Why satellites matter
The relevance of commercial satellites in the 21st century – a perspective 2012-2020
Did you know that...?

... Billions of people around the world rely on satellite infrastructure every day to communicate, travel and get informed and entertained

... Since the eighties, the €300 billion global TV industry relies mostly on satellites to gather and distribute regular programming as well as live coverage of political, social and sports events like the London Olympics

... 80 million European households get information and entertainment directly via satellite TV, and an additional 66 million households' cable is fed by satellite—as satellite is highly cost and spectrum efficient for broadcasting data and media to a large audience

... Satellites provide global connectivity, enabling communication on a worldwide scale of essential information about critical human, social, political and economic events such as the Euro crisis and the Arab Spring

... Satellite networks underpin many voice, data and mobile networks, providing them with a means to carry traffic overseas when other alternatives like undersea cables are absent

... Internet connections on planes, cruise ships and oil platforms are all provided via satellites

... Precision agriculture, tracking of fishery policies and weather and climate-change predictions all rely on satellites

... Thousands of companies and governments around the world use satellites as a “safety net” and for critical communications and data distribution

... Daily operations of most communications and energy networks, including data centers providing services for financial markets, rely on precise timing information received by satellite

... Satellites provide critical communications capabilities in support of rescue and relief efforts during emergency and disaster situations such as the 2010 earthquake in Haiti, the tsunami in 2004 and hurricane Katrina in 2005

... Satellites offer Internet connectivity to all citizens in rural and remote areas in Europe and around the world within a matter of days

... Satellites provide fast broadband, which in combination with terrestrial infrastructure, is a fast and cost-effective way to deliver the EU’s Digital Agenda 2020 goals

... The use of satellites as a highly efficient technology for distribution of large amounts of data helps to ease discussions about lower network quality of service or high-bandwidth service limitations depending on tariff chosen

... Peacekeeping missions, troops abroad and border security around the world rely on secure communications provided by satellites

... The satellite industry is strategically important for Europe, supplying thousands of high-tech jobs, accounting for more than half of all commercial communications satellites in space with a value of over €20 billion, enabling independent launch and defense capabilities and putting Europe at the leading edge of new state-of-the-art technologies
A vision of 2020…

... Everyone in Europe will have access to broadband services and a next-generation service experience

... Most Europeans will experience HD and ultra-HD media and TV viewing at home on multiple sets as linear viewing continues to be the mode of choice for consuming TV content

... Media content will be delivered using a combination of fiber, cable networks, wireless terrestrial networks and satellites, leveraging the strengths of each individual technology and forming “hybrid satellite-terrestrial” networks

... Future terrestrial and mobile networks will rely on satellites for cost-efficient multicast of high-bandwidth data streams and high-definition media, delivering a next-generation converged service experience to consumers in the most effective way—in an environment where it is predicted that video may represent more than 85% of consumer IP traffic

... Satellite technology will be a key solution for wide-scale media and data distribution, whether for digital cinemas, private homes or enterprises in urban or remote locations

... Satellite services will remain a non-intrusive, instant infrastructure, neither harming protected areas nor disturbing delicate ecosystems

... Terrestrial networks will rely on satellite and fiber for efficiency, e.g., to distribute high-demand content to the network edges speedily

... Remote facilities, energy plants and industrial processes will be monitored 24/7 by satellite

... Maritime and aeronautical users will have access to fast data and voice communications around the globe via innovative satellite systems, allowing ultimate advanced traffic monitoring and management

... Europe will lead the global effort to establish internationally accepted modeling and forecasts for climate change using satellite information

... and how it could be achieved

... Policies should recognize, enable and make use of multiple technologies in the context of developing cost-effective next-generation networks that respond to real user needs based on market expectations

... The satellite should be understood and supported as a long-term enabler as it helps relieve data volume, allowing users to enjoy the best speed experience possible, as well as being a key enabler of immediate connectivity anywhere

... The global nature and specific architecture of satellite services should be taken into consideration when evaluating spectrum allocations and determining sustainable spectrum usage
Why satellites matter

The relevance of commercial satellites in the 21st century – a perspective 2012-2020

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Executive Summary

In the last fifty years, satellites played a key role in the growth of global communications, media and technology industries. During these years satellite communications grew to a €100 billion industry, enabling breakthroughs like intercontinental telephony, live television from remote regions, the broadcasting of television channels to all citizens, global positioning, trunking for telecom operators and reliable data networks for private companies. In recent years, satellite technology has seen a significant leap in advancement. Multi-spot beams allow for much higher throughput and lower costs, and are using frequencies even more efficiently.

In today’s European society, free and open communication is anytime, anywhere and accessible by everyone. The public values the availability of a multitude of open communication channels, catering to and fulfilling the different needs of citizens. And the ubiquitous nature of satellites—out of view from earth, high in outer space, but in view of wide regions of the globe, make them unique beacons for robust communications and instruments of democracy and freedom in Europe and around the globe.

Europe has recognized the relevance of communications early, and the EU aims to accelerate the ongoing digitization within and across European countries. But the magnitude of the debt crisis and its effect on employment is forcing EU governments to rethink their approach to stimulating growth and set new horizons. The ongoing crisis is a wake-up call to the EU. It is now determined to capitalize on its strengths and establish ambitious objectives to ensure a sustainable future. The Agenda 2020, and in particular its ambitious Digital Agenda component, equips the EU with a roadmap and a series of initiatives to deliver smart, sustainable and inclusive growth. This is an opportunity but also an imperative for the EU to leverage its successful technology capabilities. Among these, satellite systems and services, whose economic benefits are often overlooked, have the potential to contribute greatly towards these objectives.

In this context, satellites have a key role to play in bringing digital content, delivering very high quality video and enabling efficient broadband networks.

Satellites will—and must—be an integral part of the future communications ecosystem

In the foreseeable future, communications will be based on a multitude of technologies. Existing infrastructure based on copper cables will continue to play a major role for the provisioning of telephony line as well as DSL. With the further roll-out of fast and ultra-fast broadband based on new DSL standards, fiber will be rolled out to local concentration points. Cable networks will continue to provide ultra-fast broadband and broadcast services in densely populated areas. In parallel, the first fiber-to-the-home connections have become available and will be rolled out further in bigger cities and selected suburban and densely populated rural areas.

On top of that, mobile networks will continue to offer 3G/HSPA services, allowing mobile Internet access. With the emergence of LTE, fast mobile broadband will become available in cities and use of the digital dividend will allow basic mobile broadband in more rural areas. Digital terrestrial TV will continue to broadcast channels to households.

This mostly terrestrial-driven vision might sound appealing, but based on our analysis of technologies, use cases and economics, we are convinced that, beyond all of these networks and applications, an efficient communications ecosystem will require satellites to cope with the immense volume of data that will have to be distributed throughout these networks, to ensure fast roll-out, superior economics and robust network operations. According to Cisco, the sum of all forms of video will be approximately 86% of the consumer IP traffic by 2016. Terrestrial networks will not be able to cope with those volumes alone: satellite will have to be used for offloading traffic.

1 In this report, billion refers to 1,000 million
Some examples to illustrate the need:

- In coming years, the resolution of TV channels will increase and provide a superior user experience. Linear TV will continue to be the mode of choice for most consumers, with online viewing increasing to coexist alongside but not replace linear viewing. These linear HD and Ultra-HD TV channels will require significant bandwidth, which can only be provided by DTH satellite, costly fiber and potentially cable. But only the satellite’s intrinsic point-to-multipoint broadcast capabilities allow cost- and spectrum-efficient content distribution across larger geographic regions.

- Mobile video consumption is the major capacity driver in today’s mobile networks. Providing media content everywhere would require an expensive fiber roll-out to feed mobile base stations everywhere. Satellites offer alternative, cost-efficient solutions by feeding these high-demand data streams directly to the mobile towers in mobile-satellite hybrid networks.

- Rolling out fiber to the home or to enterprises in rural and remote areas is often expensive and time consuming. New innovative satellites offer a solution to provide broadband access directly to the end users at home, or as a backhauling component for terrestrial technologies (e.g., providing media content to the local DSLAM for DSL customers).

In addition to being part of the terrestrial communications system, satellites can provide services where other technologies struggle or fail, such as decongesting airwaves for air-traffic management in complex and dense airspace, or providing broadband access to aerial or maritime users. We therefore envision a future communications ecosystem leveraging all terrestrial wired and wireless and satellite technologies based on their respective key capabilities.

Satellites provide unique and differentiating key capabilities for communications systems
Satellite communications offer differentiating capabilities, which enable specific use cases and illustrate the role satellites will play in the overall communications ecosystem.

Satellite communications allow for high data rates and highly efficient broadcasting

- **Broadcast efficiency**: given the large coverage and limited need for terrestrial infrastructure, satellites offer unique broadcasting capabilities. They are highly cost efficient for broadcasting, allowing distribution of data and media to a broad audience with limited cost and requirements for spectrum when compared with any other technology.
- **High bandwidth with efficient spectrum usage**: new technologies (multi-spot beams in the C, Ku, and Ka bands) make it possible to provide tailored content two-way to small areas. This further increases spectrum efficiency and reduces cost for applications targeting small areas, enabling very high data rates/bandwidth services irrespective of landmass or maritime location, e.g., for fast broadband.

Satellite communications do not require complex ground infrastructure while being interoperable with terrestrial services and running on solar power during their entire lifetime

- **Limited technical requirements**: satellites require only small and simple ground equipment to enable communications services. This simplicity not only allows for machine-to-machine use cases but also allows satellite communications to act as an enabler of democracy in times of crisis, since satellites remain resilient to terrestrial infrastructure tampering or destruction and can maintain communication links, e.g., as seen by the broad availability of reports from the Arab Spring, using satellite equipment for transmission.

- **Interoperability with terrestrial services**: satellite communications can be combined with terrestrial communications technologies, making it possible to provide services in hybrid scenarios, e.g., to provide triple play (telephony, broadband Internet and TV) everywhere, where satellite technology provides part of the service and terrestrial technology the rest, increasing the overall efficiency of the solution by off-loading terrestrial networks. Another example for a hybrid system could be a VSAT installed in a village library/school to be extended via terrestrial wireless to the surrounding homes.

- **Simple redeployment of earth equipment**: given the simple and standardized ground equipment, a redeployment of customer equipment is very easy. For example, in case a fiber roll-out reaches an area, ground equipment can be repurposed in a different service area with limited costs/efforts. This is an especially interesting feature that helps accelerate broadband for all, noting however that already today satellites offer consumer broadband download speeds of 18 Mbit/s.

- **Satellites run on solar power**: these complex yet far-reaching pieces of infrastructure make use of solar power to offer uninterrupted services to users for fifteen to twenty years. In addition, reception of satellite services does not imply disruption of protected landscapes through civil works and creates very limited electro-magnetic emissions.

![Satellite Use Cases Diagram](image-url)

- Examples: volcano watch, landslide monitoring, security watch, satellite quota management.
- Examples: container, shipments.
- Examples: airport/airliner traffic management, GNSS approaches, 4D trajectory management.
In the overall communications ecosystem, satellites can ensure transparent and uncensored communications and drive net and technology neutrality

- Transparent and neutral communication: due to its independence from terrestrial services, broad coverage profile and resilience against political disturbance, satellite technology provides reliable, technologically neutral service. Satellite communications therefore support unrestricted and uncensored communication, e.g., from and within conflict zones, and contribute to spreading democracy.

- As the satellite has clear advantages when it comes to dissemination of high-bandwidth services, e.g., by offloading traffic in hybrid solutions, its use for such services significantly lowers the overall cost of network deployment and as such weakens the argument that high-bandwidth services should be left to individual commercial agreements (e.g., regarding quality of service or services carried depending on tariff) between service providers and network operators.

- Ensuring technology redundancy and reducing risk within the communications mix: today, the majority of new communications services rely solely on fiber as the primary method for backhauling of cable, DSL and mobile networks. Satellites provide a redundant and robust alternative to fiber for a multitude of use cases, making the end-customer service technology neutral, more economical and thus more competitive, and mitigating the risk of a single point of failure of communications. An example of the importance of alternative technologies was the 2005 undersea cable disruption in Pakistan, where Internet access and international phone calls were provided via satellite during the eleven days of service interruption.

Satellite communications offer global coverage with instant and interoperable services

- Distance-agnostic global and cross-border coverage: a single satellite can cover a significant area and a small fleet (e.g., three geostationary satellites) can achieve global coverage with communications services. Maritime and aerial services benefit especially from this large coverage, allowing for anytime/anywhere communications; in addition, satellites can augment terrestrial services in rural and remote areas. Such coverage also enables global propositions, where European companies and experts support other regions, e.g., with tele-education or tele-medicine/health. Many global corporations and governmental agencies run their global network via satellite in order to have one robust provider and not a number of providers for various countries.

- Speed and versatility of deployment/instant infrastructure: once designed, manufactured and launched, a satellite stays an always-on infrastructure for the rest of its lifetime. This allows a very fast roll-out of the service on the ground (irrespective of distance from the nearest central office of a communications company), e.g., in case backhaul for a mobile network is needed, a company needs IP connectivity (VSAT) or to roll-out ITS (Intelligent Transport Systems) services broadly.

- Interoperability with other satellite services: satellite communications can be combined very easily with other satellite services like remote sensing/earth observation and global positioning. Combined with global coverage, this enables integrated applications, such as advanced fleet and traffic management and monitoring applications.

Orbital services are resilient and reliable with predictable quality independent of terrain or distance

- Independence and resilience to earth events: satellites are not influenced by events on earth, such as natural or man-made disasters and social or political events. This makes satellite communications key for emergency services but also as backup to terrestrial infrastructure. Furthermore, providing service by satellite is independent of the local terrestrial environment, i.e., there is no need for civil works and the service can be supplied in difficult environments (e.g., mountain areas) and therefore has a speed advantage when it comes to rapid deployment of critical communications services.

- Reliability and security of communications: satellites are carefully engineered to allow operation for fifteen to twenty years in a very harsh orbital environment, out of reach for maintenance. This high-quality infrastructure has very limited planned downtimes and rarely suffers service disruptions. In addition, satellite communications offer a predictable and stable quality of service, independent of distance (unlike terrestrial wireless or copper-based technologies, where distance is a limiting factor for speed and quality). This reliability is why security and military services, as well as news-gathering services, all rely on satellite communications.
Satellite services significantly contribute to European policies and their implementation

The Agenda 2020, and the Digital Agenda, is a chance for satellite industry to contribute further to Europe’s development and competitiveness, and assert its leadership. Satellites constitute key communication channels to support the growth of high-definition video and high data-rate applications expected by everyone in an increasingly demanding converged digital environment.

Many EU policies already rely on satellites for implementation—e.g., digital divide, global environment monitoring—or for the monitoring of conformance to EU rules and regulations. Satellite systems enable commercial and institutional services that continue to grow in strategic importance for Europe. Already many European policies depend on satellite technologies to provide cost-efficient and effective monitoring of resources (e.g., fish stocks, fair access to natural resources), monitoring of policy implementation (e.g., border control) and Common Agricultural Policy (CAP).

With the now well-established link between a knowledge-based economy and the diffusion and use of information through network access, policy instruments are being designed at EU and national levels to promote access to next-generation networks. These networks are to benefit from a technology mix in which satellites contribute to the resilience of the overall infrastructure. The EU’s goal is for 500 million EU residents to have a connection speed of 30 Mbps by 2020. With quick deployment times, satellite terminals can already provide more than the average ADSL speed anywhere within Europe, thanks to high-throughput satellites that represent a quantum leap, and this is likely to increase beyond fast broadband as technology further improves by the end of the decade. In addition, advanced modem and satellite technologies will further improve spectrum efficiency by several orders of magnitude. There has been tremendous improvement in satellite capacity over the last three to five years—the three most advanced satellites launched recently for broadband services together have more capacity than all satellites available in 2010 combined. These broadband services are delivered in addition to satellites’ essential role of off-loading video content from terrestrial networks in order to free them up for more revenue-generating applications.

The increasing complexity and interdependence of information technology, telecommunications, transportation, energy and health-care systems make them extremely vulnerable in case of man-made or natural disasters; satellites bring unique complementary strengths to these infrastructures and lower the risks.

As needs for mobility and connectivity grow further, the satellite is well suited to support a growing range of applications fulfilling EU policies’ needs (e.g., maritime safety, Single European Sky and traffic challenges) and enabling

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agenda goals (e.g., reducing congestion in urban centers by enabling broadband in less urban areas for teleworking).

Satellite services enable governments around the world to reach their policy goals. In addition to providing broadband for everyone, satellite services also support tele-education and telemedicine, disaster preparedness, mobile banking applications, e-government services and many more applications.

**Several prerequisites are required to implement a future communications ecosystem**

Despite many hurdles, the satellite industry has successfully permeated many ICT sectors and developed into a multi-billion-euro industry, yet it remains highly vulnerable to regulations and policies. For European economies and citizens to reap the full benefits of satellites, several prerequisites have to be fulfilled and need to be considered in future policies and direction setting.

**Secure orbital slots and spectrum for services**

Satellite systems are dependent on two critical regulatory resources to operate: orbital slot and spectrum.

Satellite services are inherently global and as such, regulators should take the global component into consideration with regards to the allocation and usage of spectrum. Satellite operators have invested substantially in new satellites based on increasing demand. This investment would be stranded if the spectrum for which these satellites have been designed could no longer be used, as once in orbit the spectrum specifications on a satellite cannot be altered. Furthermore, crucial services that were supposed to be provided on these frequencies might no longer be provided, once these frequencies are no longer available or holes appear in the satellite footprint because of European or other regional-only decisions on use of spectrum.

One example would be C-band services, which are in high demand in Africa but not as widely used in Europe. Due to the broad coverage zones, any regulation in Europe also affects North African service delivery.

The ITU plays a central role in allocating and managing the process of coordination of orbital slots and associated spectrum rights, as well as spectrum allocations in general and the recording procedures for space systems and Earth stations.

Securing spectrum is critical for the success of satellite applications, and allocated spectrum is a valuable asset in global competition. Without strong support from the EU and ESA, the European satellite industry could be at risk of losing some of its critical spectrum resources.

**Policies need to enable hybrid solutions and not negatively impact their roll-out**

Europe’s Digital Agenda foresees a wide-scale broadband roll-out and adoption in order to enable economic growth driven by the next level of digitization. A challenge for policymakers is to design policies that are technology neutral and cost optimal, since the next-generation service experience requires bandwidths that can be delivered by only few technologies today.

But this intended service experience is also possible with hybrid networks, which combine multiple technologies into one solution: for example, terrestrial-satellite or mobile-satellite hybrids. These would allow a cost-efficient service delivery, requiring less roll-out of costly fiber and leveraging the unique efficiency of satellite technology.

In order to enable these hybrid networks, policymaking needs to foresee the option of combining technologies on different levels, from the last mile to direct broadcast to mobiles to content distribution in backhaul networks.

One example would be broadband roll-out aid in rural areas. A next-generation service with a net ultra-fast bandwidth could be enabled by a hybrid system of 3G or LTE for Internet data access together with satellite broadcast for HDTV and large data-file distribution. This would require development of new home gateways but could still speed up the roll-out and improve the take-up rate of ultra-fast broadband.

**Global market access is required to reap full benefits of global coverage**

Satellite services are capable of connecting Europe to the rest of the world. While most countries allow market access for foreign satellite operators in an open and transparent manner the way Europe does, some countries have a more or less closed regime, favoring their national satellite industry or hindering foreign satellite industries. In order to reap the benefits of global satellite communications services, Europe should in trade negotiations
ask for an open-skies regime, which would grant foreign operators the same or very similar rules and regulations as for local operators.

Summary
The commercial satellite services industry has been growing at a sustained pace for decades, and its relevance to economic growth as well as its role in ensuring Europe’s position as a leading space power is well established. Satellite communications can support the further growth of Europe’s and the global digital society with unique capabilities, enabling cost-efficient, fast service delivery. Satellites will continue to deliver efficient broadcast services on a global basis but will also serve a multitude of unique use cases in innovative solutions and/or infrastructure mixes.

*Broadcast and multicast services are most efficient with satellites, making them a key building block of hybrid networks*

Satellites should be part of the future telecommunications ecosystem to continue efficient media delivery. For now, satellite communications will remain the most cost-efficient solution to provide a next-generation service experience in a hybrid setup with terrestrial networks.

Future terrestrial networks should leverage the efficient distribution of data and media via satellite to avoid network overload, reduce the need for roll-out of costly backhauling solutions as well as to reduce last-mile infrastructure requirements in rural areas.

*Satellite communications can speed up broadband roll-out in Europe and allow access for all already today*

Satellite broadband services are already available today for European citizens and in many developing economies. Incentivizing and promoting the use of satellite services can for a significant part of society make the difference between no network access and a viable connection and inclusion in the digital society.

With new technologies, fast broadband access via satellite is a viable option for consumers and businesses in remote and low-density-population areas, where alternative technologies are not available or too costly to roll out.

*Satellites offer irreplaceable capabilities for emergency communications, navigation, remote sensing,…*

The unrivaled options for emergency services, positioning and navigation, disaster recovery and Earth observation need to be recognized and protected.

Satellite communications are often the only viable technology for disaster-related services, where rapid deployment and reliable communications are critical and when other networks may be destroyed or overloaded.

Satellite-based imaging services support the development and implementation of future resource- and environment-management solutions. Already today, satellite-gathered data help to implement, monitor and manage policies such as fishery quotas, agricultural policies and forestry strategies.

Modern traffic navigation and management services for all modes of transport are dependent on satellite-provided position and timing data. Applications from 4D aerial trajectory management to precision agriculture and fleet management are only possible thanks to satellites.

*Satellites’ benefits need to be enabled by policies, including securing the key resources of orbit and spectrum*

The satellite is an unobtrusive technology that is often overlooked, especially in policymaking. In order to allow a better integration in the communications ecosystem, satellites should be made more visible, especially the options and potential benefits of hybrid networks and solutions.

To reap the benefits of satellites, key resources need to be secured. Satellite communications are extremely dependent on a well-protected and managed spectrum on a global level, since signals from the orbits are susceptible to interference from terrestrial applications.

In light of the essential role that satellite systems play and will continue to play in enabling Europe 2020 objectives to be achieved, regulators and government organizations should support the satellite industry and operators in international negotiations for frequency allocations in order to secure uninterrupted service provisioning today and further roll-out tomorrow.
The satellite industry contributes significantly to the European economy and is a major exporter of services
With the four major satellite operators, the most important launch company and a significant share of satellite manufacturers, Europe is the major hub for the commercial satellite industry. Due to the global footprint and nature of the industry, satellites are a large contributor of exports to the rest of the world. This not only creates jobs and generates revenue in Europe but also allows the Europe to increase its political and economic strength.

The European satellite industry today directly and indirectly creates more than 200,000 highly qualified jobs and €10 billion of revenue. Future satellite services have the potential to contribute more than €100 billion of benefits to Europe, to help avoid billions of costs in the roll-out of networks and to increase the European GDP by accelerating broadband roll-out and closing the digital divide.
1. Introduction

Dear Reader,

The following report, *Why satellites matter – The relevance of commercial satellites in the 21st century*, provides an in-depth perspective on a technology everybody knows and uses but few people truly understand. With this comprehensive report on what the satellite does for individuals, enterprises, countries and regions, we lay the fact-based foundation for a discussion on the emerging future communications ecosystem, in which satellites will play a critical role.

The report explains why satellites are more relevant than ever, outlines the large number of use cases that satellites support and answers key questions regarding the future of commercial satellites:

- How do we use satellites today and how will we continue to use them in the future?
- What is the relevance of satellites with the advent of new technologies?
- Why does the satellite provide sustainable economic benefits for specific use cases?
- In which domains is the satellite’s potential not yet fully realized?

In addition we explain why satellites are required to make today’s technology work and outline the current and potential future role of commercial satellites in the communications ecosystem.

In summary, the report provides a perspective on how satellites can support Europe’s agenda and growth ambitions (e.g., via satellite-based hybrid broadband access, support of net neutrality). While it focuses on Europe for most of the examples, analyses and conclusions apply to most mature countries around the world.

The authors of the report—Booz & Company, a global management consulting firm—have long-standing experience working in this industry and with its players. As an independent observer and advisor we base this report and the analyses within on available facts, not opinion. Therefore we have aimed to use a fact-based language and ensure a balanced perspective, including the limitations of the technology where they exist.

The report has been commissioned by the European Satellite Operators’ Association (ESOA), and we thank their members for access to their archives for data and statistics.

We wish you an interesting read.
Commercial satellites have been in use for half a century—with exciting innovations to come in the next years. The first satellite with radio-transmission capabilities was Sputnik in 1957. Since the middle of the sixties, commercial communications satellites in geosynchronous and geostationary orbits have been in use. In the late eighties, medium-powered satellites became available, enabling direct-to-home (DTH) television reception with smaller antenna dishes for low cost. In recent years, new technologies, such as spot beams and the use of higher frequency bands, have even further improved the efficiency of satellites. Highly efficient multicasting and broadcasting satellites are today in use for TV, media and data distribution around the globe.

![Communication Satellite Timeline](Image)

Figure 1. Communications satellite timeline

In the coming years, two major European initiatives will be developed and implemented further: Galileo, the European positioning and navigation system, and GMES, the European earth observation program. In parallel, new commercial communications solutions in lower orbit will provide data services in Europe but especially also in developing markets, thus allowing countries around the world to partake in services like telemedicine or telelearning.

Satellite industry overview

The communications satellite industry's value chain includes developing and manufacturing systems on the ground, building, launching and operating satellites and providing end users with equipment and services (see Figure 2).

Development and manufacturing is concentrated in fewer than thirty companies around the globe, which provide systems for commercial, government and military uses. Around fifty satellite operators are active, but with only a few clear leaders operating larger fleets and constellations.

Equipment manufacturing is a very broad market, covering everything from handheld GPS devices to TV receivers and decoders; this is a dispersed market without clear leaders. The actual service provisioning lies in the hands of telecom operators, Internet service providers and TV broadcasters/pay TV providers. Several thousand companies use satellites to provide a service to their end customers.

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2 Note: if not mentioned otherwise, source of all figures Booz & Company
### Satellite Industry Value Chain

<table>
<thead>
<tr>
<th>Ground Systems</th>
<th>Satellite Manufacturing</th>
<th>Launcher &amp; Launch Services</th>
<th>Satellite Operations</th>
<th>Equipment Manufacturing</th>
<th>Service Provisioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Engineering, manufacturing, and testing of equipment for</td>
<td>- Develop and manufacture satellite systems</td>
<td>- Launch of satellite (Launch insurance)</td>
<td>- Manage and operate satellite fleet</td>
<td>- Develop, manufacture and sell equipment for end customer (e.g. GPS devices, DTH receivers, VSAT terminals)</td>
<td>- Provide service to end customer</td>
</tr>
<tr>
<td>- Space companies</td>
<td>- Satellites (Telecommunications, Earth Observation, Navigation Systems)</td>
<td>- Scientific systems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Ground stations and ground control center</td>
<td>- Scientific systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Engineering and consulting services</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Satellite Manufacturing Industry** (including launch vehicle)

- Number of companies (global):
  - < 20 companies: 6 leaders
  - < 10 companies: 3 leaders
  - ~ 50 companies: 5 leaders

**Launch Services**

- Dispersed

**Service Provisioning**

- Telco > 1,000
- ISPs > 1,500
- TV > 10,000

Source: ESOA, ADS-Eurospace, SIA / Futron, ITU, Booz & Company analysis

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Figure 2. Satellite industry value chain
2. Satellites’ Role in Today’s Communications Technology Mix

Satellite technology developed significantly in the last fifty years, from the simple relaying of information to multi-spot beams leveraging multiple frequency bands. In the following section, we describe a vision for the role of satellites in the communications ecosystem and compare them to other technologies. For a detailed description of satellite technology please see the Appendix.

2.1 Satellites in the communications ecosystem

For the future European communications ecosystem, we see satellites as a key component, as many terrestrial technologies rely on or at least interact with satellite services. In addition, satellite-based systems provide distinct and complementary capabilities to terrestrial networks. To understand the use cases for satellites in the future, the value proposition of satellites needs to be considered and will be explained in the next section.

![Future European Communication Ecosystem](image)

Figure 3. Communications ecosystem

2.2 Value proposition and constraints of satellite technology

Satellites provide unique capabilities but, as with every technology, also has some constraints. In the following section, the main differentiating capabilities and key limitations are described.³

**Orbital services are resilient and reliable with predictable quality independent of terrain or distance**

Being in orbit, satellites are out of reach—making them independent but also vulnerable. This environment requires specific engineering, which in return enables key differentiating capabilities.

- **Independence from and resilience to earth events**: satellites are not influenced by events on earth, such as natural or man-made disasters and social or political events. Furthermore, providing service by satellite is independent of the local terrestrial environment, i.e., there is no need for civil works and the service

³ For a description of satellite technology please see the Appendix
can be supplied in difficult environments (e.g., mountain areas) and therefore has a speed advantage when it comes to rapid deployment of critical communications services.

- **Reliability and security of communications**: satellites are carefully engineered to allow operation for fifteen to twenty years in a very harsh orbital environment, out of reach for maintenance. This high-quality infrastructure has very limited planned downtime and rarely suffers service disruptions. In addition, satellite communications offer a predictable and stable quality of service, independent of distance of communication (e.g., unlike terrestrial wireless or copper-based technologies, where distance is a limiting factor for speed and quality).

**Satellites offer global coverage with instant service**

Some key advantages of satellite communications are driven by physical properties due to the orbital position, the use of high-frequency radio spectrum and the standardization of satellite platforms:

- **Distance-agnostic global and cross-border coverage**: a single satellite can cover a significant area, and a small fleet (e.g., three geostationary satellites) can achieve global coverage with communications services. Maritime and aerial services benefit especially from this large coverage, enabling anytime/anywhere communications; in addition, satellites can augment terrestrial services in rural and remote areas. Such coverage also enables global propositions, in which European companies and experts support other regions, e.g., with tele-education or telemedicine/telehealth. Many global corporations and governmental agencies run their global network via satellite in order to have one provider and not a number of providers for various countries.

- **Speed and versatility of deployment/instant infrastructure**: once designed, manufactured and launched, a satellite stays in an always-on infrastructure for the rest of its lifetime. This allows a very fast roll-out of the service on the ground (irrespective of distance from nearest central office of a communications company).

- **Interoperability with other satellite services**: satellite communications can be combined very easily with other satellite services like remote sensing/earth observation and global positioning. Combined with global coverage, this enables integrated applications.

**Satellite communications allow for high data rates and highly efficient broadcasting**

In addition to general physical and technical properties, the development of new technology for satellite payload solutions increased the efficiency and communications options of satellites:

- **Broadcast efficiency**: given the large coverage and limited need for terrestrial infrastructure, satellites offer unique broadcasting capabilities. They are highly cost efficient for broadcasting and multicasting, enabling the distribution of data and media to a broad audience with limited costs and requirements for spectrum when compared with any other technology.

- **High bandwidth with efficient spectrum usage**: new technologies (multi-spot beams in C, K, and K bands) make it possible to provide tailored content two-way to small areas, further increasing spectrum efficiency and reducing cost for these applications targeting small areas and enabling very high data rates/bandwidth services irrespective of landmass or maritime location.

**Satellites do not require complex ground infrastructure while being interoperable with terrestrial services and running on solar power during their entire lifetime**

In addition to the space segment, satellite communications also offer some distinct advantages in the ground segment (i.e., the equipment and service components on earth):

- **Limited technical requirements**: satellites require only small and lightweight ground equipment to enable communications services; even media broadcasting requires limited technical effort to send and receive.

- **Interoperability with terrestrial services**: satellite communications can be combined with terrestrial communications technologies, making it possible to provide services in hybrid scenarios, in which satellites provide part of the service and terrestrial technology the rest, increasing the overall efficiency of the solution by off-loading terrestrial networks.
• **Simple redeployment of earth equipment**: given the simple and standardized ground equipment, a redeployment of customer equipment is very easy. For example, in case a fiber roll-out reaches an area, ground equipment can be dismounted and moved to a different service area with limited costs/efforts.

• **Satellites run on solar power**: these complex yet far-reaching pieces of infrastructure make use of solar power to offer uninterrupted services to users for fifteen to twenty years. In addition, reception of satellite services does not imply disruption of protected landscapes through civil works and creates very limited electromagnetic emissions.

**In the overall communications ecosystem, satellites improve net and technology neutrality and risk profile**

Looking at space and ground segments as part of the overall communications ecosystem reveals additional strengths of satellite communication:

- **Transparent and neutral communication**: due to its independence from terrestrial services, broad coverage profile and resilience to political disturbance, satellites provide reliable, technologically neutral service. Satellite communications therefore support unrestricted and uncensored communication, e.g., from and within conflict zones, and contribute to spreading democracy.

- **Positive impact on net neutrality discussion**: as the satellite has clear advantages when it comes to dissemination of high-bandwidth services, e.g., by offloading traffic in hybrid setups, its use for such services significantly lowers the overall cost of network deployment and as such weakens the argument that high-bandwidth services should be left to individual commercial agreements (e.g., regarding quality of service or services carried depending on tariff) between service providers and network operators.

- **Ensuring technology redundancy and reducing risk within the communications mix**: today, the majority of new communications services rely solely on fiber as the primary method for backhauling of cable, DSL and mobile networks. Satellites provide a redundant and robust alternative to fiber for a multitude of use cases, making the end-customer service technology neutral, more economical and thus more competitive, and mitigating the risk of a single point of failure of communication. An example of the importance of alternative technologies was the 2005 undersea cable disruption in Pakistan, where Internet access and international phone calls were provided via satellite during the eleven days of service interruption.

**Inherent limitations of satellite communications due to physics are mitigated by new technologies**

In addition to numerous advantages, satellite communications also have some restrictions, which are mainly driven by physics:

- **Using microwaves for communications requires a line of sight** from the receiver to the satellite, limiting the possible indoor coverage. This can be mitigated, however, with the use of lower frequency bands, enabling coverage almost comparable to mobile networks. In addition, terrestrial components (repeaters) can be used to amplify the signal in a hybrid setup. In addition, **weather affects** the communications in certain bands (e.g., rain fade). Thanks to research in new communications protocols and receiver technology with better caching, the impact of rain can be mitigated for many use cases. Furthermore, bands in lower frequencies, where weather does not affect communication, can be used, especially for areas with tropical climates.

- Since data travel several thousand kilometers from the satellite's position in orbit, satellite communications have a higher **latency**. For many use cases (e.g., broadcasting, broadband for latency-insensitive traffic like e-mail or file transfer) this is no significant disadvantage and can be further improved by faster on-board processing. New ground-processing technology further reduces the impact on the user experi-

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4 The majority of Internet traffic is insensitive to latency; only some services cannot mitigate it, e.g., online gaming.
ence, e.g., in satellite telephony the latency is not noticeable due to signal processing. For services requiring lower round-trip times, constellations in lower orbits are possible (e.g., as currently in development by O3b networks).

- Satellites require a significant initial investment to develop and launch. But compared to large-scale terrestrial roll-outs (especially continent-wide to achieve the same coverage as satellites), the costs are limited.

**Satellite communications are threatened by terrestrial spectrum use**

Using satellite spectrum for other technologies decreases the signal quality for satellites and negatively affects quality of service. Better ground and space technology cannot mitigate these interferences completely, especially when it comes to high data rates. In order to provide stable and predictable quality of service, satellite communications rely on the protection of spectrum.

The increasing demand for terrestrial use of spectrum (e.g., as seen in the digital dividend discussion and the current spectrum review) therefore threatens service quality. Due to the large coverage zones of satellites, the requirements and regulation of spectrum in one region also have high impacts on neighboring areas. For example, C band is used heavily in Africa (one reason is the limited impact of atmospheric water and rain on these frequencies) but less used in Europe (since K_0 band allows for smaller dishes and monsoon rains are not a problem). Allowing the usage of these bands in Europe for terrestrial systems would not only impact users in Europe but also North African citizens who rely on the technology today.

### 2.3 Comparison to other communications technologies

Generally, the purposes of the communications systems have to be distinguished in order to compare apples with apples (see Figure 4). The purposes are now more difficult to separate, however, with the advent of new communications forms and user behaviors (e.g., watching linear TV content on a mobile phone). Each communications system is normally optimized for one purpose (e.g., broadcasting) and can only be used for alternative purposes to a limited extent, if at all. For all media, the available bandwidth for all uses has to be considered and can then be split into the different use cases. Figure 4 gives an overview of communications technologies and their characteristics.

<table>
<thead>
<tr>
<th>Broadcast (unidirectional)</th>
<th>Wired</th>
<th>Wireless</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid fiber/coax (HFC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phone line (copper, POTS/DSL with FTTN/FTTC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fiber-to-the-home (FTTH)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leased line (dark or lit fiber)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microwave connections (backhauling)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broadcast satellite – Fixed: DVB-S – Mobile phones: DVB-SH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bidirectional, point-to-point connection (e.g., backhauling)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broadcast satellite – Fixed: DVB-S – Mobile phones: DVB-SH</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Bidirectional, voice and data | Mobile networks – 2G: GSM and GPRS and EDGE – 3G: UMTS and HSPA – 4G: LTE

Figure 4. Overview communications technologies for different uses (end-user focus)

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5 Latency-reduction technology depends on the traffic type. For example, in data communication TCP optimization (like ACK spoofing, pre-fetch and fast-start) and local DNS lookups/buffering are used, in voice communication echo cancellation reduces the perceived effect to an unnoticeable level.

6 Note: LTE considered at least a candidate for 4G; not in all definitions considered a 4G system
2.3.1 Terrestrial wireless

Satellites share a lot of characteristics with terrestrial wireless technologies. In particular, newer satellite-based systems (Ku-band satellites) are especially comparable to mobile phone networks (with very large cells).

Wireless technologies are generally shared media, meaning that all users access the same spectrum and can block each other in communicating, as well as that all users have to share all the available bandwidth. Therefore, for bidirectional systems (i.e., mobile networks), separating users is relevant. Physics supports this effort by reducing signal strength with distance (free-space path loss), therefore allowing for a honeycomb cell structure (see Figure 6, where cells without a common border can reuse frequencies (also allowing for spectrum efficiency—comparable to spot-beam technology in satellites, see also Figure 63).

- **Regional availability**
  - Urban: Practically everywhere
  - Suburban: Depending on competition, mainly urban to dense rural (but only in spot areas)
  - Rural: Practically everywhere, also for remote areas
  - Dense Rural: Practically everywhere, also for remote areas
  - Remote: Practically everywhere, also for remote areas

- **Achievable end-user bandwidth**
  - Broadband (2+ Mbit/s)
  - Narrowband (64 Kbit/s with ISDN)
  - Ultra-broadband (1 Gbit/s)
  - Broadcast, several hundred channels receivable (per orbital slot)

- **Marginal cost to add new users in coverage area**
  - Practically already existing infrastructure (at least to the curb)
  - New infrastructure to household
  - Usually not required, can be covered with existing infrastructure

- **Cost to increase coverage area**
  - Fiber to the node (DSLAM)
  - Microwave roll-out for low-bandwidth tower; otherwise fiber roll-out
  - Fiber to the household

---

7 Note: Broadband starting at 2 Mbit/s, fast broadband starting at 30 Mbit/s, ultra (ultra-fast) broadband starting at 100 Mbit/s (comparable to WIK Consulting and the EC’s definition, see (2))
Based on this honeycomb structure, mobile network antennas (towers) are built to cover their area. Each tower has one or several antennas with dedicated spectrum. Depending on the standard, mobile networks today allow for a bandwidth per user of up to 100 Mbit/s (LTE), but due to the shared medium, this is a theoretical value—practical average rates will be lower (especially if a cell is full). To enable this bandwidth, each tower has to have backhauling capacity, i.e., connectivity to the central backbone of the network. Mobile networks today mainly use three backhauling technologies: DSL-based (allowing for only a limited bandwidth, not relevant for LTE or HSPA), microwave (depending on setup, several hundred megabits per second with up to several gigabits per second possible) and fiber (several gigabits per second possible). Network planning tries to leverage existing fiber connectivity to reduce the cost for roll-out (since fiber roll-out is a major cost driver for mobile networks).

![Mobile Network Cell Structure](image)

**Table: Mobile Network Cell Structure**

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Cell Radius (km)</th>
<th>Cell Area (km²)</th>
<th>Relative Cell Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>48.9</td>
<td>7,521</td>
<td>1</td>
</tr>
<tr>
<td>950</td>
<td>26.9</td>
<td>2,269</td>
<td>3.3</td>
</tr>
<tr>
<td>1,800</td>
<td>14.0</td>
<td>618</td>
<td>12.2</td>
</tr>
<tr>
<td>2,100</td>
<td>12.0</td>
<td>449</td>
<td>16.2</td>
</tr>
</tbody>
</table>

Figure 6. Cell structure of mobile networks

Terrestrial wireless broadcast systems (antenna TV) in most parts of Europe today are mostly digital and based on DVB standards (the same as for cable and satellite). These systems are comparable to mobile networks, but simpler, since no return channel has to be implemented.

### 2.3.2 Terrestrial wired (wireline)

Compared to wireless technologies, all terrestrial wired systems have significantly more physical infrastructure. Wired technologies all rely on a direct wire to the end user (typically inside a house). This also drives the majority of the roll-out effort and cost (labor drives around 70% of FTTH cost, see Figure 7), despite new means of deployment and infrastructure sharing.

![Typical FTTH Cost Split](image)

Figure 7. Typical FTTH cost split

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Figure 8. Overview wired technologies

**Phone line/copper (POTS) and DSL**

Traditional telephony is based on a copper-cable network. These copper cables in the past were used for analog voice traffic, and traditional analog modems could modulate data on those voice frequencies (i.e., dial-up Internet). This technology allowed for less than 70 Kbit/s (narrowband).

DSL (Digital Subscriber Line) uses the same copper cable but different frequency bands (outside the band used for voice) to transmit more data over the same cable (local loop, i.e., the cable to the local telephone exchange). In the local exchange, the DSL connection terminates at a DSLAM (Digital Subscriber Line Access Multiplexer), which aggregates all data streams to hand them off to the backbone network (normally a fiber network).

With all copper-based technologies (xDSL), data rates deteriorate with increasing loop lengths. Figure 9 shows typically achievable data rates, depending on the distance from the exchange (i.e., fiber node). As can be seen, with distances of more than 2 km from the nearest fiber node, only limited broadband connectivity is possible. Only the newest technology (VDSL) on loop lengths shorter than 1 km allows for fast broadband (i.e., 30+ Mbit/s). In most regions and geographies, this will require a fiber-to-the-curb (FTTC) rollout.

**Cable/HFC**

Cable networks replace the “last mile” (local loop) with the coaxial networks, used for analogue cable TV in the past. Due to the better electrical properties of coax cables, these networks suffer significantly less data-rate decrease with loop length. Furthermore, a larger frequency band can be used to achieve higher bandwidth. Combining these two effects, HFC (hybrid fiber coax) networks leveraging the newest standard (DOCSIS 3.0) can achieve more than 100 Mbit/s (with a theoretical maximum of 400 Mbit/s) per user. Due to the architecture, HFC acts like shared medium, i.e., in practical scenarios, the achievable bandwidth will be lower.
In addition to data access, HFC networks can be used for broadcast of analogue and digital TV channels (depending on the bandwidth split between data and television, several hundred channels are possible).

Fiber-to-the-home (FTTH)

FTTH uses a fiber network that extends into the premises of the end user. Even with simple technology, this allows bandwidths of 100 Mbit/s and more, without degradation due to loop length increases. In contrast to DSL and HFC, though, no reuse of existing technology is possible. Therefore, significant civil works are required for a FTTH roll-out, increasing the cost especially in rural areas. Depending on the region and the required civil works (e.g., if duct sharing is possible), the cost of bringing FTTH to one home might be up to ten times the cost of HFC or DSL.

2.3.3 Open access and technology/service neutrality

Satellites permit open access— but in a different way than terrestrial technology

One complex topic when comparing inherently different technologies is open access, i.e., wholesale access to a technology by third parties. While this is rather well defined for wireline products (e.g., by BEREC (1)), it is more complex for wireless and especially satellite services. Based on the ladder of investment, we suggest a similar structure for satellite access. It is often stated (e.g., in (2 S. 155)) that satellite technology can only provide bitstream access due to the fact that all other forms of access would require using the spectrum of the operator. While this is

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Figure 10. Cost for infrastructure roll-out

Figure 11. Open access to satellites

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9 Based on (1 S. 11), adapted by Booz & Company
in theory not an issue, especially as bitstream access will become more important in the future (see (3 S. 23)), we also see opportunities for a higher degree of sharing.

One step higher than bitstream, we identified exclusive transponders with dedicated teleport services as a level of unbundling. In this case, the alternative provider would leverage the spectrum and transponders of the operator, while providing the radio communications with the satellite (and therefore with the customer) itself (via its own teleport facilities and exclusive access to the corresponding transponders). In comparison to the terrestrial model, this would be a type of MVNO (mobile virtual network operator).

In addition, a model is possible in which the alternative operator provides its own payload (or parts of a payload) including its own spectrum access. In this case, the alternative operator would only leverage the satellite bus—the only alignment needed is the orbital slot (in analogy to the terrestrial model, this would mean agreeing on the area of operation for a fiber roll-out or MVNO model).

2.4 Summary: role of satellites in the communications ecosystem

Compared to other communications technologies, satellite communications offers distinct and unique capacities.

Broadcast and multicast services are most efficient with satellite communications
Satellites make possible a high spectrum and cost efficiency for broadcasting a large number of programs over a large region. Compared to terrestrial digital TV, satellite broadcast allows for a significantly higher number of channels and only requires a single satellite to cover large geographical areas, compared to a high number of antenna towers for terrestrial systems. Compared to wired solutions, satellites require fewer infrastructure components to distribute large amounts of data or media.

New technologies enable efficient high-bandwidth services in targeted areas
Spot-beam technologies in C, Ku and Ka bands make it possible to provide high data rate services in small, targeted areas. Compared to terrestrial technologies, the cost to add additional users is marginal and satellites can cover large areas with the services out of a single orbital position. Furthermore, the user experience is independent of location and local geography, i.e., even far away from a central office of a telecommunications company, the full service experience can be guaranteed (unlike DSL, where bandwidth degrades significantly with distance).

Satellites support multiple uses at once but are limited in their overall flexibility
Modern communications satellites can support multiple use cases at once, e.g., broadcasting of TV, multicasting of data and providing EGNOS data. But due to the given orbital position and frequency bands, the overall flexibility is limited. Especially the potential use of different spectrum is very limited—requiring long-term commitments of regulators to use of frequencies by satellite services.

Satellite technology allows for technology and service neutrality
Since satellites always need an operator, wholesale access is limited to the payload of the system. For these payloads, an open-access model is possible in different ways. The most simple and practical form is bitstream access, but hosted payload models (comparable to MVNOs in mobile networks) are possible—but require long lead times due to the three to four years of planning, construction and launch phases for satellites.
3. Use Cases of Satellites

Given the advantages and unique properties, but also constraints, of satellite technology, there are several major use cases for satellites, where satellites offer either significant advantages to other technologies (e.g., very efficient point-to-multipoint distribution), are more efficient than alternatives (e.g., connectivity in rural areas) or offer unique options (e.g., earth observation). These use cases are relevant for telecommunications operators, companies and governments with communications needs and consumers (see Figure 12 for an overview):

- **Media content distribution** includes the use of satellites to broadcast media content (audio and video) to consumers and the exchange of this content between media companies (e.g., a video feed from the Olympic Games to the broadcaster for editing). Furthermore, hybrid scenarios for content distribution are part of these use cases, e.g., connected devices or hybrid triple play (media content distribution via satellite with broadband based on terrestrial technologies).

- **Broadband access for all** encompasses three use cases. Basic broadband everywhere describes provisioning of satellite-based broadband, including hybrid scenarios (i.e., media content from satellites but on separate bands, comparable to cable TV). Special uses (fast) broadband includes scenarios in which terrestrial broadband solutions are not possible (e.g., aerial application or remote areas) and fast broadband is delivered via new satellite technologies. Hybrid broadband is the combination of satellite-based broadband with other, terrestrial broadband technologies (e.g., mobile networks), in order to achieve higher coverage with optimum speed and high efficiency (e.g., via offloading traffic to satellites).

- **Remote data connectivity and backhaul** describes scenarios that allow companies to access data networks (VSAT, corporate networks). Furthermore, backhauling and multicasting for telecommunications companies and Internet service providers is an important use case.

- **Telemetry and M2M**: Within this group of use cases, the application of satellite communications for machine-based communications is covered. This includes machine-to-machine (allowing devices to communi-
cate with each other and systems in the network) including the future Internet of Things, telemetry applications like supervisory control and data acquisition (SCADA) that allow remote monitoring and control of infrastructure, and Intelligent Transportation Systems (ITS).

- **Public protection and disaster relief** includes all uses of satellites for safety and security services (e.g., protection of citizens or infrastructure) as well as emergency communications (i.e., crisis response and humanitarian relief).

- **Earth observation** mainly describes remote sensing and landscape imaging, including the special use case of weather observation.

- **Navigation and positioning** naturally deals with navigation uses (from classical in-car navigation to more complex aerial navigation with 4D trajectory management), as well as fleet management and tracking (e.g., of containers or shipments) and in addition, timing data/timing synchronization.

In the following, these major use case groups will be described in more detail.

### 3.1 Media content distribution

For more than twenty years, satellites have been used in the media industry to gather content, exchange and distribute it between media companies and broadcast it to the public. In Europe, direct-to-home satellite broadcasting is used by around a third of households, making it one of the most important technologies for informing and entertaining citizens. In addition, 96% of European cable networks rely on satellites for content provisioning (4).

With the continued growth of TV consumption, the trends toward non-linear viewing and connected devices and increasing consumption of media on mobile devices, satellites will continue to play a major role in broadcasting and multicasting content—and even become more important with increasing bandwidth requirements of ultra-high-definition programs requiring cost and spectrum efficient distribution.

![End-to-end Media Network](http://www.cisco.com/en/US/netsol/ns987/networking_solutions_solution_category.html#~architecture)

**Figure 13. End-to-end media network**

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10 Source: Cisco

3.1.1 Satellites enable fast and global news gathering

As already mentioned earlier (see Figure 13), the role of satellites for media starts with production. One of the key features of television today is a broad live or near-live coverage of events around the world, from major sport events (e.g., the Olympic Games) to political and social events (e.g., elections) to wars and natural disasters (e.g., the earthquake in Haiti). One of the key enablers for this development in television is digital satellite news gathering (DSNG or SNG), as a form of electronic news gathering.

Different satellite solutions enable news gathering for a broad range of events

Satellite news gathering enables journalists around the world to create TV reports and transport them via satellite to post-production or broadcast (the same system can of course also be used for radio or newspaper reports). This ranges from single journalists with video cameras in war zones to full production crews in a satellite truck. Depending on the available time for planning as well as the local conditions, a variety of solutions can be employed for SNG:

- Mobile satellite solutions in the L band: these systems allow for very small terminal sizes (around the size of a PC laptop, see Figure 50 for an example of an Inmarsat’s BGAN and Mini-M devices), providing basic broadband (around 0.5 Mbit/s) access globally. These are for example used for first reports from disaster locations or in war zones, normally providing audio and basic picture/video reports (video phone).

- Flyaway\(^{11}\) or van-based systems, normally in the K\(_u\) band and increasingly also in K\(_b\) band: these systems use antenna dishes with up to 1.5-m diameters, allowing for enough bandwidth for the transmission of professional audio and video (see left side of Figure 14 for examples). These systems are often used to broadcast from a sports or social event.

- Larger production trucks, in K\(_u\), K\(_b\) or C bands: these systems can also use C band (outside Europe), to take advantage of more available capacity (as K\(_u\) is often limited) with larger dishes (see right side of Figure 14 for examples). These solutions are also used to provide coverage from larger events, with multiple streams, cameras in high definition or even 3D programs, leveraging a significantly larger team on the ground (i.e., it is practically a mobile TV Studio).

Technically comparable to SNG are also fixed contribution connections between media producers, studios, broadcasters and play-out centers, where satellite links are used to transport the program from one location to the other.

Satellite-based news gathering enables independence and mobility of journalists

Satellite news gathering has several advantages compared to the use of physical media or terrestrial connections:

- Easy to overcome first mile. Terrestrial high-bandwidth solutions are not (reliably) available at every location. Especially in rural areas, a reliable high-band connection for live video is difficult to find. In addition, satellites deliver a predictable performance.

- Global coverage for news reports. From dense urban America to remote Africa, the same technology can be used. Furthermore, a single satellite link can cover huge distances from recording to the studio, where otherwise several operators and technologies would have to be used to guarantee an end-to-end connection.

- Independence of terrestrial infrastructure allows reports from conflict situations without censorship.

- Usable in emergency scenarios due to speed and size. Small systems in the L band can be set up within minutes to provide live coverage, e.g., in case of a natural disaster.

- Works well within the media ecosystem, e.g., uses the same standards as broadcasting.

\(^{11}\) Flyaway describes a small system to be stored and easily transported in boxes, e.g., on a flight or small truck. It has minimal size and weight but provides basically the same functionality as a van-based system. Compared to fully mobile solutions it is significantly heavier and takes more time to transport and set up.
3.1.2 TV Broadcasting is highly efficient with satellites

TV consumption is constantly growing
In recent years, media consumption has grown constantly. In 1994 the average daily TV viewing time in Europe was 3 h 8 min. By 2001 it had increased to 3 h 23 min and by 2011 to 3 h 48 min—a 40-minute increase in seventeen years, equal to more than 1% per year (5). In parallel, multitasking behavior increased, especially among teenagers and young adults, leading to a disproportionate consumption of media compared to the time invested. American teenagers today are able to consume 10 h 45 min of media each day this way, while only investing a bit more than 7 h 30 min (6).

Around a third of households in Europe receive TV via satellite
Within the European Union, television access is nearly universal—98% of households have access to a television (7). Aerial reception is used by more than half of households (DTT and with an aerial), cable (analog and digital) by around a third. Satellites are used by around 25% to 30% of households to receive TV, though with a broad range from almost 50% to close to 0% in different regions. The use of different broadcasting platforms by which TV is received in households has also been stable over recent years.

---

Trends in TV consumption: non-linear viewing and high definition

Two major trends are now influencing TV consumption significantly: non-linear viewing/OTT offers and HD/Ultra-HD channels.

**Non-linear viewing share increases but absolute linear consumption remains almost constant**

With the increasing availability of online video content (e.g., on YouTube, Hulu and various broadcaster websites), non-linear TV consumption also increases. Today, around 90% of TV content is still watched linearly and live, up to 95% including “near-live” (8 S. 21), which equals more than 200 minutes per day. Non-linear TV con-

---

13 Source: OECD Communications Outlook 2011 (72) and EC’s indicators on the electronic communications market (66)
Consumption today is primarily used to catch up on content (e.g., missed episodes of TV shows), and to a lesser extent to watch different content.

### Figure 17. Definitions of linear and non-linear TV

For the coming years, a stronger shift toward non-linear consumption is widely expected (9). For example, in Germany, linear consumption on the TV is expected to decrease to around 70% in 2015 from 90% in 2010. Given the increase of overall media consumption and the shift to different screens (e.g., tablets), the absolute linear TV consumption will still remain almost constant, with around 210 minutes in 2010 and more than 200 minutes in 2015 (see Figure 18). On the other hand, the non-linear consumption is expected to increase from a mere 22 minutes per day in 2010 to more than 1 hour in 2015.

Despite the increase of online alternatives and a long tail of programs, it is reasonable to assume the majority of non-linear consumption will be used for **schedule shifting**, i.e., catching up with popular content as a form of “re-run” TV only hours or days after the original broadcast.\(^\text{15}\)

---

\(^\text{14}\) Based on the Booz & Company report: 2015: A Video Space Odyssey – Value Shifts in the TV and Video Ecosystem (9)

\(^\text{15}\) For a detailed discussion of why schedule shifting will be the most common use of non-linear consumption, see Deloitte’s TMT Predictions 2012 (8 S. 21ff). This can also be illustrated, e.g., by the huge success of the BBC iPlayer or Hulu, where the content consists almost exclusively of TV show re-runs.
In combination with the ubiquity of mobile devices (see also chapter 3.2), the concept of the catch-up commuter will become increasingly popular. It describes the behavior of watching time-shifted TV content (mainly TV shows) on demand during commute, in order to be up-to-date for the discussion with colleagues and friends.

HD and Ultra-HD TV significantly increase the required bandwidth for TV distribution

Today, the majority of TV channels in Europe are available in standard definition (SDTV), meaning a resolution comparable to old analog TV. In the last years, more and more channels are available in high-definition television (HDTV), providing a resolution of up to five times that of SDTV and therefore significantly improving picture quality. Today, still fewer than 10% of TV channels are available in HD, but with strong growth over the last years that is expected to continue.

In parallel, the next evolution of TV program resolution is Ultra-HD (UHDTV), which will again increase the number of pixels by a factor of four (called 2K, with a potential of up to 16 times the resolution of HD in further expansion stage called 8K). Ultra-HD is expected to be launched commercially in 2015, while equipment suppliers and media producers are already Ultra-HD ready today (e.g., today’s cinema productions already use 2K, 4K or even higher resolutions).

The increase of resolution significantly improves the viewing experience for consumers on large screens, but also increases the required bandwidth of networks to transport the media content. While a SD channel in traditional encoding (MPEG-2 as used by DVB-S) requires around 4 Mbit/s, a HD channel in MPEG-4 encoding (as used by DVB-S2) requires around 10 Mbit/s. A future Ultra-HD channel would require around 40 Mbit/s in the same compression; assuming the use of improved compressions algorithms in the future (e.g., h.265), the required bandwidth per channel will still be around 20 Mbit/s.

**Table 1: Bandwidth Requirement of TV Standards**

<table>
<thead>
<tr>
<th>Resolution</th>
<th>MPEG-2</th>
<th>MPEG-4</th>
<th>HEVC 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SD</td>
<td>ca. 4 Mbit/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HD</td>
<td>ca. 19 Mbit/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UHD</td>
<td>ca. 80 Mbit/s</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) HEVC: High Efficiency Video Coding

**Table 2: Resolution of TV Formats**

<table>
<thead>
<tr>
<th>Resolution</th>
<th>UHD 8k 7680 x 4320</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD</td>
<td>UHD 4k 3840 x 2160</td>
</tr>
<tr>
<td>SD</td>
<td>HDTV 720p</td>
</tr>
</tbody>
</table>

16 Source: SES based on Satellite Communications and Broadcasting Market Survey, EuroConsult 2012

17 Source: SES
Summary: the bandwidth and capacity requirements double within five years – two-thirds remain broadcast

In total, the trends towards non-linear consumption and Ultra-HD will lead to an overall increase in required bandwidth for TV consumption. Assuming a shift toward high bandwidth based on the predicted consumption change, the required capacity for linear TV will grow by 9% per year, for non-linear consumption by almost 50% per year. Overall this will lead to a doubling of the required capacity within five years, where two-thirds will be linear TV consumption, which can be broadcasted.

Figure 21. TV consumption capacity development

Satellite broadcasting is the most efficient technology to distribute linear TV in a large region

Linear TV is most efficient to distribute with a shared point-to-multi-point medium, i.e., a dedicated broadcast technology. At the moments these are largely satellite, DTT (both wireless) and cable (HFC) networks. Fiber-based networks and DSL are designed to provide point-to-point connectivity and only allow broadcasting to a certain extent while sharing bandwidth with the data network.

As already detailed in Figure 5, broadcasting technologies have low costs to add new users, mainly requiring customer-premises equipment to receive and decode the program (in case of cable/HFC, the cost also depends on the availability of the cable infrastructure in the premises). In addition to these low costs, broadcasting technologies use spectrum highly efficiently compared to traditional unicast wireless technologies when it comes to delivering the data stream, leading to an overall very high scalability (see Figure 22 and Figure 23).

Figure 22. Efficiency of satellites vs. other wireless technologies for broadcasting18

<table>
<thead>
<tr>
<th>3G (CDMA 2000)</th>
<th>Max 2.5</th>
<th>0.0025</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTE</td>
<td>Max 16.32</td>
<td>0.01632</td>
</tr>
<tr>
<td>Satellite Communications (Ku band, DVB-S2 QPSK)</td>
<td>1.63</td>
<td>1.63</td>
</tr>
</tbody>
</table>

18 Source: SES Corporate Development
In order to understand the preferable use of broadcasting technologies, a few key aspects are important to understand:

- The linear part of programming is inherently a point-to-multi-point communication (i.e., broadcast to all consumers of the program), and will also in the future represent the majority of consumed content (especially in high quality like Ultra-HD).

Viewership distribution per channel suggests that, at least for the top channels, broadcasting is more efficient than uncasting the linear program to the individual consumers (see Figure 24).

- The time-shift of a program for a few minutes can be achieved by the TV or set-top box (as already today implemented in many cable and satellite receivers).

- Catch-up with popular content can be efficiently enabled with Push-VOD solutions, where the local devices proactively (i.e., without user intervention) record popular content and keep it available for on-demand consumption.
Satellites are and will be a key technology for media broadcast
Satellites are a prime technology to distribute linear (or near-linear) TV programming efficiently in form of a broadcast to all users.

- IP-unicast-based technologies (DSL, Fiber) today are not well equipped for large-scale linear TV content distribution—the technology and protocols don’t support efficient point-to-multi-point communications, and limited bandwidth (especially with DSL) does not allow TV consumption of multiple channels with parallel Internet activity.

- HD and Ultra-HD channels can only be distributed in high-bandwidth technologies (i.e., fast broadband), which at the moment are fiber and satellite, and to some extent cable (HFC).

- Based on the predicted bandwidth consumption for media (see Figure 21), using satellites for broadcasting can significantly reduce the required bandwidth. New technologies (see next section) also allow a simple integration with broadband technologies to enable connected devices.

3.1.3 Distribution—connected devices and hybrid triple play

Consumers more and more consume media on several screens, connected devices and mobile
As already briefly mentioned in the last section, consumer behavior for media consumption is changing, especially in three aspects: (1) consumers are watching more video across all screens (as already detailed, see Figure 18), (2) consumers adopt more video-enabled connected devices (TVs, game consoles) and (3) consumption of video is changing (e.g., consumption on tablets and multi-tasking).

Figure 24. Broadcast vs. unicast efficiency

Figure 25. Consumer behavior trends in video consumption
Satellite broadcast can be combined with broadband for hybrid triple plays, enabling connected TVs

Connected TVs or Hybrid TVs are an emerging trend for television at home. An increasing number of TV sets (as well as set-top boxes and media players) integrate Internet and Web 2.0 with traditional broadcast TV to enhance the user experience and provide more features. Connected TV services are currently starting in Europe, with a growing number of devices being sold, though only about 20% connected to the Internet so far (10).

In addition to connected TVs, home gateways are an emerging technology, combining broadband Internet, broadcast and other data/media for joint access by all devices of a consumer (see also Figure 13; this role today is partly also fulfilled by Hybrid Broadcast Broadcast TV (HbbTV), which aggregate different IP streams into one media experience). These gateways provide an integrated data/media stream for the TV or media player. This trend is mainly fuelled by the emergence of tablet PCs, smartphones and other connected devices (e.g., ebook readers), where every device needs access to the Internet and is often used to access media or watch TV.

Emerging new technologies now make it possible to combine broadcasting efficiently with other data connectivity in the home gateways. To enable this, small gateways are implemented, which encode the received TV program into IP data streams19 that can be integrated into a home network (e.g., NAGRA (11) and SES (12) announced these devices in recent months). There are intentions to create a Sat-IP industry standard based on the first implementations, and the first devices to fully implement Sat-IP will be available in 2012.

Figure 26. Multi-screen consumption

Satellite broadcast can be combined with broadband for hybrid triple plays, enabling connected TVs

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19 Technically, the DVB-S2 layer of the received data stream is removed and the underlying media stream is transparently packaged in IP without any transcoding (60)
These new technologies make it possible to combine the broadcasting advantages and value proposition of satellites (see previous chapter) with broadband technologies to leverage the best of both worlds.

Mobile network traffic explodes—satellites can reduce the need for media distribution and backhauling

In addition to at home, connected devices are also in use in mobile scenarios. Especially smartphones and tablets are often used on the go, also to consume media. Mobile data traffic is increasing exponentially at the moment (see Figure 28), and tablet use with video is a main driver of bandwidth consumption: European mobile users at the moment consume around 1 GB per month with video (13), with power users consuming up to 4 GB per month (equal to several hours per month). For 2016, Cisco predicts that 70% of mobile traffic will be video content (14).

![Global Total Traffic in Mobile Networks 2007-2012](image1.png)

**Figure 28. Global total traffic in mobile networks 2007–2017**

In mobile scenarios, hybrid solutions can also provide the video streams in a point-to-multi-point setup, creating local satellite downlinks to limit wide-area backhauling of video content:

- LTE base stations are normally designed with a 50–300 Mbit/s backhauling capacity (microwave based; with fiber up to several GBit/s possible, but limited today to urban scenarios). Broadcast video streams could be transported via satellite to the local distribution nodes (via DVB-SH or traditional satellite broadcast technology) and also be stored for VOD distribution on the last mile.

- In addition, DVB-SH can be used to distribute media content directly to a mobile device.

DVB-SH is a video distribution standard based on satellite for mobile devices. The standard relies on mobile satellite service frequencies, close to UMTS and LTE mobile frequencies; this makes it possible to rather simply adapt a mobile device to also receive DVB-SH in order to receive media broadcasts. DVB-SH roll-outs can be significantly simpler than tradi-
tional DVB-H roll-outs, since no countrywide terrestrial wireless broadcasting technology is needed, but instead the service can be provided by a single GEO satellite with European coverage. In concrete implementations, hybrid scenarios are possible, where the satellite can provide up to 18 channels (with a 30 MHz S-band spectrum) in the whole region, and terrestrial technology (relays plus additional backhaul in cities) can provide further channels, e.g., in urban areas for local program.

Summary
New technologies make it possible to leverage satellite broadcasting to be seamlessly integrated in connected-device and hybrid-triple-play scenarios. In fixed use, satellite-to-IP conversion allows connected and hybrid TVs to use the most efficiently distributed broadcasting data stream and combine it with alternative data sources. In mobile scenarios, satellite broadcast can be used by the terrestrial wireless infrastructure to reduce backhauling requirements. In addition, mobile devices could directly receive media content from satellites via DVB-SH.

3.1.4 Summary: combining satellites with terrestrial technology enables modern media consumption

Satellite broadcast is the most efficient technology for media distribution
For the foreseeable future, satellite will be a major mode of TV distribution in Europe, and also difficult to replace given bandwidth requirements. Satellite offloading will be a major bandwidth saver going forward:

- A fiber roll-out to whole countries, including rural and remote areas, is not economically feasible for TV distribution (see also chapter 4.3).
- A wider HFC roll-out is possible but limited to sub-urban and dense rural areas but not economically feasible in rural and remote regions.
- DTT and DSL do not support the bandwidth requirements for several channels in HD or Ultra-HD.
- Traditional mobile technologies do not allow efficient point-to-multipoint distribution.

In addition, satellites also offer an efficient method to provide linear TV content to regional cable/HFC and IPTV providers, without expensive backbone infrastructure for TV content distribution.

The integration of terrestrial technologies with satellite communications enables hybrid, efficient networks
To enable interactive programs and integration of social networks and apps, hybrid solutions will have to be developed further, e.g., linear content via satellite, interactive parts via DSL with an aggregation in the STB

- Switching to all IP technology will simplify the process. The first Satellite -> IP converters exist and will enable an end-to-end IP experience.
- With intelligent STBs, linear content can also be cached for non-linear consumption (proactive PVR functionality)—this further optimizes network utilization and therefore build-out cost.

These future hybrid networks will be able to leverage satellites for media content, which can be injected into the ecosystem at multiple points (see Figure 30). These multiple injection points make it possible to bring content closer to the network edges, therefore reducing the need for expensive, high-bandwidth backhauling. This will lead to an overall efficiency increase and cost reduction.

Figure 30. Broadcast injunction points in communications infrastructure
3.2 Broadband access for all

In today’s Europe, access to the Internet is recognized as key to the further development of society and business. Providing broadband services to all citizens is one of the major goals in Europe’s agenda (15), and the public values access to information everywhere and anytime, which is also a reason why Europe will significantly invest in the further roll-out of broadband technology (16). While a majority of citizens today accesses the Internet with terrestrial technologies, satellites can support the faster roll-out of broadband and enable use cases otherwise not possible.

Satellites have a threefold value proposition for broadband

Satellites have several capabilities that enable broadband access for all in different use cases:

- Satellites today could provide broadband access to all European households. Especially in rural and remote areas, satellite is already today an option to get basic broadband service (up to 4 Mbit/s).
- New technologies (Ku-band satellite), deliver faster-than-DSL broadband (up to 18 Mbit/s) for consumers and fast broadband (up to 40 Mbit/s) for corporate customers. Future MEO constellations (like those planned by O3b networks) will provide even lower-latency, high-bandwidth broadband data access options.
- In addition, satellites can provide high bandwidth content in a hybrid network scenario. For example, DSL or mobile technologies can provide low-latency services with limited bandwidth requirements (e.g., e-mail, web surfing), and satellites can deliver high bandwidth services like video streams.

3.2.1 Satellites today can provide broadband to all households

All European citizens should have access to broadband by 2013

The European Digital Agenda (15) foresees broadband coverage (DSL or cable) for all by 2013 and fast broadband (>30 Mbit/s, e.g., with VDSL, FTTH or Cable Docsis 3.0) for all by 2020. While there was strong improvement in broadband connectivity across the European Union in recent years (Figure 31), there is still a significant spread between countries and regions. Especially in eastern and southern countries, the household broadband penetration is very low, e.g., in Romania 31%, Greece 45%, Italy 52% (see Figure 32).

![Figure 31. Broadband connectivity in Europe](image)

Figure 31. Broadband connectivity in Europe

22 Source: (70)
This spread in connectivity is also driven by the availability of broadband. The fixed broadband coverage in Europe (Figure 33) shows the limited availability of fixed broadband access, especially in rural areas, for these countries. In addition to the regional spread, the statistics also shows that in highly connected countries like Sweden, Finland or Germany more than 10% of the population has no access to broadband Internet due to missing coverage. Across the EU-27, more than 15% of citizens in rural areas and around 5% of the overall population has no fixed broadband coverage.

Satellites can support the vision of broadband for all — new technologies also enable fast broadband
Given the ubiquitous coverage of satellites and the current availability of satellite based broadband Internet access, satellite communications can immediately bridge the broadband coverage gap, even in remote regions, where other wireless technologies on their own cannot be used. Not only do satellite communications provide full reach, they also provide broadband speeds comparable to terrestrial connections. Due to innovative encodings and new satellite architecture, broadband connectivity with up to 30 Mbit/s is now available.
Satellites have several key advantages for providing broadband (17):

- Ubiquitous coverage, enabling service to all citizens
- Quick deployment of satellite terminals, enabling a fast roll-out without civil works
- Resulting cost efficiency for rural, remote and low population areas
- Always-on service
- Very low marginal cost to add a new user to the service (in the backbone) and limited cost for the user (antenna and receiver together are slightly more expensive than cable or DSL modems)

**Satellite TV and broadband complement each other and enable a NGN service experience**

In addition to the previously mentioned advantages for broadband access via satellite, it is also important to consider triple play. Since a user of (fixed) satellite broadband will require a satellite dish, the same antenna can optimally also be used for satellite broadcast reception. The combination of broadcast and broadband enables a double play (TV and Internet) service without the need to transport broadcast media content over IP. Therefore, the user can consume broadcast media while the full broadband bandwidth is still available for Internet.

This is a significant improvement over DSL solutions, where the media content needs to be transported over the broadband connection (IPTV) and reduces the available bandwidth for other services. Even considering a good DSL connection with 25 Mbit/s, the parallel consumption of 2 HD channels (10 Mbit/s each) will only allow for 5 Mbit/s for Internet.

Leveraging new Sat-IP technology (see chapter 3.1.3) also enables an on-premise combination of the satellite broadcast and the satellite broadband into one unified service experience. Considering this, a standard satellite broadband will enable a next-generation service experience with multiple HD and Ultra-HD channels and parallel Internet access.

**For example, NBN in Australia relies on satellites for broadband access in rural and remote areas**

The Australian National Broadband Network (NBN) is Australia’s first national wholesale-only, open-access communications network that is being built to bring high speed broadband and telephone services within the reach of all Australian premises.

NBN is currently in the development and roll-out phase and will leverage all communications technologies to achieve its goals. NBN mainly relies on fiber (FTTH) to deliver broadband services. But in order to reach the 100% coverage goal, satellite communications will be used to reach rural and remote areas, where other technologies are currently not available or feasible (i.e., too costly) to roll out.
At the moment, NBN’s interim satellite service uses existing satellite capacity from commercial operators (with up to 6 Mbit/s). NBN plans to launch two K-band satellites in 2015; these satellites will deliver 12 Mbit/s to premises outside the fiber and wireless footprint (18). Up to now, the service has received positive feedback and take-up of Internet services has increased.

As this example shows, satellites can be an integral part of the ecosystem to deliver countrywide broadband service. Developing economies are actively driving the implementation of data networks, to a big extent also leveraging satellite communications. For example, the Liberian Telecommunications Authority announced the West Africa Regional Communications Infrastructure Program (WARCIP) in September 2011 (19).

**Emerging markets leverage satellite broadband for Internet access, e-health and distance learning**

In emerging and developing markets with limited terrestrial Internet access, satellites are a key technology for broadband service. For example, Liberia leverages several satellite systems to provide narrow- and broadband access to consumers. Egypt developed a satellite-based distance-learning environment, enabling students to interact with lectures at comparably low cost. In India, e-health systems for the transmission of digital images (like X-ray, computer tomography and MRI) are in use. These systems allow global experts to receive the images, interpret and diagnose and provide instant feedback to the local doctors. E-health breaks down geographical barriers and helps to achieve an accurate diagnosis in a short time, ensuring quality care for the patients.

### 3.2.2 Satellites can support special broadband use cases like aerial and maritime

There are several use cases where other technologies offer no reasonable solution for connectivity. Examples are in oceans and remote areas (e.g., mountains or deserts where terrestrial technologies are too cost-intensive, as well as offshore platforms) or aerial solutions in high altitudes or over oceans.

**For example, demand for aerial Internet is growing and satellites are the key technology to provide service**

Today, only around 5–10% of commercial and business aircraft use aviation broadband, i.e., provide Internet access while in travel. In 2010, only around 2,000 aviation broadband units were installed globally, with 40% of them based on WiFi or mobile networks (limiting usability to densely populated regions and low altitudes), the rest mainly using L-band satellite connectivity.

With consumers globally getting used to “always-on,” the demand for in-flight connectivity is rising constantly. Especially business travelers want to continue working on flights, which today often requires connectivity to process e-mail or look up data. But leisure travelers on long-haul flights also appreciate connectivity to browse the Internet or download the latest novel on their e-book reader.

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24 Based on (19)

25 Note: In addition to commercial airlines, the military is increasingly using aviation broadband. The main purpose is the connectivity to ISRs (airborne intelligence, surveillance, and reconnaissance platforms) and the control of unmanned aerial vehicle (UAV/drones), as well as high bandwidth connectivity for larger jets (e.g., transporter, tankers, bombers). Civil UAVs have also become increasingly available and use similar technology.
Given this demand, by 2020 the adoption rate for aviation broadband will increase to more than 50% for commercial twin-aisle (i.e., large long-haul) jets and around 30% for single-aisle (short-haul) and business jets (see Figure 35). This will lead to more than 17,000 aviation broadband units in use by 2020, whereas more than two-thirds will rely on satellites (L, Ku and Ka bands). With the growing demand for higher bandwidth, around 20% of these units are expected to use Ka-band satellites, providing fast broadband access.

Satellites are the only technology that can provide aerial broadband, given the global coverage, reliability and simplicity and high achievable data rates (see Figure 36). Existing L-band systems provide high coverage with very high reliability (the same systems are also used for distress signals), while newer Ku- and Ka-band solutions allow for higher bandwidth but require more complex technology onboard the aircraft (making them more practical for commercial large jets than business or military jets).

![Estimated Global Aviation Broadband by Solution Type](image1)

![Evaluation of Aviation Broadband Solutions](image2)

Figure 35. Aviation broadband market evolution

Figure 36. Evaluation of aviation broadband solutions
Satellites can also provide fast broadband access to remote areas
The same technology used for aircraft can of course also be used in other remote areas. Possibilities range from maritime applications on ships26 to connectivity for oilfield engineers in a desert or on an offshore platform (this use case is often called “digital oilfield”).27 Given recent development in technology, this area connectivity is now starting to overlap with the VSAT connectivity employed by companies (see chapter 3.3).

3.2.3 Hybrid satellite broadband enables efficient traffic offloading
In addition to providing broadband services to rural areas directly with satellites, hybrid network architectures are possible to augment existing fixed networks and technologies.

Telecom operators face increasing demand for bandwidth but have limited resources for FTTH
With consumers and business converting to a digital lifestyle, telecom operators today face exponentially increasing data traffic and accompanying demand for bandwidth. A few years ago, downloading a music album from the Internet was a rare activity, and consumers were willing to wait a few minutes with simple broadband connectivity. Today, downloading a movie in DVD-quality is a simple activity, and users are not willing to wait for hours to finish the download. Looking at typical download times (Figure 37), users today will not be satisfied with less than 10 Mbit/s connections, with 30 Mbit/s (fast broadband) becoming increasingly important.

![Typical Download Times Based in Relation to Available Bandwidth](image)

<table>
<thead>
<tr>
<th>How Long Does It Take to Download</th>
<th>Size MB</th>
<th>1 mbps</th>
<th>10 mbps</th>
<th>30 mbps</th>
<th>100 mbps</th>
<th>1 gbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>... a graphical website</td>
<td>0.5</td>
<td>4 sec</td>
<td>&lt; 1 sec</td>
<td>&lt; 1 sec</td>
<td>&lt; 1 sec</td>
<td>&lt; 1 sec</td>
</tr>
<tr>
<td>... a music track</td>
<td>5</td>
<td>40 sec</td>
<td>4 sec</td>
<td>1 sec</td>
<td>&lt; 1 sec</td>
<td>&lt; 1 sec</td>
</tr>
<tr>
<td>... a music album</td>
<td>100</td>
<td>13 min</td>
<td>1 min</td>
<td>27 sec</td>
<td>8 sec</td>
<td>&lt; 1 sec</td>
</tr>
<tr>
<td>... 3D CT scan image</td>
<td>500</td>
<td>1 hour</td>
<td>7 min</td>
<td>2 min</td>
<td>40 sec</td>
<td>4 sec</td>
</tr>
<tr>
<td>... 250 photos from family vacation</td>
<td>2,000</td>
<td>4.5 hours</td>
<td>27 min</td>
<td>9 min</td>
<td>2.5 min</td>
<td>16 sec</td>
</tr>
<tr>
<td>... a DVD movie</td>
<td>4,500</td>
<td>10 hours</td>
<td>1 hour</td>
<td>20 min</td>
<td>6 min</td>
<td>36 sec</td>
</tr>
<tr>
<td>1 hour of HD video from John’s birthday</td>
<td>12,000</td>
<td>27 hours</td>
<td>2.5 hours</td>
<td>53 min</td>
<td>16 min</td>
<td>1.5 min</td>
</tr>
<tr>
<td>... the latest HD movie blockbuster</td>
<td>25,000</td>
<td>2.5 days</td>
<td>4.5 hours</td>
<td>1.5 hours</td>
<td>27 min</td>
<td>3 min</td>
</tr>
<tr>
<td>... a full online file back-up</td>
<td>150,000</td>
<td>14 days</td>
<td>1.5 days</td>
<td>11 hours</td>
<td>3.5 hours</td>
<td>20 min</td>
</tr>
</tbody>
</table>

X Inacceptable by current standards

Figure 37. Bandwidth requirements for typical user behavior

Global IP traffic is expected to grow by approximately 29% per year from 2011 to 2016 (20), with consumer traffic growing slightly faster than business traffic. Especially consumer video traffic will be a major driver of traffic, with 24% growth per year, reaching more than 45,000 PB per month globally in 2016 (Figure 38).28 Note that

26 E.g., to enable the crew of a ship to use Internet or voice-over-IP services as also stipulated by the Maritime Labor Convention (65)
27 *Digital Oilfield* describes the possibility a drilling operation with very limited local staff. This requires a combination of broadband connectivity in remote areas, M2M and SCADA systems as well as hardware and software (51)
28 1 petabyte (PB) equals 1 million gigabytes (GB) or 1,000 terabytes (TB)
around two-thirds of the video traffic is some form of broadcast (live Internet TV), video-on-demand broadcast (i.e., time shift, e.g., Internet video to TV) or long enough to benefit from offloading to a broadcast technology.

![Global IP Traffic Forecast](image)

Figure 38. Global IP traffic forecast 2011–2016

For telecom operators, providing the high bandwidth demanded by this growth to all users will require significant upgrades of the network infrastructure. A roll-out with DSL will require at least VDSL technology with a local loop length of less than 1 km to achieve fast broadband (Figure 9), requiring a wide fiber rollout (FTTC). A pure fiber roll-out (FTTH) will be even more capital intensive as the cost per household increases significantly for suburban and rural areas (see Figure 10). In order to reduce or at least defer the required investment, operators increasingly adopt hybrid network concepts.

**Hybrid networks create one, cost-efficient user experience out of several broadband technologies**

Hybrid networks build on the idea of combining several technologies into one user experience, to achieve an overall higher efficiency in service delivery. As Figure 39 shows, a typical user traffic pattern has a few big-block items like movies and audio streaming, which require a steady but limited bandwidth, e.g., a few Mbit/s for several hours (orange area in the left chart). In addition, users surf the web, receive e-mails or use cloud applications, which all require high bandwidth (in order to provide a good user experience) but only for a few seconds or minutes (the blue spikes in the left chart). Looking at typically available technology, fixed solutions can provide steady low bandwidths (e.g., DSL with up to 10 Mbit/s in suburban areas, around 2–4 Mbit/s in rural areas), whereas mobile technology (HSPA, LTE) can provide higher bandwidth but only for a short time (since the medium is shared, efficiency and bandwidth can only be achieved if a high number of users use the data transmission for a short time).

---

29 Source: (20), chart by Booz & Company
Satellite based broadband can offload long-running data streams and leverage broadcast efficiency

As already described in chapter 3.1.3, satellite broadcast can be combined easily with other broadband technologies. The same is of course true for satellite broadband, which can also be combined with terrestrial broadband technologies. In the scenario of a (fixed) hybrid network, satellites can provide broadband access for rural areas in order to augment mobile networks (LTE, HSPA) and also ADSL to offload traffic.

From a user side, the service experience would be a normal fixed broadband connection with a local home gateway. The home gateway would then use two or three technologies to connect to the Internet, with an intelligent routing algorithm to determine the best path. For example, if the user wants to use VoIP, the router would use ADSL, providing low latency with enough bandwidth. In case the user starts watching an HD video channel, the data would be transported via satellite, since satellite broadband provides the required bandwidth. In this case, the backbone systems might even distribute the program via broadcast if enough users watch the same content (see also Figure 24 for a discussion of the most efficient way of distribution).

In the future, mobile hybrid networks linking terrestrial mobile networks and satellites will be possible

Amongst others, the International Telecommunication Union (ITU) is at the moment investigating potential solutions to combine terrestrial mobile networks with satellite systems. The idea is to use satellites as a coverage extension for mobile networks while also leveraging terrestrial components to communicate with the satellite (see Figure 40 for an illustration). In the depicted scenario, the satellite provides the service, while complementary ground components (CGC) act as a signal amplifier/repeater in areas with limited satellite signal reception (e.g., for indoor coverage in urban areas with high buildings). Given that future satellites and terrestrial networks will use compatible frequencies, mobile devices will be able to use both networks and services, e.g., the terrestrial network in areas with good coverage and the satellite-based service in rural regions. This interoperability is for example currently tested for WiMAX (17 S. 20).

---

**Figure 39.** Daily traffic patterns and technology strike zones

**Figure 40.** Hybrid mobile network architecture

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30 Source: (17)
3.2.4  **Summary: satellites can significantly improve the broadband ecosystem**

Satellite communications can significantly support Europe’s Digital Agenda as well as the digitization of emerging regions. Satellite broadband today is a viable technology for providing basic broadband access globally as well as fast broadband in first markets (where the first Ka-band satellite service is available). This enables citizens in areas without fixed or terrestrial wireless broadband coverage to participate in the digital economy today. In addition, satellite broadband can support use cases in remote areas and in maritime or aerial setting.

**Going forward, a mix of access technologies will be used to provide broadband to consumers**

With the emergence of hybrid networks, satellites will be one addition to the overall communications mix (Figure 41). Satellite technology allows a simple and cheap roll-out while also providing high data rates. This puts satellite broadband in a good position to provide the high-bandwidth portion of the typical IP traffic mix until fiber and other terrestrial technologies are rolled out further. Especially in the case that broadcast programs are watched by the broadband customer, satellite communications are in the perfect position to switch to broadcasting and integrating the media data stream on-premise into one overall product, providing a next-generation service experience.

![Emerging Access Technology Portfolio](image)

**Figure 41. Emerging access technology portfolio**

Based on (68), enhanced based on the newest satellite technology and hybrid network developments.
3.3 Backhaul and remote data connectivity

Backhauling and remote data connectivity are closely linked to broadband services, but focus more on business-to-business connectivity in the background than an end-customer-facing service. Telecommunications companies, Internet service providers and other companies today use satellite communications for several purposes (see also Figure 42):

- **Backhauling** of voice and data in mobile networks: connectivity of individual mobile network cells with the backbone network
- **Multicast content distribution** to the edge: satellites are highly efficient to multicast content to the edge of the network, e.g., to distributed content delivery networks (CDNs)
- **Point-to-point trunk interconnect** in the core network: e.g., for connectivity between continents or distant regions if fiber is not available or too expensive

Telecommunications companies use all of these services with different equipment and spectrum (e.g., C band for trunk interconnect). VSAT (very small aperture terminal) networks normally provide multicast and point-to-point connectivity for private and public companies. Technically, VSAT networks are closely related to the solutions used by telecommunications companies, but rely on additional spectrum (Ku, Ka band) to allow for smaller antenna sizes (but compromising on rain fade).

![Global Broadband Satellite Network Scenarios](image)

Figure 42. Backhauling and broadband overview

On important additional use case, which is a combination of broadband, data communications and M2M is maritime usage. Satellites provide the global, anytime availability for distress service required by maritime users, as well as the infrastructure for communications and vessel tracking (see also chapters 3.2 and 3.4).

---

32 Source: (17)
3.3.1 Telecommunications companies leverage satellites for interconnection

Satellites allow backhauling in mobile networks, enabling faster roll-out in underdeveloped areas

In mobile networks, the local cells (see Figure 6) need to be connected to the backbone network. This is done via backhauling connections, which can be any data transmission technology: fiber with high bandwidth (but only available in urban areas), microwave with a broad range of bandwidth (but limited in distance and requiring good line of sight) and DSL with medium bandwidth (for short distances to the nearest fiber node).

In addition to these traditional backhauling technologies, satellite communications can be used for backhauling, enabling medium to high bandwidth, unrestricted by distance or terrain. In addition, satellites can also speed up the roll-out and extension of mobile networks due to already available (instant) infrastructure and the limited need for civil works. Satellite technology helps to bridge the “last mile” problem of mobile networks, especially for cases where DSL is not sufficient (i.e., with HSPA or LTE networks).

These backhauling connections are normally based on C or Ka band, providing stable connectivity even in bad weather conditions. New technologies like MEO constellations in Ka band are currently in development and deployment, which will provide even higher bandwidth with low latency in the future.

Core network connections can be realized with satellite trunking

As shown in Figure 42, satellite communications can also be used to create point-to-point connections within the telecommunications core networks. The classic example for this is the satellite connection in telephony, where in the past oversea telephone calls were routed via satellite. While this is not done any more for transatlantic phone calls (today only 1% of oversea traffic is routed via satellite, the rest in submarine cables (21)), satellite communications still provide a fallback technology in case cables break. Especially in areas with limited submarine cable connections (e.g., in areas of Africa), satellites provide a more reliable connectivity to the rest of the world.

In addition to overseas connections, connectivity between very distant continental locations can be achieved with satellites. An example would be connectivity to Siberian cities, where connectivity with terrestrial technologies is extremely challenging (due to permafrost ground and large distances to the nearest communications hubs).

3.3.2 Satellites can multicast content globally for fast and efficient distribution

Satellites can efficiently multicast content to the network edges

As already detailed in chapter 3.1.3, DVB-SH can be used to distribute media content directly to mobile devices or to the mobile network infrastructure. In addition, mobile operators and Internet service providers can use satellite communications to multicast large data packages (e.g., the currently available video-on-demand program) to different sites in their coverage area to store them locally.

In these scenarios, satellite-broadcasting technology is used to send content to all sites, in order to limit the required terrestrial connectivity between sites, especially if there are large distances to be covered. Normally a receive-only setup is used in the distributed sites, i.e., as in broadcast, the receiver of the data only has a simple antenna setup to receive and decode the signal but does not have the capabilities to send out a signal. In order to implement a return path (e.g., to send a confirmation), the terrestrial backbone network is used (i.e., some type of hybrid network setup).

33 Another use case for satellites instead of submarine cables is military and intelligence communications. Cable-based communications can be intercepted more easily than a direct satellite link

34 Multicast builds on the same technology and principles as broadcast. The wording just describes the intent that only a limited group of users receive the data (versus a very large group for broadcast) in a point-to-multipoint communication
Examples for multicast by satellite are content delivery networks or digital cinema distribution

The idea behind content delivery networks (CDN) is bringing content closer to the edge of the network (i.e., closer to the consumer) in order to optimize the service experience. CDNs augment the Internet infrastructure with additional caching and load-balancing servers distributed around the globe (see Figure 43 for the working principle). Large providers of CDNs (e.g., Akamai) operate more than 100,000 servers in several thousand local networks. This federation of servers and content makes it possible to optimize traffic flows, improve response times and reduce the required bandwidth by the providers of the content.

One of the key challenges of CDNs is the fast and efficient global distribution of the content to the individual servers. For caching servers in well-connected areas fiber can be used, but for the distribution of large content in remote areas, often satellites are employed. The same principle of content distribution is also used by cinemas and movie distributors in the digital cinema. Here the need for and advantage of satellites is even greater, since most movie theaters do not have the necessary bandwidth to transfer several hundred gigabytes of movie data. Alternatively, hard drives are shipped to the cinema, which is more complex, suffers from more loss/theft and requires complex logistics.

![CDN Working Principle (Example Akamai)](image)

**Figure 43. CDN Working Principle**

### 3.3.3 Companies use VSAT for point-to-point remote data connectivity

The term very small aperture terminal (VSAT) refers to a satellite communications system with comparably small antenna sizes (depending on used frequency band, between around 45 cm to 3 m). VSAT connectivity is very close to that of satellite-based broadband systems, with the difference that it is dedicated to a single customer.

VSAT terminals can provide data-network access in areas with limited connectivity, especially also for data streams that require high reliability and security, e.g., financial applications (ATM or lottery terminal connectivity, e.g., Camelot in UK) or very broad coverage in different terrains (e.g., connectivity for gas stations, e.g., Agip in Hungary). Given the reliability, broad coverage and limited need for additional infrastructure or civil works, demand for VSAT service in Europe is expected to grow in the next years by around 15% annually to almost 200,000 sites in service (22). Especially in emerging markets, VSAT applications are widely used due to the limited availability of other data-connectivity technologies.

**Emerging market example: VSAT access in Israel enables voice and data communications**

In Israel, four major and more than thirty smaller service providers utilize VSAT technology for high-speed connectivity. Israeli companies like banks, retailers and hotels use VSAT service for voice and data communications,

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35 Source: (73)
36 VSAT is not a clearly defined term, sometimes also referring to one-way (point-to-multipoint/multicast) systems but mostly used for bidirectional communication systems
37 Based on (19)
enabling services like database updates and replications, financial management, training and education, backup and disaster recovery.

In addition to companies, the Israeli military leverages VSAT heavily for command, control and communications capabilities, supporting their military operations. Satellites provide coverage and reliability paired with quick and economical deployment, enabling a secure network of voice and broadband data also in the field.

### 3.3.4 Summary: the communications infrastructure of companies relies on satellites

Due to the many options for how satellites can be part of the communications infrastructure of a company, satellite-based data access and distribution is key for many businesses. While some business models like CDN or digital cinemas depend on satellites to allow cost-efficient production of the service, other business leverage satellites for ongoing global connectivity in addition to terrestrial technology. And telecommunications companies use satellites as one of many solutions to interconnect their network and provide backhauling in mobile networks.
3.4 Telemetry/M2M

In the following, we will describe a few examples for telemetry/machine-to-machine applications. We will detail satellites’ value for intelligent transportation systems (ITS) as one example where satellites have a unique value for the service.

3.4.1 Machine-to-machine solutions and SCADA via satellite communications

Machine-to-machine increases process efficiency by ongoing measurement and capturing of events

Machine-to-machine (M2M) describes technologies that allow devices (normally attached to assets) to communicate via some infrastructure with an application/back-end system. The devices are often sensors or meters, which capture data and events (e.g., fuel consumption, current position) and relay it through a wireless communications channel to the backend system, which creates meaningful information (e.g., reports that a shipping container arrived at the final destination or a fuel tank is almost empty and needs to be refilled). Figure 44 shows an overview of this communications architecture. Modern M2M systems also go beyond this one-to-one communication to a system of networks that communicate with each other and transmit data to personal appliances (23); this will in the future also evolve into the Internet of Things.

Figure 44. Machine-to-machine communications architecture

M2M solutions are employed in a variety of fields, in order to track assets (e.g., shipping containers), improve efficiency of processes (e.g., by knowing exact inventory levels per location), continuously measure information (e.g., throughput in a pipeline) and also remotely control assets (e.g., to turn on pump systems of a pipeline or to update information on a digital billboard). Figure 45 provides an overview of the M2M service sectors and typical applications.
Satellites enable M2M in remote areas and are independent from terrestrial infrastructure

The M2M market today is mainly served by mobile cellular networks: 98% of volume and 94% of revenue are captured by mobile operators (24). Nevertheless, satellites have differentiating capabilities, which other technologies cannot offer, e.g., global coverage and resilience to terrestrial events and secure communications. Satellite M2M therefore is an important technology not only for fleet management and maritime applications, but also increasingly for energy and security/military applications.

There are several factors that drive the need for satellite-based M2M (24):

- **Need for global coverage**: despite significant coverage of GSM and 3G, satellites are the only communications solution for large areas of the globe, e.g., in large deserts, mountainous/glacial areas or on oceans. Examples for use cases requiring this coverage are the tracking of fishing vessels or dangerous cargo and the monitoring of offshore wind farms.

- **Increase of applications requiring M2M**: smart grids, shipment tracking and military combat-asset tracking are three applications that drive the need for M2M, largely also in remote areas.

- **Fallback or complement to terrestrial networks**: satellites can provide an alternative to terrestrial networks to deliver M2M links end-to-end. In recent years, hybrid solutions (i.e., communicating via terrestrial networks and satellites) became more and more available and used.

- **Requirements by regulation**: e.g., for tracking of commercial vessels.

With the evolution of the technology, new features can be offered to enable more applications with satellite M2M (see Figure 46 and Figure 47). Satellite-based M2M solutions normally leverage L- or S-band satellite systems in geostationary or LEO orbits. Today, the differentiation between M2M and broadband or data services is getting more difficult, as modern applications rely on higher bandwidth than traditional M2M systems. Also here, hybrid solutions are emerging, combining the qualities (e.g., no rain fade, use of simple antennas) of traditional mobile spectrum (mainly L band) with the higher data rate of K_a and K_u bands.
Figure 46. Satellite M2M services evolution

### Evolution of Satellite M2M Services

<table>
<thead>
<tr>
<th>Gen 1</th>
<th>Gen 2</th>
<th>Gen 3</th>
<th>Gen 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Track &amp; Monitor</strong></td>
<td><strong>Control &amp; Communicate</strong></td>
<td><strong>Conditional Analytics</strong></td>
<td><strong>Advanced Telemetry</strong></td>
</tr>
<tr>
<td><strong>Need</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Simplex store and forward</td>
<td>• Duplex messaging</td>
<td>• Duplex transmission</td>
<td>• IP full-duplex communications</td>
</tr>
<tr>
<td>• High latency (min. to hours)</td>
<td>• Mid latency (&lt; 60 sec)</td>
<td>• Low latency (&lt; 10 sec)</td>
<td>• Near real-time</td>
</tr>
<tr>
<td>• Tx: &lt; 50 bytes</td>
<td>• Tx: 100-300 bytes</td>
<td>• Tx: 1-2 kB</td>
<td>• Tx: 5-10 kB</td>
</tr>
<tr>
<td>• Rx: N/A</td>
<td>• Rx: 200-500 bytes</td>
<td>• Rx: 2-5 kB</td>
<td>• Rx: 10-20 kB</td>
</tr>
<tr>
<td>• Data Rate &lt;1 kbps</td>
<td>• Data Rate: 1-10 kbps</td>
<td>• Data Rate: 10-50 kbps</td>
<td>• Data Rate: 100-500 kbps</td>
</tr>
<tr>
<td><strong>Features</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Position reporting</td>
<td>• Smart metering</td>
<td>• Condition based maintenance</td>
<td>• SCADA monitoring and control</td>
</tr>
<tr>
<td>• SOS alerting</td>
<td>• Passive asset tasking</td>
<td>• Multi-sensor reporting</td>
<td>• Automated resource management / deployment</td>
</tr>
<tr>
<td>• Geo-fencing</td>
<td>• Health / status reporting</td>
<td>• Environmental feedback</td>
<td></td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Environment protection standards compliance</td>
<td>• Seamless and transparent regulatory compliance</td>
<td>• iGPS palletized in-route cargo monitoring (leased pallet service)</td>
<td></td>
</tr>
<tr>
<td>• Health monitoring of remote assets (e.g., heavy equipment)</td>
<td>• Reduced downtime and maintenance costs</td>
<td>• Caterpillar Product Link telematics via Orbcomm</td>
<td></td>
</tr>
<tr>
<td>• Equipment telematics from austere/dangerous environments (e.g., mines)</td>
<td>• Higher asset utilization through condition-based maintenance</td>
<td>• Komatsu integrated equipment telematics via Orbcomm constellation</td>
<td></td>
</tr>
<tr>
<td>• Maintenance alerting</td>
<td>• Lower inventory and improved in-transit accounting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Forward logistics management (e.g., incoming supply chain)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Note:
Feature ranges based on ROM performance specifications of prevailing products and services

#### Source:
Intel, Satmatics, company websites and product data sheets, Booz & Company analysis

<table>
<thead>
<tr>
<th>Need</th>
<th>Value Proposition</th>
<th>Example Offerings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industrial</strong></td>
<td>• Environment protection standards compliance</td>
<td>• Seamless and transparent regulatory compliance</td>
</tr>
<tr>
<td></td>
<td>• Health monitoring of remote assets (e.g., heavy equipment)</td>
<td>• Reduced downtime and maintenance costs</td>
</tr>
<tr>
<td></td>
<td>• Equipment telematics from austere/dangerous environments (e.g., mines)</td>
<td>• Higher asset utilization</td>
</tr>
<tr>
<td></td>
<td>• Maintenance alerting</td>
<td>• Tightened workflow cycles (e.g., transmission of delivery data)</td>
</tr>
<tr>
<td></td>
<td>• Forward logistics management (e.g., incoming supply chain)</td>
<td>• Improved revenue cycle management</td>
</tr>
<tr>
<td><strong>Transportation and Logistics</strong></td>
<td>• Fuel tax, drive time, and hazardous material regulatory compliance</td>
<td>• Workflow Support</td>
</tr>
<tr>
<td></td>
<td>• Fleet dispatching, tracking, and utilization measurement</td>
<td>• Fleet Logistics</td>
</tr>
<tr>
<td></td>
<td>• Asset health monitoring</td>
<td></td>
</tr>
<tr>
<td>Need</td>
<td>Value Proposition</td>
<td>Example Offerings</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>------------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Public Safety, Defense and Security</strong></td>
<td>• Tracking assets and personnel in remote locations or austere environments</td>
<td>• Enhanced asset utilization across the globe</td>
</tr>
<tr>
<td></td>
<td>• Command and control of autonomous assets</td>
<td>• Blue Force Tracking</td>
</tr>
<tr>
<td></td>
<td>• Global inventory management</td>
<td>• Fuels Manager Defense (e.g., armies)— monitors fuel for assets across air, ground and sea</td>
</tr>
<tr>
<td></td>
<td>• Monitor assets in hazardous environment</td>
<td>• Disaster preparedness asset management (e.g., FEMA)</td>
</tr>
<tr>
<td></td>
<td>• Enhanced asset utilization across the globe</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Reduced operating costs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Assured safety of personnel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Improved operations on the field</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Better inventory and budget planning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Reduced operating costs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Assured safety of personnel</td>
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<tr>
<td></td>
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<td>• Reduced operating costs</td>
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<tr>
<td></td>
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<tr>
<td></td>
<td>• Blue Force Tracking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Fuels Manager Defense (e.g., armies)— monitors fuel for assets across air, ground and sea</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Disaster preparedness asset management (e.g., FEMA)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Wireless remote monitoring and control of tanks and wells</td>
<td></td>
</tr>
<tr>
<td><strong>Energy and Utilities</strong></td>
<td>• Remote SCADA management</td>
<td>• Wireless remote monitoring and control of tanks and wells</td>
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<tr>
<td></td>
<td>• Smart meter data transmission</td>
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<tr>
<td></td>
<td>• Remote fuel tank monitoring</td>
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<tr>
<td></td>
<td>• Pipeline and offshore platform telematics</td>
<td></td>
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<tr>
<td></td>
<td>• Hazard alerting</td>
<td></td>
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<tr>
<td></td>
<td>• Real time remote transmission and distribution management</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Reduced downtime, higher asset utilization</td>
<td></td>
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<tr>
<td></td>
<td>• Improved grid/distribution network efficiency</td>
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<tr>
<td></td>
<td>• Incorporation of demand-side management into resource planning</td>
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</tr>
<tr>
<td><strong>Maritime</strong></td>
<td>• Long Range Identification and Tracking (LRIT) and Automatic Identification System (AIS) regulatory compliance</td>
<td>• Wireless remote monitoring and control of tanks and wells</td>
</tr>
<tr>
<td></td>
<td>• En route vessel and cargo tracking</td>
<td></td>
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<tr>
<td></td>
<td>• Transit routing and management (e.g., hazard, collision avoidance)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Seamless and transparent regulatory compliance</td>
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</tr>
<tr>
<td></td>
<td>• Reduced downtime and maintenance costs</td>
<td></td>
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<tr>
<td></td>
<td>• Higher asset utilization</td>
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</tr>
<tr>
<td></td>
<td>• Reduced loss (e.g., lost cargo)</td>
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<tr>
<td></td>
<td>• Assured delivered product integrity and timeliness</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Automatic Identification System (AIS) data for routing and collision avoidance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Saffire-Online is an advanced fishing management, port, routing and vessel tracking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• NAV Tracker 1.0 for vessel tracking</td>
<td></td>
</tr>
<tr>
<td><strong>Health and Sciences</strong></td>
<td>• Remote patient monitoring</td>
<td>• Argos transmitters provide data on climate changes to the scientists and data processing centers around the world</td>
</tr>
<tr>
<td></td>
<td>• Pharmaceutical supply tracking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Rural care support (e.g., test results transmission, tele-health)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Early warning (e.g., tsunami)</td>
<td></td>
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<tr>
<td></td>
<td>• Environmental monitoring (e.g., climate, ocean, glacial)</td>
<td></td>
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<tr>
<td></td>
<td>• Reduced cost, improved access and outcomes for remote care delivery</td>
<td></td>
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<tr>
<td></td>
<td>• Assured incoming supply integrity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Timely first responder and emergency preparation management</td>
<td></td>
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<tr>
<td></td>
<td>• Patient tracking (e.g., dementia and Alzheimer’s customers)</td>
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</tr>
<tr>
<td></td>
<td>• Automatic Identification System (AIS) data for routing and collision avoidance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Saffire-Online is an advanced fishing management, port, routing and vessel tracking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• NAV Tracker 1.0 for vessel tracking</td>
<td></td>
</tr>
<tr>
<td><strong>Consumer and Retail</strong></td>
<td>• Low cost geo-location, security monitoring, SOS alerting (e.g., adventure travelers)</td>
<td>• Argos transmitters provide data on climate changes to the scientists and data processing centers around the world</td>
</tr>
<tr>
<td></td>
<td>• Remote point of sale transaction support</td>
<td></td>
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<tr>
<td></td>
<td>• High value inventory tracking and monitoring (e.g., en route from suppliers)</td>
<td></td>
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<tr>
<td></td>
<td>• Improved safety</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Timely emergency response</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Reduced cost of sales (e.g., real-time transaction processing)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Reduced loss due to theft (e.g., in transit inventory)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• SPOT Connect is a cost effective COTS transceiver that instantly turns a smart phone into a satellite phone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Delorme (Iridium) offers similar device with Android integration</td>
<td></td>
</tr>
</tbody>
</table>

Figure 47. Satellite M2M value proposition and example offerings
Emerging market example: vehicle tracking for theft management in South Africa

In South Africa, M2M systems for vehicle tracking for theft management have become a considerable business. Providers leverage GPS, communications satellites and mobile networks to track vehicles. The M2M device is fitted to the car and relays the current position in case of theft. An additional emerging use case is the tracking of vehicles to measure speed, compare to legal limits and report speeding.

3.4.2 ITS roll-out efficiency due to car-to-satellite communications

Intelligent transport systems (ITS) are closely related to M2M and are a very important telemetry application. ITS can significantly contribute to a cleaner, safer and more efficient transportation system. They will support a wide range of applications, from travel and real-time traffic information systems to road-safety information (25). ITS applications are largely based on the communication of an on-board unit (OBU, installed in a car) with either another OBU or a roadside unit (RSU), in order to exchange data (e.g., about an emergency braking situation).

A well known ITS application is eCall, the automated emergency call system, which sends important sensor data (e.g., airbag status, impact sensor information) to emergency services and dials 112 in case of a crash. This application at the moment relies on mobile phone networks, but other applications cannot rely only on this technology and will require different infrastructure components to generate the intended value.

Satellites reduce the need for roadside infrastructure and enable fast and wide ITS roll-out

Due to the infrastructure cost of a large-scale RSU roll-out, most applications and implementations focus on car-to-car communication, to distribute information over a wider area. Since the current technologies for car-to-car communications are based in the 5.9 GHz band, reliable communications in the real world can only be achieved in distances less than 1 km. In case cars are spaced further (which, especially during initial roll-out phases will be the default case), no data can be exchanged and the positive effects of ITS will not be realized.

SafeTRIP investigates the use of satellite communications in order to bridge the communications gap between cars. The project sees satellites not only as a means to overcome limitations and improve car-to-car systems but also as an additional benefit for ITS, by boosting the initial performance of applications significantly (26). SafeTRIP proposes to use S-band communications satellites (e.g., Eutelsat’s W2A) using DVB-SH (a standard to provide media and data to mobile devices).

Figure 48. SafeTRIP system overview

38 Based on (19)


40 Satellite Applications for emergency handling, traffic alerts, road safety and incident prevention. Safetrip.eu is a project co-funded by the European Commission and DG Research as part of the seventh framework program. http://www.safetrip.eu
Leveraging this combination of technologies and standards, the system will be able to combine terrestrial (wireless) networks with satellite communications. SafeTRIP sees three major advantages of the approach (27):

- **Global coverage**: with a single geostationary satellite it is possible to provide service on wide areas, such as entire countries or continents. The global coverage is fundamental to achieve truly pan-European services.

- **Immediate Full Coverage**: while a terrestrial system can take years to be deployed over a significant fraction of the territory, and usually it stops for economic reasons to about 80% of surface, a satellite can provide full coverage of an entire country. Combined with a complementary ground network, it ensures that vehicles are connected/rescued everywhere in Europe. Additionally, it means that a larger users’ base can immediately access the service, ensuring a better market penetration.

- **Energy-efficient operation**: the satellite receives its operating power from the sun, through solar panels. To provide the same level of service over a territory, any terrestrial technology would require significant construction works that would increase the environmental pollution and a large amount of electrical power to feed all transmitters.

### 3.4.3 Summary: Satellite communications are a key component for M2M and telemetry

Although M2M, Telemetry and ITS solutions are today (and will be also in the future) largely based on terrestrial technologies, satellites offer unique values for these applications. With their global coverage, resilience to terrestrial impact and fast roll-out compared to ground infrastructure, satellites enable new use cases for M2M. Especially for maritime applications and connectivity in remote areas, terrestrial technologies cannot replace satellite solutions.

Especially new use cases (e.g., monitoring of offshore wind parks, SCADA applications) rely on multiple networks and connectivity to create hybrid solutions, e.g., combining terrestrial connectivity with satellite fallbacks or combining L-Band steady connectivity with Kx-band fast broadband.

From a provider and regulation perspective, satellite spectrum for these applications needs to be considered. Especially for safety-critical M2M solutions (e.g., in health as well as utilities), terrestrial interference needs to be avoided in order to guarantee the service quality.
3.5 Public protection and disaster relief—enabled by satellites' resilience and robustness

Public safety and emergency services require earth observation and global communication

One of the key characteristics of satellite-based systems is the independence of the signals from the ground topology. Regardless of the nature and magnitude of events on earth, satellite communications signals remain available for any potential user. This behavior makes satellites key in case of emergencies, especially in response to natural or man-made disasters.

Several main activities can be identified in the realm of public protection and disaster relief (based on ISICOM mission scenarios (28)):

- **Security of citizens**: protection of citizens in public places, security of food chain and water sources, fight against organized crime and terrorism
- **Security of infrastructure and utilities**: protection of energy and water, fixed infrastructure nodes, bridges and tunnels, industrial plants
- **Transport security**: ensure vehicle and traveler security, monitor and control traffic for maritime, road, rail, aviation and multi-modal transport
- **Surveillance and border control**: prevention of illegal cross-border activities on land and sea
- **Crisis management in case of natural or man-made disasters**: efficiently and effectively respond to a disaster during and after the event (e.g., fire hazards, earthquakes, landslides, floods, hurricanes, major industrial accidents/technological disasters)
- **Humanitarian relief activities**: provide rapid and effective support to victims of a disaster in another region

The combination of different satellite services enable safety and security services

Safety and security services combine several satellite services into new applications; normally this includes earth observation, navigation/positioning, M2M services and data/voice connectivity or broadband access.41 These services all leverage the unique properties of satellites, especially the global coverage, independence of terrestrial networks and robust encrypted communication. The goal of these applications is to gather data, provide intelligence and early warning, as well as support crisis management and operations with relevant information.42 Following, we present a few examples for safety and security services using satellites.

**Critical infrastructure protection is enable by satellite surveillance and M2M systems**

The protection of infrastructure (and to some extent citizens) is mainly enabled by surveillance (earth observation) satellites. Satellites can gather optical and other (e.g., radar) pictures of critical infrastructure, to model the infrastructure components, identify any natural risks (e.g., flooding zones) and create an inventory of critical infrastructure and potential threats. For endangered facilities (e.g., nuclear plants), twenty-four-hour monitoring is possible, e.g., to monitor the correct functioning of the facility.

In combination with ground infrastructure and leveraging M2M systems, satellites can also monitor ongoing operations and, depending on the M2M sensor, detect threats. For example, small nuclear radiation detectors can be employed in harbors or large container storage areas to identify illicit traffic of nuclear material.

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41 For a detailed description of the single components of the safety and security services, please also see the respective chapters. Descriptions in this chapter based on (59)

42 Within the European Union, the European earth-monitoring program GMES (Global Monitoring for Environment and Security) acts as an umbrella for many of these services, which are developed in the projects SAFER (emergency management) and G-MOSAIC (security). For a more detailed description see also chapter 3.6
Container integrity is a key element of transport security – satellite M2M enables global monitoring
The shipping container is one of the key components of transport systems, independent of the mode of transportation. M2M transponders can be integrated into the container to track the opening of doors or movement inside the container and report back to the control center. A simpler version uses M2M tags attached to the container to track movement via GNSS and report the position, e.g., to track the route of dangerous-goods transport. Satellite based M2M enables global coverage for these applications, as well as independence of terrestrial components, therefore increasing the resilience of the overall solution.

Border security leverages earth observation and satellite communication with local ground staff
Satellite imaging makes it possible to monitor sea and land borders, track the location of vehicles and individuals, as well as biological or chemical substances. In case border control units are requested to investigate, satellite communications can be used to coordinate the activities.

Figure 49. Costal monitoring showing illegal immigrants gathering for departure

Satellite communications can replace telecommunications infrastructure in case of security incidents
Terrestrial telecommunications are clearly critical, especially since large parts of infrastructure and economy depend on it. In addition to monitoring the infrastructure components, satellite communications can also provide an additional, independent communications path. Especially in the case that terrestrial communications are suspected to be compromised, satellites provide a secure alternative.

Satellites are the preferred medium for emergency communications due to their resilience to ground events
In case of disasters (e.g., earthquakes), terrestrial communications systems and services are frequently affected and disrupted. Telecommunications networks are often severely damaged (land lines are destroyed, mobile towers and antennas damaged, functioning mobile networks are saturated due to missing or failing backhauling capacity) and cannot be used by victims and first aid personnel.

When it comes to quickly restoring an efficient communications network in case of disaster or emergencies, satellite based communications play an essential role, due to several differentiating factors:

- **Overlay communications network and interoperability**: satellite communications are independent of ground based communications systems and allow independence from terrestrial infrastructure. In addi-
tion, functioning ground-based systems (e.g., parts of mobile networks, Wifi networks) can be combined with satellite communications in one integrated communications network. This has already been demonstrated, e.g., by Isi with WiMAX and WiFi in a crisis response simulation (29).

- **Wide coverage**: depending on the disaster or emergency, large areas of a country or region can be affected. Satellite communications' worldwide coverage assures full network functionality, performance and service within the whole disaster territory. This coverage also enables humanitarian relief actions outside of an organization's home territory with the same communications equipment and processes, increasing efficiency and effectiveness of operations.

- **Rapid deployment**: satellite-based communications systems can be rapidly deployed in the affected area. Simple, voice-only systems can be deployed as handheld devices (satellite phones); data devices range from mobile, lightweight systems to small VSAT terminals (can be transported by car or helicopter) to larger-scale full communications units (see Figure 50 for examples of emergency communications devices).

- **Interworking with other satellite based systems** (e.g., earth observation and navigation/localization Systems)

Given these unique and differentiating properties of satellite-based communications, governments and non-governmental organizations around the world rely heavily on satellite communications, often cooperating with operators in advance (e.g., via Telecoms sans Frontières (TSF) or emergency.lu) to enable rapid responses to emergency situations.

<table>
<thead>
<tr>
<th>Examples for Communication Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISATPHONE PRO (Voice)</td>
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<td>MINI M (Voice)</td>
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<td></td>
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</tbody>
</table>


Figure 50. Examples for satellite communications devices for emergency communications

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Satellite is a key asset for public protection and disaster relief
As a result of satellites’ capabilities for safety and security as well as disaster relief, the demand for capacity has been increasing in Europe and will continue to grow globally by around 2% per year, in Europe even more. In order to take advantage of high-speed broadband, the security and defense use of satellites is expected to expand to the newest technologies, leveraging K-band satellite communication, where associated demand is expected to double every two years. Such growth demonstrates the strong and sustainable interest of governments in powerful satellite communications, which also play a crucial role in maintaining strategic independence.

3.6 Satellites provide unique earth observation capabilities
Satellites offer unique capabilities for earth observation (EO). Given the position in orbit, a large area can be observed at once, independent of ground conditions. Earth observation services can be roughly clustered in six domains (30):

- **Atmosphere**: Monitoring atmospheric chemistry and composition to contribute toward Essential Climate Variables (ECVs), measurement of European air quality, and monitoring of solar irradiance and UV (ultraviolet) radiation
- **Climate Change**: Monitoring in support of adaptation and mitigation policies through the production of ECVs
- **Land Monitoring**: Monitoring of land use to protect ecosystems and facilitate environmental protection and resource management
- **Emergency Management**: Services enabling better responses to natural and man-made disasters. This includes supporting pre-event preparation, providing rapid mapping during crisis, supporting post-event recovery and damage assessment, and providing early warning flood alerts
- **Marine**: Ocean forecasting and monitoring to contribute to ECVs, monitoring marine environments and contribute to maritime navigation by creating and calibrating three-dimensional models used in prediction and forecasting
- **Security**: Use of earth observation to support EU policies in the areas of EU External Action, border control, and maritime surveillance. This includes support to peacekeeping, law-enforcement and crisis-management operations, and to intelligence and early warning in respect to external regional crises

Many of these domains can also be combined with or rely on the combination with satellite communications, e.g., as described in chapter 3.5 for public protection and disaster relief, where observation and measurement of geographic features from the orbit enable a number of services.

Earth observation enables innovative services for a resource-efficient Europe
EO is widely seen as one of the most critical data sources to monitor and model major issues and develop policies for areas like climate change, energy, agriculture, etc. Earth observation satellites support environmental management (air quality, desertification and sea/marine pollution) and resource management (measure availability, usage and replenishment of natural resources and develop new methods for allocation and rationing).

For climate change, earth observation enables (30): monitoring of long term trends in the composition of the atmosphere, trends in land and ocean temperatures and trends in polar ice, sea levels and degrees of land change (e.g., desertification) that may be linked to climate change. It may also include measurements of embedded carbon, biosphere responses (land and marine) to identified changes in temperatures, and the impacts of land and oceanic reflectivity upon temperatures. This enables linkages between emissions, atmospheric composition and temperatures to be considered. However, most importantly this can also feed into improving the accuracy of climate models that forecast future scenarios that may be used to influence policy.

Satellite-gathered data help to implement, monitor and manage policies like fisheries quotas, agricultural policies and forestry strategy.

45 Source: SES Corporate development based on (67)
The socioeconomic value of a European earth observation system is around €120 billion in the next fifteen years

Several studies have been conducted to assess the value of GMES for Europe; the European Space Policy Institute (31) shows in their consolidation a socioeconomic value in the order of €120 billion for the period 2014–2030. These benefits are enabled by improvements in: forest monitoring, food security monitoring, costal monitoring, sea ice monitoring, ocean monitoring, atmosphere monitoring, humanitarian aid, urban monitoring, aqua-soil monitoring, land hazard monitoring, arctic monitoring, natural hazard monitoring, as well as strategic and political and benefits to the EU external policies.

3.7 Global navigation and positioning is only possible due to satellites

The satellite is the only technology that enables a global navigation and positioning service. Although terrestrial technologies allow for basic positioning services, satellites provide global coverage and are independent of local terrain (e.g., they works in mountains as well as cities). Modern GNSS (Global Navigation Satellite Systems) also rely on a combination of different satellite and terrestrial systems to improve the accuracy of the system. An example is EGNOS (European Geostationary Navigation Overlay Service), which supplements the orbital positioning with ground-based information that is distributed by communications satellites. Furthermore, many applications of GNSS combine satellite-based position information with satellite communications to provide a service, e.g., tracking of shipments and vehicles. As this example already shows, navigation and positioning services are closely linked to M2M and emergency services, see also chapters 3.4 and 3.5.

Modern navigation solutions (e.g., 4D trajectory management) rely on accurate satellite positioning

Navigation systems are used for all types of vehicles today, from cars and trucks to aircraft and boats/ships, as well as for hikers and bikers. Simple systems track current position, speed and direction. In combination with geographic information systems, routes can be planned and navigation instructions provided, e.g., by handheld units. Units employed on ships combine this use case with self-steering, AIS (automatic identification system) and emergency functions like man overboard.

The accuracy of modern satellite positioning (in combination with ground based systems) also enable the navigation of heavy equipment in construction, mining and precision agriculture. This equipment can be automatically controlled by a GNSS-guidance system, making possible, for example, efficient spraying or tracking of yield in agriculture. These highly accurate systems can also be used in aircraft navigation for final approaches guided by GNSS.

Fleet management and tracking (e.g., of containers) is enabled by combining several satellite technologies

This collection of uses cases relies heavily on the combination of satellite technologies. For example, as already mentioned, the tracking of containers relies on a combination of M2M devices, receiving positioning information from a GNSS and relaying it to an application often via satellite communications.

Modern fleet management solutions require the constant tracking of all vehicles and assets in order to optimize routes, time and cost efficiency. Vehicle tracking, the most basic component of fleet management, is achieved with GNSS receivers on board vehicles, in order to identify, locate and maintain contact and report in real time. More complex solutions also enable telematics as described in the M2M section.

Tracking technology also enables geofencing of assets (e.g., vehicles but also people or pets), which means continuously tracking the position of the asset and providing an alarm if it leaves a specified area. Examples for this are ankle monitors for criminals or pet-tracking solutions.

A different use of the same approach is GNSS road pricing (e.g., as used in Germany), in which toll collection depends on the distance driven on specific roads. The GNSS receiver tracks the position and enables real-time pricing not only for driving but also for parking or insurance.
The GNSS timing data is also used a requirement for modern communications networks and power grids

The time-stamp data of GNSS can not only help determine a location, it can also provide a highly accurate time with very limited cost. Modern communications networks rely on highly accurate timing data available to each sender in order to optimize efficiency and capacity usage. The same is true for energy grids, which need to exactly synchronize the phase of current to minimize inefficiencies. This very precise timing data can only be achieved with expensive cesium timers (atomic clocks) or cheaply derived out of the GNSS signal.

Timing information is used not only in communications networks and power grids, but numerous businesses also rely on it. For example financial transactions are time stamped to guarantee traceability, and banking computer systems are synchronized with GNSS time information.

More exotic uses for timing information are Doppler radars (used for weather measurement), which measure small shifts in the frequency of a signal. To enable a coherent view of a single event by several radars, exact time calibration is required. The same is true for seismic measurements—seismographs around the world must be in sync in order to determine the source of an earthquake or predict a potential tsunami.

Finally, and crucially, GPS time data is also used to synchronize the highly accurate cesium clocks around the world.
4. Socioeconomic Impact of Satellites on Europe

Four of the major global satellite operators are based in Europe, but satellites by definition are global and provide their services not only in and to Europe but also across regions. The influence of satellites on developing economies and on existing business relationships with key markets like the US should not be underestimated. Therefore, our socioeconomic view takes a global perspective, but also highlights the situation in Europe.

The following section provides an overview of the satellite industry—its size, impact on Europe and the socioeconomic value of the previously described satellite use cases.

4.1 The satellite industry created 200,000+ jobs across Europe and directly generates more than €10 billion revenue

Although the satellite industry is small compared to the total global telecommunications sector, it is very valuable and, due to the strong presence of large satellite operators in Europe, an attractive asset for the European Union.

4.1.1 The global satellite industry generates revenues of more than €135 billion

In recent years, the global satellite industry showed a steady growth of 11% per year from 2006 to 2011 (see Figure 51). In 2011, the global industry had total revenues of $177 billion (32), equal to around €135 billion. More than 60% of the revenue ($108 billion) is generated by satellite services, including satellite operations and service provisioning. In 2011, Europe accounted for 32% of satellite manufacturing and 25% of satellite launch industry revenues (32).

Satellite TV services globally generate almost half of the revenue of the industry

Out of the $108 billion service revenue, almost 80% are generated by satellite TV distribution. In 2011, satellite TV generated $84 billion, which represents 47% of the industry. The second biggest service category is non-consumer, fixed satellite service with a total of $16 billion. This includes $11 billion in transponder agreements (including capacity for DTH satellite TV platforms) and $4 billion in managed services (e.g., VSAT networks).

46 For an explanation of terms and the industry value chain please see also chapter 1 and Figure 2
The European space manufacturing industry employs 34,000 people, generating €6 billion sales revenue.

In 2010, the space manufacturing industry employed more than 34,000 people across all countries of the European Union (33). Including ground systems and scientific systems, the European space manufacturing industry had 2010 revenues of around €6.1 billion (33), an increase of more than 9% from 2009. Out of this, more than €1.3 billion were exported outside of Europe; more than €1.2 billion sold to satellite operators and €670 million generated with sales of launch vehicles to Arianespace for commercial and public missions.

Four of the five major global satellite operators are European— they generate more than €5 billion revenue.

Most of the around 50 satellite operators have only very small operations, many with only one satellite. The market is therefore concentrated in five operators, which have total revenues of €6.4 billion, representing around 80% of the total market size (34). The four European operators are also the four largest overall, and they generated €5.8 billion revenue in 2011. This shows the impact of Europe on the satellite industry globally.

<table>
<thead>
<tr>
<th>Company</th>
<th>Headquarters</th>
<th>Number of satellites in operation (2011)</th>
<th>Revenue (2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intelsat</td>
<td>Luxembourg</td>
<td>50</td>
<td>€1.9 bn (USD 2.6 bn)</td>
</tr>
<tr>
<td>SES</td>
<td>Luxembourg</td>
<td>50</td>
<td>€1.7 bn</td>
</tr>
<tr>
<td>Eutelsat</td>
<td>Paris/France</td>
<td>28</td>
<td>€1.2 bn (FY 2011–2012)</td>
</tr>
<tr>
<td>Inmarsat</td>
<td>London/UK</td>
<td>10</td>
<td>€1.0 bn (USD 1.4 bn)</td>
</tr>
<tr>
<td>Telesat</td>
<td>Ottawa/Canada</td>
<td>13</td>
<td>€0.5 bn (CAD 0.7 bn)</td>
</tr>
</tbody>
</table>

**Figure 51. Satellite industry size**

**Figure 52. Overview major satellite operators**

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Data from (32)

Note: The revenue of these operators also contains some service provisioning revenue (e.g., providing services for media companies beyond capacity leasing)

Source: company websites and annual reports, Bloomberg
European Arianespace is the world leader in launch services\(^{50}\)

Arianespace is the European launch services provider and—founded in 1980—is the oldest commercially available launch service. In 2011, Arianespace generated €1 billion in sales, performing nine launches over the year. It signed 21 new launch contracts and booked 14 orders, capturing almost 50% of the market for commercial launches of geostationary satellites—another testament to the strength of the industry in Europe.

4.1.2 The satellite industry as an innovation driver for Europe

The European space industry is working hard on developing new technologies that are revolutionizing the contribution and perception of satellite systems in years to come. The dependence on ultra-reliable space systems such as GNSS and EGNOS for air traffic management shows that the satellite services industry is able to integrate future satellite communications and other satellite solutions in intelligent ways.

By 2020, satellite technology is predicted to provide underserved rural populations with access speeds of up to several dozen megabits per second. But in parallel, next-generation modulation standards for satellite communications have been tested with speeds ranging from 300 Mbps and up to 700 Mbps for professional video applications on standard C-band transponders.\(^{51}\)

Manufacturing industry R&D areas most relevant for Europe:

- High throughput, flexibility and configurability of payloads: to further enhance the cost-effectiveness of satellite communications with even more efficient use of spectrum, capacity and throughput
- Efficiency and robustness of radio interfaces: to provide differentiated quality of service, and contribute to further improved spectrum usage
- User-friendly and reconfigurable terminals: to bring smaller and handheld terminals into play, and create new mobile services addressing broadcast and broadband needs
- Integration and convergence of networking: to further facilitate integration of satellites into terrestrial networks

A survey conducted by Booz & Company for the European Space Agency revealed that the industry has been very diligent in testing new technology prior to commercial launch to preserve the high quality and availability standards its customers and end-users are used to.

Despite the relative conservatism of the space industry, satellite communications have realized many impressive achievements in the last decades, from remarkable spectrum efficiency gains leading to more cost-effective communications, to the development of high resolution sensors and specialized radars for interferometry applications in earth observation. As a result, we see clearly an opportunity for the ESA and the EU to further stimulate and unlock the true potential of the European space industry.

Booz & Company believes that incentive schemes, like the promotion of the first heritage flight as developed by ESA/ARTES, will positively affect the industry risk culture by providing acceptable financial mitigations for first flight.


4.1.3 Wider ecosystem impact of satellite communications

The space industry is a major driver of employment in adjacent industries—estimated to support 150,000 jobs in Europe

Industries do not only generate their own revenue but also drive value generation in adjacent sectors or value chains. Although this effect is difficult to quantify due to the many interdependencies, recent studies estimated the impact of the space industry on the UK economy. The BIS study (35), for example, concluded that the space industry has a very high productivity, several times higher than the overall economy in the UK.

Since the space industry relies on other sectors, each employee drives the employment of several workers in these adjacent industries. The UK BIS study estimates a 4.2 multiplier for downstream services (like satellite operators). This means that, for every 10 employees in the satellite industry, an additional 32 jobs are created in other sectors. For upstream services (like manufacturing) this factor is 3.6. Similar studies for the US economy mention a factor of up to 6 for the overall space industry. Applying these numbers, around 150,000 jobs in the European Union are created due or supported by the satellite industry.

Satellite broadcasting contributes up to €20 billion of the media industry

European broadcasters in 2009 generated net revenues of around €60 billion (excluding free and pay TV distribution revenue shares and transmission costs of an estimated €10 billion) (36). Since more than a quarter of the European households receive TV via satellite (see chapter 3.1.2 for details), satellite broadcasting is a major contributor to and enabler of the media industry revenues.

Based on a DTT impact study by Deloitte (37), a high-level quantification of the contribution is possible. Given a similar number of households receiving broadcasts via satellite and DTT, we estimate that between €10 billion and €15 billion of TV revenues are enabled by satellite broadcasting (around €4–6 billion of pay TV contribution and €6–9 billion advertising). In addition, some €2–5 billion of pay TV retailer revenue are contributed via satellite broadcasting.

Telecommunications and service providers rely on satellite communication

As described in the use case chapter, global telecommunications and Internet service providers use satellite communications as backup and fallback for their terrestrial infrastructure, for distribution of large data blocks and for backhauling of mobile and fixed networks in remote areas. A quantification of benefits for these industries is quite complex, especially for backup services, which are highly valuable when needed but are most of the time a cost position. Based on the total market size for telecommunications, we estimate satellite communications contribute around 0.2%, equal to €5–10 billion globally.

4.2 Satellite use cases have high social value

In order to place a value on the satellite use cases, the social as well as the economic value need to be understood, similar to the recommendation for spectrum by BEREC and RSPG (38) and (39). Since there is no easy measurement, we propose a qualitative assessment of different services along several categories:

- **Number of potential users**: share of the population or businesses that can use the service directly or indirectly and the relevance it has for them (i.e., does the use case apply to them given alternatives)

- **Impact on society**: which benefits are achieved for the society as a whole by the service? Examples are development of culture, democracy, environmental or security improvements, as well as the impact on social cohesion (39).

- **Fit with the strategic EU agenda**: how does the service support Europe 2020 and the Digital Agenda?52

52 See also chapter 5.1 EU policies and instruments
All impacts have been evaluated qualitatively, from none to high, according to these categories, as shown in Figure 53. Figure 54 shows the overall social value of the different satellite use cases. Generally satellite services have a rather high impact on society due to their broad coverage and the provisioning of services that have become vital to society. Given their potentially strong support for the Digital Agenda (depending on support by future policies, see also chapter 5.2) and the high number of direct and indirect users, the overall social value of satellite services can be seen as high.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Value</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of potential users</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>None (0)</td>
<td>~0% of population or businesses</td>
</tr>
<tr>
<td>Low</td>
<td>Low (1)</td>
<td>&lt;30% of population or businesses</td>
</tr>
<tr>
<td>Medium</td>
<td>Medium (2)</td>
<td>30–70% of population or businesses</td>
</tr>
<tr>
<td>High</td>
<td>High (3)</td>
<td>&gt;70% of population or businesses</td>
</tr>
<tr>
<td><strong>Impact on society</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>None (0)</td>
<td>No or very limited impact</td>
</tr>
<tr>
<td>Low</td>
<td>Low (1)</td>
<td>Improved quality of life</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Convenience for users</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost efficiency/reduction of consumer services</td>
</tr>
<tr>
<td>Medium</td>
<td>Medium (2)</td>
<td>Improvement of cultural diversity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Improvement of social cohesion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sharing of information, enabling of democracy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Economic security</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interpersonal communication</td>
</tr>
<tr>
<td>High</td>
<td>High (3)</td>
<td>Emergency communication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Safety of life or property</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Protection of civil rights</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scientific research and discovery</td>
</tr>
<tr>
<td><strong>Fit with strategic agenda</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None/low</td>
<td>None/low (1)</td>
<td>None or limited impact on Europe 2020 and Digital Agenda</td>
</tr>
<tr>
<td>Medium</td>
<td>Medium (2)</td>
<td>Indirect contribution to Europe 2020</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Component to deliver Digital Agenda service</td>
</tr>
<tr>
<td>High</td>
<td>High (3)</td>
<td>Direct contribution to Europe 2020</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Directly supports Digital Agenda</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>Low (up to 4)</td>
<td>Sum of individual scores</td>
</tr>
<tr>
<td></td>
<td>Medium (5–7)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High (8 or higher)</td>
<td></td>
</tr>
</tbody>
</table>

Figure 53. Social value qualification framework
<table>
<thead>
<tr>
<th>Use Case</th>
<th>Number of potential users</th>
<th>Impact on society</th>
<th>Fit with strategic agenda</th>
<th>Overall Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media Content Distribution</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• TV Broadcasting</td>
<td>Medium (2) to high (3): average of use cases</td>
<td>Medium (2) to high (3): social cohesion and diversity and sharing of information. Partly also protection of civil rights (e.g., communications in war zones)</td>
<td>Low (1) to medium (2): average of use cases</td>
<td>Medium to high (5–6)</td>
</tr>
<tr>
<td>• Content Exchange</td>
<td>Low to medium: only media companies and indirectly most of the population</td>
<td></td>
<td>None/low</td>
<td></td>
</tr>
<tr>
<td>• Hybrid Triple Play (mobile)</td>
<td>High: relevant for telcos and indirectly all population</td>
<td></td>
<td>Medium: indirectly can contribute to next-generation service experience</td>
<td></td>
</tr>
<tr>
<td>• Connected Devices</td>
<td>Low: at the moment limited number but strong growth</td>
<td>Medium (2): social cohesion and diversity</td>
<td>Medium: part of the audiovisual media directive (10)</td>
<td></td>
</tr>
<tr>
<td>Broadband Access for All</td>
<td>Low (1): average of use cases</td>
<td>Low (1): mainly impacts cost for businesses&lt;sup&gt;53&lt;/sup&gt;</td>
<td>Medium (2): indirectly affects the next-generation service experience of the Digital Agenda</td>
<td>Low (4)</td>
</tr>
<tr>
<td>• Basic Broadband Everywhere</td>
<td>Low: mainly attractive in areas without fixed access</td>
<td>Low (1) to medium (2): average of use cases</td>
<td>Medium (2): indirectly supports sustainable growth targets</td>
<td>Low to medium (4–6)</td>
</tr>
<tr>
<td>• Special Uses (Fast) Broadband</td>
<td>Low: only for special uses like aerial</td>
<td>Low (1): mainly increases convenience</td>
<td>Medium (2): indirectly supports sustainable growth targets</td>
<td></td>
</tr>
<tr>
<td>• Hybrid Broadband (fixed)</td>
<td>Medium to high: relevant for telcos and indirectly rural population</td>
<td>Low (1) to high (3): for ITS, large parts of population, for M2M only selected companies</td>
<td>Low (1) to high (3): for ITS, large parts of population, for M2M only selected companies</td>
<td></td>
</tr>
<tr>
<td>Remote Data Connectivity and Backhaul</td>
<td></td>
<td></td>
<td>Low (1) to high (3): depending on use of imaging service</td>
<td></td>
</tr>
<tr>
<td>• Backhaul for Telcos</td>
<td>Medium: for telcos and indirectly for mobile users in non-urban areas</td>
<td>Low (1): mainly impacts cost for businesses&lt;sup&gt;53&lt;/sup&gt;</td>
<td>Medium (2): indirectly affects the next-generation service experience of the Digital Agenda</td>
<td></td>
</tr>
<tr>
<td>• Multicasting</td>
<td>Low: for selected companies</td>
<td>Low (1): mainly increases convenience</td>
<td>Medium (2): indirectly supports sustainable growth targets</td>
<td></td>
</tr>
<tr>
<td>• VSAT</td>
<td>Low: for selected enterprises</td>
<td>Low (1): mainly increases convenience</td>
<td>Medium (2): indirectly supports sustainable growth targets</td>
<td></td>
</tr>
<tr>
<td>• Maritime</td>
<td>Low: only for ships</td>
<td>Low (1): mainly increases convenience</td>
<td>Medium (2): indirectly supports sustainable growth targets</td>
<td></td>
</tr>
<tr>
<td>Telemetry/M2M</td>
<td>Low (1) to high (3): for ITS, large parts of population, for M2M only selected companies</td>
<td>Low (1): mainly increases convenience</td>
<td>Medium (2): indirectly supports sustainable growth targets</td>
<td></td>
</tr>
<tr>
<td>Public Protection and Disaster Relief</td>
<td></td>
<td></td>
<td>Low (1)</td>
<td></td>
</tr>
<tr>
<td>Earth Observation</td>
<td>Low (1) number of direct users but indirectly affects larger parts of society (e.g., weather forecast)</td>
<td>Low (1) to high (3): depending on use of imaging service</td>
<td>Medium (2): directly supports climate, energy and mobility</td>
<td>Medium (5–7)</td>
</tr>
<tr>
<td>Navigation and Positioning</td>
<td>Medium (2) to high (3): basic services directly affect, complex service indirectly affects large parts</td>
<td>Low (1) to high (3): depending on use case</td>
<td>High (3): directly supports climate, energy and mobility</td>
<td>Medium to high (6–9)</td>
</tr>
</tbody>
</table>

Figure 54. Evaluation of social value

<sup>53</sup> Excluding distress signals for maritime use which have a high impact on society (included in public protection and disaster relief for this analysis)
In addition to social value, the economic value of current satellite services has to be evaluated and balanced to come to an overall assessment of the importance of satellites (analog to (39)).

4.3 **Economic value of satellite use cases is significant**

In order to evaluate the economic impact of satellite use cases, we distinguish existing and future services. To simplify the analysis, we categorized satellite services in either of the two groups and picked the major application as a proxy.

For existing services we approximate the value by calculating the cost of replacement with an alternative technology. The analysis primarily focuses on satellite TV broadcasting due to its big share of the overall satellite market relevance (almost 80% of services). In addition we illustrate the potential value for Europe for:

- Hybrid broadband, as a proxy for broadband services
- Future applications beyond communications in Europe: earth observation with GMES and global positioning and navigation with Galileo

4.3.1 **Satellite broadcasting prevents opportunity cost of up to €140 billion**

In order to evaluate the value of TV broadcasting, we imagine a hypothetical scenario in which satellite broadcasting is no longer available. In order to continue to provide programming to citizens and retain the wider ecosystem impact (e.g., availability of timely information from many independent sources in different languages), we replace satellite broadcasting with an alternative technology—and this technology deployment cost we take to be the economic value of the use case. Helios (40) conducted a similar analysis based on frequency bands. Given TV broadcasting in Europe mainly uses Kᵤ band (and only to a limited extent other bands), we aligned with their calculations for Europe.

**Replacing satellite TV with largely lower quality services would cost estimated €33 billion**

As we have shown in the use case description (see chapter 3.1), around a third of European households use satellite TV as their primary mode to receive TV programs. If satellite TV were not available, consumers could instead use

- HFC/cable networks: available to around 50% of households (41), offering a choice and quality almost as good as satellite TV (strongly depending on the cable network provider and build-out of the network)
- IPTV over broadband connections: with ADSL speeds only in SD quality and with only one or maximum two programs at a time (i.e., not supporting multi-screen homes); with VDSL also in HD quality but still limited in the number of parallel received channels
- DTT: available to more than 95% of homes in Europe, offers often limited choice in programming

Helios assumes a typical replacement cost of €300 to €600 per household and a mix of these technologies (see Figure 55). In total, the replacement cost for TV broadcasting in Europe would amount to €33 billion, which is then the minimum assumption for the value of the service in Europe. But it should be noted that in many cases the cost of replacement would be prohibitive (e.g., in rural areas) or the available information (i.e., number of channels) would be rather limited (DTT case).
<table>
<thead>
<tr>
<th>Replacement Technology</th>
<th>Share</th>
<th>Households</th>
<th>Cost per Household</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFC/Cable</td>
<td>30%</td>
<td>21 mn</td>
<td>€300</td>
<td>€6.3 bn</td>
</tr>
<tr>
<td>Cable with extension of coverage</td>
<td>5%</td>
<td>3.5 mn</td>
<td>€600</td>
<td>€2.1 bn</td>
</tr>
<tr>
<td>IPTV over broadband</td>
<td>30%</td>
<td>21 mn</td>
<td>€300</td>
<td>€6.3 bn</td>
</tr>
<tr>
<td>IPTV with extension of coverage</td>
<td>7.5%</td>
<td>5.3 mn</td>
<td>€600</td>
<td>€3.2 bn</td>
</tr>
<tr>
<td>DTT</td>
<td>12.5%</td>
<td>8.8 mn</td>
<td>€300</td>
<td>€2.6 bn</td>
</tr>
<tr>
<td>DTT with extension of coverage</td>
<td>15%</td>
<td>10 mn</td>
<td>€1,200</td>
<td>€12.0 bn</td>
</tr>
<tr>
<td>C-band replacement</td>
<td></td>
<td></td>
<td></td>
<td>€0.6 bn</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>70 mn</td>
<td></td>
<td>€33 bn</td>
</tr>
</tbody>
</table>

Figure 55. DTH replacement cost

Replacing TV broadcast in current and future quality would require around €100–140 billion

As explained, the replacement approach used above implies a degradation of received service for parts of the population. In order to provide the same service experience as today (big selection of channels, HD and in the future UHD quality), only HFC and fiber-based broadband could potentially replace the satellite experience. In order to provide this, a fiber roll-out to all households that use satellite today would be required. The costs for a Europe-wide fiber rollout are estimated between €200 billion and €280 billion (42).

Assuming an equal cost and usage distribution, a third of this amount will be required, amounting to €70–90 billion; a more reasonable estimate would be a 50% share (due to higher usage of satellite outside urban areas), equal to a cost of €100–140 billion. This can be same as the upper bound for the value of TV broadcasting in Europe.

4.3.2 Hybrid satellite broadband services could increase GDP by 3% in 2020

The value of broadband roll-out and adoption is widely understood and accepted; it is also one of the drivers of Europe’s Digital Agenda (15) and the proposed investments of €9 billion to accelerate the broadband roll-out (16).

Broadband adoption increase leads to economic growth

Several studies have been conducted to quantify the impact of broadband adoption in Europe. Micus (43) analyzed several adoption scenarios and showed that a single percentage point increase of the broadband adoption rate equals a GDP increase of around 0.37%. A more recent EPC study (44) came to similar conclusions, showing a net GDP impact of 4% over ten years (equal to around 0.4% increase per year).

Fiber and cable will not be deployed fast enough to achieve digital-agenda targets

Based on the expected economic effect of broadband, the Digital Agenda targets a 100% coverage of EU citizens with fast broadband (30 Mbit/s) and a 50% take-up of ultra-fast broadband (100 Mbit/s) by households by 2020.

The European FTTH Council analyzed the expected fiber maturity of countries (42 S. 15). They defined fiber maturity as a 20% connection rate of households, which across the European Union is expected for 2020, with single countries (e.g., Sweden, Denmark) reaching maturity as early as 2015 or 2016.

In parallel, Cable Europe expects to service 27% of households with ultra-fast broadband and 55% of households with fast broadband (41). Combining these two views leads to a potential ultra-fast broadband coverage of around 47% in 2020. Fiber and cable will also be able to serve around three-quarters of European households with

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54 Source: Helios (40)

55 Note: compared to today this would be significantly less cost efficient
fast broadband; newest DSL technologies (VDSL) will provide some additional coverage. But there will still be a gap between the reality and the 100% coverage target.

**Satellite broadband can help close the gap and accelerate the roll-out—leading to faster and stronger GDP growth**

Given the large coverage of satellites (almost 100% of European citizens could use satellite broadband today), satellite broadband can help to close the digital-agenda gap stated above. Specifically, a hybrid network setup, e.g., satellites in combination with mobile or DSL data access, is able to deliver a next-generation service experience as expected by the Digital Agenda.

Assuming hybrid networks including satellites are able close the coverage gap of fast broadband left by cable fiber, around 20% of European households could be included in the digital broadband ecosystem by 2020. In addition, the roll-out speed of a next-generation service experience would be significantly increased with hybrid solutions. Assuming hybrid networks increase the adoption rate of broadband by one percentage point, the European GDP would grow by around 0.4%. Since satellite coverage is available already today, this benefit would start immediately, leading to a cumulative estimated 3% increase of GDP by 2020.

### 4.3.3 Benefits beyond communications amount to €120 billion over twenty years

**Europe’s GNSS system, Galileo, is expected to contribute €90 billion over the next twenty years**

Galileo is the Programme of the European Commission to develop a global satellite navigation system under European civilian control. It will be compatible and, for some of its services, interoperable with the American GPS and Glonass (Russia), but operationally independent from them. (45)

The total navigation market today (including core and enabled markets) is around €120 billion and is expected to grow to almost €250 billion by 2020 (46). Based on an economic impact analysis, Galileo will contribute around €90 billion over the next twenty years (45).

**GMES earth observation will deliver €30 billion in benefits by 2030**

Booz & Company conducted a detailed socioeconomic benefit analysis of GMES (30). GMES (Global Monitoring for Environment and Security) is a joint undertaking of the European Commission, its member states, the European Space Agency (ESA) and the European Environment Agency (EEA). It is an earth observation program that seeks to develop operational information services in the fields of environment and security.

Based on this analysis, GMES will have an approximate net benefit of €30 billion from 2014 to 2030; depending on specific scenario also up to €50 billion are possible (see Figure 56). (By 2020, GMES will generate €10 billion in cumulative discounted net benefits). For further details see also Figure 60.
Figure 56. GMES benefits

Source: (30)
5. **Satellites and Policies**

Satellite services significantly contribute to European policies and their implementation. In addition, satellite communications are also closely regulated by policies that need to consider the special nature of these services, compared to terrestrial technologies. EU policies and instruments

5.1 **EU policies and instruments**

Governments of advanced economies have long relied on satellites for the implementation of their policies. To be sure, satellite systems and services support many of Europe’s most successful policies. Satellite systems’ attributes fit very well the pan-European and regional dimensions of European policies and can be leveraged for addressing policy monitoring in addition to policy implementation.

The broadcast capabilities of satellite systems are unique, and far reaching. Their distant positioning on orbital locations ignores borders and politics. Combining this with fast deployment of ground terminals, and footprints potentially extending far beyond European borders, satellites maintain links over the air independently of political troubles and turmoil. Satellites are a formidable rampart against discrimination and become an instrument to freedom. The built-in attributes of satellites open a world of possibilities from remote identification of ships to combat piracy, to regulating maritime traffic and preventing illegal imports, to providing essential air traffic management communications over oceanic regions. Satellite technology has been leveraged in immense ways to achieve free trade, free movement of goods and protection of the environment.

Government policies come in a variety of formats. Once strategic policy objectives are set, implementation is usually achieved via a set of instruments or combination thereof including: directives, initiatives with or without funding mechanisms and regulations. Often these instruments involve implementation of infrastructure, compliance monitoring of directives and enforcement of regulations and monitoring. Satellite communications, EO and GNSS systems and services may contribute to enhancing the infrastructure, or contribute as a tool to monitoring results and compliance.

- For instance, in the frame of the Common Fisheries Policy (CFP), the satellite-based Automated Identification System (AIS) can help keep track of fisheries and detect breaches of policy.
- Satellites contribute to broadband Internet, data access, data exchange, data collection, monitoring and empowerment. ICT is an enabler to most policies, and satellite systems are key components of a robust ICT mix.
- EO and remote sensing satellites are observing the earth, people, movements and soil displacement, and combined with advanced adhoc processing, can deliver mapping, enable forecast and predict catastrophic events.
- Satcom contributes to the improvement of European capacity to prevent or respond to natural or man-made crises, and ensure the security of persons and goods.

**The European Digital Agenda and the Common Security and Defense Policy all benefit from satellite systems**

The EU has long recognized the benefits of satellites and, as part of its space policy objectives, is supporting the development of satellites dedicated to the advancement of global navigation and global monitoring of the environment and security.

The Europe 2020 strategy is organized around a thematic approach focusing on seven initiatives in three categories: Smart Growth, Sustainable Growth and Inclusive Growth. The seven flagship initiatives require action at both the EU and member state levels. They are implemented though a set of actions, and through policy areas.
The Three Pillars of The Commission’ Europe 2020 Agenda
Relevance to Satellite Services

<table>
<thead>
<tr>
<th>I. Smart Growth</th>
<th>II. Sustainable Growth</th>
<th>III. Inclusive Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing an economy based on knowledge and innovation</td>
<td>Promoting a more resource efficient, greener and more competitive economy</td>
<td>Fostering a high-employment economy delivering social and territorial cohesion</td>
</tr>
</tbody>
</table>

Flagship Initiatives | Policy Area | Flagship Initiatives | Policy Area | Flagship Initiatives | Policy Area |
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>• Digital agenda for Europe</td>
<td>• ICT</td>
<td>• Resource efficient Europe</td>
<td>• Energy, Climate</td>
<td>• An agenda for new skills and jobs</td>
<td>• Employment &amp; social affairs</td>
</tr>
<tr>
<td>• Innovation Union</td>
<td>• Innovation</td>
<td>• An industrial policy for the globalisation era</td>
<td>• Mobility</td>
<td>• European platform against poverty</td>
<td>• Fighting Poverty</td>
</tr>
<tr>
<td>• Youth on the move</td>
<td>• Education</td>
<td></td>
<td>• Competitiveness</td>
<td></td>
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</tr>
</tbody>
</table>


Relevant initiatives

Figure 57. The three pillars of Europe 2020 Agenda

The table below synthesizes the contribution of satellite systems to the main EU policy areas.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Digital Divide and Broadband for all</td>
<td>Key enabler</td>
<td>Integral part</td>
<td>Fast deploy.</td>
<td>Integral part</td>
<td>Fast deploy.</td>
<td>Key enabler</td>
<td></td>
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<td>Digital Literacy</td>
<td>Key enabler</td>
<td>Integral part</td>
<td>Key enabler</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health Care</td>
<td>Integral part</td>
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</tr>
<tr>
<td>Emergency / eCall</td>
<td>Gap filler</td>
<td>Integral part</td>
<td>Fast deploy.</td>
<td>Key enabler</td>
<td>Fast deploy.</td>
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<td>Key enabler</td>
<td>Key enabler</td>
<td>Key enabler</td>
<td>Key enabler</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk Management</td>
<td>Key enabler</td>
<td>Key enabler</td>
<td>Key enabler</td>
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<tr>
<td>Climate Change</td>
<td>Integral Part</td>
<td>Fast deploy.</td>
<td>Gap filler</td>
<td>Key enabler</td>
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<tr>
<td>Energy / Smart Grid</td>
<td>Integral part</td>
<td>Fast deploy.</td>
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<td>Fast deploy.</td>
<td>Integral part</td>
<td></td>
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<td>Land Management</td>
<td>Integral part</td>
<td>Gap filler</td>
<td>Integral part</td>
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<tr>
<td>Agriculture Policy</td>
<td>Key enabler</td>
<td>Gap filler</td>
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<tr>
<td>Transport &amp; Mobility</td>
<td>Integral part</td>
<td>Fast deploy.</td>
<td>Integral part</td>
<td>Key enabler</td>
<td>Key enabler</td>
<td>Key enabler</td>
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</tbody>
</table>

Figure 58. Contribution of satellite solutions to European policies

Satellites are also great tools for establishing and monitoring the reciprocal influence of policies. For instance, agriculture is highly exposed to climate change, since farming activities directly depend on climatic conditions. The climate-change impact on agriculture can be monitored via satellite in order to inform and adjust agriculture policies. But, agriculture too contributes to the release of greenhouse gases and EO satellites provide useful feedback to climate-change policymakers.
EO satellites, and those used for GMES applications in particular, have the potential to deliver significant benefits across a number of European policy domains outside the space sector. The following table identifies satellite solutions that are highly relevant to the Europe 2020 agenda, and in most cases already commonly applied in the implementation of European policies and/or associated monitoring.

<table>
<thead>
<tr>
<th>Policy Area</th>
<th>Policy</th>
<th>Selected Policy Objectives</th>
<th>Satellite Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture, fisheries</td>
<td>Rural development policy</td>
<td>More than 91% of the territory of the EU is &quot;rural,&quot; and this area is home to more than</td>
<td>Sat broadband fast internet High precision GNSS EO for land management</td>
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<tr>
<td>and food</td>
<td></td>
<td>56% of the EU's population. Some of our farming and forestry businesses still need to</td>
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<td></td>
<td></td>
<td>build their competitiveness. The EU's rural development policy is all about meeting the</td>
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<td></td>
<td></td>
<td>challenges faced by our rural areas, and unlocking their potential.</td>
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<tr>
<td>Common Agricultural</td>
<td>The CAP can contribute more to</td>
<td>High precision GNSS EO for land management, and ensuring better compliance with funding</td>
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<tr>
<td>Policy (CAP)</td>
<td>developing intelligent, sustainable</td>
<td>conditions by recipients from the Common Agricultural Policy</td>
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<td>and inclusive growth. Continue to</td>
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<td>push the competitive and potentially</td>
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<td>competitive sectors of European</td>
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<td>agriculture towards operating in a</td>
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<td>market context, giving more</td>
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<td>importance to innovation and</td>
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<td></td>
<td>dissemination of research; The CAP</td>
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<td></td>
<td>needs to anticipate the economic,</td>
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<td></td>
<td>environmental and territorial</td>
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<td></td>
<td>challenges.</td>
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<tr>
<td>Forest Action Plan</td>
<td>Forests and other wooded land cover</td>
<td>EO for forest management and monitoring (species, yield) plant</td>
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<td></td>
<td>177 million ha (over 40% of the EU</td>
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<td></td>
<td>territory). Need to map, study and</td>
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<td></td>
<td>monitor forest biodiversity. Legislation enabling the development and harmonization of</td>
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<td>forest monitoring procedures. Need</td>
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<td>for collaborative research on the</td>
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<td>effects of climate change on forests</td>
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<td></td>
<td>and on how to minimize these impacts</td>
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<td></td>
<td>Better understanding of biodiversity</td>
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<td>(e.g., deforestation, desertification,</td>
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<td>threats to sensitive ecosystems) as</td>
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<td>expressed through the Biodiversity</td>
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<td></td>
<td>Action Plan</td>
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<tr>
<td>Common Fisheries Policy</td>
<td>EU rules to combat illegal, unreported</td>
<td>Satellite vessel monitoring systems (VMS) using GNSS + Satcom AIS (Automatic Identification by Satellite)</td>
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<td></td>
<td>and unregulated fishing</td>
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<tr>
<td>Business Enterprise</td>
<td>Satellite navigation to provide</td>
<td>GNSS Cost effective Sat Broadband to NGO</td>
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<td></td>
<td>accurate and guaranteed positioning</td>
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<td></td>
<td>for all types of civilian applications:</td>
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<tr>
<td></td>
<td>including car navigators, mobile</td>
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<td></td>
<td>phones, maritime, road, rail and air</td>
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<td>transport. European Standards to NGO</td>
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<tr>
<td>The Security Research</td>
<td>Primary goal is to protect Europe's</td>
<td>GNSS Satcom EO/GMES</td>
<td></td>
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<tr>
<td>and Innovation Programme</td>
<td>citizens and society from harm, while</td>
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<td></td>
<td>enabling its economy to recover from</td>
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<td></td>
<td>man-made or natural disasters</td>
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<tr>
<td>SME</td>
<td>SME are often located in underserved</td>
<td>Sat BB</td>
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<tr>
<td>Space</td>
<td>Effective space policy that will allow</td>
<td>Commercial satellite applic-</td>
<td></td>
</tr>
</tbody>
</table>

57 See Booz & Company Cost-Benefit Analysis for GMES (30)
58 The CAP towards 2020: Meeting the food, natural resources and territorial challenges of the future, COM(2010) 672 final
60 Fisheries Control technologies http://ec.europa.eu/fisheries/cfp/control/technologies/index_en.htm
<table>
<thead>
<tr>
<th>Policy Area</th>
<th>Policy</th>
<th>Selected Policy Objectives</th>
<th>Satellite Relevance</th>
</tr>
</thead>
</table>
| Climate action                  | Adaptation to climate change | Improve knowledge management to establish a Clearing House Mechanism as an IT tool and database on climate change impact, vulnerability and best practices on adaptation  
The Commission is currently examining ways to improve the monitoring of impacts and adaptation measures in order to develop vulnerability indicators.  
Agricultural adaptation: Crop rotation, rewarding farmers who carry out sustainable practices | Satcom  
GNSS  
EO monitoring, land mapping, GNSS for precision farming                                               |
| Health impact                   |                               | Improving knowledge of the connections between climate change and health; developing guidelines on the health impacts of climate change; reinforcing disease surveillance mechanisms (e.g., vector-borne diseases across the EU); improving cooperation between health authorities and international organizations. | Accurate mapping of mosquitoes carrying diseases in Europe (including chikungunya, dengue, West Nile) by satellite |
| Environment                     | The EU Water Framework Directive—integrated river basin management for Europe | Satellite EO monitoring in support of adaptation and mitigation policies through the production of Essential Climate Variables (ECVs) |                                                                                                                                                              |
| Regional and spatial planning   |                               | Knowledge and awareness of climate change impacts and how to best adapt to them varies considerably in different regions.                                                                                                                                                      | Satellite EO land mapping, flooding and landslide risk management                                      |
| Energy                          |                               | Impacts of climate change on both energy supply and demand  
Predict hydropower production imbalances between north and south of Europe                                                                                                                                   |                                                                                                                                                              |
| Cross-cutting policies          | Multilingualism               | Promote learning of languages                                                                                                                                                                                                | Multi-spot beam Satcom with regional content                                                          |
| Culture, education and youth    | Lifelong learning             | Promotion of lifelong learning                                                                                                                                                                                               | Broadband communication                                                                             |
|                                 | Audiovisual and media         | Media literacy  
Media pluralism                                                                                                                                                                                                            | Movie distribution via satellite                                                                        |
| Economy, finance and tax        | International                 | An effective enforcement of EU competition policy in a global environment requires intensive cooperation with competition authorities outside the EU. The European Commission cooperates closely with competition authorities of countries outside the EU, both on policy and enforcement issues of mutual interest | Broadband communications in support of capacity building actions in particular with enlargement countries |

62 Vecmap tracks the Asian bush mosquito http://www.esa.int/esaTE/SEM1NLYP5H_index_0.html
63 http://ec.europa.eu/competition/international/overview/index_en.html
| Energy and natural resources | Energy roadmap | The EU is pursuing an ambitious energy policy—covering the full range of energy sources from fossil fuels (oil, gas and coal) to nuclear energy and renewables (solar, wind, biomass, geothermal, hydro-electric and tidal)—in a bid to spark a new industrial revolution that will deliver a low-energy economy, whilst making the energy we do consume more secure, competitive and sustainable. Smart Grid Energy infrastructure priorities for 2020 and beyond | Satcom for energy grid resilience GNSS for synchronization of energy grid Weather and EO for land mapping and resource management (wind mapping and prediction) |
| Environment, consumers and health | ECHO | Humanitarian aid, based on the principles of humanity, neutrality, impartiality and independence Civil protection | EO, GNSS and Satcom are essential to prediction, response and reconstruction associated with major natural disasters (through the Space and Major Disasters Charter and the Community Civil Protection Mechanism) |
| External relations and foreign affairs | EUROPAID | Building confidence in and enhancing the reliability and transparency of democratic electoral processes, in particular through monitoring electoral processes64 Strengthening the role of civil society in promoting human rights and democratic reform, in supporting the peaceful conciliation of group interests and in consolidating political participation and representation | Connectivity for NGOs Satcom broadband access, DTH Satcom broadband access, DTH |
| Science and technology | Digital Agenda | Digital single market: the objective is to boost the music download business, establish a single area for online payments, and further protect EU consumers in cyberspace65 Trust and security Research and innovation ICT for social challenges | Satcom in the technology mix of core networks, contribute to bridge digital divide Satcom contribution to resilient networks GNSS and GMES applications have the potential to lead to significant markets Adopt the Air Traffic Management Solutions for (SESAR) including safety of life Satcom for oceanic and congested airspace |
| Audiovisual and Media | | | Broadcast |
| Transport and travel | Transport | Intermodal transport | GNSS for air traffic management, in-vehicle navigation and tracking Satcom for vehicle tracking M2M for logistics |

Figure 59. European policies areas and relevance of satellites

64 http://ec.europa.eu/europeaid/how/finance/eidhr_en.htm
As part of the industrial policy initiative of the Europe 2020 agenda, the EU is also defining its space policy to provide the tools to address some of the key global challenges and in particular to deliver Galileo and GMES. Although designed to be institutional, the GMES program is expected to generate €10 billion in cumulative discounted net benefits by 2020 and €30 billion by 2030, should the EC push ahead with GMES full-continuity scenario in which satellites are continuously replaced at their end of life and full investment in services is foreseen. These benefits would stem in part in the longer term from the ecosystem of service companies developing product and services exploiting open-data policies designed to ensure maximum public benefit from the GMES space assets.

<table>
<thead>
<tr>
<th>GMES Contribution to “Europe 2020” objectives</th>
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</thead>
<tbody>
<tr>
<td>GMES Service Area</td>
</tr>
<tr>
<td>Marine Resources</td>
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<tr>
<td>Marine &amp; Coastal Environment</td>
</tr>
<tr>
<td>Climate &amp; Seasonal Forecasting</td>
</tr>
<tr>
<td>European Land Cover &amp; Land Use</td>
</tr>
<tr>
<td>Spatial Planning</td>
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<tr>
<td>Agri-Environment</td>
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<tr>
<td>Water Monitoring</td>
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<td>Forest Monitoring</td>
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<tr>
<td>Land Carbon Monitoring</td>
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<tr>
<td>European Air Quality</td>
</tr>
</tbody>
</table>

Figure 60. GMES contribution to Europe 2020 objectives

5.2 Considerations for future policies

Spectrum policy needs to consider the bandwidth requirements of satellites
Future policy needs to consider satellite communications as one of the prime technologies to distribute HD and Ultra-HD linear TV content to consumers in Europe. Capacity (spectrum) needed for this purpose needs to be reserved for TV channels, since these can be distributed most efficiently as DTH broadcast. In addition, for satellite news gathering, capacity in the right spectrum needs to be protected from terrestrial interference to allow uncensored reports from around the globe.

Policies need to enable hybrid solutions and not negatively impact their roll-out
Europe’s Digital Agenda foresees a wide-scale broadband roll-out and adoption in order to enable economic growth driven by the next level of digitization. A challenge for policymakers is to design policies that are technology neutral and cost optimal, since the next-generation service experience requires bandwidths that can be delivered by only few technologies today.

But this intended service experience is also possible with hybrid networks, which combine multiple technologies into one solution: for example, terrestrial-satellite or mobile-satellite hybrids. These would allow a cost-efficient service delivery, requiring less roll-out of costly fiber and leveraging the unique efficiency of satellite technology.

In order to enable these hybrid networks, policymaking needs to foresee the option of combining technologies on different levels, from the last mile to direct broadcast to mobiles to content distribution in backhaul networks.

66 Towards a Space Strategy for the European Union that Benefits its Citizens (56)
One example would be broadband roll-out aid in rural areas. A next-generation service with a net ultra-fast bandwidth could be enabled by a hybrid system of 3G or LTE for Internet data access together with satellite broadcast for HDTV and large data-file distribution. This would require development of new home gateways but could still speed up the roll-out and improve the take-up rate of ultra-fast broadband.
Appendix

A. How to build a satellite service — technology introduction

In this section, the technology behind satellites will be described, including a short introduction to spectrum requirements for communications satellites.

A.1 Determine the use case — satellite platforms

Satellites can be defined and clustered in different ways. In this report, we will define satellites simply as man-made (i.e., artificial) objects with communications capabilities in an orbit around the earth, excluding manned space stations and human spacecraft (spaceships). Within this definition, around 2,500 satellites are currently orbiting the earth, wherein several groups of satellites can be identified:

- Communications satellites, which can be further divided based on their specific use case (including military communications satellites)
- Navigation and positioning satellites
- Earth observation satellites including weather satellites
- Scientific research satellites (e.g., astronomical satellites)
- Special military satellites, mainly for surveillance but also “killer satellites”

Some of these satellites (especially for scientific research) are mainly developed by public agencies like ESA or NASA, but communications satellites, for example, are often developed and operated commercially. A special case are earth observation (EO) satellites, which until recently were mainly developed by government for security purposes or by agencies as research platforms to perform remote sensing. But the last decade has seen private investment directed at EO satellites (e.g., GeoEye), but agencies continue funding complex projects (e.g., ESA’s Sentinels).

Satellite platform overview

Excluding special military and scientific research satellites, satellite platforms can traditionally be classified into five broad categories with distinct service. Figure 61 provides an overview and description of these three communications-related (BSS, FSS, MSS) and two non-communications (EO, GNSS) categories.

---

67 Note: technical introduction and description based on (53)
<table>
<thead>
<tr>
<th>Platform</th>
<th>Service</th>
<th>Description</th>
<th>Business Model</th>
<th>Example Customers</th>
</tr>
</thead>
</table>
| Broadcast Satellite Services (BSS) | Broadcast and Multicast Services | • Provision of video and audio channels to end users  
• Video and audio content exchange between and among content providers and broadcasters | • Consumer pays for TV access  
• Broadcaster pays for broadcast capacity (free to air/FTA TV)  
• Broadcasters pay for video contribution capacity | • Pay TV subscribers  
• FTA broadcasters  
• Broadcasters and news gathering operators  
• Telecom operators |
| Fixed Satellite Services (FSS) | Network Trunking | • Provision of bundled point-to-point voice and data capacity in networks for Telco operators  
• Typically on thin traffic routes where terrestrial networks are insufficient or to bypass specific Telco carriers | • Telecom operators pay for bandwidth | • Telecom operators |
| Corporate and Govt. Networking | | • Point-to-point connectivity between establishments | • Enterprises pay for bandwidth consumed | • Industries with remote operations (e.g., offshore oil platform)  
• Industries requiring dedicated closed networks over dispersed locations (e.g., credit card networks) |
| Military Communications | | • Military surveillance and radio communications  
• Humanitarian aid organization radio communications | • Government funded | • Militaries  
• NGOs (e.g., humanitarian efforts) |
| Consumer Broadband | | • Direct end-user data access service (i.e., direct to home Internet) | • Users pay for bandwidth | • Satellite broadband subscribers |
| Mobile Satellite Services (MSS) | Mobile Voice, Audio and Data | • Direct end-user voice, audio and data access service to a mobile terminal (e.g., satellite phone) | • Users pay for bandwidth or by the minute for voice | • Mobile satellite phone customers  
• Aviation and shipping industries |
| Earth Observation (EO) | Earth Observation | • Science-based applications (e.g., weather, terrain mapping)  
• Reconnaissance and intelligence missions | • Government funded or public-private partnerships  
• Users pay for data or images | • Military and homeland security  
• NGOs  
• Research organizations (e.g., academia) |
| Global Navigation (GNSS) | Global Navigation and Positioning | • Geospatial positioning (i.e., GPS, GLONASS, Galileo) | • Government-funded or private operator  
• Users pay for access to positioning systems | • Government and militaries  
• Aviation industry  
• GPS consumers |

Figure 61. Classification of satellite platforms

It is important to note that the traditional platform (BSS, FSS, MSS) nomenclature can refer to two aspects: (1) a specific spectrum (there are clear distinctions between spectrum for BSS, FSS and MSS, see section A.3) or (2) the on-board architecture. In this report, the platforms refer to the architecture/purpose of the satellite.

A warning to the reader: Since spectrum and platforms do not have to be linked, the use of this nomenclature can be misleading and may no longer reflect the current use (i.e., TV broadcast was traditionally BSS and used specific BSS spectrum, whereas today, it also uses FSS spectrum and can be received by mobile users).

**Satellite orbits**

One of the major architecture levers is the orbit of the satellite, meaning the distance of the satellite from the surface of the earth (or, technically, from the earth’s axis). Three main options are relevant for satellite services today:

- **Geostationary earth orbit** (GEO, 35,786 km), a unique orbit directly above the earth’s equator. GEO satellites rotate around the earth’s axis every twenty-four hours, and from a ground perspective they appear fixed (i.e., antennas only need to be pointed at them once at installation, with no tracking required). Satellites in a geostationary orbit can cover up to 40% of the earth’s surface and a constellation of three satellites spaced 120 degrees apart can provide services around the globe.68 Compared to other orbits, the latency of communications is higher (around 250 ms for up/down link) and the look elevation angle (of the satellite dish on the ground) at very high latitudes is poor.

---

68 Note: due to Earth’s curvature, service around the north and south poles are limited with GEO satellites. Special polar orbits are used to achieve reliable service in these regions.
- **Medium earth orbit** (MEO, from 2,000 km up to GEO). Satellites in these orbits rotate around the earth every 2–24 hours, depending on altitude. Global coverage in these orbits can be achieved with a small constellation (depending on the exact orbits, around eight satellites can achieve almost global coverage; 10–15 satellites can maintain constant global coverage). For communications purposes, MEO has significantly lower latency (around 100 ms) and better look angles than GEO, though satellites normally have a lower in-orbit lifetime and ground stations need to be more complex to track the satellites.

- **Low earth orbit** (LEO, below 2,000 km). Satellites rotate around the earth every 1–2 hours, depending on altitude. This orbit has good optical properties for earth observation and enables low latency for communication. To achieve global coverage, however, a large number of satellites are required and two-way transmission is difficult, as individual satellites are only visible for a few minutes (i.e., regular handovers from one satellite to the next are required, and parabolic antennas have to follow the satellite). On the other hand, free-space loss is very low and small-gain antennas can be used on the ground. LEO satellites have a short in-orbit lifetime due to orbit degradation (atmospheric drag).

For each of the above-mentioned satellite platforms, orbits can either be favorable (e.g., for broadcasting services, a high coverage area is relevant) or of only limited use. Figure 62 shows an indicative overview of orbits and the relevant services.

![Satellite Orbits](image)

**Platforms vs. Satellite Orbits**

<table>
<thead>
<tr>
<th>Orbit</th>
<th>BSS</th>
<th>FSS</th>
<th>MSS</th>
<th>EO</th>
<th>GPSS</th>
</tr>
</thead>
</table>
| GEO    | • Provides large coverage area per satellites  
         • Ideal for broadcast and communication services | | | • Only for weather satellites | |
| MEO    | • Can provide (almost) global coverage area with a constellation of satellites  
         • Latency advantages | | Planned services  
         but not yet operational | |  
         • Provides “global” & “polar” coverage with fewer satellites required |
| LEO    | • Smaller coverage area per satellite  
         • Latency and optical advantages due to lower orbit | | | | |

Figure 62. Satellite orbits and relevant platforms

### A.2 Building communications satellite systems

A very important type of satellite is the communications satellite. Today, these provide traditional satellite TV (DTH) as well as communications services to stationary and mobile receivers. Communications satellites generally act as a switch (i.e., directing an incoming data stream to the correct outgoing stream) and signal amplifier for many types of transmissions. Figure 63 shows the layout of a satellite communications system.
If for example, should a communications satellite be used to broadcast a TV program, the following steps will take place:

1. The earth station of the satellite operator provides ongoing operations and monitoring of the satellite. The operator would also program any settings required for the transmission (e.g., activating amplifiers for certain frequencies, pointing beams toward the right region). All this communication happens via the TT&C (telemetry, tracking and command) connection, a reserved frequency for this type of communication with the satellite.

2. The TV broadcaster delivers the program via terrestrial networks (or via separate satellite communication) to one of the earth stations of the operator or a third party who is able to communicate with the satellite.

3. The video content is then staged and compressed at the earth station of the service provider (broadcast center), i.e., prepared for a transmission to the satellite.

4. The prepared data stream with the video content is then transmitted to the satellite (uplink).

5. In orbit, the satellite receives, translates, amplifies and retransmits the video content to multiple DTH receivers (downlink).

6. Dishes (DTH satellite antennas) on earth receive, amplify and filter the broadcasted signal.

7. Receivers demodulate, convert and decode the signal into video to be routed to the TV.

Based on this example, it is easy to see that a typical satellite communications service requires five key assets: the satellite, an orbital location and frequency rights for transmission, earth stations to transmit data to the satellite, a TT&C center or network and customer terminals/customer-premises equipment (CPE).

To develop a full satellite system as described above (space segment/satellite, launch, ground segment to operate, service segment), the costs can reach €300–500 million, but it can cover a continent with broadcast and data services.
Design, manufacturing and launch of a satellite

The satellite itself is of course the key requirement for any application. Satellites are developed and built by a number of specialized manufacturers, in collaboration with the satellite operator who ordered it. The cost for the satellite itself is up to €200–300 million for GEO, depending on the exact specifications.

Satellite architecture

Generally, a satellite consists of several components, broadly falling in two categories (47):

- **Spacecraft bus or service module**: the components to operate the satellite (basic structure, telemetry/TT&C, power, thermal control, attitude control)

- **Communication payload**: a number of antennas and transponders, where each is capable of:
  - Receiving uplinked radio signals from earth satellite transmission stations (antennas)
  - Amplifying received radio signals
  - Sorting the input signals and directing the output signals through input/output signal multiplexers to the proper downlink antennas for retransmission to earth satellite receiving stations (antennas)

For the purpose of communications, only the payload/transponders are relevant; the bus just “keeps the satellite in the air.”

Transponders and beams

In the past, transponders mainly acted as “bent pipe,” i.e., only amplifying and frequency shifting received signals and relaying them back to earth. In newer satellite systems, regenerative transponders apply on-board processing of the signal (i.e., demodulate and decode the received signal, reencode and modulate for sending). These generative transponders have a number of advantages:

- Improved quality and capacity (better signal-to-noise ratio, at low baseband frequencies, better amplification properties)
- Flexible and dynamic routing of messages
- Options to combine several (low bit rate) data streams into one, high data-rate outgoing streams
- Better network interconnectivity
- Independent optimization of uplink and downlink

In case of geostationary satellites, there are furthermore different beam types possible (i.e., how the antenna transmits the signal to the ground):

- **Global beam**: covers 42.4% of the earth’s surface, distributing the power over a large area and therefore requiring larger antennas for reception.

- **Hemisphere beam**: covers up to 20% of the earth’s surface.

- **Spot beam** (sometimes also zone beam): covers less than 10% of the earth’s surface. The satellite power can be concentrated on a small area, making possible smaller receiving antennas.

To enable more targeted and efficient operation, modern communications satellites use multi-spot beam technologies (see Figure 64), i.e., implement several spot beams to achieve a big overall coverage area but with several, high-power beams (which also enable frequency reuse).

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69 Transponder is short for transmitter/responder, often abbreviated as TP or XPDR. A transponder typically is composed of filters, amplifiers and frequency translators.
Spare satellites and launch

After development and construction, the communications satellite has to be launched, brought into the right orbit and orbital slot and kept stationary during the lifetime of the satellite.

Since satellite launches have a failure rate of around 10% (including both launch failure and satellite malfunction), some operators build a ground spare in parallel to the production model. In case of a launch failure, this would speed up the time to market by around two years (assuming a launch of the spare around one year after the failure versus around three years to manufacture a new satellite without a ground spare). But of course this adds an additional €200–300 million of cost for the operator.

The launch itself is conducted by a space transportation company (e.g., Arianespace or International Launch Services) with a launch vehicle (aka rocket, e.g., Arianne or Proton). Each launch vehicle normally carries more than one satellite (depending on the mass and intended orbit). The cost for a launch per satellite is around €100 million, optionally with launch insurance for an additional 10–15% of the satellite and launch cost (i.e., up to 15% of €400m, equal to €60m).

After launch, the satellite is in a temporary orbit and uses its own fuel to reach the final orbit (under control of the satellite operator’s TT&C). As soon as the satellite is in orbit, it continues to use fuel to keep its exact position, since gravitational difference or atmospheric drag would otherwise degenerate the orbit. Note that the fuel is used only to keep the orbit; all required energy for the satellite operations is generated with solar panels.

Satellite life/timeline

A satellite has a lifetime of fifteen years, mainly limited by available fuel and the lifetime of solar panels and batteries. With an additional two to four years of construction and planning before launch, the total time from initial specifications to retirement can be more than twenty years. It is important to note that, after launch, specifications cannot be changed (i.e., not like in mobile phone systems where you can upgrade to the next software and hard-
ware).\textsuperscript{71} What's more, a change of specifications after the start of construction is at the least difficult and costly, and sometimes not possible (e.g., significant changes to transponder and antenna design).

During the time a satellite is in orbit, the operator can make adjustments only within the construction and design limits (which can be very narrow for older or specialized systems):

- Change beams (e.g., use of different beams and antennas to manage coverage)
- Reconfigure transponders (e.g., use of slightly different frequencies and bandwidths, depending on capabilities of the transponder)
- Change orbital positions (i.e., not from MEO to LEO or GEO, but only the specific slot within the orbit)

At the end of the satellite's lifetime, it is decommissioned in one of several ways, depending on the orbit. For geostationary orbits, the last fuel reserves are used to push the satellite out into a graveyard orbit (several hundred kilometers outside the GEO orbit), where the satellite remains in a stable orbit. For satellites in lower orbits, a controlled reentry is used, in which the satellite decomposes (melts) while entering the atmosphere. These decommissioning efforts take up significant fuel reserves and therefore reduce the usable lifetime of a satellite by several months. Space operators take these steps to prevent "space junk" from cluttering orbits for the future.

**Acquisition of orbital location and frequency rights**
This section is about the resources that are necessary to establish and operate the service infrastructure:

- Orbital location
- Frequency rights (frequency coordination)
- Landing rights (for some countries/regions)
- Licenses (depending on the service, these might not be required)

From a use-case perspective, this means the operator secures the first two resources and then negotiates the landing rights in relevant countries. The user of a service has to obtain a license from its regulator to use the service; in some cases, the license procedure is waived (for reception only).

\textsuperscript{71} Note: Flexible new technology allows reprogramming of the satellite software and even of HF functions where frequency bands can be adjusted after launch, protocols can be upgraded, etc., but this is not yet mainstream and not available for satellites already in orbit.
**Figure 65. Orbital slot and frequency rights**

**Setup of earth stations and control of the satellite**

The earth or ground stations act as a gateway between the customers and satellites, i.e., they connect the satellite to the Internet backbone of the ISP. Earth stations host key network management functions that determine end-user data rates and service quality and contain a network operations center (NOC) that monitors service quality and acts as second line of customer support.

Satellite operators normally operate a few of their own ground stations, but also leverage third parties to provide a point-of-presence close to the customer. These third party ground stations are normally operator neutral, i.e., provide access to a range of satellites/satellite networks.

**TT&C**

The tracking, telemetry and control center is responsible for the operations and maintenance of the spacecraft; typically, one TT&C center is sufficient for a fleet of regional satellites. The TT&C center can also act as a “normal” ground station, providing services for customers. In addition, it performs several tasks to control the satellite:

- Used for operations and maintenance of the satellite
- Monitors in-orbit satellite position
- Monitors system status of spacecraft
- Manages alerts, upgrades, new service deployments
- Manages satellite position shifts, new satellite deployments

**Preparing the use—customer-premises equipment (CPE)**

Customer-premises equipment is used to receive and convert satellite signals into services for consumption by end users. It normally consists of a satellite dish (antenna) and a decoder/modem (used to convert signals).
Depending on the application, the decoder/modem has different uses:

- Converts high frequency satellite signals into IP traffic that is capable of being fed to a normal PC or other terminal
- Converts satellite signals into formats that can be fed to standard televisions
- Converts satellite signals into IPTV services

CPE equipment is produced by a range of manufacturers and based on industry standards. In recent years, cost for customer equipment (especially receivers but also VSAT) has decreased due to mass production leveraging scale effects and newer manufacturing technologies.

A.3 Securing Spectrum

Communications satellites rely on radio waves for communication. Due to the distance from the receiver (up to 40,000 km), the signal from a satellite can be quite weak and is therefore vulnerable to interference from terrestrial wireless communication. Therefore, only specific radio waves, which are standardized and protected from alternative uses, are used for communicating with satellites.

**Satellites require specific microwave spectrum for communications with earth**

In order for a satellite to be able to communicate with the ground, it uses radio in the microwave spectrum. The main reason for the choice of spectrum (i.e., wavelength and frequency of the radio waves) is the opacity of the atmosphere to electromagnetic waves. As Figure 66 shows, the earth’s atmosphere is mainly transparent to visible light (terahertz waves) and radio waves from around 20 MHz to 40 GHz.

Taking into consideration terrestrial usage and therefore available bandwidth, frequencies below 1 GHz are not relevant for satellite applications (with the exception of TT&C purposes during transfer to orbit). In addition to atmospheric opacity, rain fade affects frequencies higher than 10 GHz—the higher the frequency, the stronger the effect. Therefore, the frequencies for satellite services are practically limited to around 1-30 GHz, with critical services mainly using spectrum below 10-15 GHz.

![Figure 66. Atmospheric electromagnetic opacity](http://en.wikipedia.org/wiki/File:Atmospheric_electromagnetic_opacity.svg)

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72 V band (50–75 GHz) is being explored as innovative path for future services

Satellite spectrum is and needs to be internationally standardized and managed to avoid interference
These usable frequencies for satellite communications have been standardized by the ITU in specific bands for services. Some of these frequencies are today exclusive to satellite use (especially higher bands), though most are shared with terrestrial wireless systems. Figure 67 shows an overview of the frequency bands used for satellite communications in Europe and typical terrestrial applications using the same bands. As can be seen, not all bands are used for all satellite applications. Due to the above-mentioned physical properties (e.g., rain fade) and standardization, certain bands are used for certain satellite platforms, as detailed in Figure 68.

<table>
<thead>
<tr>
<th>Band and Spectrum Region</th>
<th>Frequency Range used by satellites in Europe</th>
<th>Satellite Application</th>
<th>Terrestrial Application (examples)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L band 1–2 GHz</td>
<td>1.5–1.7 GHz (137 MHz used)</td>
<td>Mobile voice service (“satellite phone”)</td>
<td>1.5 GHz: T-DAB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mobile satellite media and data services (two-way)</td>
<td>1.7–2.0 GHz: GSM (DCS 1800 and PCS 1900)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Medium bandwidth transportable data services</td>
<td>1.9 GHz: DECT (cordless phones)</td>
</tr>
<tr>
<td>S band 2–4 GHz</td>
<td>2.0–2.5 GHz (77.5 MHz used)</td>
<td>Mobile voice service (“satellite phone”)</td>
<td>1.9–2.2 GHz: UMTS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mobile satellite media and data services (two-way)</td>
<td>2.4–2.5 GHz: ISM band (e.g., Bluetooth, WiFi, home automation systems based on ZigBee)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.4–3.6 GHz: WiMAX</td>
</tr>
<tr>
<td>C band 4–8 GHz</td>
<td>3.4–6.6 GHz (2,130 MHz used)</td>
<td>Fixed satellite television (including distribution between broadcasters) and data backhauling/trunking services</td>
<td>3–5 GHz: Ultra-wideband wireless personal area networks (IEEE 802.15.4a)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5.7–5.9 GHz: ISM band (e.g., WiFi)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6–10 GHz: Ultra-wideband wireless personal area networks</td>
</tr>
<tr>
<td>K(_b) band 12–18 GHz</td>
<td>10.7–15.4 GHz (2,800 MHz used)</td>
<td>Fixed satellite television and data services (including broadcasting)</td>
<td></td>
</tr>
<tr>
<td>K(_a) band 18–40 GHz</td>
<td>17.3–30 GHz (3,400 MHz used)</td>
<td>Fixed satellite data services</td>
<td>24 GHz: Radar sensors, e.g., for automotive applications</td>
</tr>
</tbody>
</table>

Figure 67. Frequency bands used for communications satellites in Europe

Note to Figure 67: Terrestrial applications use spectrum above 6 GHz are very limited due to the non-preferable conditions, e.g., line of sight requirement, limited indoor coverage/limited penetration of obstacles, attenuation due to atmospheric condition (water vapor, rain fade or high pollen count) and propagation loss (limited reach/requirement for high sender density).\(^76\)

\(^74\) Spectrum regions according to ITU definition (64); combining K and K\(_a\) into K\(_a\)

\(^75\) Based on (48) and (40)

\(^76\) The free-space path loss increases with the frequency of a signal (quadratic growth)
<table>
<thead>
<tr>
<th>Platform</th>
<th>Service</th>
<th>L-Band (1-2 GHz)</th>
<th>S-Band (2-4 GHz)</th>
<th>C-Band (4-8 GHz)</th>
<th>X-Band (8-12 GHz)</th>
<th>Ku-Band (12-18 GHz)</th>
<th>Ka-Band (18-40 GHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSS</td>
<td>Broadcast Services</td>
<td></td>
<td></td>
<td></td>
<td>Incumbent legacy band</td>
<td>Incumbent for broadcasting in Europe and MENA</td>
<td>Emerging technology making more efficient use of spectrum</td>
</tr>
<tr>
<td>FSS</td>
<td>Network Trunking</td>
<td></td>
<td></td>
<td></td>
<td>Wide coverage</td>
<td>More susceptible to rain-fade</td>
<td>Enables smaller dishes and higher bandwidth</td>
</tr>
<tr>
<td></td>
<td>Corporate &amp; Govt. Networking</td>
<td></td>
<td></td>
<td></td>
<td>Requires larger dishes to receive signal</td>
<td>Not impacted by heavy rain or adverse climate conditions</td>
<td>Highly susceptible to rain-fade</td>
</tr>
<tr>
<td></td>
<td>Military Communication</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Consumer Broadband</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSS</td>
<td>Mobile Voice, Audio &amp; Data</td>
<td></td>
<td></td>
<td></td>
<td>Smaller antenna w/ coarse pointing</td>
<td>Used in niche &amp; emerging mobile services</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Earth Observation</td>
<td></td>
<td></td>
<td></td>
<td>Little to no attenuation due to rain</td>
<td>Used for radar</td>
<td>Used for radar</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Limited bandwidth allocated for mobile satcom</td>
<td>Not impacted by rain</td>
<td>Attenuation problems in heavy rain</td>
</tr>
<tr>
<td>Global Positioning</td>
<td>Global Navigation &amp; Positioning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Emerging technology for high bandwidth services</td>
</tr>
</tbody>
</table>

Figure 68. Platforms vs. transmission frequencies

Satellite technology has been specifically developed and optimized for spectrum efficiency

Satellite operators are aware of the scarcity of spectrum and its status as public good. In order to improve the efficiency of satellites’ spectrum use, several measures have been taken in recent years (48).

- **Transponder technology.** New satellites make it possible to use the same frequency band by more signal amplifiers (transponders), resulting in increased transmission capacity.

- **Digital transmission.** With the switch to digital TV and digital data transmission, new modulation and coding techniques can be applied, which are significantly more efficient than analog transmission. Encoding data streams with the newest DVB-S2 standard for video and data transmission increases the useful bit rate by at least 30% compared to the previous standard DVB-S and is already very close to the theoretically achievable maximum (Shannon limit). (49)

- **Spot beams.** In order to reuse the same frequencies in different regions, spot beams are used. A single beam only covers a limited area and so the same spectrum can be used in a second spot beam covering a different region (comparable to cell towers reusing spectrum in a mobile phone network).

- **Reuse of spectrum in different orbital slots.** Geostationary satellites separated by a minimum distance (measured in degrees along the orbital arc) can share or reuse the same frequencies (in high bands) in the same footprint. Users of the service select the right service by pointing their antenna to the right orbital position.

- **Trading.** The satellite industry is trading orbital positions and lease capacity to third parties as wholesalers.

Satellite spectrum has limited economic value for terrestrial use but high social value due to use cases

As already described in the last section, it is important to remember that satellites are normally optimized to work in one or two bands (for specific missions, satellites support up to four bands). Currently, these frequencies cannot be changed after the design and build and will be used during the whole lifetime (i.e., around fifteen years) after launch. (In the future, flexible payloads should enable re-programming the frequencies to a certain extent.) It is therefore of importance to coordinate terrestrial frequency allocations with current and future space band allocations. Furthermore, planned changes (especially for terrestrial wireless services) should be well prepared and coordinate globally as GEO satellites (especially in lower frequency bands) can cover many countries and regions at once.
The economic value of spectrum beyond 3 GHz is low due to disadvantageous propagation characteristics. On a high level, the value of spectrum depends significantly on the physical propagation characteristics: the permeability (the ability to penetrate objects) and line-of-sight requirements. As a rule of thumb, frequency bands that can penetrate objects and don’t require a free line of sight to the sender have a higher value than frequencies that are easily blocked by objects and require a clear line of sight. Furthermore, the frequencies blocked by the atmosphere have a lower value. A study by the New America Foundation (50) analyzed the actual and potential value of spectrum in the US. This analysis showed an almost steady value of spectrum from 0 MHz up to 2 GHz, which then starts to decline, with a significant drop around 3 GHz and reaching bottom at around 5 GHz.

For Europe, Helios analyzed the economic and social value of satellite spectrum in detail (40). Helios concludes that technically, satellite services are at least as efficient as terrestrial mobile services, and the relative economic value of spectrum for satellite services strongly depends on the usage and the frequency band. Satellite-used spectrum, also in low bands, has a high social value with services like broadcast or emergency communication.

As the Radio Spectrum Policy Group (RSPG) and the Body of European Regulators for Electronic Communications (BEREC) have identified, not only the economic but also the social value (i.e., the value that is not captured by the price paid resulting from spectrum assignment) of spectrum needs to be considered and balanced. In making choices between technologies or applications for a frequency band, it is appropriate to assess the social value of such elements. This means that the benefits of the application or technology to society as a whole should be evaluated e.g., in terms of development, culture, research activity, environment, security and safety. (38)

Regulators must not only pay attention to the private values of bidders (which reflect the private benefits, such as profits, that bidders expect to receive from using the radio frequency spectrum), but also to the social value (the value to society, as measured for instance by consumer surplus or increase economy-wide output) created by particular firm’s use of radio frequency spectrum. (39 S. 11)

There is a balance to be found between setting coverage obligations at a level which achieves wide scale access to broadband services, thereby releasing significant social value, but also allowing services that use the spectrum to achieve their highest possible economic value. (39 S. 26)

RSPG and BEREC, noting the challenge in defining the metrics and measurements for social value, identified the development of economic, social and possibly cultural phenomena as drivers of social value. Based on their assessment of national experiences, several criteria for social value were used in previous spectrum assignments:

- Type of use of spectrum, e.g., whether they provide public services as in the case of broadcasting [Spain]
- Social relevance of the service [Spain]
- Impact on social cohesion (e.g., as radio and television broadcasting services) [Portugal]
- Availability of service vital to society [Denmark]

Given the use cases of satellite spectrum, Helios suggests that the social effectiveness for L and Ku bands is rather high. Based on the analysis of satellite use cases (see chapter 4), which takes above-mentioned factors into account, we generally would agree on a high social value for spectrum used by satellite services.

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77 The social value is linked to benefits from the trade-off generated by the decision to release spectrum for an electronic communication service, which will allow for a number of intrinsically related developments of economic, social and possibly cultural phenomena […] (39 S. 11)
Glossary


BSS: Broadcast Satellite Services. Provision of video and audio channels to end users or video and audio content exchange between and among content providers and broadcasters

DTH: Direct to Home

DTT, also DTTV: Digital Terrestrial Television

DVB: Digital Video Broadcasting. A suite of internationally accepted open standards for digital television (including transmission of audio, video and data)

DVB-SH: Digital Video Broadcasting—Satellite Services to Handhelds. A standard for delivering media and data from satellites to handheld devices on L or S band

EGNOS: European Geostationary Navigation Overlay Service. A satellite based augmentation system, supplementing GPS, GLONASS and Galileo by reporting on the reliability and accuracy of the positioning data.

EO: Earth Observation

ESA: European Space Agency. An intergovernmental organization dedicated to the exploration of space. http://www.esa.int


FSS: Fixed Satellite services. Provision of video, audio or data services to fixed ground stations

FTA: Free-to-air

GEO: Geostationary Earth Orbit (35,786 km), directly above the earth's equator. GEO satellites rotate around the earth's axis every 24 hours, from a ground perspective they appear fixed.

GNSS: Global Navigation Satellite System

HDTV: High-definition television uses a resolution that is significantly higher than SDTV (typically 720p, 1080i or 1080p)

ISI: The Integral Satcom Initiative. ISI is the European Technology Platform on Satellite Communications, whose membership encompasses a major part of the relevant private and public stakeholders from the satellite communications (SatCom) and space sectors in Europe. http://www.isi-initiative.org

ISM: Industrial, Scientific and Medical Band. Spectrum originally designated for purposes beyond communications (e.g., microwave ovens at 2.45 GHz). In recent years used for new communications systems like WiFi or Bluetooth.


LEO: Low Earth Orbit (below 2,000 km). Satellites rotate around the earth every 1–2 hours, depending on altitude. Most commonly used for remote sensing (e.g., earth observation) and mobile communications systems

MEO: Medium Earth Orbit (above 2,000 km up to GEO). Satellites on these orbits rotate around the earth every 2–24 hours, depending on altitude. Most commonly used for navigation and positioning services

MSS: Mobile Satellite Services. Direct end-user voice, audio and data access services to a mobile terminal (e.g., satellite phone)

NASA: National Aeronautics and Space Administration. The agency of the United States government responsible for the nation's civilian space program and for aeronautics and aerospace research. http://www.nasa.gov


SDTV: Standard Definition TV is a television system that typically uses a resolution of 576i (Europe) or 480i (US).


TT&C: Telemetry, Tracking and Command (or Telemetry, Tracking and Control). Encompasses all activities a satellite ground station does to operate a satellite

VSAT: Very Small Aperture Terminal. A two-way satellite ground station with a dish smaller than 3 m (largely 75 cm to 1.2 m), which allows access to GEO satellites, mainly for data communication.
Works Cited


About this report
This report was developed by Booz & Company with funding from the European Satellite Operators’ Association. It presents an independent, fact-based view on the future of commercial satellites with a focus on communications services in and for Europe.

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