**Who can interfere or command.** A sensor holds its key in a module that may sit unattended for years, where anyone with physical access can reach it. In a store and forward network the satellite holds the message while it waits; who can read it on board and at the ground station is not published by any operator read for this chapter. The operator commands the satellites, and in a standards-based network the mobile operator's core authenticates the SIM; in a proprietary network one company holds both roles. The uplink of a battery device is very weak, so a transmitter on the same frequency, strong enough at the satellite's receiver, can drown it. **How it is seen.** Missing messages at the customer's server, against the device's own send log, may be the only sign a customer sees. A buyer should ask the operator whether it reports interference per beam or per region. **How it is recovered.** A device that can be updated only over the same narrow link recovers slowly, if at all: a firmware update must cross a link built for small messages, within whatever downlink, message size and energy the operator and the battery allow. Ask how keys are changed and how updates arrive before the first device is installed.

**Monday rule:** write bytes per day, the longest acceptable delay, the delivery probability you need and the years of battery; then ask the operator for the energy per delivered message and its delivery statistics, not the data rate.

CHAPTER TWELVE

# Which Service Fits Which Need: From a Requirement to a Shortlist




On 17 November 2026 Iridium announced that its standards-based narrowband service, Iridium NTN Direct, was activated, and named the first module approved for it. Six days later, on this book's date, a buyer who needs forty bytes a day from a remote pump has one more candidate than a week before, and no answer yet to whether it fits. The announcement says what the operator turned on. It does not say whether the buyer's module, site, message count and battery fit it. This chapter turns the eleven chapters before it into a procedure: write the requirement first, filter by category, compare the numbers that decide, ask the questions a brochure does not answer, and plan the trial that settles what is left.

## Write the requirement first

Field 1 of the service ledger is the requirement, and it comes first for a reason. A buyer who starts from a product sheet compares what the sheet chose to print. A buyer who starts from the need compares what the need requires, and finds the gaps where the sheet is silent.

A usable requirement has eight lines. Each is a number or a short list, not an adjective.

- **Size.** Bytes per message and messages per day; or sustained megabits per second in each direction at the busy hour.
- **Deadline.** The longest acceptable time from sending to delivery: milliseconds for a voice call or a remote control loop, seconds for a chat, hours for a meter reading.
- **Coverage.** The sites or the route, with latitude and the lowest elevation the antenna can see over trees, hills, masts or buildings.
- **Availability.** The share of time the link must work, over a stated period, and what counts as working (section four).
- **Device.** What the user can carry, mount or power: a phone, a handheld, a flat panel on a roof, a module in a sensor.

- **Power.** Mains, a vehicle supply, a solar panel, or a battery that must last a stated number of years.
- **Who must reach whom.** User to internet, user to user, device to a company's server, or a vessel to a rescue center. This decides where the traffic must land.
- **Delivery probability, for messages.** The share of messages that must arrive within the deadline. A store and forward network gives a probability, not a promise (chapter 11).

Two more lines are often left out and matter most later. The first is the jurisdiction: in which countries the service must be lawful, and in which the traffic may or may not land. The second is the exit: how long the buyer needs the service, and what happens to the terminals if it ends. Chapter 13 treats both as risks; here they are simply lines of the requirement.

## The fit table, a first filter

Figure 12.1 sets twelve typical needs against the four buying categories of the Reader's Brief: broadband to a fixed or moving terminal; mobile satellite service to a handheld or small terminal; direct to a phone; and narrowband IoT to a module. Each cell says "fits", "fits if" with the condition, or "does not fit" with the reason.

The table is a filter, not a verdict. Every cell assumes a generic case: an ordinary site, a typical requirement, a service in commercial service where the user is. A real site can fail a "fits" cell for a reason the table cannot see, such as a mountain to the south of a high-latitude camp, which hides the low sky where the satellites pass (chapter 2), a mast that blocks part of the sky on a ship, or a country where the service is not authorized. A "No" means one of two things, and the cell gives the reason: the category cannot carry the need, or, where the reason is cost or power, it is usually out of proportion for it. The second kind can be reopened by a buyer with a special case. A filled service ledger for each remaining candidate does the rest.

FIGURE 12.1

## The fit table: twelve needs against the four buying categories, a first filter and not a verdict

| Need | Broadband terminal | Mobile satellite terminal | Direct to a phone | Narrowband IoT module |
|---|---|---|---|---|
| Remote site office link | Fits, with power and open sky | No: rates too low | No: messages, little data | No |
| Ship's crew and operations | Fits if built for motion, route covered and authorized | Voice and low rate data only | Messages only, where covered and authorized; not crew broadband | Telemetry only |
| Aircraft cabin | Fits if certified for the airframe | Low rate data; cockpit safety use needs aviation approval | No | No |
| Field team's phones | Fits with a portable terminal and power | Fits, a handset each | Fits if country, carrier, phone and qualifier allow; mostly messages on the book's date | No |
| Lone worker's alarm | Rarely: a terminal is heavy to carry | Fits, a messenger or handset | Fits if emergency messaging works where the worker is | Fits if a wearable message is enough |
| Vessel's recognized safety service | No, unless the service holds the recognition | Only a recognized service (chapter 6) | No: not a recognized safety service | No |
| Vehicle fleet tracking | Rarely: cost and power per vehicle | Fits: position and short data | Drivers' messages; a fleet system needs integration | Fits, a module per vehicle |

| Need | Broadband terminal | Mobile satellite terminal | Direct to a phone | Narrowband IoT module |
|---|---|---|---|---|
| Pipeline sensor | Rarely: power at a sensor | Fits if power can be supplied | No | Fits if delivery probability and delay meet the need |
| Buoy | Rarely: power on a buoy | Fits for low rate data | No | Fits if the battery covers the energy per delivered message |
| Branch office backup | Fits if gateway, power and exit differ from the main link | No: too slow | Staff messages only | No |
| Trunk to an island | Fits: medium orbit or geostationary capacity; low orbit if capacity is contracted and a gateway is in view, or reached by crosslinks, with landing rights | No | No | No |
| Network that must stay national | Fits if command, gateways and core are where the state requires | Same condition | Same condition, rarely met by a foreign operator | Same condition |

Each cell assumes a generic site and a service in commercial service where the user is; a real site is checked with a filled service ledger and a trial. "Fits if" names the condition that must hold. The conditions are the author's generic assumptions, not service-specific restrictions. "No" with a reason of cost or power means usually out of proportion, not impossible.

*Author's analysis from chapters 3 to 11 of this book; no new facts. As of 2026-11-23.*

Three patterns stand out. First, broadband is the only category that carries a branch office or a ship's crew at office rates, and it needs a terminal with its own power. Second, the direct to phone category fits a lone worker and a field team's messages, under conditions that are written in the cell: the country, the carrier, the device and the qualifier of chapter 10. Third, a recognized safety service for a vessel is a specific service with a specific recognition (chapter 6); no other category substitutes for it, whatever its link can carry.

### The numbers that decide

Once the filter leaves two or three categories, a handful of numbers decides between the services inside them. Each number has an evidence class, and the class matters as much as the value: an operator claim is what a company says; a measurement names who measured, where and when; a calculation follows from stated inputs.

- **Reply time.** Physics sets a floor. Through one geostationary satellite with both ends near the point under it, the radio path alone from one end to the other, up and down, is about 239 milliseconds, a quarter second, and a reply over four legs about 477 milliseconds, before any processing. For the same reply over four legs, one satellite at 550 km gives about 7 milliseconds straight overhead and 15 at 25 degrees elevation (one way from end to end, about 3.7 and 7.5); at 8,062 km, the altitude the regulator's record gives for the medium orbit fleet of chapter 5, the reply floor is about 108 milliseconds overhead and 141 at 25 degrees (one way, about 54 and 70). These are calculations from distance and the speed of light. What the user sees is larger: one university team that measured Starlink, a crosslinked low orbit service, from terminals in many countries reported a round trip from the terminal to the network's point of presence of 36 to 48 milliseconds, about 40 at the median (Mohan and others, ACM Web Conference 2024, measured by the authors; chapter 4 gives the conditions). Ask for a measured value at a named point, not "low latency".
- **Sustained rate in each direction.** A peak rate is what one terminal can reach in an empty cell; a sustained rate at the busy hour is what the buyer lives with. Chapter 4 explains contention and fair use. The upstream rate is the one most often missing from a sheet.
- **The network service.** Address sharing, IPv6, inbound reachability, how a VPN behaves, packet loss and jitter during a handover between satellites (chapter 4). Each is a question to the supplier with a dated written answer.
- **Coverage at the user's latitude and elevation mask.** Not a map's shading, but the share of time a satellite is in view at the user's site above the angle the user can see (chapter 2).

- **Device and power.** The terminal's power draw and size; for a phone, whether that phone model on that carrier is supported on the book's date; for a sensor, the module.
- **Energy per delivered message.** For a battery device, the transmit energy is only part of it. Acquisition, failed attempts, waiting for a pass and sleep current count too (chapter 11). Ask for the whole figure and its conditions.
- **Price shape.** Per month, per megabyte, per message, per terminal, with what each leaves out. Amounts change too fast for a book and are not printed here; costs are compared in depth later in this series.

Figure 12.2 lays the book's worked services side by side on these lines: four broadband configurations and seven for handhelds, messages and sensors. Chapter 5's enterprise VSAT case has no row: no operator's service description could be read. Each cell carries its class. The figure does not rank them. A geostationary service with a half second reply is the right answer for a site that needs a stable link and has no interactive traffic; it is the wrong answer for a fast control loop. The objective decides, and the objective is the requirement.

FIGURE 12.2

**Two decision spreads: the book's worked services on the lines that decide, each value with its class, and no ranking**

| Ledger and configuration | Reply floor, calculated | Capacity or traffic stated | Spectrum and permission | Status on the stated date |
|---|---|---|---|---|
| **Broadband** | | | | |
| LL-2026-04 · low orbit, crosslinked, consumer (ch. 3) | 7 to 15 ms at 550 km | Terminal speed tests by Mohan and others, 2021 on: about 50 to 100 Mbit/s down, 4 to 12 up *(measured, historical)*; one V3 satellite rated about 1 Tbit/s, a rating only *(operator claim, via trade press)* | Uplink 14.0 to 14.5 GHz; US license, FCC 18-38 *(standard)* | **Worked page evidence: 2021 to 2023: measured by researchers.** Ledger not checked (it describes 2021 to 2023). Operator reports 13.6 million consumer subscribers at 2026-09-30 *(operator claim)* |

| Ledger and configuration | Reply floor, calculated | Capacity or traffic stated | Spectrum and permission | Status on the stated date |
|---|---|---|---|---|
| LL-2026-05 · low orbit, transparent, enterprise via a partner (ch. 3) | 16 to 29 ms at 1,200 km | No primary rate read | Ku and Ka bands for US access; system authorized by the UK, FCC 17-77 *(standard)* | **Worked page evidence: 2026-08-07: operator claim; 2017 order.** Ledger not checked (no partner, country or terminal record read). More than 600 satellites on 2026-08-07 *(operator claim)* |
| LL-2026-06 · medium orbit trunk to an island (ch. 5) | 108 to 141 ms at 8,062 km | Per contract; not printed | Ka band for US access, FCC 18-70; operates under UK authority, FCC 20-13 *(standard)* | **Worked page evidence: 2026-03-05 and 2026-09-13: operator and builder claims.** Ledger not checked: the island's move to the newer satellites is not confirmed. Earlier satellites in service by 2026-03-05; final three launched 2026-09-13, expected operational mid 2027 *(operator claim)* |
| LL-2026-07 · geostationary Ka, home terminal (ch. 5) | 477 to 521 ms | ViaSat-3 F2 and F3 each above 1 Tbit/s, a rating only *(operator claim)* | Ka band *(operator claim)* | **Worked page evidence: 2026-03-31 operator filing; 2026-09-21 builder.** Ledger not checked: newest residential record 2026-03-31. Three ViaSat-3 satellites in service by 2026-09-21 *(builder's claim)* |

| Ledger and configuration | Reply floor, calculated | Capacity or traffic stated | Spectrum and permission | Status on the stated date |
|---|---|---|---|---|
| **Messages, phones and sensors** | | | | |
| LL-2026-02 · text from a phone on carrier spectrum, low orbit (ch. 10) | As low orbit; delivery time not in the sources read | Messaging at launch, app capabilities announced for October 2025 *(operator claim, carrier's release)* | Carrier's PCS license, leased under the FCC 24-28 framework; satellite use secondary *(standard)*; the service's own grant and lease not in the sources read | **Worked page evidence: 2025-07-23 release; 2026-05-12 FCC order.** Not checked on the book's date. Launched 2025-07-23 by the carrier's release *(operator claim)*; service described in FCC DA 26-471, 2026-05-12 *(standard)* |
| LL-2026-09 · phone message via a partner geostationary satellite (ch. 10) | About 477 ms | Texting on two named phone lines from 2025-03-19 *(operator claim)* | Partners' mobile satellite licenses *(operator claim)* | **Worked page evidence: 2025-03-19: operator claim; IoT measurement, 2026.** Ledger not checked on the book's date. Texting commercial in the US on one carrier from 2025-03-19; coverage not worldwide *(operator claim)* |

| Ledger and configuration | Reply floor, calculated | Capacity or traffic stated | Spectrum and permission | Status on the stated date |
|---|---|---|---|---|
| LL-2026-10 · phone voice or data via a very large array (ch. 10) | As low orbit | Intermittent US service expected by end 2026: announced *(operator claim)* | Partner carriers' spectrum; about 100 MHz targeted (2026-11-09) *(operator claim)* | **Worked page evidence: 2026-11-09: operator filing.** Planned: no activation verified in the sources read. 12 satellites operating, 2026-11-09 *(operator claim)* |
| LL-2026-11 · NB-IoT, store and forward via a CubeSat (ch. 11) | Minutes to hours: two waits | Standard Release 17 NB-IoT devices *(operator claim, via trade press)* | Not in the sources read | **Worked page evidence: 2026-10-02: trade press.** Ledger not checked. Fleet of eleven after a launch of five, 2026-10-02 *(operator claim, via trade press)* |
| LL-2026-12 · proprietary UHF IoT (ch. 11) | Set by passes and 20 ground stations | Short messages; Argos heritage *(operator claim)* | Below 1 GHz, under a CEPT decision (ch. 11) | **Worked page evidence: 2025-03-18: space agency.** Ledger not checked. 25 satellites, complete 2025-03-18 *(operator claim)* |
| LL-2026-08 · regional geostationary handheld, L band (ch. 6) | At least 477 ms | Calls and messages *(operator claim)*; handset rate not in the sources read | L band mobile satellite service; national licenses not in the sources read | **Worked page evidence: 2025-11-05: operator release.** Commercial from November 2025; ledger not checked since *(operator claim)* |

| Ledger and configuration | Reply floor, calculated | Capacity or traffic stated | Spectrum and permission | Status on the stated date |
|---|---|---|---|---|
| LL-2026-14 · low orbit L band data terminal, crosslinked (ch. 6) | As low orbit | Per the operator's terms (ch. 6) | Operator's L band *(operator claim)* | **Worked page evidence: 2026-09-30: operator filing.** Ledger not checked (no country, terminal or plan record read). Acquisition agreed 2026-06-28 *(operator claim)* |

Numeric reply floors are calculated by the author from altitude and the speed of light over four slant legs (up, down, up, down) through one satellite, both ends below it or at 25 degrees, before processing; a user sees more. For store and forward and pass-limited services the cell names the waits instead, which are not propagation times. Each status cell opens with the dates and kinds of the evidence on the worked page, and later dated records follow, so a measurement of 2021 to 2023 is not read as equal to a claim of 2026. The status cell gives the worked ledger's status on the book's date first, then the dated record. Devices are in the chapters; statuses with sources are in Appendix D. Iridium NTN Direct (chapter 11) has no worked page and no row.

*Author's comparison from the service ledgers of chapters 3, 5, 6, 10 and 11 (the enterprise VSAT case of chapter 5 has no ledger: no operator's service description was read) and their sources; delays calculated by the author. As of 2026-11-23.*

Read the figure by rows of the requirement. A buyer who needs a reply in under 100 milliseconds strikes the geostationary rows and the medium orbit row, whose floor alone is about 108 milliseconds, and keeps the low orbit ones for the trial to confirm, since a floor is not what the user sees. A buyer whose sensor sends a few hundred bytes a day strikes nothing on rate and decides on the device, the delivery path and the battery. A buyer who needs an ordinary phone to work strikes every row that needs a dedicated terminal, which the chapters name for each configuration. Two or three rows survive; those are the shortlist.

## Service assurance: what a commitment looks like

An availability figure means nothing until four things are stated: what counts as an outage, over what period it is measured, where it is measured, and what the supplier owes when it is missed. Restoration and priority complete a commitment.

- **What counts.** A link that is up but delivers a tenth of its rate may or may not count as an outage. So may a terminal that loses service when a satellite passes behind a tree, or a planned maintenance window. A written commitment defines each case.
- **Over what period.** 99.9 percent of a 30-day month allows about 43 minutes without service; 99.5 percent allows about 3.6 hours. This is arithmetic, not a claim about any service. A percentage does not cap the longest single outage; a commitment can, separately.
- **Where it is measured.** At the satellite network's edge, at the point of presence, or at the user's terminal. A commitment measured at the network edge says nothing about a terminal under a blocked sky.
- **What the supplier owes.** The remedy when the figure is missed: a service credit, a right to end the contract, or nothing; and how it is claimed, by when.
- **Restoration and escalation.** How fast service is restored after a fault, who the buyer calls, and how the call escalates. For a service bought through a reseller (chapter 3), the reseller's support path is the one that counts.
- **Priority.** Whether the buyer's traffic keeps its rate when the cell is busy, and whether that is written into the contract or only into a plan's name.

A marketing figure is a number without those four. A written commitment has them, signed, with a remedy. A remedy that only refunds a fraction of a month's fee may be the honest limit of what a supplier can promise from orbit; it is still worth knowing before the outage, not after it.

## The supplier questions

Appendix A prints the questions in full. They follow the parts of a service from chapter 1 and the risks of chapter 13, and each asks for a written answer.

- For each of the six parts (space segment, terminal, gateways, core and point of presence, spectrum, operating company): who owns it, which state has lawful authority over it, and who holds command access.
- Which gateway and point of presence will my traffic use, in which country, and what happens to my service when that site is down?
- Where is the core network, and which country's law governs data retention and lawful interception there?
- Whose license carries my traffic, in which band, primary or secondary, and until when?
- What are the service's status fields in my country: authorized by which instrument, in service since which date, with which qualifier?
- What do the terms say about priority, fair use and suspension?

- What happens to my terminals and my contract at a change of control or at the end of the service?

A refused answer is itself a finding. A supplier may have good reasons not to name its gateway sites; the buyer then knows that this part of the risk is unmeasured, and can weigh it.

### Proving it: a trial as requirements

A shortlist is a hypothesis about a site. A trial tests it. Written as requirements, a trial plan has five parts.

- **What to measure.** Throughput in both directions, reply time to a named server, packet loss, outages with their start and end, and for messages the delivery time and the share delivered. Each measurement names its tool and its endpoint.
- **Where.** At the real site, with the real mounting and the real obstructions; for a moving service, along the real route.
- **For how long.** Long enough to include the busy hour on several days, a change of weather, and for a low orbit service many passes. A trial of one afternoon measures one afternoon. A trial of weeks settles function and performance; it cannot show a 99.9 percent availability or a rare rain fade. For those the buyer relies on the written commitment, the supplier's record at comparable sites and a longer log after acceptance, and the plan says which lines the trial settles and which it does not.
- **Against what.** The requirement of field 1, line by line, each with a pass threshold written before the trial starts, and the supplier's written answers. Missing records count as missing, not as passes. A trial that passes on rate and fails on reply time has failed.
- **Who measures.** The buyer or an independent party, with the method written down, so that the result can be repeated and is not an operator claim.

This book has not run such a trial, and prints no result of its own. The series method for measuring a service's throughput, delay and outages against its ledger is written as what each step requires; its results will be published with their evidence when they exist.

### When nothing fits

Sometimes every row of figure 12.2 fails a line of the requirement. There are three ways forward, and the first is the most often missed.

- **Cut the requirement.** A phone that cannot carry a call to a satellite can carry a short text; an emergency message that cannot be a conversation can be a few fixed fields and a position. The first book of this series, *The Bit's Path*, shows how far a link closes when the

message is cut to what is really needed. Ask which line of the requirement is a need and which is a habit.

- **Rent capacity and build the service.** A buyer with a large and specific need can lease capacity and run its own hub or gateway (the enterprise VSAT of chapter 5 is one form). Renting before building is covered in depth later in this series.
- **Build and license.** The last resort, and the slowest; permission is covered in depth later in this series.

THE TRADE-OFF: ONE SITE, THREE WAYS

Take one site: a field office at a mine, with no ground network, that needs a shared office link, voice calls to the head office, and a lone worker's alarm. Assume, for illustration, an office link of 20 Mbit/s down and 5 up at the busy hour, calls with a reply under 300 milliseconds, and an alarm that must arrive within a minute; the numbers are the author's, not a standard. Built from this book's services, each candidate is held up on a different line.

- **Low orbit broadband** is not ruled out on the reply line by its floor (7 to 15 milliseconds, figure 12.2); a trial to the head office shows the real reply. On the rate line nothing is settled: old measurements and a capacity rating (figure 12.2) are not a rate for this site, so a committed rate in writing and a busy-hour trial must decide it. It fails, or passes, on lines that no rate shows: where the traffic lands, who holds command access, and whether the terminal keeps working if the operator changes the service (chapter 13).
- **Geostationary broadband** keeps a stable look angle with a terminal that does not track, but on the rate line it is as unsettled as low orbit: the plan rates of chapter 5 were not read, so a committed rate and a busy-hour trial decide it. It fails the assumed reply line: the radio path alone is about 477 milliseconds for a reply, by calculation, before any processing. Calls work but carry the pause; whether a remote control loop tolerates it depends on the loop.
- **A phone on a carrier with a satellite fallback** needs no new terminal, but it does not meet the office link: the service of chapter 10 was launched in the United States on 23 July 2025 for messages, with apps announced for later, by the carrier's own release, and its availability on the book's date was not checked. It is a fallback for messages, not an office link.

The lesson is bounded. None of the three is "the" answer for a mine; the requirement decides, and in this case it probably needs two services, one for the office and one for the worker. None is shown to meet the alarm line, which needs a written delivery probability within the minute, an acknowledgment and a site trial. Nothing here is a new fact: each failure is a line already sourced in its own chapter.

**SECURITY NOTE**

**Who can interfere or command.** Ask each shortlisted supplier, in writing: who is authorized to use the service and to command it, in the three senses of chapter 1 (who holds the credentials, who can change the service under contract, which states can compel either). A satisfactory answer names parties and states, not "industry standard". Ask who can intercept the traffic, on the radio link and at the gateway and core; a satisfactory answer says what is encrypted, between which points, and who holds the keys. Ask who can interfere with the link, and how the operator finds an interferer. **How it is seen.** Ask how a user or a station is authenticated, and how the buyer learns of an incident: which notice, how fast, with what detail. A satisfactory answer is a named procedure with a time. **How it is recovered.** Ask how service is restored after a fault, an attack on the terminals or a lost site, and whether terminals can be recovered remotely or must be replaced by hand (chapter 4 tells the case that made this question concrete). The notes in this book cover only what is publicly documented; operational assurance comes from the contract or from the authority concerned.

**Monday rule:** take the requirement to the supplier, not the supplier's product sheet to the requirement.

CHAPTER THIRTEEN

# Supplier, Spectrum and Sovereignty Risk




On 2 February 2026 Ukraine's Ministry of Defence announced that only Starlink terminals on a government whitelist would keep working in the country: "All others will be disconnected." The Cabinet of Ministers had adopted the resolution; the ministry was implementing it "in cooperation with SpaceX". Three days later it reported that whitelisted terminals were operating and that Russian terminals had been blocked. No link budget changed. A state decided, an operator acted, and a set of terminals stopped working. This chapter asks what can end or change a service that no link budget shows, and sorts the answers into three risks: the supplier, the spectrum and the state.

## Supplier risk: who owns the operator

A buyer depends on a company as much as on a constellation. In the sixteen months before this book's date, ownership or control changed, or began to change, for a large part of the industry. Each event below is dated and carries its record.

- **SES and Intelsat.** SES completed its acquisition of Intelsat on 17 July 2025, creating, in its words, a fleet of about 120 satellites, about 90 geostationary and nearly 30 in medium orbit (SES release).
- **SpaceX filed for a public offering.** Its registration statement became public on 20 May 2026 (Form S-1), and a quarterly report for the quarter to 30 September 2026 followed (Form 10-Q); that report counts more than 11,100 satellites in low orbit (operator claim). Public reporting changes what a buyer can read about a supplier, not who controls it.
- **Amazon and Globalstar.** Amazon announced on 14 April 2026 a definitive agreement to acquire Globalstar, expected to close in 2027, subject to regulatory approvals and to milestones for Globalstar's replacement satellites (Amazon, Form 8-K exhibit 99.1). The failure box below tells why this one matters to a user.

- **Rocket Lab and Iridium.** Rocket Lab and Iridium entered a merger agreement on 28 June 2026 (Rocket Lab, Form 8-K); Iridium expects to complete the mergers in mid 2027 (Iridium, Form 8-K of 18 September 2026). The terms are in the filings; this chapter needs only the fact and the dates.
- **Lynk and Omnispace.** The two completed a merger on 14 August 2026 as Elveo Mobile, as trade press reported; services are targeted for early 2028.
- **EchoStar.** Three EchoStar units filed for chapter 11 bankruptcy protection between 30 June and 2 August 2026, after the regulator approved the sale of its spectrum. Chapter 9 tells the case in full; here it stands for one kind of supplier risk, a company that sold the asset its network stood on.

One more change is a name, not an owner. Amazon's constellation has been called Amazon Leo since 13 November 2025, by the company's own note; a buyer searching for "Project Kuiper" finds the old name of the same system.

FIGURE 13.1

**Sixteen months of ownership, spectrum and state decisions, July 2025 to November 2026**




Each mark is a dated record: an announcement, an agreement, a filing, an order or a state decision. A mark is not a forecast of the service.

*Source: SES release (2025-07-17); Amazon progress page; Amazon Form 8-K exhibit 99.1; Rocket Lab Form 8-K; trade press (Elveo); FCC DOC-421651, DA 26-553, FCC 26-26 (91 FR 26928); EchoStar Forms 10-Q and 8-K; Ukraine Ministry of Defence (2026-02-02). Read 2026-11-22 and 2026-11-23.*

None of these events, by itself, says that a service will get worse or better. An acquirer may invest more than the seller could. What changes is the party that decides: what the service will carry, at what price, with which terminals, for how long. The second book of this series, *From Telstar to the Phone in Your Pocket*, shows that the first low orbit systems kept

serving their users under second owners after their bankruptcies; a change of owner is not an end of service. It is a moment when the terms can be rewritten, and a buyer should know it is coming.

## Customer concentration

A supplier can depend on its customers as much as they depend on it. Most operators do not say how their capacity is divided. One did. In a filing reporting agreements of 7 September 2022 Globalstar disclosed that it would allocate 85 percent of its current and future network capacity to Apple's services, with Apple paying 95 percent of approved capital spending on new satellites (Globalstar, Form 8-K). A second filing, reporting an agreement of 29 October 2024, added an infrastructure prepayment of up to 1.1 billion dollars and a 400 million dollar purchase of a 20 percent equity interest in a Globalstar subsidiary that owns the new network assets, not in Globalstar itself (Globalstar, Form 8-K).

Two cautions limit what this case shows. Capacity is not revenue: the share of a network's capacity allocated to one customer says nothing, by itself, about the share of the operator's income. And the case is one dated disclosure, not a pattern: no such figure was found in the sources read for the other operators in this book, so no comparison can be drawn. For a buyer who is not that customer, the question is direct. If one customer holds most of a network's capacity, what happens to everyone else's service when that customer's needs grow, or when the network changes hands?

## Vertical integration

An operator that builds its own satellites and launches them on its own rockets carries its supply risk inside one company. SpaceX describes "extensive vertical integration" in its registration statement, and states that the average cost of making a Starlink kit fell by about 59 percent between 2022 and 31 March 2026 (Form S-1, operator claim). An operator that buys its satellites and its launches carries a different risk: a launch failure is someone else's event and its own schedule. Chapter 3 tells the loss of 40 Amazon Leo satellites on 15 November 2026, on Amazon's first mission on a Vulcan rocket, by Amazon's own progress page; for a buyer waiting for that service, the lesson is a date that moves.

Neither model is safer in general. A single company can recover a failure quickly and can also fail as a whole; a supplier chain spreads the failure and slows the recovery. The buyer's question is which parties stand between the service and the next satellite, and how many of them can delay it. Launch itself is covered in depth later in this series.

### Spectrum risk

A license is a set of conditions, and each condition is a way for the service to change. Four kinds have appeared in this book.

- **Milestones.** A constellation that misses its deployment schedule can lose priority. Chapter 1 tells the conditional waiver the regulator granted Amazon Leo on 5 June 2026 for its half-way milestone, with the loss of processing-round priority for satellites not operating by 30 July 2026 and the forfeit of its bond (FCC, DA 26-553).
- **Secondary status.** On the first road to a phone (chapter 9) the satellite uses a ground carrier's spectrum under a secondary allocation. In the regulator's words, these operations "may not cause harmful interference to, and shall not claim protection from, any station operating in accordance with ITU provisions" (FCC 24-28, as published at 89 FR 34148).
- **A license sold over the customer's head.** Chapter 9 tells how EchoStar's spectrum was sold to two buyers; the licenses moved, and the networks built on them were left to their courts.
- **Coordination limits on capacity.** A low orbit system shares bands with geostationary networks, and the rules that protect those networks cap what the low orbit system can transmit. This last kind is changing in 2026, and is worth a closer look.

Since the World Radiocommunication Conference of 2000, low orbit systems in several shared bands have had to meet limits on the equivalent power flux density, or EPFD, they produce at geostationary terminals; the limits sit in Article 22 of the ITU Radio Regulations. WRC-23 revised Resolution 76, which deals with the aggregate of all such systems (ITU). It did not adopt a proposal to review the limits at WRC-27, and instead invited studies to inform WRC-27 "without any regulatory consequences", according to the FCC's account; by that account the studies feed the debate, but WRC-27 has no agenda item to change the limits themselves.

The United States then moved on its own. On 30 April 2026 the FCC adopted an order, published in the Federal Register on 13 May 2026, that "replaces the EPFD framework with modern, performance-based GSO protection criteria" for operations in the United States in the 10.7 to 12.7, 17.3 to 18.6 and 19.7 to 20.2 GHz bands, with coordination between operators first and technical backstops where they do not agree. The rules took effect on 13 July 2026, except two amendments whose effective date was left open (FCC 26-26, 91 FR 26928). The FCC states that the Radio Regulations allow the limits to be exceeded on the territory of a country whose administration authorizes it, and that it will continue to require systems notified by the United States to respect the limits over neighboring countries that have not.

For a buyer the consequence is narrow and concrete. The capacity a low orbit system can offer in a shared band can differ by country, because the rule that caps it now differs by country. A service's capacity in the United States says nothing about its capacity next door. How the international debate ends is for WRC-27 and is not forecast here; the treaty layer and its clock are covered in depth later in this series.

### Sovereignty risk: the three kinds of control

Chapter 1 named three kinds of control. *Technical command access* is holding the credentials that command the satellites, the network and the terminals. *Contractual control* is what a carrier, reseller or integrator can do to the service under contract. *Lawful authority* is what a state can compel or forbid. A state with lawful authority does not thereby hold command credentials; but it can compel the party that holds them, as the whitelist in the opening of this chapter shows.

For any service, four state roles can have a say, and they need not be the same state.

- **The licensing state of the satellites.** It is not necessarily the owner's home. The FCC's records describe the OneWeb system as "authorized by the United Kingdom" (FCC 17-77, 2017), and the medium orbit fleet now owned by SES as operating under the authority of the United Kingdom (FCC 20-13, 2020). Each also needed separate permission to serve the United States.
- **The states that host the gateways and the core.** Where traffic lands decides which law applies to it there: for retention, interception and shutdown (chapter 4).
- **The state where the user is.** It authorizes, or does not authorize, the service in its territory, and decides on the import and use of terminals. Ukraine's whitelist is a user state using that authority.
- **The state of the operating company.** Its law can impose obligations on the company wherever its satellites are, as far as that law and the company's connection to it reach.

Some states go further and require that traffic land, and certain functions sit, inside the country. Such a rule is a domestic regulatory requirement, and it shapes the service: a crosslinked network may then be barred from carrying a user's traffic to a gateway abroad, even when the domestic gateway is down. Trade press and law firms reported rules of this kind in 2025; this book read no such instrument in full, so it names none and gives no detail. A state can also build its own system to keep the control in its hands; IRIS2, Europe's program, is told as a program with its status fields in chapter 7.

Figure 13.2 reads the owner and trust fields of the eleven worked services in these terms. Where a source names the party, the cell names it; where the sources read do not, the cell says so.

FIGURE 13.2

## Who owns each end, read as three kinds of control: command access stays with the space operator, contractual control often sits with a third party, and the states multiply with the path

| Ledger and service | Space segment owner; licensing state | Ground, core, customer | Command access | Contractual control | Lawful authority (beyond the user's state) |
|---|---|---|---|---|---|
| LL-2026-04 · low orbit, crosslinked, consumer | SpaceX; United States | Operator's ground stations and points of presence; sold by the operator or a reseller | Operator | Operator's terms, or the reseller's | US; gateway host states |
| LL-2026-05 · low orbit, transparent, enterprise | Eutelsat Group; United Kingdom (FCC 17-77), which keeps a special share (ch. 3) | Operator's gateways; partner holds the customer | Operator | The partner | UK; gateway host states; US for US access |
| LL-2026-06 · medium orbit trunk to an island | SES; United Kingdom (FCC 20-13) | Operator's gateways; island carrier holds customers | Operator | Island carrier, capacity contract | UK; the island's state; gateway host state |
| LL-2026-07 · geostationary Ka, home | Viasat; not in the sources read | Operator's gateways; direct or resellers | Operator | Operator or reseller | Licensing state; gateway host states |

| Ledger and service | Space segment owner; licensing state | Ground, core, customer | Command access | Contractual control | Lawful authority (beyond the user's state) |
|---|---|---|---|---|---|
| LL-2026-08 · regional geostationary handheld | Regional operator (ch. 6) | Operator's own core | Operator | Operator or distributors | Operator's state |
| LL-2026-14 · low orbit L band data terminal | Iridium (sale agreed 2026-06-28); United States (US space station license, Form 10-K) | Operator's own core; service providers | Operator | Service providers | US (licensing state); gateway host states |
| LL-2026-02 · phone text on carrier spectrum | SpaceX; United States. Spectrum: the carrier's license, leased under the FCC 24-28 framework | Carrier's core and customer | Satellites: SpaceX; core: carrier | Carrier, under its plan | US: satellite and carrier licenses |
| LL-2026-09 · phone message via partner geostationary | Partner operators, not all named | Service's core, then the carrier | Satellites: partners; core: service | Carrier and device maker | Partners' licensing states; carrier's regulator |
| LL-2026-10 · phone via very large array (announced) | AST SpaceMobile; not in the sources read | Partner carriers *(operator claim)* | Satellites: operator; core: carriers | Partner carriers | Licensing state; carriers' regulators |

| Ledger and service | Space segment owner; licensing state | Ground, core, customer | Command access | Contractual control | Lawful authority (beyond the user's state) |
|---|---|---|---|---|---|
| LL-2026-11 · NB-IoT store and forward | Sateliot; not in the sources read | A mobile operator's core (ch. 11) | Satellites: operator; core: mobile operator | Not read: a partner operator or the satellite operator | Licensing state; core's state |
| LL-2026-12 · proprietary UHF IoT | Kinéis (CLS, CNES support); not in the sources read | Operator's 20 ground stations and platform | Operator | Operator or integrators | Licensing state; ground station states |

Fields 6 (who owns each end) and 7 (trust) of the eleven worked services, read in the three kinds of control of chapter 1. "Not in the sources read" means no primary record named the party; it is not a finding that the party does not exist. The command access column names the party the sources make responsible for commanding the space segment; other credential holders, such as contractors, are not documented in the sources read.

*Author's reading of the ledgers of chapters 3, 5, 6, 10 and 11 and their sources: FCC 17-77, 18-38, 18-70, 20-13, 24-28; operators' filings and releases as cited in those chapters. As of 2026-11-23.*

Three patterns appear in the figure. First, in every worked service the sources name the operator of the space segment as the party that commands it, and none gives command access to the buyer. Who else holds credentials, a contractor or a ground service provider, is not in the sources read; that is a question for the supplier. Second, contractual control is often held by a third party: a carrier, a reseller, a device maker, an integrator. That party can end a service that the satellite operator would keep. Third, the number of states with lawful authority grows with the path: a phone on a carrier's spectrum through a satellite owned elsewhere answers to three roles of lawful authority (the licensing state, the carrier's regulator and the user's state), which may be one state or several.

## When the owner stops selling, or stops the service

The plainest supplier risk is a decision by the owner to stop selling a service, or to end it. It needs no failure in orbit and no order from a state. Chapter 11 tells the lead case: a narrowband IoT network, bought by a larger company in 2021, ended new device sales in July 2023 and pointed its customers to a future product of its new owner, as trade press

reported. What stopped was the sale of new devices, by the owner's choice; chapter 11 prints no date for the end of service to installed devices, because the operator's own notice was not read and secondary sources differ, and the sources read report no spacecraft failure.

Three things decide how much such a decision costs a user. The first is notice: how long between the announcement and the last day of service, and whether the contract fixes a minimum. The second is the terminal: a device that works only on that network becomes scrap on the last day, while a standards-based device may move to another network in the same band, where one exists and accepts it. The third is the data path: where messages and records go after the end, and whether the buyer can take them out in a usable form. None of the three is in a coverage map or a link budget, and all three can be asked before the purchase.

### What a buyer can do

None of these risks can be removed by buying a better radio. Each can be reduced, documented and priced.

- **A second supplier with documented common dependencies.** Chapter 7 gives the test: list what the two services share (a gateway site, a reseller, a management network, a power feed, a licensing state), reduce what can be reduced, and write down what remains. Two networks that share a licensing state can be stopped by one order.
- **Terminals that work on more than one network**, where they exist. A standards-based device (chapter 8) may move to another operator's network on the same standard and band, if its firmware supports that network's features, the second operator accepts and provisions it and a subscription there is on offer; a proprietary terminal usually cannot. Ask for a shown migration path for the exact device, not only for a second network in the country.
- **Contract terms on change of control and end of service.** Notice periods, the right to end the contract, what happens to terminals bought outright, and data return. These are questions for counsel; this book gives information, not legal advice.
- **An exit plan with dates.** How long it would take to move to another service, what would have to be bought, and who would do it. A plan written before it is needed takes a day; one written during an outage takes the outage.
- **A dated page per service**, kept current: the Monday rule below.

The page is short. Filled for one service of this book, the text to a phone on a carrier's spectrum through low orbit satellites (chapter 10), it reads as the table below on the book's date. Every line comes from a source already cited; where the sources read are silent, the line says so, and that silence is the next question to the supplier.

**One service on one page, as of 23 November 2026**

| Line | Entry | Source |
|---|---|---|
| Service and qualifier | Text by satellite from supported phones in the United States; launched 23 July 2025 by the carrier's release, messaging first, app capabilities announced for October 2025; not checked on the book's date | T-Mobile release of 23 July 2025 (operator claim); FCC order DA 26-471 of 12 May 2026, the newest primary record (chapter 10) |
| Owner of the space segment | SpaceX; its registration statement became public on 20 May 2026, and it has filed a quarterly report since | Form S-1; Form 10-Q |
| Licensing state | United States | FCC grants (chapter 3) |
| Spectrum right | The carrier's terrestrial license, leased under the supplemental coverage from space framework; satellite use secondary. The service's own grant and lease terms are not in the sources read | FCC 24-28, 89 FR 34148 (the framework rule); ask the carrier for the grant and lease |
| End date of the right | Not in the sources read | Ask the carrier |
| Gateway and core states | Core: the carrier's; gateway sites not in the sources read | Ask the carrier |
| Command access | Satellites: the satellite operator, as the responsible party; subscriber authentication: the carrier's core. Other credential holders not in the sources read | Chapters 8 and 10 |
| Contractual control | The carrier, under the customer's plan | The plan's terms |

| Line | Entry | Source |
|---|---|---|
| Pending changes | None for this pair in the sources read; the regulator has consented to the satellite operator's purchase of further spectrum, with final closing expected about 30 November 2027 | FCC DA 26-471 |
| Sources reviewed | 23 November 2026; service status not checked | |

### THE SYSTEM'S FAILURE: A DEPENDENCY THAT CHANGED HANDS

Nothing here failed in orbit or on a link, and no outage or breach is on record. What failed is an assumption a buyer could easily make: that the network under a service stays in the same hands. In 2022 Globalstar committed 85 percent of its current and future network capacity to one customer's services, Apple's, which paid most of the capital spending on new satellites (Globalstar, Form 8-K of 7 September 2022). In 2024 that customer added a prepayment of up to 1.1 billion dollars and took a 20 percent stake in the subsidiary that owns the new network (Form 8-K reporting an agreement of 29 October 2024). On 14 April 2026 Amazon agreed to acquire Globalstar, and stated that Amazon Leo will power Apple's satellite features for the iPhone 14 and later, and that Amazon will deploy its own direct to device system from 2028 (Amazon, Form 8-K exhibit 99.1). Closing is expected in 2027.

The sources show a service that one large customer depends on changing its arrangements twice in under four years: first a commitment of most of the network to that customer, then an agreed sale of the network to a third company. They show nothing about the quality of the service, before or after, and this chapter claims nothing about it. The failure, if it comes, is a buyer's plan that assumed the dependency was stable. The lesson is narrow: when a service a buyer relies on runs on another company's network, the buyer's supplier risk includes that company's owner, and it can change without any change in the buyer's own contract.

**SECURITY NOTE**

**Who can interfere or command.** At the level of states, the five questions of this book change shape. Who is authorized to use and command the service: the operator holds the credentials, but lawful authority can compel the operator, and the opening case shows a government's decision carried out through the operator's own controls. Who can intercept: whoever has lawful access where the traffic lands and where the core sits, which is jurisdictional exposure, not a legal conclusion. Who can interfere: anyone with a transmitter, including a state jamming in its own territory. **How it is seen.** A suspension by order may arrive as a notice, or as a terminal that stops working; ask the supplier whether, and how, it informs customers of a government order, where the law allows that. **How it is recovered.** When a state stops a service, recovery is a political or legal act, not an engineering one; the engineering answer is a second service that the same order does not reach.

**Monday rule:** for every service you depend on, keep one page: owner, licensing state, gateway state, who holds command access, spectrum right and its end date, and the date you last checked.

# Epilogue: The Register Will Change, the Questions Will Not




This book is fixed to 23 November 2026. On that date Amazon's progress page listed its next launch for the following morning. Some of what the book prints was already out of date when the page was read, and more will be by the time anyone reads it. That is why the volatile facts sit in one dated register, Appendix D, and the chapters carry the analysis.

## What will be wrong first

- **Counts.** Satellites in orbit change with every launch and every reentry, and the counters disagree with each other. A count from this book is a count on its date, by its counter.
- **Owners.** Several transactions in this book were agreed or pending on its date. When they close, are blocked or change terms, the owner field of a service changes with them.
- **Device lists.** Which phones support which satellite service changes with each software release and each carrier agreement. The book prints device classes for that reason, never a list presented as complete.
- **Qualifiers.** A preview becomes general commercial service; an intermittent service becomes continuous, or is suspended. "In service" with its five fields, country, operator, device, date and qualifier, is the field most likely to move.

## What should hold

The six parts of a service should hold, whoever owns them: space segment, terminal, gateways, core, spectrum rights and the operating company. So should the eight axes on which services differ, because each is a choice that physics, law or money makes every system settle: the orbit and the number of satellites, the payload, routing, gateways, the spectrum road, the air interface, the device and the delivery model. The four status fields will still be needed for whatever is announced next, and announced, authorized, in orbit and in service will still be four different facts.

The three kinds of control should hold too: who holds command access, who has contractual control, and which states have lawful authority. So should the three risks a coverage map does not show. **Supplier risk** is what happens to a buyer's terminals and contract when the operator changes hands or ends a product. **Spectrum risk** is whose license carries the traffic, on what terms and until when. **Sovereignty risk** is which states can compel the parties that run each part. None of the three depends on a satellite count.

**OUR VIEW, AS OF NOVEMBER 2026**

Four constraints look likely to bind the next round of services, and the reader should watch them rather than the satellite counts. **Spectrum:** the services that reach ordinary phones depend on licenses that are scarce, leased or contested, and the EchoStar spectrum sales the FCC approved on 12 May 2026 (chapter 9) were sales of licenses, not of satellites. **Orbital space:** the low shells are filling, and coordination between systems may become one of the limits on how many more satellites a band can carry, beside launch, capital and demand. **Terminal cost:** a flat terminal is still a purchase a household or a firm must decide on, and its price shapes who buys broadband from orbit. **Device support:** a service direct to a phone exists for a user only when the phone, the carrier and the operator all support it in that country. These are the author's expectations, not findings, and no winner follows from them.

## Where the series goes next

The permissions behind every row of the register, from the ITU filing to a national license and a landing right, are covered in depth later in this series, and so are the choices of a builder who rents ground stations, relay capacity and launches before building a satellite, and the case for computing in orbit. The question stays the same in each book: how is the work divided between user, space and ground, what limits drove that split, and does it work, as a link, as a service and as a business?

The register will change. A reader who keeps one page per service, with its owner, its licensing state, its gateway state, who holds command access, its spectrum right and the date it was last checked, will notice when it does.

APPENDICES

APPENDIX A

# The Link Ledger: Blank Page, Index of Worked Ledgers, the Supplier Questions

This appendix holds three tools: the blank form with a guide to filling page 1 for a service sold today, the index of the services worked in this book, and the questions a buyer puts to a supplier in writing before depending on a service. The form is the one the first book of this series, *The Bit's Path*, uses for a single link; this book uses its first page to compare services.

## Filling page 1 for a service sold today

- **One configuration per page.** One terminal or device class, one plan, one country, one path and one point where performance is measured. Alternatives are separate pages, never one page that blends them.
- **Header.** The date the page describes and the status on that date: Planned, In service, Suspended, Retired, Failed, or Not checked when no source that speaks for that date was read. Put the qualifier in the system line: trial, preview, limited commercial, general commercial or intermittent.
- **Fields 1 to 3.** Write the requirement in the buyer's numbers (chapter 12), the ends and the path kind, and the orbit with the delay a user will see. For messages, the delay is a distribution and the requirement includes a delivery probability (chapter 11).
- **Field 4.** For each hop: the band, whose license, primary or secondary, under which instrument, in which country (chapter 9). "Not read" is an honest entry; a guess is not.
- **Fields 5 and 6.** Capacity up and down, peak against sustained, and who shares it (chapter 4); then the owners of each end and the exit.
- **Field 7.** The three kinds of control: who holds command access, who has contractual control, which states have lawful authority (chapter 1).
- **Fields 8 and 9.** The silent failure and the record that would show it; the shape of the price (per month, per megabyte, per message, per terminal), with amounts only in a dated register.
- **Field 10.** The few numbers that carry the argument, each with one of the seven classes of the Reader's Brief, its source and the date it was read. In this book most are operator claims.

Page 2, the hop budget, is printed blank for completeness. This book fills it for no service of its own: the operators of today's services rarely publish the antenna and receiver figures a budget needs. The one exception in the index below, LL-2026-02, keeps the illustrative uplink model of the second book of this series, *From Telstar to the Phone in Your Pocket*; its class column reports that model, which is not a qualification of the service and is not reprinted here, so its budget column says that page 2 is not printed in this book. *The Bit's Path* shows how to fill it, and how to solve for a missing line rather than invent it.

# The blank pages

**LINK LEDGER · BLANK · SERVICE LEDGER**

Link id (LL-year-nn) Date System

Status: Planned | In service | Suspended | Retired | Failed | Not checked

Class: full | service only | budget only

| | |
|---|---|
| **1 Requirement**<br>What must be delivered: size, deadline, coverage, availability. | |
| **2 Ends and path**<br>Who talks to whom; the path as it really is (transparent, regenerative, crosslinked, store and forward). | |
| **3 Orbit and time**<br>Altitude, pass or continuous; delay one way and round trip; scheduling and queueing; Doppler. | |
| **4 Band and permission**<br>Frequencies per hop; who holds the license, under which rule, in which country. | |
| **5 Capacity**<br>Up and down separately; peak against sustained; contention. | |
| **6 Who owns each end**<br>Space segment, ground segment, customer relationship, the exit. | |
| **7 Trust**<br>Who can command it; whose keys; how it is updated and recovered; jamming and spoofing. | |
| **8 How it fails, and how we would see it**<br>Silent failure named; the evidence that shows it. | |
| **9 Cost shape**<br>Per minute, per megabyte, per month or per terminal; per kilogram for launch; a price only with its date and what it leaves out. | |
| **10 Evidence**<br>Each number with its evidence class, source and date; an assumption is marked so. | |

### The six questions

1. What must be delivered, and by when?
2. How is the work divided between user, space and ground?
3. Does each hop close, with what margin, under which assumptions?
4. Who owns each end, and who gave permission?
5. How does it fail, who can interfere, and what would show us?
6. What can I use or rent before I build?

### The evidence classes

**measured** From an instrument or a log; who and when.
**calculated** From stated inputs by a formula the text gives.
**simulated** From a named model and its settings.
**operator claim** Stated by the operator; not independently checked.
**standard** From a named standard or rule, clause or table.
***assumption*** To verify: no primary source read; name what settles it.
**published history** Published history: an agency history or labeled scholarship.

## LINK LEDGER · BLANK · HOP BUDGET

**Hop name: _____ (one block per radio hop; a variant of it is a case: Case A, Case B)**

From ____ to ____ · frequency · distance · reference plane · information rate · symbol rate · stated error rate

| Part | Line | Value, in its own unit | dB, signed | Evidence | Source and date |
|---|---|---|---|---|---|
| TRANSMIT POWER AND ANTENNA GAIN | Transmitter output (dBW) | | | | |
| | Feeder loss | | | | |
| | Transmit antenna gain (dBi) | | | | |
| LOSSES | Free space path loss | | | | |
| | Atmosphere and rain | | | | |
| | Polarization and pointing | | | | |
| RECEIVE SENSITIVITY | Receive G/T: antenna gain less system noise temperature (dB/K) | | | | |
| | Boltzmann's constant: add 228.6 dB (it is -228.6 dBW/K/Hz) | | | | |
| BANDWIDTH | Information rate (bit/s): for Eb/N0, subtract 10 log10 of it | | | | |
| | Symbol rate (baud): for Es/N0, subtract 10 log10 of it instead | | | | |
| INTERFERENCE | Interference, as the step from C/N0 to C/(N0+I0) | | | | |
| CODING | Modulation, code and implementation loss | | | | |
| REQUIRED SIGNAL QUALITY | Required Eb/N0, Es/N0 or C/N0 (choose one; the same quantity as above) for the stated error rate | | | | |
| RESULT | **Achieved Eb/N0, Es/N0 or C/N0: the sum of every line above the required one** | | | calculated | |
| | **Required: the Eb/N0, Es/N0 or C/N0 for the stated error rate** | | | source: | |
| | **Margin: achieved less required** | | | design minimum: ___ dB | |

Verdict (circle one): CLOSES · DOES NOT CLOSE, with a margin of _____ dB

**Operating point** (rate, direction, elevation, weather, availability):

**Source of the required value** (a standard or a published curve):

**If it does not close, the line that fails, and by how many dB:**

**Transparent circuit: the combined line.** Combine C/N0 (or C/(N0+I0)) of each hop, before the rate and the implementation loss. Uplink C/N0: _____ dBHz. Downlink C/N0: _____ dBHz. Combined (the inverse ratios add): _____ dBHz. Less the rate and the implementation loss, once: _____ dB. Required: _____ dB. Margin: _____ dB. Two passing hops are not a passing circuit.

**How to add it up.** Write every line in decibels with its sign: gains positive, losses negative. Beside each number you may write the level after that line (dBW after the transmitter, dBW/K after G/T, dBHz after Boltzmann's constant, dB after the rate). After Boltzmann's constant the level is C/N0 in dBHz. Es/N0 = C/N0 minus 10 log10(symbol rate in baud); Eb/N0 = C/N0 minus 10 log10(information rate in bit/s). Compare like with like: the required value is the same quantity as the achieved one. Write a dB value on one rate line only, and on neither for C/N0. The achieved value is the sum of every line above the required one. The margin is the achieved value less the required value. The hop closes when the margin is at or above the design minimum you wrote down before you started.

## Index of the worked services

Each id names one link across the whole series. A service another book of the series also treats keeps that book's id and numbers, and this book prints only page 1 of it. Every worked page in this book is a service page; the page column gives where each one is printed.

### The worked Link Ledgers in this book

| Id | Date | System | Class | Status | Budget | Requirement | PDF page |
|---|---|---|---|---|---|---|---|
| **LL-2026-02** | 2026-11-23 | A text from a compatible phone over a carrier's terrestrial spectrum: T-Mobile's T-Satellite on Starlink direct to cell satellites, United States (page 2: an illustrative model) | full | Not checked | page 2 not printed in this book | A listed phone, outdoors with open sky and no tower in reach, sends a short text. The rate is not published; page 2 assumes one. | 99 |
| **LL-2026-04** | 2021 to 2023 (historical) | Low orbit broadband: terminal, satellite, ground station, PoP (one operator, many users' sites) | service only | Not checked | service only | Illustrative: a field office needs 25 Mbit/s down, 3 Mbit/s up and a reply under 100 ms in the busy hour, 99 percent of each month. | 36 |
| **LL-2026-05** | 2026-11-23 (sources dated 2017 to 2026) | Low orbit broadband, transparent with gateways: enterprise terminal, sold through a partner (Eutelsat OneWeb) | service only | Not checked | service only | Illustrative: 50 Mbit/s down, 10 up, a reply under 150 ms, one contract. | 37 |
| **LL-2026-06** | 2026-11-23 | Medium orbit trunk to an island operator: SES O3b mPOWER, for example CNT in the Galapagos (operator claims, calculated delay) | service only | Not checked | service only | Carry an island operator's traffic to the mainland with less delay than geostationary. CNT stated 2.5 Gbit/s on O3b in April 2023 and a planned move to mPOWER (SES). | 56 |

| Id | Date | System | Class | Status | Budget | Requirement | PDF page |
|---|---|---|---|---|---|---|---|
| **LL-2026-07** | 2026-11-23 | Geostationary Ka band broadband to a home terminal: Viasat residential service, United States (operator claims, calculated delay) | service only | Not checked | service only | Home internet where cable or fiber is not offered. Viasat reported about 130,000 US fixed broadband subscribers on 2026-03-31. Plan speeds and data rules were not read. | 51 |
| **LL-2026-08** | 2026-11-23 | Regional geostationary mobile satellite service to an L band handheld: Thuraya One through Thuraya-4, Space42, UAE (operator claims) | service only | Not checked | service only | Calls and messages from one handset inside and beyond cellular coverage. Space42 states service in over 100 countries across Europe, Africa, Central Asia and the Middle East (2025-11-05). | 64 |
| **LL-2026-09** | 2026-11-23 | Satellite texting from a listed phone through partner geostationary satellites in mobile satellite spectrum: Verizon with Skylo, United States (service ledger) | service only | Not checked | service only | Outside terrestrial coverage, a listed phone sends a text to any other device. Skylo names select Galaxy S25 and Pixel 9 models. No rate, delivery time or availability is published in the sources read. | 103 |
| **LL-2026-10** | 2026-11-23 | Voice or data from a compatible phone through very large arrays in low orbit: AST SpaceMobile, United States. Planned: intermittent service expected before the end of 2026; activation not verified on the book's date (service ledger; every number an operator claim) | service only | Planned | service only | An ordinary compatible phone, outdoors with no tower in reach, makes calls and uses data. The company expects to activate intermittent nationwide US service before the end of 2026; no general commercial date appears in the sources read. | 101 |

| Id | Date | System | Class | Status | Budget | Requirement | PDF page |
|---|---|---|---|---|---|---|---|
| **LL-2026-11** | 2026-11-23 | Sensor message from a standard NB-IoT device, store and forward through low orbit CubeSats, delivered into a mobile operator's network: Sateliot, Spain (service ledger) | service only | Not checked | service only | A battery sensor with a Release 17 NB-IoT module (company's claim) sends a few small messages a day from outside terrestrial coverage and accepts delays of minutes to hours (this ledger's requirement). | 115 |
| **LL-2026-12** | 2026-11-23 | Sensor message on a proprietary IoT network of 25 nanosatellites and 20 ground stations, Argos heritage: Kinéis, France (service ledger) | service only | Not checked | service only | Connect and locate any object anywhere, with near real-time, low-rate delivery and low energy use, in the words of the space agency that built it with the operator (CNES, 2025). A buyer adds bytes per day, delay and battery life. | 113 |
| **LL-2026-14** | 2026-11-23 | Low orbit mobile satellite data to a small L band terminal on a crosslinked network: the Iridium Certus family (operator claims; per-class figures not in the filing read) | service only | Not checked | service only | IP data and voice to a small terminal on land, at sea or in the air (Certus 100, 200, 700). The operator reports subscribers to 2026-09-30 on a global network under a US license; no country, terminal or plan record was read. | 62 |

## The supplier questions

Ask each question in writing and keep the answer with its date. A refused answer is a finding: it tells the buyer which part of the risk the supplier will not disclose. The first seven questions apply to every service; the rest apply to one buying category.

| Question | A satisfactory written answer | Chapter |
|---|---|---|
| For each of the six parts (space segment, terminal, gateways, core and point of presence, spectrum, operating company): who owns it, which state has lawful authority, who holds command access? | A named party and a named state for each part; "not disclosed" stated as such | 1, 13 |
| Which gateway and point of presence will my traffic use, and what happens when that site is down? | Site countries, the failover design, and whether service continues, degrades or stops | 4, 7 |
| Where is the core network, and which law governs data retention and lawful interception there? | The country of the core and the instruments that apply; for a roaming design, both operators' countries | 4, 13 |
| Whose license carries my traffic, in which band, primary or secondary, and until when? | The license holder, the instrument, the band, the status and the end or renewal date | 9, 13 |
| What are the service's status fields in my country? | The authorizing instrument, the date in service, the qualifier, and the device or terminal it covers | 1, 10 |
| What do the terms say about priority, fair use, suspension and availability? | The contract clauses, with what counts as an outage, the period, where it is measured and the remedy | 4, 12 |
| What happens to my terminals, devices and contract at a change of control or at the end of the service? | Notice period, support period, and whether the devices can move to another network | 11, 13 |
| *Phones:* which models and software versions are supported on which date, and what does the service carry on them? | A dated device list; text, data or voice per device; whether the sky must be open | 10 |

| Question | A satisfactory written answer | Chapter |
|---|---|---|
| *Phones:* how are emergency messages routed in my country, and is the service a recognized safety service? | The routing path and the rule that requires it; recognition named by the authority, or "not a safety service" | 6, 10 |
| *Sensors:* what is the energy per delivered message for my module, at my message interval? | A measurement with its module, firmware, network, interval and method, covering access, retries and sleep | 11 |
| *Sensors:* what are the delivery statistics: share delivered, delay distribution, queue limits and message lifetime? | Per-message statistics over a stated period and region; for store and forward, the expiry rule | 11 |
| *Sensors:* how are keys changed and firmware updated over the satellite link? | The procedure, its size limits and who can start it | 11 |
| *Broadband:* what network service do I get: address type, IPv6, inbound reachability, handover interruptions, priority? | Each item stated in a dated document, or a measured value with its method | 4 |

The answers fill page 1. A page with every field answered in writing, and a trial that logs what the page predicts, are the inputs to acceptance; a coverage map is neither.

APPENDIX B

# Cases: Who Was Selected, Under Which Test, Who Was Sought and Not Sourced

Chapter 1 sets the test a case must pass to get a section of its own. **C1, decision relevance:** it answers a buyer's question that the chapter asks. **C2, public evidence:** its architecture and status can be stated from a primary source (its own terms or service page, a regulator's record, a securities filing). Trade press, always labeled, may add dates and details a primary source does not state, such as a partner model or a count, but carries a case's status alone only under the second exception below. **C3, distinct contribution:** it shows an architecture, an ownership model or a delivery model that no other case in the same chapter shows. Fleet size and news volume are not part of the test. Two labeled exceptions exist: a case below the C2 bar when it is the only case of its region in a chapter (Tiantong), and labeled trade press dating or describing a case whose own primary page could not be read (Swarm's end of device sales; OneWeb's partners; Sateliot's launches and design). Each such row says so. A system known only from an announcement is a table row with its status field, never a section. The status fields below are those the chapters print, as of 23 November 2026; the dated counts are in Appendix D.

**Cases with a section or a worked service page**

| Case | Ch. | C1: the buyer's question | C2: the primary record read | C3: what only it shows | Status fields printed |
|---|---|---|---|---|---|
| Amazon Leo, milestone waiver | 1, 3 | What does "authorized" promise? | FCC order DA 26-553; operator's progress page | A milestone missed and waived | Authorized; in orbit (launch count); enterprise preview |
| Eutelsat OneWeb | 2, 3 | Transparent pattern; wholesale delivery | FCC 17-77; Eutelsat release, 2026-08-07; partners from trade press, 2022 | Gateways in view; sold through partners (trade press) | Sold through partners, revenue reported (trade press, 2026-10-30); no country, device or partner record read: not checked |

| Case | Ch. | C1: the buyer's question | C2: the primary record read | C3: what only it shows | Status fields printed |
|---|---|---|---|---|---|
| Starlink | 2, 3 | Crosslinked pattern; direct delivery | Operator's quarterly report to the SEC | Routing in orbit; sold direct | General commercial in 174 markets by the operator's own filing (operator claim); terms per country not read |
| KA-SAT modem attack, 2022 | 4 | Is the terminal fleet part of the service? | UK government statement, 2022-05-10 | Loss through the management network | Incident; history |
| Viasat home service on ViaSat-3 class satellites | 5 | What does a geostationary home service sell? | Viasat Form 10-K, fiscal 2026 | Very high throughput geostationary broadband | Fleet in service (operator); home service not checked after 2026-03-31 |
| Eutelsat Quantum and Space INSPIRE | 5 | Who may move capacity in orbit? | ESA releases | Software defined geostationary payloads | Quantum launched 2021; INSPIRE launch not confirmed |
| SES O3b mPOWER, island trunk | 5 | Is medium orbit a middle way on delay? | SES releases; FCC 18-70; Boeing | The medium orbit broadband case | 10 of 13 launched by 2026-03-05, the latest pair then in service; last 3 launched 2026-09-13, service forecast mid 2027 |
| SES with Intelsat | 5 | One owner of two orbits | SES releases and site | A merged multi-orbit operator | Completed 2025-07-17 |

| Case | Ch. | C1: the buyer's question | C2: the primary record read | C3: what only it shows | Status fields printed |
|---|---|---|---|---|---|
| Iridium Certus and GMDSS | 6 | Small terminal data; a recognized safety service | Iridium Form 10-K for 2025; Forms 8-K, 2026; IMSO | Crosslinked low orbit mobile service | Operator's subscriber count to 2026-09-30; ledger not checked (no country, terminal or plan record read); sale to Rocket Lab approved by stockholders, pending regulators |
| Thuraya-4 and Thuraya One | 6 | A regional handheld service | Space42 releases, 2025 | Geostationary handheld service, sold through partners | Commercial from November 2025; not checked later |
| Former Inmarsat L band fleet | 6 | Maritime safety service | Viasat Form 10-K; operator's safety page; IMSO | Geostationary GMDSS provider | In service |
| Tiantong | 6 | An Asian mobile satellite service | State press, 2020, and a phone maker's support page: below the C2 bar, admitted as the one Asian mobile satellite service case and labeled so | Mobile satellite service sold through a state carrier | Commercial for domestic users from 2020 |
| Two orbits sold as resilient | 7 | Are two orbits two suppliers? | FCC 26-47 (multi-orbit licensing); no integrator's service document read | Common dependencies | A trade-off, no new case |

| Case | Ch. | C1: the buyer's question | C2: the primary record read | C3: what only it shows | Status fields printed |
|---|---|---|---|---|---|
| AST SpaceMobile | 8, 10 | Where does a phone's missing gain go? | Operator filings with the SEC | A very large array in low orbit | Intermittent service as a target |
| EchoStar spectrum sale | 9 | Whose license carries the traffic? | FCC release and order DA 26-471 | A license that outlived its network | Sales approved 2026-05-12; units in bankruptcy |
| US supplemental coverage from space; Japan's 2 GHz license | 9 | Road one, by jurisdiction | FCC 24-28 (89 FR 34148); MIC release, 2024-12-25 | A lease against a carrier's own license | Rules in effect; license granted |
| Phone services in the United States, Japan and Australia | 10 | What is in service, where, on which phone? | Carriers' and operators' pages | Five device and operator designs | Qualifiers per row of figure 10.1 |
| Iridium and Qualcomm | 10 | Who decides device support? | Iridium Form 8-K, 2023-11-09 | A route to devices that closed | Ended 2023 |
| Kinéis, Sateliot, Skylo, Iridium NTN Direct | 11 | Proprietary or standard IoT | CNES (Kinéis); Skylo and Iridium releases; Sateliot from labeled trade press reporting the company (second exception: its own pages refused) | Store and forward against real time | Per row of figure 11.2 |

| Case | Ch. | C1: the buyer's question | C2: the primary record read | C3: what only it shows | Status fields printed |
|---|---|---|---|---|---|
| Swarm | 11 | What happens when the owner stops? | Trade press reporting the owner's decision, 2023, labeled; the owner's notice was not read | A service wound down by its owner's decision | New device sales ended July 2023 |
| Globalstar and its main customer | 13 | Customer concentration ; change of control | Globalstar Forms 8-K, 2022 and 2024; Amazon release | A dependent service changing hands | Acquisition agreed; closing stated for 2027 |

**Table rows only: announced, or without the evidence for a section**

| Case | Ch. | Why a row, not a section |
|---|---|---|
| Telesat Lightspeed | 3 | Announced and building; none in orbit on 2026-10-29 |
| IRIS2 | 3, 7 | Contracted; nothing in orbit; first launches stated from 2029 |
| Guowang, Qianfan | 3 | In orbit by tracker count; no service record or operator statement read |
| Rassvet (Bureau 1440) | 3 | Specialist press only; no service date |
| NSIL (India) | 5 | Operator page read, but no fleet count or service terms |
| Elveo Mobile; Amazon Leo's own phone service | 10 | Announced; services targeted for 2028 |
| Myriota, ORBCOMM OGx, OQ Technology | 11 | Partial records only; fields left blank where not read |

### Sought and not sourced (searched on 2026-11-22 and 2026-11-23)

| What was sought | Ch. | Why it is not printed |
|---|---|---|
| An enterprise Ku band VSAT service description from an operator, for a service page | 5 | No operator's published description was read; the page is not printed, and only the standards are used |
| Fleets of SKY Perfect JSAT (Japan), Telkomsat (Indonesia), Telebras SGDC (Brazil), Arabsat and Yahsat (Gulf), Türksat (Türkiye), Thaicom (Thailand), Hispasat (Spain) and an African operator | 5 | No operator page or filing was read; no fleet is printed |
| The technical cause of the O3b mPOWER satellites' loss of capacity; ViaSat-3 F1's antenna problem | 5 | No operator statement of either was read; the trade press is not used for causes |
| Viasat's residential plan speeds and data rules | 5 | Plan pages were not read; no speeds are printed |
| Globalstar's own phones and asset trackers, with rates | 6 | No operator page or filing was read |
| Iridium Certus rates per class; Iridium's own service pages | 6 | Operator pages were not read; only the annual report's top rate is printed |
| Thuraya-4's orbital slot, gateway and handset rates | 6 | Not stated in the releases read; no operator page was read |
| Later Tiantong satellites; China Telecom's own service page | 6 | Not found in a primary source |
| Aviation safety approvals for satellite services | 6 | No aviation authority's document was read |
| Direct to device frameworks of the United Kingdom (Ofcom), Australia (ACMA) and New Zealand (Radio Spectrum Management) | 9 | No regulator's text was read; the chapter describes no framework |
| Canada's bands, satellite status and license holders under its 2025 framework (ISED pages) | 9 | Only the government's announcement was read |

| What was sought | Ch. | Why it is not printed |
|---|---|---|
| India's satellite communication security conditions (in-country gateways, routing), from the Department of Telecommunications or Parliament | 13 | No government text was read; only press and law firm summaries, so chapter 13 names no rule |
| A Chinese low orbit operator's own status page, or a regulator's record of its foreign service (for example SpaceSail in Brazil) | 3 | Trade press only; no service status is printed |
| The launch provider's own statement on the Amazon Leo launch failure of 15 November 2026 | 3 | Not read; the chapter follows Amazon's page and its date |
| Viasat's own overview of the 2022 KA-SAT incident | 4 | Not read; the route is printed from trade press reporting Viasat, with UK and US government statements |
| Starlink and OneWeb address terms (carrier-grade NAT, IPv6, public addresses) | 4 | Operator support pages were not read; no values are printed |
| Measured performance of OneWeb from an independent study | 3, 4 | The study was not read; no measured value is printed |
| The stated cause of the 2025 Starlink outage; an official account of jamming of user terminals | 3, 4 | No operator or government statement was read; neither is described |
| The completion date of the Eutelsat and OneWeb combination | 3 | No company statement was read; only the UK statement of 2022 is used |
| Thaicom's own fleet page | 5 | No page of the operator's own was read |
| T-Mobile's own T-Satellite service page | 10 | Not read (plans, phones, coverage); the carrier's release of 2025-07-23 and an FCC order of 2026-05-12 were read, and neither speaks for the book's date |
| Phone satellite services in New Zealand (One NZ) and Canada (Rogers) | 10 | Trade press only; no row is printed |
| Tiantong service on ordinary phones in China | 10 | No primary page read |

| What was sought | Ch. | Why it is not printed |
|---|---|---|
| Kinéis's exact band and two-way service; Sateliot's bands, operating count, commercial status and roaming terms | 11 | Operator pages were not read; the ledgers say "not read" |
| Other IoT constellations a specialist would expect, such as Astrocast, Lacuna Space and Fleet Space | 11 | Not researched for this edition; no status is printed, and their absence is not a judgment of them |
| Swarm's end-of-service notice | 11 | Not read; secondary sources disagree on the date, so only the end of device sales is printed |
| The WRC-27 agenda item number and dates for direct to device | 9 | Not in the resolution read; not printed |

APPENDIX C

# Glossary

The terms the chapters use, in plain words. The number in brackets is the chapter where a term is introduced or worked; R is the Reader's Brief, A the appendix of the ledger and D the dated register. The radio theory behind several terms is worked in the first book of this series, *The Bit's Path*.

| Term | Meaning |
|---|---|
| **3GPP** | The partnership of standards bodies that writes the mobile network standards in numbered releases; its non-terrestrial network specifications define how a phone or module can work through a satellite [1, 8] |
| **Air interface** | The radio protocol between the user's device and the network: a published standard or a proprietary link that only the operator's devices speak; one of the eight axes [1, 8] |
| **Announced** | Status field: a dated statement by a company or agency that a system or service is planned; proves nothing about authorization, orbit or service [1] |
| **Authorized** | Status field: an instrument (an order or a license), the state that issued it, the band and the generation it covers [1, 9] |
| **Buying categories** | Four reading routes into this book: broadband to a terminal, mobile satellite service to a handheld or small terminal, service direct to a phone, and narrowband IoT to a module; a route, not a classification [R, 1] |
| **C/N0** | Carrier power against noise density, in dBHz; the level a hop delivers before the rate is taken into account [8, A] |

| Term | Meaning |
|---|---|
| **Carrier-grade NAT** | Carrier-grade network address translation: many customers share one public IPv4 address, so connections started from the internet usually do not reach a customer's site without a public address or a tunnel [4] |
| **Contention** | Sharing of a beam's capacity by the terminals active in a cell; the more active terminals, the lower each one's rate [4] |
| **Contractual control** | One of the three kinds of control: what a carrier, reseller or integrator can do to the service under its contract, such as suspend an account or change a plan [1, 13] |
| **Crosslink** | A radio or laser link between two satellites, which lets traffic cross space before it comes down; it reduces the gateways that coverage needs but does not remove them [3] |
| **Delivery model** | How a service reaches its buyer: sold direct, wholesale through carriers and integrators, or integrated across orbits; one of the eight axes [1, 3] |
| **Digital transparent processor** | A transparent payload that divides and routes channels in digital form without recovering the bits [1] |
| **Direct to device** | Satellite service to an ordinary or satellite-capable phone, or a module, with no external satellite terminal; the standard, the spectrum road, device support and each operator's design are four separate things [8 to 10] |
| **Distribution partner** | A company that buys a satellite operator's capacity and sells service to end users under its own contract, often with its own terminals and support [3] |
| **Eb/N0, Es/N0** | The energy of one information bit, or of one symbol, against the noise density; a coded link needs a stated minimum for a stated error rate [8, A] |

| Term | Meaning |
| --- | --- |
| **Eight axes** | The choices on which services differ: orbit and number of satellites, payload, routing, gateways, spectrum road and license, air interface, user device, delivery model [1] |
| **Elevation** | The angle of a satellite above the horizon as seen from a terminal or a gateway; a service sets a minimum, below which it does not use the satellite [2, 3] |
| **EPFD** | Equivalent power flux density: the sum of the power flux densities that all satellites of a non-geostationary system produce at a geostationary network's earth station in a shared band, each weighted by that station's reference antenna pattern toward the satellite (the downlink case); ITU limits on it protect geostationary networks and cap what a low orbit system can transmit there [13] |
| **Feeder link** | The link between a satellite and its gateway, usually in a higher band than the user's link [1, 4] |
| **Gateway** | The earth station where a satellite's traffic meets the ground network; it is licensed by the state that hosts it [1, 4] |
| **Geostationary orbit** | A circular orbit about 35,786 km above the equator in which a satellite turns with the Earth and stays over one point [2, 5] |
| **Handover** | The move of a terminal's connection from one satellite or beam to the next; it can cause a short interruption, loss or jitter [4] |
| **In orbit** | Status field with three separate counts: launched, in orbit and working, each with its date and who counted [1] |
| **In service** | Status field: country, operator, device or terminal and date, with a service qualifier [1] |

| Term | Meaning |
|---|---|
| **IPv6** | The internet's newer addressing scheme; with a delegated prefix and a permitting firewall it can make a site reachable where IPv4 addresses are shared [4] |
| **Landing rights** | Permission from a state to offer a satellite service in its territory; granted country by country [4, 13] |
| **Lawful authority** | One of the three kinds of control: what the licensing state, the gateway host state and the user's state can compel or forbid; a state with lawful authority does not thereby hold command credentials [1, 13] |
| **Link Ledger** | The series' form for one link: page 1, the service ledger with ten fields; page 2, the hop budget, one page per hop. This book prints page 1 [R, A] |
| **Low orbit** | Orbits below about 2,000 km; satellites close to the Earth, each in view for minutes, so a service needs many of them [2] |
| **Management network** | The operator's systems that configure, update and monitor the terminals and the network; a path to every terminal at once [4] |
| **Medium orbit** | Orbits between low orbit and geostationary; fewer satellites, each tracked for hours [2, 5] |
| **Mobile satellite service** | Service to handheld and small portable or mobile terminals in bands allocated to satellites for that purpose, such as L band [6] |
| **Non-terrestrial network (NTN)** | 3GPP's term for a mobile network that includes satellites or high-altitude platforms [8] |
| **Operator claim** | A number stated by the operator or supplier that nobody independent has checked; never restated as measured [R, A] |
| **Phased array** | An antenna made of many small elements whose beam is steered electronically, with no moving parts [4] |

| Term | Meaning |
| --- | --- |
| **Point of presence** | The place where an operator hands traffic to the internet or to a customer's network, and where the user's address appears to the rest of the internet [4] |
| **Regenerative payload** | A payload that demodulates, switches and modulates on board, recovering the bits; not necessarily a whole base station in orbit [1, 3] |
| **Routing** | Whether traffic can cross satellites by crosslinks before it lands, or must come down from the satellite that received it; one of the eight axes [1, 3] |
| **Scan loss** | The gain a flat phased array loses when its beam points away from the panel's face: the projection of its area, plus element and mismatch losses that only its maker can state; for a panel facing straight up it grows as the satellite gets lower [4] |
| **Service qualifier** | The word that follows "in service": trial, preview, limited commercial, general commercial, intermittent, suspended or retired [1] |
| **Spectrum road** | The kind of spectrum a service uses: bands allocated to satellites and licensed to the satellite operator, or a mobile carrier's terrestrial spectrum used from space under the carrier's license [1, 9] |
| **Status fields** | Announced, authorized, in orbit and in service, recorded separately, per part and per jurisdiction; never added together [1] |
| **Store and forward** | A satellite records a message and passes it on later, when a ground station is in view; delivery is delayed and not guaranteed [11] |
| **Technical command access** | One of the three kinds of control: who holds the credentials to command the satellites, the network and the terminals [1, 13] |

| Term | Meaning |
| --- | --- |
| **Three verdicts** | The link, the service and the business, kept apart for every system: a link can work while a service fails or a company goes bankrupt [R] |
| **Transparent payload** | A payload that does not demodulate or decode the user's data; it filters, converts and amplifies, and in a digital transparent processor divides and routes channels. 3GPP's reference case is "an analogue RF repeater with no on-board processing"; the base station functions stay on the ground, behind the gateway [1, 3] |
| **Wholesale** | Selling capacity to carriers, integrators or distribution partners, which sell service to end users under their own contracts [1, 3] |

APPENDIX D

# Dated Register: Fleets, Owners, Spectrum and Service Status as of 2026-11-23

The chapters of this book carry the analysis; the facts that will change first live here. How many satellites a fleet has, who owns whom, whose license carries the traffic and what is in service where are all true on a date and will not stay true. Each row below gives the fact, the date it describes, the date its source was published, the date the source was read, who stated or counted it, its class and the chapters that use it. Before relying on a row, read its source again.

## How to read a row

- **Event or as of** is the date the fact describes: the day of a launch, the end of a quarter, the date an order was adopted.
- **Published** is the date of the source itself, and **Read** the date it was read for this book. The three dates differ, and a reader comparing two rows compares like with like: a count as of 30 September published on 22 October is not a count of 22 October.
- **Who stated or counted** names the source: the operator, a regulator, an independent tracker or a trade publication. A count is printed with who counted it and what was counted; counts of different kinds (launched, in orbit, working) are never added.
- **Class** is one of the seven of this series. Most rows are operator claims: what a company or agency says of itself. A regulator's order or a standard is "standard". A figure that trade press reported from a company is the company's claim, and the row says it was reported by trade press. A service start date known only from trade press is printed as an assumption, to verify, as its worked ledger prints it, because a status rests on it. An independent tracker's count is classed as measured by that tracker: it counts cataloged objects by its own method, and a "working" label is the tracker's inference from orbit data, not proof that a payload carries service.
- **Status words** follow the four fields of the Reader's Brief: announced, authorized, in orbit and in service, with the qualifier. An agreed transaction is not a completed one.
- No row is a price. Amounts in money appear only where a filing states a transaction or an accounting average, such as revenue per user, and then as the filing states them.

This is a print extract of the book's register, numbered extract 3.1 and dated 23 November 2026. The full record of every row, with the address of its source and where in the source the fact sits, is in the book's claim tables, not printed in this edition.

What the register does not hold is as telling as what it does. Gateway countries for the low orbit broadband services, the licensing states of several operators, and the bands of several sensor networks were not in the sources read; the rows say so rather than guess. A buyer who needs one of those facts asks the supplier for it in writing (chapter 12).

FIGURE D.1

## Fleets and counts: each number with its date and who counted

| Fact | Event or as of | Published | Read | Who stated or counted | Class | Ch |
|---|---|---|---|---|---|---|
| Starlink: more than 11,100 satellites in low orbit; 13.6 million consumer subscribers | 2026-09-30 | 2026-10-22 | 2026-11-23 | SpaceX, Form 10-Q | operator claim | 3, 12 |
| Starlink: 10.3 million subscribers | 2026-03-31 | 2026-05-20 | 2026-11-23 | SpaceX, Form S-1 | operator claim | 3 |
| Starlink: 26 third generation satellites deployed on one Starship flight, each rated about 1 Tbit/s down | 2026-09-28 | n.r. | 2026-11-22 | Light Reading | operator claim, via trade press | 3, 12 |
| Eutelsat OneWeb: more than 600 low orbit satellites | 2026-08-07 | 2026-08-07 | 2026-11-22 | Eutelsat release | operator claim | 2, 3, 12 |
| Eutelsat: 669 OneWeb refresh satellites on order | quarter to 2026-09-30 | 2026-10-30 | 2026-11-22 | Via Satellite, reporting Eutelsat | operator claim, via trade press | 2 |
| Amazon Leo: nearly 400 satellites deployed over 14 missions | page update 2026-11-23 | 2026-11-23 | 2026-11-23 | Amazon, mission updates | operator claim | 1, 3 |
| Amazon Leo: payload lost in a launch anomaly on Amazon's mission LV-01, its first on Vulcan (40 satellites listed for the mission) | 2026-11-15 | n.r. | 2026-11-23 | Amazon, mission updates | operator claim | 3, 13 |
| Guowang: 222 cataloged satellites; Qianfan: 233 working of 251 objects | October 2026 | n.r. | 2026-11-22 | KeepTrack | measured (independent tracker) | 1, 3 |
| Telesat Lightspeed: no satellites in orbit; plan raised from 156 to 225 | 2026-10-29 | 2026-10-29 | 2026-11-22 | Telesat, results release | operator claim | 1, 3 |
| IRIS2 low orbit part: 264 dual Ka and Ku plus 66 military Ka satellites; first launches from 2029 (announced) | 2026-08-07 | 2026-08-07 | 2026-11-22 | Eutelsat release | operator claim | 3, 7 |
| SES after Intelsat: about 120 satellites, about 90 geostationary and nearly 30 in medium orbit | 2025-07-17 | 2025-07-17 | 2026-11-22 | SES release | operator claim | 5, 13 |
| O3b mPOWER: 10 of 13 launched | 2026-03-05 | 2026-03-05 | 2026-11-22 | SES news flash | operator claim | 5 |
| O3b mPOWER: final three launched; operational expected mid 2027 | 2026-09-13 | n.r. | 2026-11-22 | SES, nine months results | operator claim | 5, 12 |
| ViaSat-3: three geostationary Ka band satellites, all in service | 2026-09-21 | 2026-09-21 | 2026-11-22 | Boeing feature; Viasat page | operator claim | 5, 12 |
| AST SpaceMobile: 12 satellites operating (1 to 6 and 8 to 13); BlueBird 7 written off | 2026-11-09 | 2026-11-09 | 2026-11-22 | AST SpaceMobile, Form 8-K exhibit 99.2 | operator claim | 8, 10, 12 |
| Elveo Mobile: nine satellites (six Lynk low orbit, two Omnispace low orbit, one medium orbit) | 2026-08-14 | n.r. | 2026-11-22 | Light Reading | operator claim, via trade press | 10 |

| Fact | Event or as of | Published | Read | Who stated or counted | Class | Ch |
|---|---|---|---|---|---|---|
| T-Mobile said more than 657 direct to cell satellites were in orbit | 2025-06-26 | 2025-06-26 | 2026-11-23 | Broadband Breakfast | operator claim, via trade press | 10 |
| Sateliot: a fleet of eleven satellites after a launch of five | 2026-10-02 | 2026-10-03 | 2026-11-22 | SatNews | operator claim, via trade press | 11, 12 |
| Kinéis: 25 satellites in five planes of five; 20 ground stations; complete | 2025-03-18 | n.r. | 2026-11-22 | CNES | operator claim | 11, 12 |
| Swarm: about 160 satellites | 2022 | 2023-07-27 | 2026-11-22 | Via Satellite | operator claim, via trade press | 11 |
| Starlink first generation: 4,408 satellites authorized in shells at 540 to 570 km (center altitudes) (an authorization, not a count in orbit) | 2021-04-23 | 2021-04-27 | 2026-11-23 | FCC 21-48 | standard | 1, 2 |
| Viasat: 23 satellites in service or operational (13 Ka band, eight L band of which three contingency, one S band, one Ka and L band) | 2026-03-31 | 2026-05-29 | 2026-11-23 | Viasat, Form 10-K | operator claim | 5 |
| Viasat: about 130,000 US fixed broadband subscribers; average monthly revenue per user 113 dollars (an average, not a price) | 2026-03-31 | 2026-05-29 | 2026-11-23 | Viasat, Form 10-K | operator claim | 5 |
| Iridium: 66 operational satellites with in-orbit spares | 2025-12-31 | 2026-02-12 | 2026-11-23 | Iridium, Form 10-K | operator claim | 6 |
| Iridium: 2,696,000 billable subscribers (396,000 commercial voice and data; 2,163,000 commercial IoT; 16,000 broadband; 121,000 government) | 2026-09-30 | 2026-10-20 | 2026-11-23 | Iridium, Form 8-K (Q3 results) | operator claim | 6 |
| AST SpaceMobile: target of about 45 satellites in orbit by mid 2027 (target) | 2026-11-09 | 2026-11-09 | 2026-11-23 | AST SpaceMobile, Form 8-K exhibit 99.1 | operator claim | 8, 10 |

A count is never added to another count of a different kind (launched, in orbit, working). Published and read are the dates of the source; n.r.: not recorded in the source read.

*Source: the book's claim tables for the chapters named in the last column; their sources are listed in Appendix E. Register extract 3.1, as of 2026-11-23.*

FIGURE D.2

## Owners, transactions and company status

| Fact | Event or as of | Published | Read | Who stated or counted | Class | Ch |
|---|---|---|---|---|---|---|
| SES completed its acquisition of Intelsat | 2025-07-17 | 2025-07-17 | 2026-11-22 | SES release | operator claim | 5, 13 |
| Amazon's constellation renamed Amazon Leo (formerly Project Kuiper) | 2025-11-13 | n.r. | 2026-11-22 | Amazon, mission updates | operator claim | 1, 13 |
| Amazon agreed to acquire Globalstar; closing expected in 2027, subject to approvals and replacement satellite milestones (agreed, not completed) | 2026-04-14 | 2026-04-14 | 2026-11-23 | Amazon, Form 8-K exhibit 99.1 | operator claim | 10, 13 |

| Fact | Event or as of | Published | Read | Who stated or counted | Class | Ch |
|---|---|---|---|---|---|---|
| SpaceX registration statement public; quarterly reporting since | 2026-05-20 | 2026-05-20 | 2026-11-23 | SpaceX, Form S-1 | operator claim | 13 |
| Rocket Lab and Iridium entered a merger agreement (agreed, not completed) | 2026-06-28 | 2026-06-29 | 2026-11-23 | Rocket Lab, Form 8-K | operator claim | 6, 13 |
| Iridium expects to complete the mergers in mid 2027 | 2026-09-18 | 2026-09-18 | 2026-11-23 | Iridium, Form 8-K | operator claim | 6, 13 |
| Lynk and Omnispace completed their merger as Elveo Mobile | 2026-08-14 | n.r. | 2026-11-22 | Light Reading | operator claim, via trade press | 10, 13 |
| DISH DBS and DISH Wireless filed prepackaged chapter 11 cases | 2026-06-30 | n.r. | 2026-11-23 | EchoStar, Form 10-Q | operator claim | 9, 13 |
| EchoStar and AT&T closed their spectrum sale | 2026-07-28 | n.r. | 2026-11-22 | Broadband Breakfast | operator claim, via trade press | 9 |
| Hughes Satellite Systems and US subsidiaries filed chapter 11 petitions; 622,000 broadband subscribers at 2026-06-30 | 2026-08-02 | 2026-08-03 | 2026-11-23 | EchoStar, Form 8-K; Form 10-Q | operator claim | 9, 13 |
| DISH DBS entities emerged from chapter 11 | 2026-10-01 | 2026-10-02 | 2026-11-23 | EchoStar, Form 8-K | operator claim | 9 |
| Globalstar allocates 85 percent of network capacity to Apple's services | 2022-09-07 | n.r. | 2026-11-22 | Globalstar, Form 8-K | operator claim | 10, 13 |
| Apple prepayment of up to 1.1 billion dollars; 400 million dollars for a 20 percent equity interest in a Globalstar subsidiary that owns the new network assets (not in Globalstar itself) | 2024-10-29 | 2024-11-01 | 2026-11-23 | Globalstar, Form 8-K | operator claim | 13 |
| Viasat acquisition of Inmarsat cleared by the UK, US and EU regulators | 2023-05-25 | n.r. | 2026-11-22 | Viasat release | operator claim | 6 |
| Kinéis operations to transfer from CNES to Kinéis (planned; later status not read) | 2026-01-01 | n.r. | 2026-11-22 | CNES | operator claim | 11 |
| Swarm, owned by SpaceX since 2021, ended new device sales | 2023-07 | 2023-07-27 | 2026-11-22 | Via Satellite | operator claim, via trade press | 11 |
| Viasat completed its acquisition of Inmarsat | 2023-05-30 | 2026-05-29 | 2026-11-23 | Viasat, Form 10-K | operator claim | 6 |
| Iridium stockholders approved the merger with Rocket Lab; completion expected by mid 2027, subject to approvals | 2026-09-24 | 2026-09-24 | 2026-11-23 | Iridium, Form 8-K | operator claim | 6 |
| Qualcomm gave notice to end its smartphone agreement with Iridium, effective 2023-12-03 | 2023-11-03 | 2023-11-09 | 2026-11-23 | Iridium, Form 8-K | operator claim | 10 |

An agreed transaction is not a completed one; each row says which. Published and read are the dates of the source; n.r.: not recorded in the source read.

*Source: the book's claim tables for the chapters named in the last column; their sources are listed in Appendix E. Register extract 3.1, as of 2026-11-23.*

FIGURE D.3

## Spectrum rights, permissions and rules, with end dates where public

| Fact | Event or as of | Published | Read | Who stated or counted | Class | Ch |
|---|---|---|---|---|---|---|
| OneWeb system of 720 satellites authorized by the United Kingdom; US market access in bands from 10.7 to 30 GHz | 2017-06-22 | 2017-06-23 | 2026-11-23 | FCC 17-77 | standard | 12, 13 |
| Starlink user uplink 14.0 to 14.5 GHz in the US grant | 2018 | n.r. | 2026-11-23 | FCC 18-38 | standard | 12, 13 |
| O3b next satellites at 8,062 km; Ka band grant for US market access; deployment authorized by the UK Space Agency | 2018-06-06 | 2018-06-06 | 2026-11-23 | FCC 18-70 | standard | 5, 12 |
| O3b operates under the authority of the United Kingdom | 2020-02-25 | 2020-02-25 | 2026-11-23 | FCC 20-13 | standard | 13 |
| Supplemental coverage from space: lease from the terrestrial licensee; secondary MSS allocation; phones licensed by rule; interim 911 routing | rules effective 2024-05-30 | 2024-04-30 | 2026-11-23 | Federal Register 89 FR 34148 | standard | 9, 12, 13 |
| Amazon Leo first generation: 1,616 of 3,232 satellites due 2026-07-30 (waived with conditions on 2026-06-05); all 3,232 due 2029-07-30 | 2026-06-05 | n.r. | 2026-11-22 | FCC DA 26-553 | standard | 1, 13 |
| FCC approved EchoStar's sale of about 65 MHz to SpaceX and about 50 MHz to AT&T | 2026-05-12 | 2026-05-12 | 2026-11-22 | FCC DOC-421651 | standard | 9, 13 |
| AWS-4 (2000 to 2020 and 2180 to 2200 MHz), H block and unpaired AWS-3 to SpaceX through a trust; final closing expected about 2027-11-30 | 2026-05-12 | n.r. | 2026-11-22 | FCC DA 26-471 | standard | 9 |
| SpaceX application pending for up to 15,000 satellites at 226 to 435 km | 2026-05-12 | n.r. | 2026-11-22 | FCC DA 26-471 | standard | 2, 9 |
| EPFD framework replaced for US operations in 10.7 to 12.7, 17.3 to 18.6 and 19.7 to 20.2 GHz; effective 2026-07-13, two amendments delayed | 2026-04-30 | 2026-05-13 | 2026-11-23 | FCC 26-26, 91 FR 26928 | standard | 13 |
| WRC-23 revised Resolution 76 (aggregate EPFD); invited studies of the EPFD limits for WRC-27 without regulatory consequences | 2023-12-15 | October 2026 (update) | 2026-11-23 | ITU backgrounder; FCC 26-26 | standard | 9, 13 |
| 3GPP Release 17 NTN bands n255 (L) and n256 (S); Release 18 adds n254 and Ka bands n510 to n512 | June 2022 (Release 17 frozen) | n.r. | 2026-11-22 | 3GPP TS 38.101-5 V17.8.0, Table 5.2.2-1; Release 18 additions: 3GPP, NTN overview | standard | 8 |
| Elveo Mobile holds 60 MHz of S band mobile satellite rights internationally | 2026-08-14 | n.r. | 2026-11-22 | Light Reading | operator claim, via trade press | 9 |
| AST SpaceMobile targets about 100 MHz of shared carrier and controlled MSS spectrum in the United States (target) | 2026-11-09 | 2026-11-09 | 2026-11-22 | AST SpaceMobile, Form 8-K exhibit 99.1 | operator claim | 9, 12 |
| Supplemental coverage from space framework adopted (FCC 24-28) | 2024-03-14 | 2024-03-15 | 2026-11-23 | FCC 24-28 | standard | 8, 9 |

| Fact | Event or as of | Published | Read | Who stated or counted | Class | Ch |
|---|---|---|---|---|---|---|
| Part 100 adopted; effective date to be set by public notice, not set when checked | 2026-07-22 | n.r. | 2026-11-23 | FCC 26-47 | standard | 9 |
| Iridium: licenses for up to 8.725 MHz of contiguous L band spectrum; US space station license expires 2032-02-23 | 2025-12-31 | 2026-02-12 | 2026-11-23 | Iridium, Form 10-K | operator claim | 6 |
| Japan: KDDI licensed for a 2 GHz band satellite constellation system for mobile phones; ordinances in force | 2024-12-20 | 2024-12-25 | 2026-11-23 | Ministry of Internal Affairs and Communications, Kanto Bureau | standard | 9 |
| Canada: decision on a framework for supplemental mobile coverage by satellite published | 2025-02-20 | 2025-02-20 | 2026-11-23 | Government of Canada | standard | 9 |
| European Union: proposal to select mobile satellite providers in the 2 GHz band for use beyond 2027, when current licenses expire (a proposal) | 2026-05-27 | 2026-05-27 | 2026-11-23 | European Commission | standard | 9 |
| 3GPP Release 19 complete; implementable specifications at the end of December 2025 | December 2025 | n.r. | 2026-11-23 | 3GPP, Release 19 page | standard | 8 |

A US instrument is labeled as a US case; Part 25 applies until Part 100 takes effect (adopted 2026-07-22; effective date not set when checked). Published and read are the dates of the source; n.r.: not recorded in the source read.

*Source: the book's claim tables for the chapters named in the last column; their sources are listed in Appendix E. Register extract 3.1, as of 2026-11-23.*

FIGURE D.4

## Service status by country, with the qualifier

| Fact | Event or as of | Published | Read | Who stated or counted | Class | Ch |
|---|---|---|---|---|---|---|
| United States and Canada: emergency messaging by satellite on the iPhone 14 line, on Globalstar; general commercial | 2022-11-15 | 2022-11-15 | 2026-11-22 | Apple Newsroom | operator claim | 10 |
| United States: Verizon with Skylo, emergency messaging (announced for autumn 2024) | 2024-08-28 | 2024-08-28 | 2026-11-22 | Verizon release | operator claim | 10 |
| United States: Verizon with Skylo, texting to any device on Galaxy S25 and Pixel 9; general commercial | 2025-03-19 | n.r. | 2026-11-22 | Skylo newsroom | operator claim | 10, 12 |
| United States: T-Mobile with SpaceX (T-Satellite) available from this date "for everyone", by the carrier's release; app capabilities announced for October 2025; not checked on the book's date | 2025-07-23 | 2025-07-23 | 2026-11-23 | T-Mobile newsroom release (trade press had reported the date in advance, 2025-06-26) | operator claim | 10, 12 |

| Fact | Event or as of | Published | Read | Who stated or counted | Class | Ch |
|---|---|---|---|---|---|---|
| United States: the FCC describes supplemental coverage from space as having brought connectivity to consumers in dead zones, so far for text-based services; T-Satellite not checked on the book's date | 2026-05-12 | 2026-05-12 | 2026-11-22 | FCC DA 26-471 | standard | 10 |
| Amazon Leo enterprise service; preview; Ultra terminal (figure D.5); country not in the source read | 2025-12-01 | n.r. | 2026-11-22 | GSMA, reporting Amazon | operator claim, via an industry body | 3, 4 |
| Ukraine: Starlink terminals not on the government whitelist disconnected; whitelisted terminals operating; Russian terminals blocked (state decision) | 2026-02-05 | 2026-02-05 | 2026-11-23 | Ministry of Defence of Ukraine | operator claim (governme nt statement) | 13 |
| Iridium NTN Direct, standards-based NB-IoT in Iridium's L band; activated (operator's word); global coverage stated by the operator; first module in figure D.5 | 2026-11-17 | 2026-11-17 | 2026-11-23 | Iridium release | operator claim | 10, 11, 12 |
| United States: AST SpaceMobile intermittent nationwide service expected by the end of 2026 (announced, not in service) | 2026-11-09 | 2026-11-09 | 2026-11-22 | AST SpaceMobile, Form 8-K exhibit 99.1 | operator claim | 10, 12 |
| Elveo Mobile services targeted for early 2028 (announced) | 2026-08-14 | n.r. | 2026-11-22 | Light Reading | operator claim, via trade press | 10 |
| Amazon Leo's own direct to device system from 2028 (announced) | 2026-04-14 | 2026-04-14 | 2026-11-23 | Amazon, Form 8-K exhibit 99.1 | operator claim | 10, 13 |
| ORBCOMM OGx satellite IoT service; commercial (countries and devices not in the source read) | 2024-06-18 | 2024-06-18 | 2026-11-22 | ORBCOMM release | operator claim | 11 |
| Japan: au Starlink Direct (KDDI with SpaceX satellites), messaging on 50 listed phone models at start; free for the time being | 2025-04-10 | 2025-04-10 | 2026-11-23 | KDDI release | operator claim | 10 |
| Australia: Telstra Satellite Messaging on Starlink Direct to Cell, text only, on listed iPhone and Samsung models; "an intermittent service", not an emergency service | 2025-06-07 | 2025-06-07 | 2026-11-23 | Telstra Exchange | operator claim | 10 |
| O3b mPOWER: the pair launched in July 2025 in commercial service (fleet event; end-user service is per contract) | 2026-03-05 | 2026-03-05 | 2026-11-23 | SES news flash | operator claim | 5 |
| ViaSat-3 launches: F1 2023-05-01, F2 2025-11-13, F3 2026-04-29 (fleet events, not service status) | 2026-04-29 | n.r. | 2026-11-22 | Viasat, ViaSat-3 page | operator claim | 5 |
| Thuraya-4 launched (early January 2025); commercial availability in over 100 countries announced | 2025-11-05 | 2025-11-05 | 2026-11-23 | Space42 release | operator claim | 6 |
| China: Tiantong service to domestic users from January 2020 | 2020-01 | 2020-01 | 2026-11-23 | China Daily (state press) | operator claim, via state press | 6 |

| Fact | Event or as of | Published | Read | Who stated or counted | Class | Ch |
|---|---|---|---|---|---|---|
| GMDSS satellite elements provided by Inmarsat and Iridium | 2026-11-23 | n.r. | 2026-11-23 | IMSO, About us | standard (intergovernmental body) | 6 |

In service needs country, operator, device, date and qualifier; announced and in service are kept apart. Where a field is not in the source read the row says so; fleet events are marked as such. Published and read are the dates of the source; n.r.: not recorded in the source read.

*Source: the book's claim tables for the chapters named in the last column; their sources are listed in Appendix E. Register extract 3.1, as of 2026-11-23.*

FIGURE D.5

## Device classes and terminals

| Fact | Event or as of | Published | Read | Who stated or counted | Class | Ch |
|---|---|---|---|---|---|---|
| Handheld power class 3 supported for NR-NTN in Release 17 | June 2022 | 2024-08 | 2026-11-22 | 3GPP TS 38.101-5 V17.8.0, Table 6.2.1-1 | standard | 8 |
| Emergency messaging by satellite on the iPhone 14 line (2022); satellite features for iPhone 14 or later to be powered by Amazon Leo after closing (announced) | 2026-04-14 | 2026-04-14 | 2026-11-23 | Apple Newsroom; Amazon, Form 8-K exhibit 99.1 | operator claim | 10, 13 |
| Satellite texting on Galaxy S25 and Pixel 9 phones (Verizon, Skylo) | 2025-03-19 | n.r. | 2026-11-22 | Skylo newsroom | operator claim | 10 |
| Nordic Semiconductor nRF9151: first module approved for Iridium NTN Direct | 2026-11-17 | 2026-11-17 | 2026-11-23 | Iridium release | operator claim | 11, 12 |
| Amazon Leo Ultra enterprise terminal: up to 1 Gbit/s down and 400 Mbit/s up | 2025-12-01 | n.r. | 2026-11-22 | GSMA, reporting Amazon | operator claim, via an industry body | 4 |
| Swarm M138 modem: new sales ended | 2023-07 | 2023-07-27 | 2026-11-22 | Via Satellite | operator claim, via trade press | 11 |

Named devices are examples on the date shown; no list here is complete. Published and read are the dates of the source; n.r.: not recorded in the source read.

*Source: the book's claim tables for the chapters named in the last column; their sources are listed in Appendix E. Register extract 3.1, as of 2026-11-23.*

FIGURE D.6

## Licensing states and gateway states where public

| Fact | Event or as of | Published | Read | Who stated or counted | Class | Ch |
|---|---|---|---|---|---|---|
| Starlink: licensed by the United States (FCC); gateway countries not in the sources read | 2018 | n.r. | 2026-11-23 | FCC 18-38 | standard | 13 |
| OneWeb: authorized by the United Kingdom; gateway countries not in the sources read | 2017-06-23 | 2017-06-23 | 2026-11-23 | FCC 17-77 | standard | 13 |
| O3b medium orbit fleet: under the authority of the United Kingdom | 2020-02-25 | 2020-02-25 | 2026-11-23 | FCC 20-13 | standard | 13 |
| Amazon Leo: licensee Kuiper Systems LLC | 2026-06-05 | n.r. | 2026-11-22 | FCC DA 26-553 | standard | 13 |
| Kinéis: 20 ground stations worldwide; their countries not in the sources read | 2025-03-18 | n.r. | 2026-11-22 | CNES | operator claim | 11, 13 |

A blank in the sources read is printed as such; it is not a finding that the state does not exist. Published and read are the dates of the source; n.r.: not recorded in the source read.

*Source: the book's claim tables for the chapters named in the last column; their sources are listed in Appendix E. Register extract 3.1, as of 2026-11-23.*

APPENDIX E

# Sources

Every dated fact in this book was checked against the source listed for its chapter in November 2026. Primary sources come first: original papers, standards, treaties and regulations, regulator filings and orders, official reports, operator documents and institutional histories. Trade press is labeled as such. Every number in a Link Ledger also carries one of seven evidence classes: measured, calculated, simulated, operator claim, standard, assumption (to verify) or published history. This list holds 297 chapter source entries, including repeated works and notes on the illustrative case. It is drawn from the book's claim tables, which pair each claim with its source and the date it was checked; those tables are part of the book's sources.

## Reader's Brief: Eight Axes, Four Status Fields, One Ledger


- 3GPP, "Non-Terrestrial Networks (NTN) overview" https://www.3gpp.org/technologies/deep-dive/ntn-overview


## Prologue: One Message, Four Ways Up


- Author's calculation from an orbital period of one sidereal day on a spherical Earth (R = 6,378 km), as worked in The Bit's Path


## Chapter 1. A Service Is a Network: The Parts, the Axes, the Owners and the Words


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- "Evolution of High-Throughput Satellite Systems: A Vision of Programmable Regenerative Payload", IEEE Communications Surveys and Tutorials, 2024 https://doi.org/10.1109/comst.2024.3450292; (preprint https://arxiv.org/abs/2310.04389 )
- Telesat, "Telesat Reports Results for the Three and Nine Months Ended September 30, 2026" (release, via Finviz) https://finviz.com/news/411261/telesat-reports-results-for-the-three-and-nine-months-ended-september-30-2026
- Amazon, "Amazon Leo mission updates" https://www.aboutamazon.com/news/innovation-at-amazon/project-kuiper-satellite-rocket-launch-progress-updates; FCC Order DA 26-553 https://docs.fcc.gov/public/attachments/DA-26-553A1.txt
- FCC, Order DA 26-553 (adopted and released 5 June 2026) https://docs.fcc.gov/public/attachments/DA-26-553A1.txt
- KeepTrack (independent tracker), "How many Chinese satellites are in orbit" https://keeptrack.space/live-count/how-many-chinese-satellites-are-in-orbit
- T-Mobile, "T-Satellite Now Available" (newsroom release, 2025-07-23) https://www.t-mobile.com/news/network/t-satellite-now-available


## Chapter 2. Shells and Coverage: How Many Satellites, and Where


- FCC 21-48, Space Exploration Holdings, Order and Authorization (adopted 23 April 2021, released 27 April 2021) https://docs.fcc.gov/public/attachments/FCC-21-48A1.pdf
- FCC 17-77, WorldVu Satellites Limited, Order and Declaratory Ruling https://docs.fcc.gov/public/attachments/FCC-17-77A1.pdf
- "Phasing Parameter Analysis for Satellite Collision Avoidance in Starlink and Kuiper Constellations" https://arxiv.org/abs/2109.13994

- Author's calculation on a spherical Earth (R = 6,378 km, c = 299,792.458 km/s, circular orbits); formulas in chapter 2 and figure 2.1
- FCC, Memorandum Opinion and Order DA 26-471 (adopted and released 12 May 2026) https://docs.fcc.gov/public/attachments/DA-26-471A1.txt
- Eutelsat press release, "Eutelsat to play central role in delivering the next phase of Europe's sovereign IRIS2 connectivity infrastructure" https://www.mynewsdesk.com/eutelsat/pressreleases/eutelsat-to-play-central-role-in-delivering-the-next-phase-of-europes-sovereign-iris2-connectivity-infrastructure-3460240
- Via Satellite, "Eutelsat Sets 10B Target for OneWeb Revenue from 2032 to 2040" https://www.satellitetoday.com/connectivity/2026/10/30/eutelsat-sets-10b-target-for-oneweb-revenue-from-2032-to-2040/
- SpaceX, Form 10-Q for the quarter ended 2026-09-30 https://www.sec.gov/Archives/edgar/data/1181412/000162828026066880/spcx-20260930.htm

## Chapter 3. Broadband from Low Orbit: Two Reference Patterns and Their Hybrids

- Amazon, Amazon Leo mission updates https://www.aboutamazon.com/news/innovation-at-amazon/project-kuiper-satellite-rocket-launch-progress-updates
- Amazon, same page
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- FCC 17-77, Order and Declaratory Ruling https://docs.fcc.gov/public/attachments/FCC-17-77A1.txt
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- Calculated: slant range from altitude and elevation (calc_budget formula, Earth radius 6,371 km) divided by the speed of light
- Calculated, same method; as printed in The Bit's Path, chapter 10
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- FCC 21-48 https://docs.fcc.gov/public/attachments/FCC-21-48A1.txt
- Light Reading (trade press), Starship reaches orbit, releases 26 high-capacity V3 Starlink satellites https://www.lightreading.com/satellite/starship-reaches-orbit-releases-26-high-capacity-v3-starlink-satellites
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- KeepTrack, How many Chinese satellites are in orbit https://keeptrack.space/live-count/how-many-chinese-satellites-are-in-orbit
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- Milbank (counsel to the debtors), Milbank Guides OneWeb Global Through Chapter 11 Plan Confirmation https://milbank.com/en/news/milbank-guides-oneweb-global-through-chapter-11-plan-confirmation.html
- UK Government, UK Government to acquire cutting-edge satellite network https://www.gov.uk/government/news/uk-government-to-acquire-cutting-edge-satellite-network
- UK Government, OneWeb merger with Eutelsat https://www.gov.uk/government/news/oneweb-merger-with-eutelsat

## Chapter 4. The Terminal, the Gateway and the Network Service


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- Calculated: 10 log10(cos(90 degrees minus elevation)); the projection only, a lower bound on the real loss
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## Chapter 5. Geostationary and Medium Orbit Broadband: What the High Orbits Sell


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- ETSI EN 302 307-1 V1.4.1 (2014-11), DVB-S2 https://www.etsi.org/deliver/etsi_en/302300_302399/30230701/01.04.01_60/en_30230701v010401p.pdf
- DVB Project, DVB-S2X standard page https://dvb.org/?standard=second-generation-framing-structure-channel-coding-and-modulation-systems-for-broadcasting-interactive-services-news-gathering-and-other-broadband-satellite-applications-part-2-dvb-s2-extensions
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- Series calculator (first book of this series, model ledger); NIST CODATA speed of light; ITU-R P.525 for free space
- FCC, O3b Limited, Memorandum Opinion and Order FCC 20-13, released 2020-02-25 https://docs.fcc.gov/public/attachments/FCC-20-13A1_Rcd.pdf

## Chapter 6. Mobile Satellite Services as Sold Today: Handhelds, Small Terminals and Safety

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