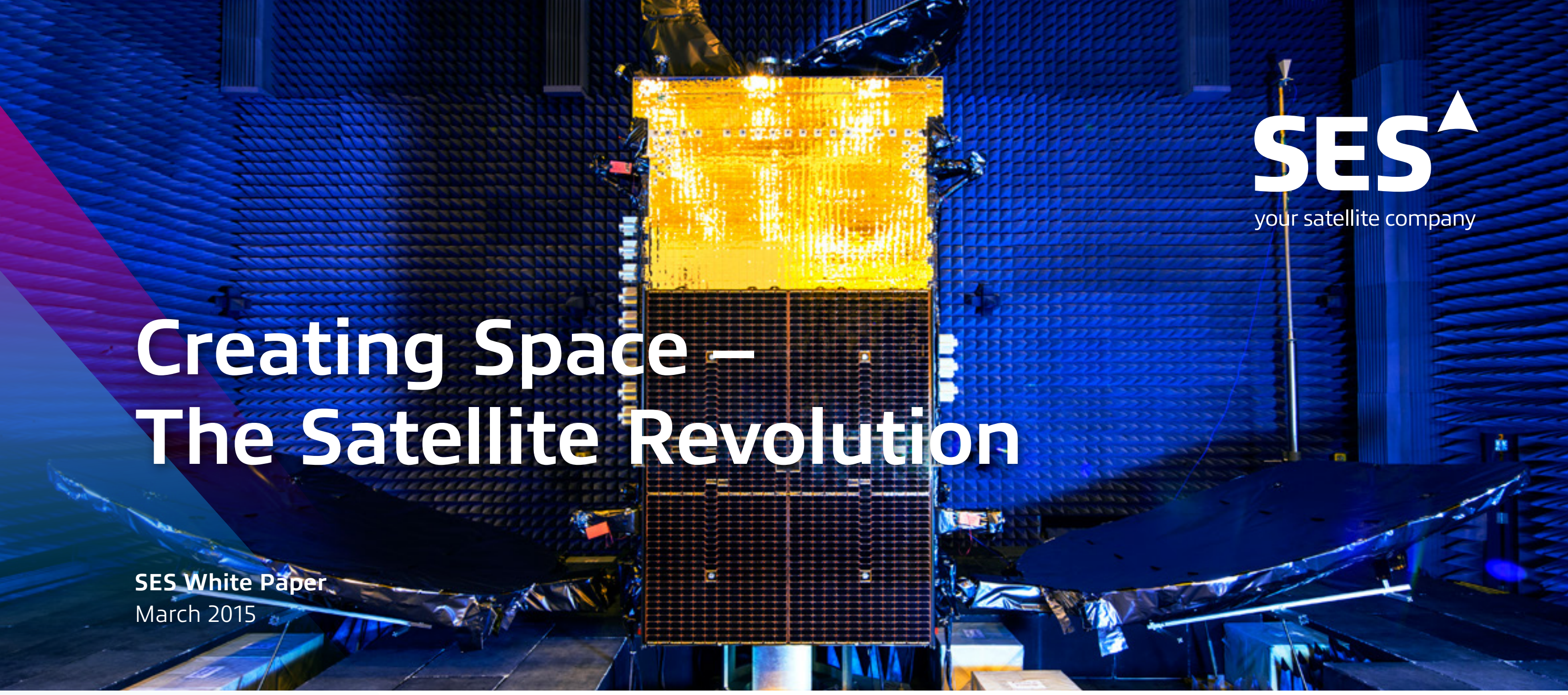


SES your satellite company

# Creating Space – The Satellite Revolution

**SES White Paper**
March 2015

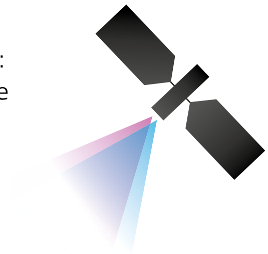
## Satellites are on the Rise

A proven technology that has built a stunning track record over more than a generation – helping to create multi-billion broadcast, content and data businesses and markets – is now making another quantum leap into a new era of connectivity.

Satellites, and the launch industry needed to get them into space, are both undergoing amazing changes. While the tried and tested methods of building and launching satellites are well understood, there is now a true revolution under way, bringing dramatic savings and a real democratisation of the industry.

The sophisticated skills of brilliant satellite builders are being combined with equally exciting developments in rocketry, resulting in a 'best of both worlds' approach to the satellite industry. These improvements are already achieving tangible benefits for satellite operators, and promise even greater advantages for generations to come.

## The Proven Method



The proven method to getting a satellite into orbit is fully understood: you design and build a heavy satellite and fill it with enough chemical fuel both to get it to its orbit and to keep it on station for its lifetime.

The satellite might typically weigh about 6 tonnes, of which half or more is fuel and two thirds or more of this half is burnt within one or two days on the satellite's flight to its final destination. The rest of the fuel, a little more than a quarter, has to be enough to fly your satellite for at least 15 years. The satellite requires a large rocket able to lift the burden of its satellite cargo plus the rocket's own massive weight into space.

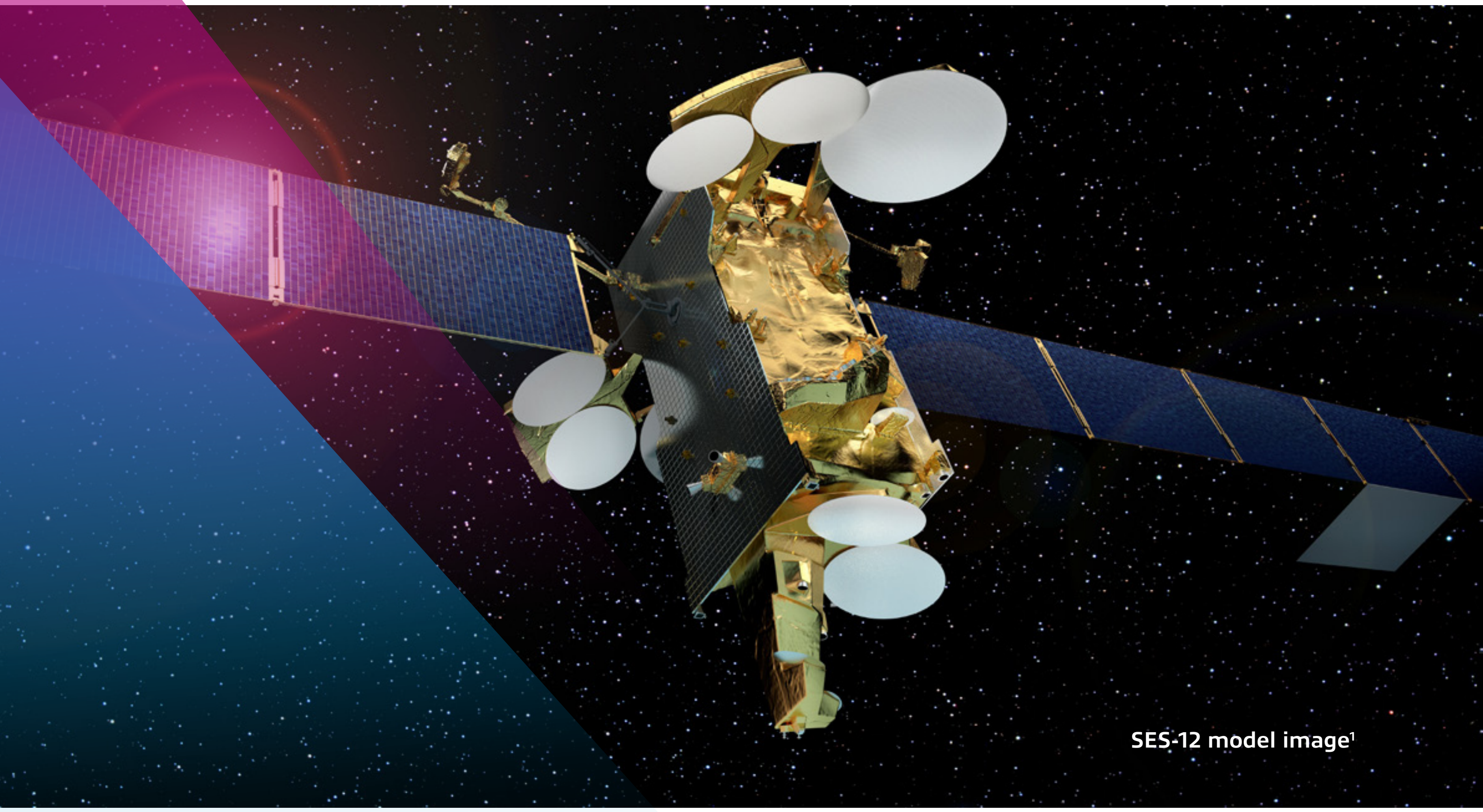
## The New Thinking

The new thinking combines a radical step-change in how satellites are built, and then marries the results to equally dramatic re-engineering as to how satellites are launched, financed, operated and commercialised. The enormous commercial advantages will take satellite well beyond its boundaries, and enable to embrace new markets, new businesses and many new customers.

## The New Satellite Mantra

The new mantra for satellites consists of three key elements:

1. **Light in weight**
2. **Efficient in beams**
3. **Fast to market**



SES-12 model image[1]

## 1. Light in Weight: Electric Propulsion

Imagine for a second that you could remove the huge propellant weight from the satellite, it would become much lighter.

Its lighter weight could result in a reduced launch cost, or could allow the inclusion of an additional commercial payload.

Electric propulsion is exactly that. The chemical propulsion system that makes a large part of the mass of a classic geostationary satellite is replaced by an electric propulsion system that requires only a fifth of the chemical propellant mass, in the form of non-toxic Xenon gas which is carried in on-board tanks. Thanks to the lower mass and the high density of the compressed Xenon gas, tanks can be up to 10 times smaller, giving more room for payloads.

Technically, the Xenon gas is ionised by an electric cathode and accelerated in a strong electric field created by a high electric tension of up to 2,000 volts. This expels the Xenon particles out of the engine with extreme velocity of 50,000 km/h and higher – and creates the thrust that pushes the spacecraft along to its orbit.

The good news is that the required electricity comes "free" from the satellite's solar panels, which can generate 20 Kilowatts or more on a constant supply.

The price paid for this is in loss of speed: instead of a few days, the satellite needs some months to travel to its final destination. But what are months compared to decades of operational time? More importantly, the travel time can easily be factored into the original launch plan.

A large, state-of-the-art satellite such as SES-12, which will weigh 4 tonnes without propellants, would weigh 10 tonnes if it carried chemical propellant.  A 10-tonne weight would need a complete Ariane 5 launch rocket, which normally carries two payloads.  Even with a full Xenon supply, SES-12 will only weigh 5 tonnes and can be launched on medium-sized rockets like Falcon 9 or paired with another similar satellite on Ariane 5.

1 *Credit - Airbus Defence and Space*

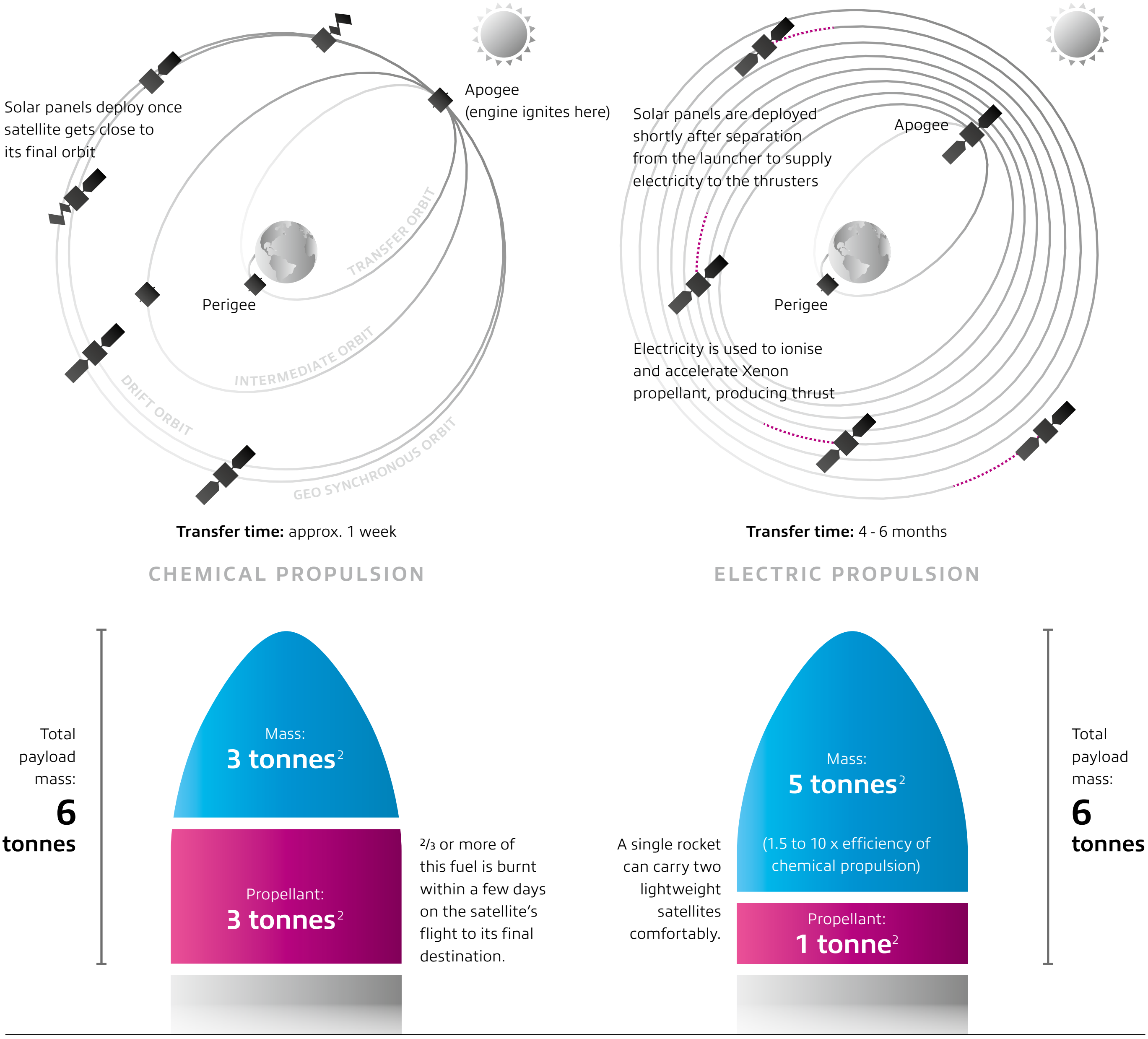
The use of all-electric satellites gives operators immense flexibility in how they utilise their orbital assets. A single rocket might now handle two lighter weight satellites comfortably with a commensurate saving in launch costs, and yet still have both satellites achieving their traditional 6-tonnes operational and full mission life.

Alternatively, the choice could be that the two tonnes of saved weight could lead to extra functionality and capability. Satellites can then more easily be configured to handle multiple markets, boosting revenue possibilities and preparing for new markets and fresh demands.

The benefit could also be about lifetime. Normally satellites have a design life of some 15 years. Good husbandry of the on-board chemical propellant can extend this to 17 years or more. Electric propulsion removes this limitation. Of course, other components might fail in the 15 years or so of planned operation, but electric propulsion means that even with a natural decline of functionality a satellite might have many years of useful life well beyond its initial mission.

Industry forecasts suggest that, by 2020, 50% of all commercial telecommunications satellites will be all-electric for their propulsion.

**CHEMICAL AND ELECTRIC PROPULSION**




*2 Values based on approximation*

## 2. Efficient in Beams: Digital Processing

The classic wide-beam linear mass market broadcast is an established and extremely successful business.

However, in an increasingly complex world, where customers need more cost-efficient two-way data connectivity, satellites now have to cope with much more varied and more challenging demands.

For example, two-way traffic on numerous multiple beams means that four routes have to be managed each time in multiple geographical focuses: the input from a teleport or gateway up to the satellite and the output back down from the satellite to the user, and both back and forth.

Instead of a static pre-allocation of spectrum capacity to various services, the satellite's on-board computer now digitises those signals and processes them. This Digital Transparent Processor routes customer signals on multiple beams in a single loop and therefore connects gateways and users anywhere and seamlessly within the satellite's footprint.

The consequences are a better allocation of spectrum and a larger variety of services for customers. Satellites are becoming cleverer at targeting new markets from existing orbital positions and with existing spectrum. The use of focused spot beams combined with frequency re-use and digital processors results in a highly adaptable satellite that can satisfy many different missions. One portion of the craft might be used for conventional Direct-To-Home transmissions, while another – using dedicated spot beams and processed by the on-board computer – might be addressing completely different markets with a wholly different set of parameters.

With all-digital usage, satellites achieve new levels of flexibility and adaptability and are ready for new and different customers and customer missions.

## 3. Fast to Market: Modular Construction

Technicians on both sides of the Atlantic are looking at how satellites are designed and built. They have asked whether it is really necessary to start each new satellite's design project from a completely clean sheet every time. This methodology has meant that the time to design and build a satellite takes at least 3 years, and sometimes even 5 years from concept to launch. This is no way to address fast-moving demand from consumers and businesses.

Instead, the engineers are now looking at modular construction, using proven components that do not have to be re-invented – or at best re-engineered – for each satellite mission. Satellite builders are increasingly using 'fast-to-market' concepts where a series of basic elements are provided. It is something like the latest version of a car. The outer skin might look the same but there will be a cluster of engine options, and a choice of manual, automatic or even all-electric transmission. It is much the same with today's new breed of satellites.

Today's satellites should be highly adaptive and responsive to a market's demand. No market is going to wait between 3 and 5 years while a satellite is designed and built. Satellite must anticipate these demands, and respond quickly.

## "Space Tugs" or Orbital Transfer Vehicles

The concept of a space tug is one of the most audacious under examination, and could easily revolutionise how satellites are planned and used.

Small powerful tugs are already used in world's maritime harbours to help move a large ship into its final docking position. A satellite-based tug can do the same.

Indeed, yesterday's science fiction is now quite likely to become science fact. Many operators are looking closely at how space tugs – also called Orbital Transfer Vehicles – can be used to transfer a low-Earth orbiting (LEO) craft to a higher orbit. One concept might be the lower-cost launch of a satellite to a lower or so-called rendez-vous orbit, and then use the space tug to move it to its geostationary position. Operators are also looking at transforming a rocket's final or upper stage and creating a use for a secondary space tug mission beyond its initial launch.

A space tug typically could have a powerful electric propulsion system, with the necessary solar arrays, and a 4-7 metre cylinder with thrusters. It could include modular solar array deployments and docking functionalities and it could transport other payloads, thrusters or tanks with propellant or Xenon gas to other spacecraft in higher orbits.

Other schemes include using space tugs on a refuelling mission to extend the life of an otherwise healthy satellite. NASA has been working on these developments and, along with Russia, has mandated the use of common docking mechanisms for cargo and personnel journeys to the International Space Station. NASA is also researching projects for launching satellites from high-flying jet aircraft, and also to salvage existing expensive satellites in space.


## Re-Engineering the Rockets

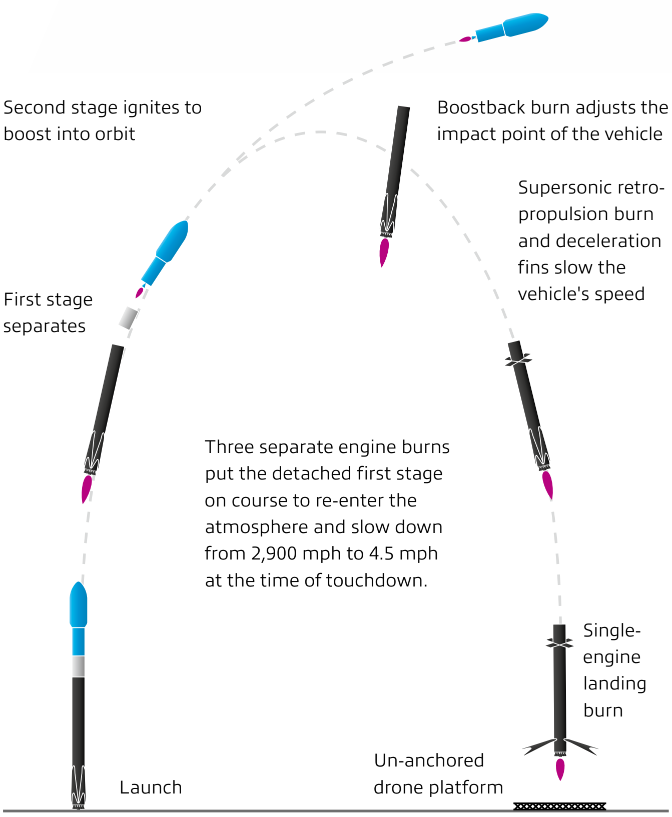
And finally, the rocket.

It is perhaps a 'chicken and egg' question as to what came first: lower cost rockets or lighter weight satellites? However, the arrival on the satellite launch scene of SpaceX is having a spectacular impact on how satellites are designed, built and launched.

In barely a dozen years, SpaceX has completely re-thought the satellite launching business. In order to fully control costs, the engineers design, fabricate and test the majority of the rocket's components in house. This strategy includes the construction of the powerful engines used in the rockets. SpaceX has a comparatively light administrative bureaucracy, and the end result is that its launch costs are amongst the lowest in the business.

But SpaceX and its owner Elon Musk, whose longer term plan is to bring people to Mars, also want some of the rocket's components to be recovered in a 'dry' state. The aim is to have the rocket's first stage land on a sea-floating platform following its launch. This has already been tested, and the concept includes returning humans to Earth after a space mission.

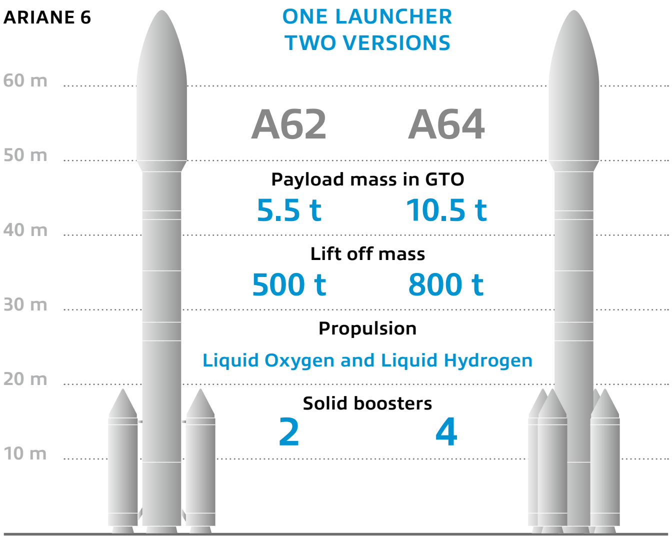
**REUSABLE ROCKET**



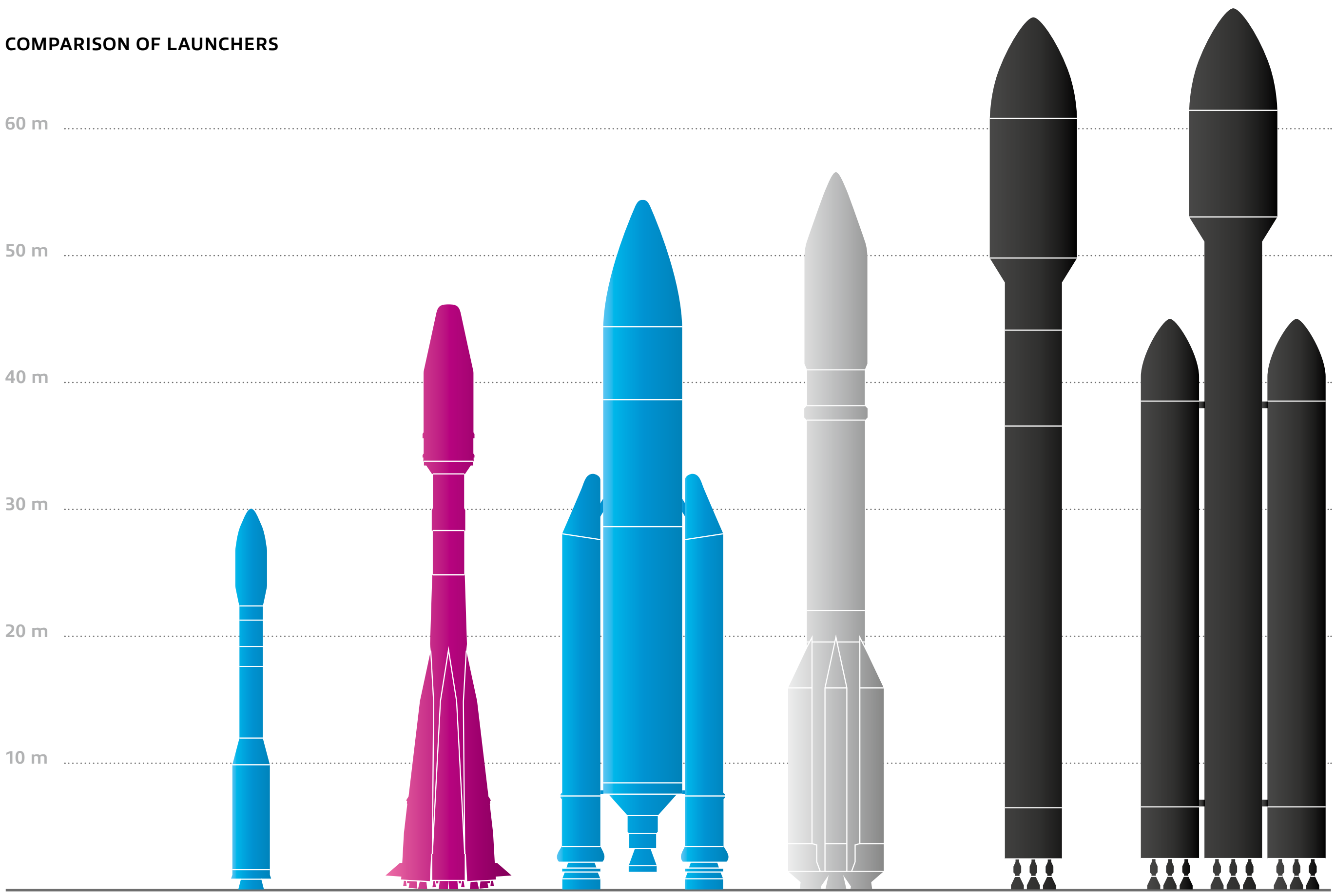
Overall, the aim of SpaceX is to build rockets faster, and to launch them much more frequently, and thus provide lower charges to clients – given that the overall costs are amortised over a wider range of tasks.

Already satellite operators are benefitting from extremely competitive launch costs, and with reusable rockets these costs could fall to one fourth of the price some years ago. That would be a dramatic change in the overall cost equation.

Arianespace is also completely re-thinking how it needs to attack the market. The next few years will see a new Ariane launch vehicle emerge, Ariane 6, which is due for its maiden launch in 2020, and when combined with Arianespace's existing portfolio of launch rockets, will take Arianespace forward to the next decade.




**COMPARISON OF LAUNCHERS**




| | VEGA | SOYUZ-2 | ARIANE 5 ECA | PROTON M | FALCON 9 | FALCON HEAVY |
|---|---|---|---|---|---|---|
| **Height** | 30 m | 46.1 m | up to 53 m | 58 m | 68.4 m | 68.4 m |
| **Diameter** | 3 m | 2.95 m | up to 5.4 m | 7.4 m | 3.7 m | 11.6 m |
| **Liftoff mass** | 137 t | 305 t | 780 t | 712.8 t | 505.8 t | 1,462.8 t |
| **Payload mass in GTO** | 1.5 t[3] | 3.25 t | 10 t | 6.7 t | 4.85 t | 21.2 t |

3 *Launch in circular orbit, 90°inclination, 700 km*

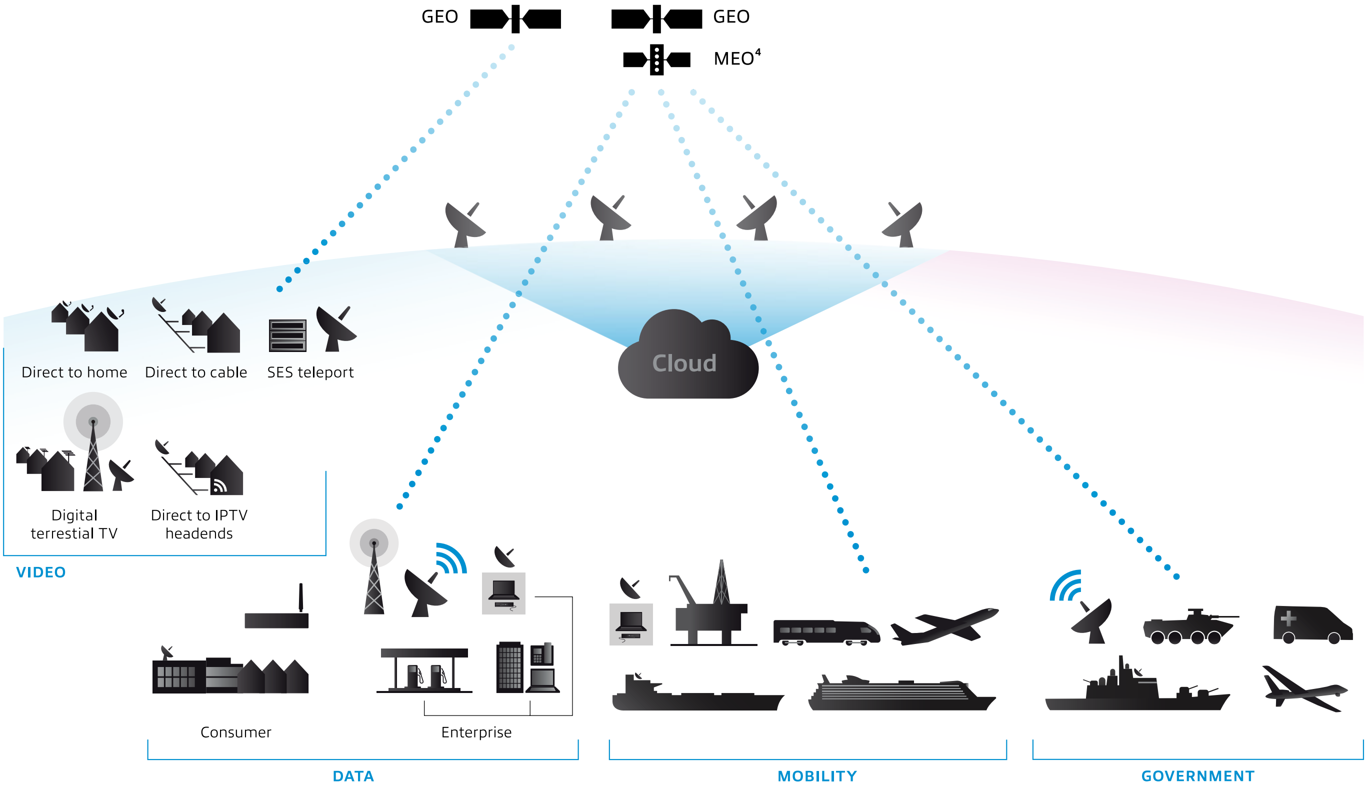
## The Bottom Line Consequences

This new equation for satellite, together with increasingly competitive conditions for its suppliers and the availability of new launch options through innovation and investment, is a quantum leap for the industry, representing both a critical improvement of the bottom line and a rising trajectory of commercial opportunities towards the horizon of global digital connectivity.

Most consumers are happy enough to receive more TV channels, with more programming options and at ever-higher resolutions. But video is just one element in the new mix of services that satellite is capable of providing. Whether video, fixed data, mobility or government, the demand for these services from satellite continues to grow exponentially.

In the hardware equivalent of a market trump card, SES is unique in being capable of handling geostationary and medium earth orbit services through its participation in O3b, and linking the two.  Combined with the changing technical profiles and economies of rockets and satellites, this allows for a much greater flexibility in terms of the operational tasks and commercial missions. The upside potential to play a key role in the world's ongoing digitisation is dramatic.

**SES'S UNIQUE OFFERING**




4 SES holds a strategic partnership of 45% in O3b

## Space innovation is driving development and global competitiveness of the industry

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