



**Leading insights on
the space sector**

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Prepared by PwC

Luigi Scatteia

Partner

PwC Space Practice

Yann Perrot

Manager

PwC Space Practice



Resilience of the Space Sector to the COVID-19 Crisis

An assessment of the impacts and
resilience to the COVID-19 crisis of
the various domains in the space
sector

Executive summary

The shock and the consequent crisis caused by the COVID-19 coronavirus is creating disruptions across all sectors of the global economy, with varying degrees of impacts. The space industry, while less exposed than other industries like Commercial Aviation, Tourism and others, is also impacted, with launches getting postponed, supply chains being disrupted, access to finance issues threatening the survival of start-ups, and events getting cancelled. Given the diversity of the broad space sector, the expected degree of impact varies for each specific space domain. In this paper, we analyse the recorded and expected impacts of the crisis on specific segments of the space value chain and on individual space domains including Satellite Manufacturing, Access to Space, Earth Observation, Satellite Communications, Navigation, Space Exploration and Space Situational Awareness and Space Surveillance & Tracking., in order to develop a view on the resilience of the space sector as a whole. We characterise, for each domain, the impact of the crisis on the demand, the supply, public policy & strategy impacts and actions, and on access to finance, in order to derive a qualitative view on the resilience per space domain. We aim at deriving, to the extent possible, direct impacts (i.e. impacts during the crisis core) and medium/long term impacts (i.e. after the main shock has been overcome).

The direct operational impacts of the COVID-19 crisis are delays in the supply chain, while mission operations are still generally ensured during the crisis core

The most visible consequence of the current COVID-19 crisis is the current slow-down of the activities along the space supply chain, with production activities either progressing at a reduced pace or being on hold. Specific impacts include manufacturing plants on hold for primes and suppliers, and delayed launches in major launch facilities (like GSG), due to the interdependence among the actors, and their global footprint. Only Russia and China remain on track with their initial schedule for 2020. On the other hand, demand for satellite services including Earth observation, communications, navigation services, space surveillance remains mostly unaffected - mission operations are maintained facilitated through remote working.

Cash flow and financing issues for small and medium enterprises and for start-ups pose risk of business continuity and possible supply chain disruptions

Most prime integrators have communicated on measures to mitigate financial impact and prepare for a still undetermined period of crisis after the shock. Small/medium enterprises, a category that includes including sometimes critical suppliers of large integrators, have strong cash flow impacts from order delays or cancellations, only partially mitigated by measures to maintain and/or anticipate payments. Start-ups are exposed to liquidity dry-ups and to financing risk, becoming much higher in a heavily impacted general economy: these include small-scale businesses but also large constellations projects (Earth Observation and Communications). The business continuity of such players is at higher risk both during the crisis and in its aftermath, based on the prospected outlook of the financial markets.

In the medium/long term, after-crisis, the space sector is likely to be shaped by wider impacts at public policy and procurement level

The COVID-19 crisis impacts the economy at large and extensive government intervention is already in place to provide an interim lifeline support and to foster a recovery. Space, as a sector heavily tied to institutional budgets and overall wider public agendas, is expected to be impacted by changing government priorities and agendas, in most space-faring regions. Governments have a prominent role in driving orders and setting up programmes and will have a direct impact on the manufacturing industry depending on the revised budgets. The case of space exploration programmes is particularly striking, as they quasi-exclusively rely on nations' space policies (Artemis) and budgets. While they play a key role in geopolitical relationships and cooperation (ISS), scientific exploration missions are not considered as a strategic asset, and could face reallocations of budget lines to other sectors. Similarly, SSA activities such as Space Traffic Management could suffer from the pressure on institutional budgets in the following months. Even civil Earth Observation institutional programmes, touted in the last years as major enablers of green agendas, might see impacts as priorities shift away from environmental issues towards general economic activity recovery. Disruptions to applications-oriented segments (EO, Navigation and Communications) fuelled by large civil programmes, could have a negative impact not only on manufacturers, but also on downstream companies often benefitting from these programmes, typically through development initiatives, R&D grants etc.

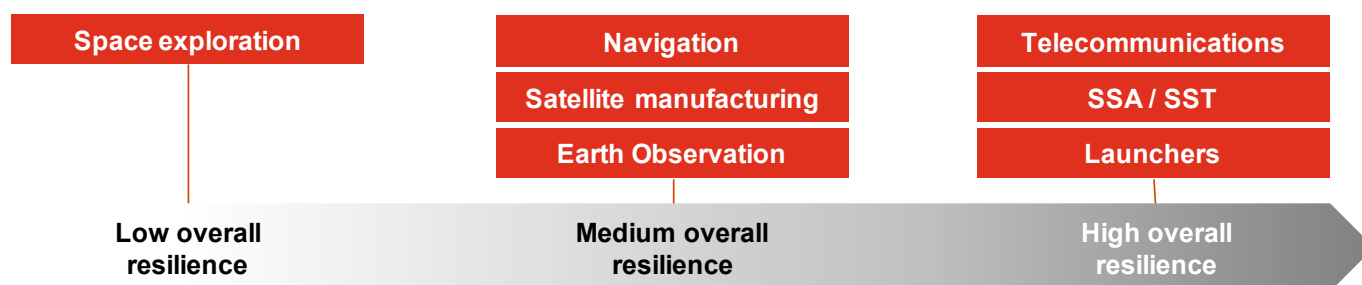


Figure 1: Resilience of space domains to COVID-19

Impacts of COVID-19 on the Space Industry

	Driver	Impact Level negative <-> positive	Comments
Satellite Manufacturing	Demand	<div><div></div><div></div><div></div><div></div><div></div></div>	Prime integrators should be able to mitigate direct impacts, by relying on their order backlogs. Small-Medium Enterprises and start-ups are naturally exposed to liquidity dry-ups, especially with the likely decrease of private investments, both at the core of the crisis and in the short/medium term. While long term demand should drive order back to nominal levels, institutional budgets will play a decisive role in normalizing demand. From that perspective, the broader economy outlook will have a significant impact.
	Supply	<div><div></div><div></div><div></div><div></div><div></div></div>	
	Private investment	<div><div></div><div></div><div></div><div></div><div></div></div>	
	Public policy	<div><div></div><div></div><div></div><div></div><div></div></div>	
Earth Observation	Demand	<div><div></div><div></div><div></div><div></div><div></div></div>	Incumbent players owning operational capacities are expected to be relatively resilient to the crisis. However, the spurt of start-ups and new entrants in the could face liquidity dry-ups leading to dramatic issues and potential business discontinuities. While there is a growing demand for Big Data Analytics services in which satellite data may play a role, the industry is still very dependent on public demand and so potentially at risk in case of budget revisions for EO-related programmes, particularly for non-defence related topics on the medium/long term.
	Supply	<div><div></div><div></div><div></div><div></div><div></div></div>	
	Private investment	<div><div></div><div></div><div></div><div></div><div></div></div>	
	Public policy	<div><div></div><div></div><div></div><div></div><div></div></div>	
Satellite Communication	Demand	<div><div></div><div></div><div></div><div></div><div></div></div>	The impact on satellite communications is expected to be localized on some downstream verticals (in-flight connectivity for ex) while most of the market is expected to cope well, or even experience a relaunch, due to an expected increased need for ubiquitous communication in the medium/long term as a result of this crisis. Manufacturing and launch delays will push back the rollout of new constellations from existing actors, and a liquidity dry-up could hit risky NewSpace constellation projects hard. Resilience is overall expected to still be high, with satellite communications remaining a key business in Space.
	Supply	<div><div></div><div></div><div></div><div></div><div></div></div>	
	Private investment	<div><div></div><div></div><div></div><div></div><div></div></div>	
	Public policy	<div><div></div><div></div><div></div><div></div><div></div></div>	
Satellite Navigation	Demand	<div><div></div><div></div><div></div><div></div><div></div></div>	The demand for and supply of GNSS infrastructures and signals are almost not affected by the COVID-19 crisis. The user segment is more impacted in the short and medium term. Main markets for GNSS receivers (phones and road transportation) are directly hit by the crisis, and GNSS chipsets supply chain itself suffers slowdowns and bottlenecks. Government funding should be rather resilient, as GNSS represents key assets to operate critical infrastructures.
	Supply	<div><div></div><div></div><div></div><div></div><div></div></div>	
	Private investment	<div><div></div><div></div><div></div><div></div><div></div></div>	
	Public policy	<div><div></div><div></div><div></div><div></div><div></div></div>	
Space Exploration	Demand	<div><div></div><div></div><div></div><div></div><div></div></div>	The level of impact on exploration missions will depend on the type of missions with those based on national space policies (Artemis) and international collaboration (ISS) less likely impacted while scientific missions such as JWST, JUICE and WFIRST more likely impacted, through delays and budget cuts. Space exploration is not expected to be as resilient in the medium to long term as other space domains which could be considered relatively more essential to national security and the overall space economy.
	Supply	<div><div></div><div></div><div></div><div></div><div></div></div>	
	Private investment	<div><div></div><div></div><div></div><div></div><div></div></div>	
	Public policy	<div><div></div><div></div><div></div><div></div><div></div></div>	
Space Situational Awareness	Demand	<div><div></div><div></div><div></div><div></div><div></div></div>	The inability to access information supporting collision avoidance activities could lead to catastrophic impacts. Demand and supply for space surveillance data is expected to stay sustained during and after the COVID-19 crisis. Initiatives towards the development of STM activities may be slowed down due to budgetary constraints implied by the need to deploy priority initiatives to address the crisis. The implications of COVID-19 on manpower and staff dedicated to satellite operations, exacerbates the relevance of developing automated solutions.
	Supply	<div><div></div><div></div><div></div><div></div><div></div></div>	
	Private investment	<div><div></div><div></div><div></div><div></div><div></div></div>	
	Public policy	<div><div></div><div></div><div></div><div></div><div></div></div>	
Access to Space (Launchers)	Demand	<div><div></div><div></div><div></div><div></div><div></div></div>	The administrative shutdown of spaceports around the world, except China and Russia, is creating launch delays that imposes a reshuffling of launch schedules. Prime integrators have, overall, maintained manufacturing lines open, while manufacturers of small launchers are less concerned by shutting down their factories since they are able to stock units. While launch prime integrators and operators are expected to be impacted by reduced demand from corporate bankruptcies, access to space is ensured an intrinsic resilience, due to its strategic position.
	Supply	<div><div></div><div></div><div></div><div></div><div></div></div>	
	Private investment	<div><div></div><div></div><div></div><div></div><div></div></div>	
	Public policy	<div><div></div><div></div><div></div><div></div><div></div></div>	

Figure 2: Impacts of COVID-19 based on drivers



Introduction

The crisis caused by the COVID-19 coronavirus is creating disruptions across all sectors in the economy, with each sector impacted in different ways. With at least 170 countries infected, governmental institutions are scrambling to respond to the changing events on a daily basis. As of April 24th, over 2.7 million cases have been reported with over 190,000 deaths^[1]. Major economies are coming to a standstill with strict lockdown policies being imposed across cities and countries around the world. The global economy is hit hard with studies estimating that the global GDP could be shrinking between 1 and 2 percent by the end of this year^{[2], [3]}. Industries such as manufacturing and aviation are being highly impacted as quarantine measures have led to lowering demand for non-essential goods and caused severe disruptions to the movement of people among borders.

As a result of this huge magnitude of the crisis, swift economic measures have been taken around the world, with central banks cutting interest rates and agreeing on liquidity injections in the economy^[4] and massive stimulus bail-out packages have been approved such as the \$2 trillion bill passed by the US Congress, or the half-trillion euro bailout package passed by the European Union^[5]. Worldwide, the stimulus from governmental spending is expected to exceed 2% of global GDP, with countries like France, Germany and the United Kingdom increasing spending and granting corporate credit guarantees. Hard-hit industries

such as aviation seek government bailouts, while those such as automotive are facing both disruptions to their global supply chains as well as a nosedive in customer demand^[6].

The space sector, while less exposed than hard-hit sectors like aviation or tourism, is also directly impacted by the crisis, with launches being delayed^{[7][8]}, significant events getting cancelled around the world^[9], operational missions being scaled down^[10] as well as private companies shutting down operations.^[11] In the past few years, the global space industry has been enjoying a period of growth, both in terms of access to finance as well as technological achievements. About 170 space start-up space ventures^[12] attracted \$5.7 billion total funding in 2019, the year with the most amount of funding for the space industry^[13]. A number of technological advances were made in the last few years, in both the upstream and downstream domain, including in satellite manufacturing, launch, ground services as well as in data downlink, data analysis and exploitation. Advances were made in all domains including infrastructure for space exploration, advances in in-orbit economy services such as in-orbit servicing and satellite refuelling, as well as innovations in development of downstream services based on navigation, earth observation and telecommunications.

Given the diversity of the broad space sector, the expected degree of impact from the COVID-19 crisis varies for each specific space domains. In this paper, we analyse the recorded/expected impacts of the crisis on specific segments of the space value chain and on individual space domains. Specifically, seven domains are analysed: Satellite Manufacturing, Access to Space,

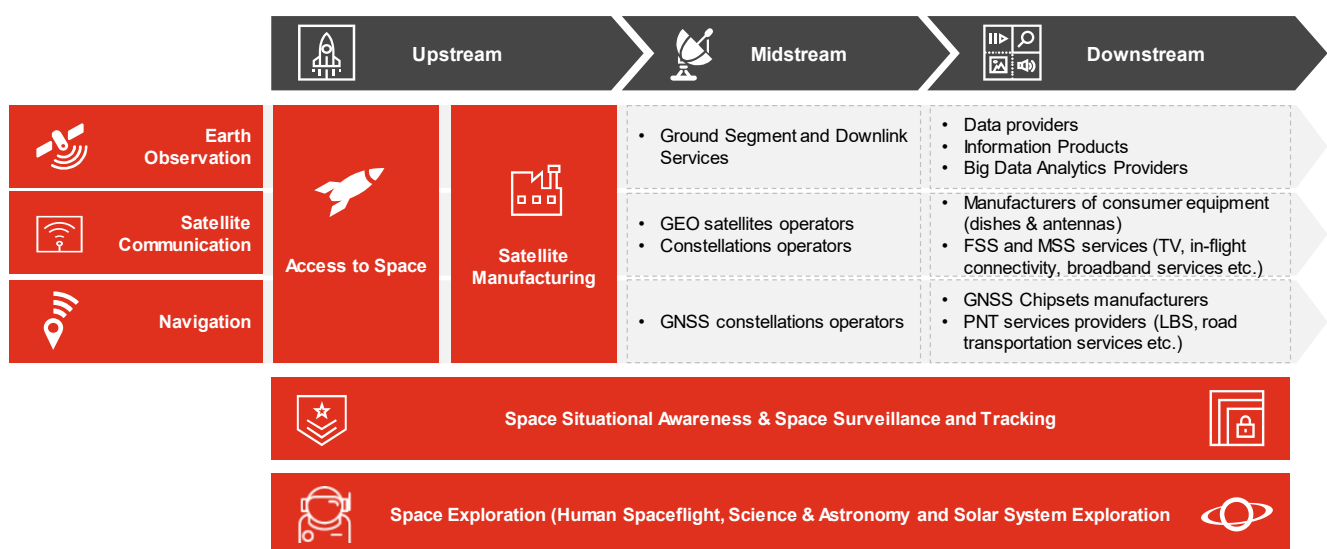


Figure 3: Illustration of the assessed domains in the space industry along the value chain



Earth Observation, Satellite Communications, Navigation, Space Exploration and Space Situational Awareness & Space Surveillance & Tracking (see the following figure).

We look, to the extent possible; at direct impacts (i.e. impacts during the crisis core) and medium/long term impacts (i.e. after the main shock has been overcome). We assumed a “U-shaped”

curve to infer the medium/long term impacts of the crisis. This assumes that the lockdown period (or the period equivalent to a lockdown in the cases where limited movement is allowed by governments) lasts a couple of months, and that the economic activity (in terms of GDP growth) will grow back to its pre-crisis level, after several months of recovery period. This scenario sits in-between the optimistic scenario of a quick return to nominal

GDP change (monthly)

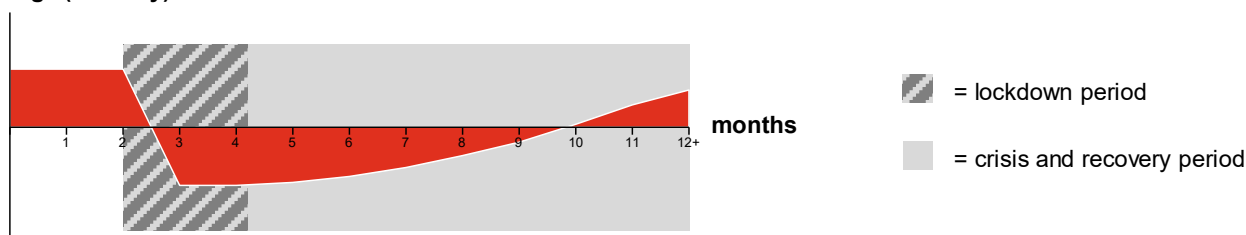


Figure 4: Anticipated monthly GDP change in the economy due to the COVID-19 crisis

activity once deconfinement measures are implemented, and the pessimistic scenario where the economy does not totally recover from the crisis even in the long term. Under this scenario, we characterise the level of impact of the COVID-19 crisis per space domain as well as the resilience of the sector, both in the short term and in the long-term.

In order to identify the level of impact, per domain, we analyse each domain looking at four key drivers: Demand, Supply, Public Policy and Procurement and Access to Finance. Although these four drivers could work differently for different domains, the approach normalizes the impacts analysed in the frame of these KPIs in order to provide a modular, yet consistent view of the impact of the COVID-19 crisis on the space industry. A short

Key Drivers	Description
Demand	Impact of the Covid-19 crisis in the demand for products and services, per domain. This includes the impact of the covid-19 crisis on the demand stemming from both institutions and commercial providers
Supply	Impact of the Covid-19 crisis on the products and services that enable the fulfillment of the demand, considered above, per domain. As above, this includes supply from both the institutions and commercial providers
Private Investment	Impact of the Covid-19 crisis on the access to funding for both major players and the growing startups in the space industry, per domain
Public Policy	Impact of the Covid-19 crisis on the policies of global institutions, the change in space strategies expected as well as the resulting modifications to budgets and procurement strategies. Here, a global approach in identifying the impacts is considered rather than an impact-per-geography approach.

Figure 5: Descriptions of each driver assessed






Level of Impact		Description
Positive		The Covid-19 impact will have a strong, demonstrably positive impact and can be proven with sufficient examples, and quantified, wherever possible
Slightly Positive		The Covid-19 impact will have a sufficiently positive impact with some examples of the impact already available and/or foreseen
Neutral		The impact of the Covid-19 impact is neutral due to reasons of uncertainty and/or absence of examples showing any significant impact
Slightly Negative		The Covid-19 impact will have a negative impact with some examples of pessimistic nature already available and/or foreseen
Negative		The Covid-19 impact will have a strong, demonstrably negative impact and can be proven with sufficient examples, and quantified, wherever possible

Figure 6: Description of the 5-point scale used in the assessment

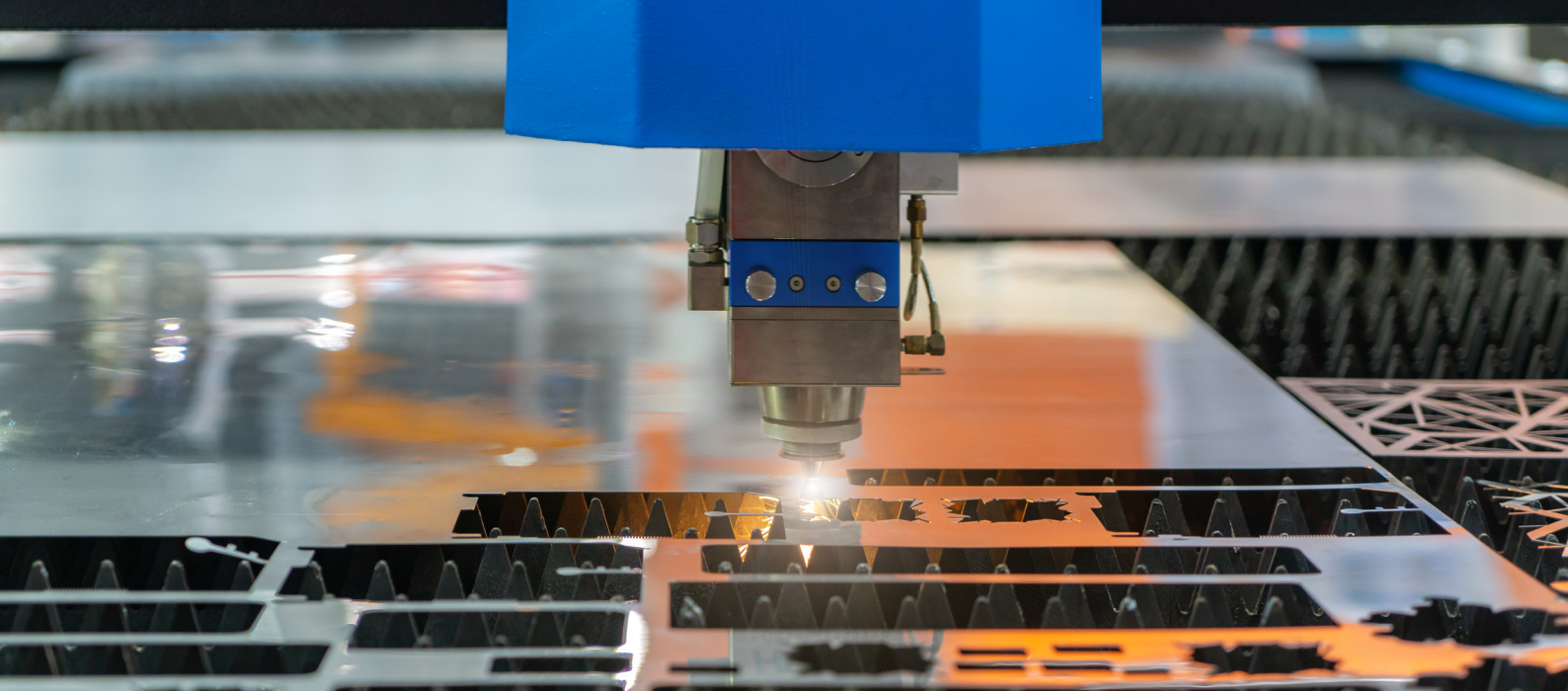
description of each driver is given in the table below:

The aforementioned drivers are analysed and the impact per driver is quantified on a 5-point scale, described in the table above. After identifying the level of impact for all the domains, the resilience of the domains are analysed in chapter 3. Resilience

is defined as the ability to withstand the disruptions due to the COVID-19 crisis in the short-term and the capacity to bounce back to business-as-usual in the post-COVID-19 phase. Each domain is assigned a resilience score on a 3-point scale (High, Medium, Low), as explained in the table below.

Resilience Score	Description
HIGH	Highly resilient; ability to easily weather the crisis and the capacity to return to business-as-usual once the crisis is over.
MEDIUM	Moderately resilient; the crisis has some immediate impact, however sufficient capacity to return to business-as-usual post crisis.
LOW	Low resilience; with limited ability to withstand the crisis, there are huge impacts, with low capacity to return to business-as-usual post crisis.

Figure 7: Description of level of resilience



2. Impacts per Space domains

2.1. Satellite Manufacturing

This section focuses on the impact of the COVID-19 crisis on the satellite manufacturing industry, looking at the impacts for satellite integrators and their supply chain, startups activities and their continuity in the market as well as the role governments are playing to protect small and medium-sized businesses that produce highly valuable assets in the frame of spacecraft manufacturing programs.

2.1.1. Demand

Level of Impact: Slightly Negative



The satellite manufacturing market oscillates between 14 B€ and 18 B€ per year with estimates from 2019 foreseeing similar figures in the coming decade, but the sector has not been immune to the quick spread of the coronavirus pandemic, both concerning the legacy satellite manufacturers and the more recent players such as large smallsat constellations (illustrated for instance by SpaceX's Starlinks and One-Web's first batches and privately-funded New Space start-ups). The impact on demand varies with the profile of the actors and with the time horizon considered.

For most satellite orders, procurement contracts last up to a few years, and activities are not expected to be much disturbed in the short term thanks to the on-going contracts, in particular, large incumbent contractors with a large backlog of governmental and commercial contracts.

In the medium term (few months) , new procurements might be more impacted with a smaller appetite from smaller actors. Governmental budgets will therefore play an even more preponderant role, transversally but even more for institutional-

driven domains such space exploration or for Scientific spacecraft. The risks of reallocation of budgets to critical sectors and for economic efforts is non neglectable, in particular for large scale institutional programmes such as in Earth Observation. In this landscape, the players part of the supply chain for space programmes remaining more critical (such as military programmes and navigation constellations for instance) can be expected to be more protected.

In the longer term, the persistent demand for earth observation and communication services globally, even during such crisis times, will drive a rebound of the demand for both governmental and commercial satellites, although the unknown remains on the time to wait before reaching back to the current levels.

In this landscape, the most exposed to a negative impact demand in the short term are new entrants in particular start-ups which may not have a guaranteed backlog from larger integrators, or may see their funding from space agencies at risk, while overall those who are mainly privately-funded may not survive the crisis.

2.1.2. Supply

Level of Impact: Slightly negative



COVID-19 is bringing the satellite manufacturing industry to a partial halt in the short-term. Government's announcements on the continuity of "essential" industries operations and whether satellites manufacturers are part of it or not is decisive. Indications on this aspect are more or less specific depending on the countries, and has led to complications for satellites manufacturers whose supply chains span around the world. In the United States, central government announcements encounter state-mandated lock-down orders, restricting the normal flow of goods across the nation. European satellite manufacturers face a similar situation, since the production of their spacecraft equipment and AIT activities are typically spread across European Community countries that have taken different lock-down measures against COVID-19, as illustrated by Airbus following Spanish national guidelines pausing all but essential production activities in Spain until April 9th^[14], while its other facilities in Europe keep operating.

The supply chain for satellite manufacturers is also affected by concomitant parameters such as the conflict of supply for semiconductors, also required for the healthcare industry, legitimately prioritised during the crisis with companies focusing on serving medical equipment manufacturers (for instance Analog Devices or Cobham^[15]). In addition, most superconductors foundries are located in China and Korea, with therefore risks of shortage for these types of equipment^[16].

Such global disruptions led for instance Maxar to warn its customers that they may not be able to deliver spacecraft on time or on budget due to the coronavirus pandemic, since they are already observing stress on their supply chain^[17]. In order to prevent last-minute stock ruptures, manufacturers encourage their suppliers to communicate with them (such as Boeing, Northrop Grumman or Honeywell Space^[18]) in case of potential impact to their supply chain. Lockheed Martin took a step further to secure the continuity of its supply chain, by advancing more than \$50 million to the small and medium-sized suppliers and partners, and is sending encouraging signals to the market by continuing their planned recruitment activities^[19].

In general, big satellite manufacturers and their suppliers are being able to continue operating thanks to the precautionary measures they have put in place to protect their personnel. This includes for instance rearranging the workbench locations and organisation to ensure distancing, working with a fraction of their employees or stopping activities that need a high concentration of people on site like AIT campaigns^[20],^[21],^[22]. While companies such as SpaceX and Kuiper have long pursued their activities without needing to reduce their personnel, others such as Cubesat manufacturer AAC Clyde, succeed to maintain their activity by relying on part on-site staff and part remote working workforce^[23]. Overall, small actors remain more exposed to uncertain demand with their supply capacity potentially disrupted, with risks of potential temporary or permanent layoffs of their personnel in the worst cases.

In the meantime, idle facilities are not being left unused, as many governments have requested companies to put their industrial assets to support the medical sector needs. Some companies, such as for instance Airbus, Thales and Lockheed Martin, are using their production lines to manufacture masks and respirators at scale^[24], and put to service their research personnel and facilities to design and print 3D respirator accessories, masks, protective visors and other medical gear^[25].

2.1.3. Private investment

Level of Impact: Negative



Due to liquidated damages clauses that can be triggered if programs miss contractual milestones, manufacturers like Maxar have already sent force majeure notices to customers to protect their legal rights given the uncertain nature of the current pandemic and its impact on cost and schedule^[26].

The general trend among big companies in the space sector is attempting to keep liquidity for 2020 by reducing the payment of 2019 dividends to shareholders, like Airbus, who has taken the decision to withdraw \$1.4 billion from the dividends

offering^[27], Thales, who has suppressed the remaining \$430 million of 2019 dividends^[28], and Boeing, who has suspended dividends payment as well, and extended the pause of its shares buyback^[29]. In this landscape German satellite manufacturer OHB is more optimistic, having stated it will not revise its forecasts of \$1.2 billion in revenue this year thanks in part to its backlog of largely government contracts that do not seem to be threatened by cancellation^[30].

While spacecraft integrators secure credit lines as part of their COVID-19 resilience plan and are being supported by their governments^[31],^[32],^[33], space industry start-ups, which had seen their financing flourish in 2019 with no sign of slowing at the beginning of 2020, risk potentially adverse impacts on both their revenue and their ability to raise money^[34]. Investors may hold back on putting capital into new companies, which could cause start-ups to struggle^[35]. To avoid the collapse of start-ups, different institutions around the world are advocating for them in front of governments, like Access.Space, a London-based non-profit representing European small satellite manufacturers and operators, which has called for a pan-European effort to support the small satellite sector^[36].

2.1.4. Public policy

Level of Impact: Neutral



While big players in the satellite manufacturing industry may be able to endure the crisis due to their solid financial backings, small and medium-sized businesses may be more exposed to cashflow dry-outs and will require governmental support, and some institutions have highlighted the risks of not protecting small companies during the COVID-19 crisis. For instance, the Space and Missile Systems Center (SMC) in the United States has stressed out the critical role of small companies in the supply chain of national defense supply programs, and the risk of potential bankrupts^[37]. On March 28th, the American Department of Defense allocated \$ 1.54 billion out of its \$ 10.5 billion aid package to mitigate the impact of COVID-19 on production lines, supply chain, military depots, and labs.

In Europe, specific measures on the rescue of aerospace companies and start-ups have not been issued yet. Nevertheless, countries are already racing to save their tech start-ups, in general^[38]. France has led the pack in the continent, launching a \$ 4.4 billion liquidity plan to support its start-ups' cash flows. As well, the German government has said it would provide \$ 2.2 billion in financial assistance to help keep its young tech businesses afloat and it's also considering a longer-term fund of \$ 11 billion for bigger start-ups. On the other side, the U.K., is facing calls from its own tech industry to bail out start-ups that could collapse in the coming months without access to government support.

However, these aid packages to the industry remain contingency measures, and the still uncertain evolution of institutional budgets for Space in the coming months puts at risk the current governmental activity of satellite manufacturers, with the potential reallocation of budget shares to critical industries.



Image Credit: European Space Agency

2.2. Earth Observation services

This section focuses on the impact of the COVID-19 crisis on the EO downstream industry, looking at implications for companies delivering EO data and EO services & applications/ analytics. Hence, some implications related to the upstream part of the value-chain (i.e. satellite manufacturing, launch) have been included in the analysis, as they impact the supply of EO downstream services.

2.2.1. Demand

Level of Impact: Slightly Positive



The COVID-19 seems to have a positive short-term impact related to the demand for crisis monitoring, evidence-based cases and business intelligence, looking at the impact of COVID-19 on the global economy. We note a very strong increase in demand from existing but also from new clients, especially for Big Data Analytics (BDA)^[39] services, both from commercial players (e.g. large retail companies, logistics companies, business intelligence, trading, etc.) and public entities (e.g. local authorities, municipalities, civil protection forces, police forces, etc.). A growing interest for innovative imagery-based applications has also been expressed through open rapid responses procurement opportunities from space agencies like ESA or NASA^[40] but also from non-space organizations such as the U.S. Air Force Small Business Innovation Research office (SBIR)^[41] or the French “Agence de l’innovation de défense.”^[42] Another very positive impact of

the COVID-19 episode is that the EO downstream industry is currently under the spotlight thanks to a growing interest from prestigious newspapers all around the globe (e.g. Financial Times, New York Times, Huffington Post, Business Insider, etc.), showcasing imagery and outputs of imagery-based applications related to the impact of COVID-19 on the global economy; such publicity may indirectly stimulate demand for EO data and services in the future for additional use cases. A specific interest for the Copernicus programme and its Sentinels fleet has also been clearly demonstrated over the past weeks: data from Sentinel 5P/TROPOMI (S5P) are being processed to map and monitor the impacts of COVID-19 on the emissions derived from production, by comparing periods of time before and after the enforcement of restriction, in China and Northern Italy notably^[43]. The use of these data by public entities (e.g. ESA, NASA, KNMI) and private entities (e.g. Descartes Labs) have become viral in the news of past weeks, raising a lot of interest for the potential offered by satellite imagery, merged with additional sources of data.

On another hand, the COVID-19 is expected to have very negative impacts on the short and mid-term of the energy and financial services sectors, with the stock market and the price of oil collapsing in Q1 2020. As those industries are expected to drive part of the demand for EO data and services in the next 5 years, notably for the EO Big Data Analytics (BDA) market, we can expect some delays in the uptake of these sectors to introduce new innovative products and services based on EO imagery. Nevertheless, this delay in customer uptake for these domains is expected to be compensated by the strong increase in demand for imagery-based services.

2.2.2. Supply

Level of Impact: Neutral



Common to all satellite-based services, delays in satellite manufacturing activities and satellite launches will have impacts on the supply of imagery, delaying some missions, even if not any discontinuity from existing services is expected. In that context, the impact of such delays may be stronger on new entrants currently developing and launching their capabilities than on long established players such as Airbus, Maxar or e-Geos. As an example, the 6 satellites of the US company Planet (Flock V1 to V6) that were supposed to be launched on Vega on March 24 2020 have been delayed until April 15 2020 or later, if the confinement's period is extended for the French spaceport. Such type of delays related to launch but also related to manufacturing activities, due to slow-down and/or shutdown of activities, is expected to have negative impacts for mostly all NewSpace players vertically integrated, such as Capella, IceEye, HEAD, Satellogic, Astro Digital or UrtheCast, thus delaying the full deployment of their capabilities. This delay in capacity to operate at full scale should lead to delays in their capacity to go-to-market and start selling data & services. Such impact on the business plan may deteriorate the financial sustainability of some of these initiatives, especially the ones with no or limited assets currently in orbit.

When looking at companies already operating and selling EO data & services, the impact of the COVID-19 is expected to be rather small, apart from the limitations due to forced e-working, common to all service industries. The crisis does not seem to have significant impacts on pricing nor on data availability on the short and mid-term. Satellites tasking capabilities (i.e. priority data acquisition) do not seem to be impacted, even with confinement restrictions.

2.2.3. Private Investment

Level of Impact: Negative



One of the most significant impacts of the COVID-19 crisis on the EO downstream industry could be on the access to funding. If some R&D opportunities (e.g. rapid response call, grants, etc.) are arising especially from the government to support the monitoring and prevention of the Covid pandemic using satellite imagery, access to finance from private investors, especially from Venture Capitalist, may be at risk in the short and mid-term.

In a crisis context, investors tend to reduce their risks by investing in their current portfolio to protect investments already made, more than investing in new ones. With the equity markets collapsing for Q1 2020, the start-ups currently raising funds may be at high risk, with Venture Capitalists (VCs) investment expected to be drastically reduced in the short and mid-term. Some segments of the EO downstream value-chain are

expected to be in a better position than others to keep attracting investments. Given the strong interest and spotlight given to Big Data Analytics (BDA) firms such as Descartes Labs or Orbital Insights in the news, and the expected increase in demand for services in the future, such companies may be considered as solid investments for private investors, with existing customers and strong positioning on the downstream market. On another hand, companies focusing on data distribution and aiming at building capacity in space seem to be in a weaker position, especially the ones with no or limited number of satellites in orbit today. Indeed, companies with not yet operational capabilities are more vulnerable to reduction of liquidity as they do not yet generate any revenues. Reduction in private investments, especially from VCs, should then lead some vertically integrated players to go out of business in the near future.

2.2.4. Public policy

Level of Impact: Slightly Negative



With large stimulus packages being pushed forward by governments all around the globe, economic priorities for public investment may be impacted. These new bills pushed by governments may lead to some budgetary reduction in some governmental initiatives, potentially including space programmes. Even if there is currently no clear indication that the Covid crisis may lead to a budget reduction attributed to national EO missions, large scale programmes such as Landsat or Copernicus can potentially be at risk. If Landsat 9 is already being manufactured, and planned to be launched by March 2021, to ensure Landsat programme continuity, the future of the Landsat programme may be at risk if funding allocated would be reduced, especially in a context where more and more US commercial companies are launching EO satellites in orbit. If the Copernicus programme is not facing any cancellation risk, the COVID-19 crisis in the context of the negotiation of the next Multi-annual Financial Framework (MFF) between EU Member States (i.e. already complex due to UK withdrawal from the EU) may put at risk the overall envelope attributed to the EU space activities. With several EU flagships programmes to be supported, including the Galileo programme but also the newcomers GovSatcom and SST, the overall budget for the Copernicus programme may potentially be reduced.

On another hand, as we see globally a strong involvement of governments to support companies in this context of crisis, industrial and scientific support programmes such as ESA FutureEO (formerly known as Earth Observation Envelope (EOEP)) are not expected to be negatively impacted (i.e. especially in a context of increased budget attributed to EO activities during last ESA Ministerial in November 2019). Supporting the recovery of the global economy could become a new priority for such programmes, together with topics such as climate change, environmental monitoring and sustainability.



2.3. Satellite Communication services

The satellite communication domain is by far the largest satellite services market^[44] with a market worth €130bn in 2017. A powerful network infrastructure (led by satellite operators such as Eutelsat) allows the downstream segment to operate. Downstream satcom represents up to 80% of the value of the sector as a whole, offering telephone, television and broadband internet access among other services.

This section covers the effects of COVID 19 in both these aspects of the satellite communications market.

2.3.1. Demand

Level of Impact: Slightly negative



The main service provided by satellite communications is television broadcast. With the cancellation of many sports events and the postponing of the Olympics, demand for satellite uplinks will likely be lower in the short-term. At the same time, as the confinement of large parts of the population keeps people home, revenue could increase downstream in the video and television broadcast. This would only mildly increase demand to the midstream actors, with a threshold effect. This will mainly have a stabilizing effect, with EUTELSAT estimating the risk for this year at 20million on its 1.2B revenue. To their own admission, a few verticals are hit harder than others by the effects of this crisis.

Indeed, as a direct impact of the crisis, some downstream

service providers will see a dip in revenue due to the collapse of air and maritime traffic. Due to the crisis, international transit of passenger and cargo is being reduced: the AITA expects passenger air traffic to be at least 20% lower in 2020 than usual, passenger cruises have been almost completely canceled worldwide, and the maritime cargo activity is expected to follow reductions in industrial production in eastern Asia, especially China.

This will mean decreased revenues for the companies, especially the ones downstream (like the Chicago-based GoGo Internet) centered on in-flight connectivity. Moreover, as the dip in oil prices will reduce activity on offshore forages, the consequential reduction in the demand from Oil and Gas affects negatively an historically high-willingness-to-pay market downstream.

On the other hand, pure satellite broadband use is on the rise worldwide due to generalized confinement, and satellite IP providers see an increase in usage of their services from existing customers^[45], as well as an influx of new customers for these services. This increased use, estimated by Viasat on their network around 10% in instantaneous bandwidth requirements, raises concerns on the fair use policies that limit the overall data transfer allowance in a satellite internet plan. As an example, users of the satellite internet operator NBN in Australia were reportedly going through what is usually a monthly plan in a week.

This new level of activity will propagate to the midstream segment, as downstream actors cancel bandwidth agreements or scale up their contracts, changing the cash flow to the satellite operators.

2.3.2. Supply

Level of Impact: Slightly negative



The impact on the supply of satellite communication is different depending on whether it is the downstream services or the satellite infrastructures that are considered.

The current supply for satcom services will suffer little disruption from this crisis, as it is currently mainly supplied through large GEO satellites that can be remotely steered and maintained. Similarly, the supply of satellite communications to governments is expected to remain solid. This with the relative demand stability overall for satellite services should not add to the current pressure top-line satellite operators are reported to have because of the strong competition in this market^[46].

The increased demand from ground Internet data centers for server hardware meets delays in production of electronic components in Asia. This competition could bottleneck the production of end-user mobile terminals and components for the ground operations.

Next-generation fleets from current industry players could be delayed some months, but the larger supply chain disruption will come from newcomers. Indeed, the numerous satcom mega constellations planned for the near-future could suffer from financing difficulties, as they are often supported by a tight investor base and in a very competitive market. This could lead to market consolidation of these actors: had OneWeb just ran out of cash that many industry leaders (SpaceX, Amazon, Eutelsat) were rumoured to be stating interest in buying the assets, especially the rights to frequency bands. This market consolidation could prove beneficial in the long run, by creating more robust projects that will reliably transform the market, but until then, it could create a large deficit in the number of small to medium satellites manufactured.

2.3.3. Private investment

Level of Impact: Negative



The established satcom companies started the month of March on a strong correction of their stock price, that looked disproportionate with the moderate decline in revenue in that period (Average -40% decrease in share price compared to a -6% in revenue on top-line satcom actors^[47]). This could indicate a decrease in the confidence of investors in the satcom market,

and could lead to a weakening of the financing for costly, high-risk projects like space startups.

In fact, this lack of confidence led Softbank to re-center its capital, bringing the OneWeb project to the brink of collapse. According to a OneWeb press release^[48], turbulence on the global market due to COVID-19 destabilized the funding process ongoing at the time.

This lack of capitals will hurt the smaller companies first, both suppliers and startups. Industry advocates such as Access. space are therefore already calling for specific financial assistance from states to help save these new projects.

Overall, this crisis shows that the NewSpace satcom projects could be more fragile than past investments could have made them look like. The bankruptcy of OneWeb could be announcing a new phase in the life of the satcom and IoT-related satellite constellations projects. They could be facing investors that are harder to convince, and would need to adapt business plans and improve differentiation from each other.

2.3.4. Public policy

Level of Impact: Neutral



This crisis has led to the realization by some public actors of the importance of broadband and content delivery services. As an example, initiated in the wake of the coronavirus outbreak in the US, the FCC-led Keep Americans Connected initiative^[49] aims at sustaining broadband access for struggling households, e.g. through the waiving of late fees. Most satellite broadband providers and resellers will likely get involved in this initiative that protects consumers. This will require financial efforts in the short-term, but could be rewarded by a greater importance of broadband infrastructure investments in the future.

Public investment policies in the aftermath of the crisis will likely involve strengthening infrastructures, including high-speed Internet to the more remote areas. These broadband infrastructure bills could help satellite broadband providers take a share of budgets and bring in new customers. Policy makers already show interest in satellite access to bridge the gap in broadband internet access: EU's satellite broadband vouchers included in the Broadband for all policy are one example of how public policies can indeed stimulate the influx of new customers to these services, increasing the customer base for European satellite operators.



2.4. Navigation services

Positioning services are ubiquitous in our daily lives, whether for transport optimization, for aviation approach procedures, for the numerous location-based apps on our phones, or for operations of critical infrastructures ranging from electrical grids to financial networks. Constellations of navigation satellites deliver Positioning Navigation and Timing (PNT) signals to serve these applications, sometimes combined with networks of terrestrial antennas, and have therefore a crucial role in the activities of many industrial sectors. We analyse in the chapter below how the COVID-19 crisis has some impacts on the sector, in particular on the terrestrial segment of navigation services, linked to the user receivers.

2.4.1. Demand

Level of Impact: Negative



The demand for SatNav applications relies on the exploitation of the positioning signal coming from Space but drives also the manufacturing of GNSS receivers to be incorporated in the various devices.

Current signals from the different GNSS constellations remain available (GPS, Galileo, Glonass, Compass) and the constant uniform coverage of the planet with GNSS signals make it non sensitive to variations of the signal usage and geolocation needs on the ground. In times of crisis, GNSS signals remain a vital service to support a number of emergency services, (for instance for civil protection, but also for sanitary services) and critical infrastructure operations (for instance power grids).

In the context of confinement measures, positioning signals are widely used for consumer location based services, in particular for groceries and food delivery services, and more generally home delivery services, which work around the clock to answer the skyrocketing demand^[50]. Illustrating this situation, Amazon recently announced a strong need for hiring (+100,000 people) to support its services in the current context^[51]. In efforts to contain the COVID-19 spread, several countries (primarily in Asia, joined later by other countries) have experimented the use geolocation data to map the displacements of persons infected with the virus based on their mobile phones, in combination with history of

medical facilities and pharmacies, credit card transactions and CCTV^[52].

For these different services, mobile phone grids are primarily used for geolocation, but offer a limited accuracy and are therefore completed with satellite signals to reach the required geolocation precision.

The market for GNSS user equipment is driven largely by consumer equipment receivers (1.6 billion units per year, of which 90% cell phones and wearables) and road transportation devices, dominated by Personal Navigation Devices and In-vehicle systems (110 million units sold per year, but representing more than half of the total revenues^[53]). Some activity decrease is already witnessed for electronics and cars, with a direct impact on GNSS components manufacturers, system integrators and system providers. The impact is particularly strong due to the correspondence between the geographical footprints of COVID-19 sanitary crisis and of their markets: Asia-Pacific concentrates 50% of the global GNSS receivers shipments for consumer equipment, while 90% of the road transportation market is distributed between Europe (40%), Asia-Pacific (30%) and North America (25%), which are also concentrating COVID-19 cases.

As a consequence, reports from market intelligence firms ABI and IDC suggest that production of smartphones could decrease by up to 30% in the first half 2020, due to the COVID-19 situation^[54],^[55], mostly due to a drop in production from major China-implanted mobile phone producers such as Apple, Huawei, Xiaomi and from components providers such as Qualcomm, Broadcom, Qorvo etc. The Electronic Engineering Times reports more conservative forecasts values, yet with a drop in mobile phones production volumes by 10% already just for January and February 2020^[56], completed by numerous testimonies from executives from electronics companies implanted in Asia and in the US, expressing their concerns about the impacts of the COVID-19 situation on their supply chain and the expected slow down of business for the coming weeks. India, one of the main mobile phone producers in the world, also expects an estimated 700 M€ production loss in March and April 2020 due to China factories shut downs^[57].

The automotive market is also experiencing production issues, with many major car producers having made announcements of

the suspension of some factories due to the COVID-19, including for instance Ford, Nissan, Volkswagen or PSA^[58]. The Electronic Engineering Times reports revised production volumes (- 8 pts) for January and February 2020, from 21 million units down to 19.3 million, while Moody's forecasts have also been revised, decreasing by 1.6 point for the overall 2020 production^[59].

In many industries and GNSS markets, the duration of the effects of the crisis throughout 2020 remains uncertain, with a progressive industry recovery, meaning few months before returning to nominal production rates. Hence beyond the direct negative impact, the medium and long term impact will also remain slightly negative.

2.4.2. Supply

Level of Impact: Slightly negative



The delivery and maintenance of SatNav constellations should not be affected by the crisis situation in neither on the short term nor the long term, mostly for two reasons. First, navigation constellations represent strategic assets, controlled by governmental budgets – and for most countries, by military budgets – supporting critical infrastructures for time synchronization (banks and stock markets, energy networks, telecom networks). Secondly, they rely on steady orders and commissioning plans over several years to deploy full constellations, with few impacts on the launch manifest for navigation satellites. The main impact is a GPS-III satellite to be launched by SpaceX, planned on 29th April from Cape Canaveral, delayed with the current sanitary measures. Next launches for GPS are Galileo are planned for August, October and December, giving time for the context to improve in Florida and Kourou, while the launches for Glonass and Beidou-3 have not been affected, with launches continuing in March. In parallel, the GNSS signals augmentation systems such as EGNOS, WAAS, GAGAN etc., largely used by the aviation sector for airport approaches procedures, continue to operate nominally, with for instance the 3rd GEO swap operation performed for EGNOS in the second half of March and the nominal signal availability in April.

Regarding the user segment, the production capacity of GNSS receivers can be expected to be affected by the crisis in the short term, mostly because of the geographical impact of the sanitary crisis. Many major manufacturers are located in affected areas such as North America (Qualcomm, Avago, Garmin, HoneyWell, Trimble, Mediatek etc.) and Europe (Tomtom, Hexagon, U-blox etc.). Equipment integrators and system suppliers are also impacted, both for mobile phones devices (Apple, Samsung) and for cars (Japan, USA and Europe). However, the effects seem to vary between the different providers. Qualcomm executives for instance expressed some concerns with respect to the resilience of their own supply chain during the crisis, with potential throttle of production capacities of the different suppliers, due do quarantine measures and factory closures^[60]. Others such as Hexagon communicate on a continuous delivery of their products despite some factory closures in Italy or perturbations in China^[61]. U-blox also reassured its customer on the absence of perturbations, relying on suppliers from Austria

and Taiwan^[62]. Overall this situation is expected to be limited to the direct impact of the crisis, and the situation should be back to normal in the longer run (a few months from now) for the different providers.

2.4.3. Private investment

Level of Impact: Slightly negative



On GNSS receivers markets, the main suppliers are large companies with usually a good resilience to short term economic pressure, and are not dependent on external funding, neither from private investors nor through public subsidies. Their financial resilience can however be reflected in their stock price, and although it can be expected that the stock market will recover in the coming months, the uncertainties and worries around the COVID-19 and its impact on the global supply chain has led to a high volatility of the stock values between February and March. Stock values for GNSS providers crashed for USA and European companies^[63], linked to their strong reliance on China-implanted suppliers and customers. On this period, many leading companies have undergone stock price drops from -30% to -40% (Qualcomm, Hexagon), down to -45% or -50% for some (Broadcomm, HoneyWell, Trimble, Tomtom).

Symptoms of the companies worries about the coming months, some of the actors have announced a slight decrease of their guidances (Qualcomm^[64]), while others such as Tomtom decided to withdraw them^[65], considering the uncertainty generated by COVID-19 on their financial results for 2020.

In the long run however, mirroring the impacts on the supply chain, the actors of the supply chain should fully recover from the situation, once the levels of demand will drive the market back to its pre-crisis levels.

2.4.4. Public policy

Level of Impact: Neutral



Public policy and strategy for Navigation programmes should not be impacted by the COVID-19 crisis, neither in the short term nor in the longer term. The current satellite developments and future launches are part of long term public visions, aiming at procuring strategic assets for the concerned regions, hence with a high priority to maintain such capabilities. GPS, Glonass and Beidou/Compass constellations are military-controlled constellations, being replenished and upgraded along the new launches, in order to maintain and improve their performances. They have a strategic role for the USA, Russian and Chinese governments, which are expected to maintain their efforts and protect their assets, should the COVID-19 related crisis last longer than a few weeks. Similarly in Europe, the Galileo constellation is still ramping-up, and plays a crucial role in European non-dependence objectives with a sustainable financial effort associated. The recent figures presented by its manufacturer, OHB in March 2020 highlighted the current 1.65 B€ order backlog for its Space Systems business segment (to which Galileo substantially contributes), which ensures stable future for the company^[66].

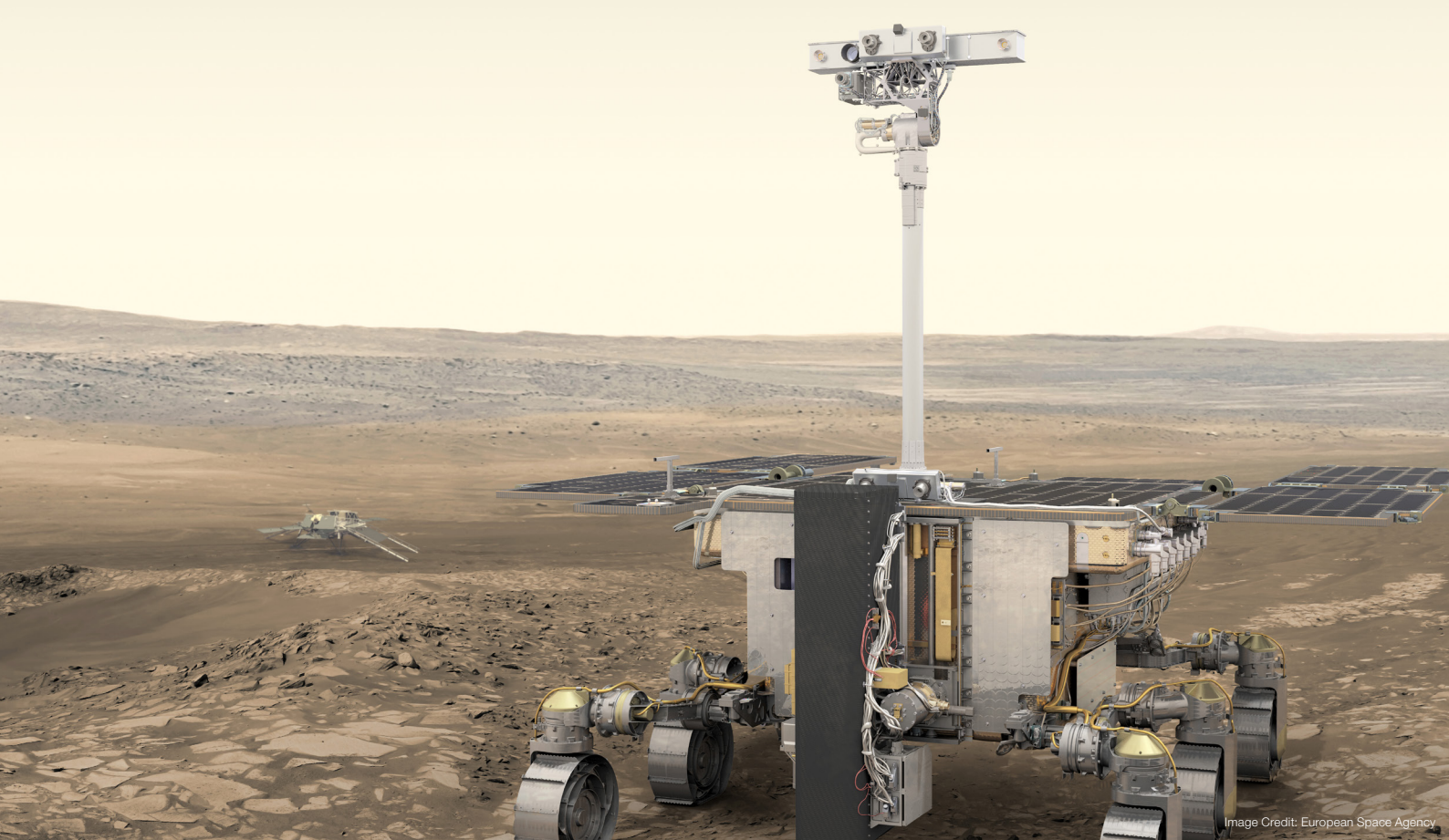


Image Credit: European Space Agency

2.5. Space Exploration

Space exploration missions are critical for not only understanding the science beyond the low earth orbit such as astronomy and cosmology but also to enhance the public interest in the space sector which contributes a huge societal impact. This section will focus on the impact of the COVID-19 crisis on the ongoing and planned missions focused on space exploration including both missions to outer space as well as to Low-Earth-Orbit (LEO), for instance to the International Space Station (ISS).

2.5.1. Demand

Level of Impact: Neutral



Demand for space exploration missions, both to outer space and to LEO stems primarily from national space agencies. Recent trends in the privatisation of the space industry, for instance from companies such as SpaceX and Astrobotic [1] [AR2] for missions to the Moon and Mars and companies such as Virgin Galactic and Blue Origin for space tourism, may point a potential private economy. But, most of these privatisation efforts depend on the demand from space agencies in the short to medium term.

The demand for science exploration missions is not expected to be impacted by the COVID-19 crisis in the short-term considering that these missions are usually a result of long-term feasibility studies as well as considered national and/or regional assets. Although depending on the evolution of the COVID-19 crisis, the impact on the global economy could be large, it is not expected to cancel ongoing mission activities. NASA is proceeding with plans for the ARTEMIS mission^[67] and Lunar Gateway^[68], and the UAE's mission to Mars is on track to launch in the summer^[69]. Although ESA had put some of its science

missions on standby^[70], it is still planning to conduct the gravity-assist flyby of BepiColombo mission to Mercury^[71]. ExoMars, the joint ESA and Roscosmos mission, however, has been postponed to 2022, due to need for testing further complicated by ongoing force majeure circumstances^[72]. Demand for missions to the International Space Station is not expected to be impacted given its strategic importance to all its partners^[73], ^[74]. Given the requirement to maintain a crew continuously on the ISS, these missions are not expected to be impacted. It can however be expected that demand for space tourism could be slightly impacted given the large scale economic impacts of the COVID-19 crisis, further complicating the willingness to pay for space tourism experiences.

As such, the impact on the demand for space exploration in the short-term can be considered as very limited, however the impact on the long-term is heavily dependent on the policies and strategies adopted by institutions around the world. Considering that market demand for space exploration missions stem directly from space policies, the private sector is mostly bound by the policies and strategies adopted by the institutions. Hence, companies in the private sector could expect some delays and uncertainties with public procurement at least until the economic repercussions of the crisis are understood and quantified.

2.5.2. Supply

Level of Impact: Slightly negative



Supply for exploration missions cover the manufacturing of products including the launchers, the space crafts along with the services that support these operations such as transportation, maintenance and ground services. Although the supply for exploration missions is mostly concentrated on the private sector stimulated by the demand from the governmental institutions,

research and development within the space agencies and research institutions also contribute to the supply.

Some parts of the supply are expected to be strongly impacted such as the manufacturing and testing of launchers and space crafts. Missions such as the James Webb Telescope and Space Launch System have been put on hold^{[75], [76]} as almost all of NASA employees are working remotely^[77]. Nonetheless, NASA is proceeding with the selection of suppliers for Lunar Gateway with SpaceX being selected for its “Gateway Logistics” contract^[78]. Despite being the epicenter of the COVID-19 pandemic, China is proceeding with its launch of the Long March 5B vehicle designed for future exploration missions^[79]. However, impact on the supply with respect to continued services for the ISS is not expected to be affected^[80], with both NASA and SpaceX continuing work on the upcoming commercial crew mission to the ISS^[81]. Although the number of private companies in the exploration domain do not match with those in the other domains discussed previously in this paper, the major contractors for space agencies are expected to face some uncertainties in the long-term. Some casualties can also be expected in the market due to a potential decrease in demand from the space agencies, as was the case with Bigelow Aerospace, which had some financial concerns before the COVID-19 crisis.^[82] As such, the impact on the supply for exploration missions is expected to be slightly negatively impacted at least in the short-term, with long-term impacts seemingly uncertain due to the dependency on the space policies and procurement strategies of space agencies.

2.5.3. Private investment

Level of Impact: Slightly negative



Even with the evolution of NewSpace and the privatisation of the space industry, access to finance for exploration missions has been largely restricted to institutional procurements, which are directly related to the space policies, strategic roadmaps of space agencies and thus the institutional space budgets. Access to private capital has rather been sparse for companies working on exploration missions, with most private funding being raised by Astrobotic, SpaceX and Blue Origin, with long-term exploration goals. As mentioned, companies such as Bigelow Aerospace have laid off employees, due to a lack of access to finance amid the COVID-19 crisis while startups such as Orbit Fab continue to receive grants from NASA. It is uncertain how the economic impacts of the crisis will affect the access to finance, particularly

with respect to public funding. However, it can be argued that given the historical difficulties in access to private funding will only be worsened by the ongoing coronavirus crisis. As a result, access to finance is expected to become difficult especially for projects aimed at future exploration missions, which are largely subject to changes through national space strategies.

2.5.4. Public policy

Level of Impact: Neutral



Budgets of major space agencies around the world have been growing in the last few years^{[83], [84]}, thanks to global renewed interest in space exploration activities, specifically with respect to the Moon, fueled by the Artemis mission by NASA and the corresponding Lunar Gateway. The evolving procurement strategies for exploration missions included an increased participation from commercial providers for both launch and manufacturing, with companies like Boeing, SpaceX and Blue Origin leading the way for the Artemis and Lunar Gateway programs, along with a number of contracts for small and medium sized enterprises, as part of the NASA Commercial Lunar Payload Services program (CLPS)^[85].

The ongoing COVID-19 crisis, however, may potentially impede the development of space exploration policies and strategic roadmaps around the world, due to fears of an impending economic recession. The crisis has already led to reprioritization of efforts towards addressing the health crisis and recovery measures^[86]. Although space agencies are continuing work on the ongoing and planned exploration missions, as detailed in the previous sections, the disruption for space exploration policies and therefore, the reduction of budgets seems inevitable, given the large scale economic impacts of the crisis. While the ESA budget has been finalized for the next five years, including over 1.9 billion euros for exploration, it can be expected that there might be revisions to the agreed budget as a result of revisions in the European Union budgets^[87]. It is uncertain how space budgets with respect to exploration missions will evolve, which could, in turn, result in a change of procurement strategies as well as revised exploration roadmaps for space agencies. Hence, the impact on policy and strategy is largely uncertain and cannot be determined without quantifying the impact of the crisis on the global economy as well as the cost of getting it back to normalcy.



2.6. Space Situational Awareness

Space Situational Awareness (SSA) refers to the capability of detecting and tracking man-made and natural threats, predicting and assessing the risks involved, and providing services enabling the implementation of appropriate mitigation measures aiming at protecting space and ground assets. The outbreak of COVID-19 implies a threat on SSA activities, as the ability to sustain the prediction, assessment and mitigation of potential collisions between space objects, re-entry and fragmentation, might be hindered by the several effects of the pandemic.

The following section identifies and analyses the overall impact of the COVID-19 outbreak and crisis on SSA operations mainly, but also investigates on the impacts of the crisis on the development of technical means supporting SSA activities, and on the crisis' effects on the implementation timeline of policies towards the development of Space Traffic Management activities.

2.6.1. Demand

Level of Impact: Neutral



Operational activities ensure that space surveillance information and data is properly collected, processes and delivered to users. A potential disruption in the chain of SSA operations could lead to catastrophic impacts. Indeed, the sudden inability to collect and process information on the positioning, velocity and direction of space objects, as well as the inability to coordinate between several satellite operators could lead to a potential collision between two space objects and trigger an uncontrollable creation of space debris following a chain reaction mechanism known as the Kessler syndrome.

Demand for space surveillance data is primarily emitted by

satellite operators, being public, private or military, who require data such as two-line element sets (TLE) that provide a list of orbital elements of an Earth-orbiting object, and Conjunction Data Messages (CDM) which are pieces of information that notifies close approaches of two or more space objects. Demand for SSA information is not expected to decrease during and after the COVID-19 crisis. Considering the capital importance for satellite operators to be constantly aware of the existence of any external threat to their spacecraft, and the fact that basic SSA information is accessible free of charge, it seems quite unlikely that satellite operators deprioritize their access to SSA information products. Furthermore, it appears that demand for SSA information is not hindered by a potential absence of operational means and access to capabilities. Indeed, most satellite operators have ensured that their staff dispose of the necessary tools to assess and conduct collision avoidances even when working remotely from spacecraft control centres.

It is important to understand that satellite operators need to be provided with precise and timely space surveillance information. Under the status-quo, satellite operators receive a large volume of CDMs, with a very high percentage of false alarms. The need to receive timely and precise space surveillance data is not expected to reduce during and after the COVID-19 crisis.

2.6.2. Supply

Level of Impact: Neutral



The provision of SSA information appears not to be hindered by the COVID-19 crisis. Space surveillance data providers claim that they are sustaining their activities, and key milestones towards the deployment of SSA capabilities are not being delayed.

As a key actor supporting the EU SST programme, GMV is in charge of the development of the operations centre in Spain (S3TOC) and contributes to the support of the European

catalogue of space objects. Such catalogue allows satellite operators to be informed of collision alerts that support them in forecasting and avoiding potential collisions. Following the State of Emergency declared by Spain in early March 2020, GMV has deployed its business continuity plan in order to ensure the sustainability of its key operations and the provision of key services. The US Space Command states that its activities have not been affected by the pandemic. The Space Fence situational awareness radar was declared operational at the end of March 2020. The new radar is capable of tracking objects smaller than 10 centimetres and is expected to enhance the catalogue of space objects of the US Space Surveillance Network. In the meantime, the Space Surveillance Telescope based in Exmouth, Australia, took its first astronomical image recently.

The coronavirus outbreak emphasises on the need for the development of automation processes supporting collision avoidance manoeuvres. Indeed, as a routine task performed by spacecraft operators, active collision avoidance manoeuvres require the constant availability of experts capable of analysing a large set of different parameters. Moreover, when two active spacecraft run the risk of colliding into one another, both operators concerned by the potential event must cooperate and coordinate their manoeuvre plans to prevent the collision from occurring. In order to reduce efforts, costs and simplify coordination activities amongst operators, the need for the development of automated concepts is more relevant than ever under the context of the COVID-19 crisis. Within its Space Safety Programme, ESA has initiated the CREAM (Collision Risk Estimation and Automated Mitigation) initiative which aims at developing automated solutions that would greatly facilitate collision avoidance tasks for spacecraft operators. The application of such a concept would greatly support spacecraft operators when facing the effects of the COVID-19 crisis.

2.6.3. Private investment

Level of Impact: Slightly negative



The Space Data Association (SDA) which gathers satellite operators who share together critical data for the safety of their spacecraft and the sustainability of the space environment may be threatened by the impacts of the COVID-19 crisis. SDA's Space Data Center is fully funded by SDA members to integrate

flight dynamics information from SDA spacecraft operators and to provide them with consolidated and reliable space surveillance data. The financing of the Space Data Center may be hindered by the potential difficulties met by the major financial contributors of the SDA: communication satellites operators who may suffer a loss of revenues due to the reasons exposed in the section reflecting upon the impact of COVID-19 on Satellite Communication.

2.6.4. Public policy

Level of Impact: Slightly negative



Political and strategic decisions towards the development and consolidation of regulatory aspects of Space Traffic Management may be temporarily put on hold due to the political attention and attempts required to solve the COVID-19 crisis.

In June 2018, the United States issued the Space Policy Directive 3 (SPD3) which defines an approach for Space Traffic Management. The SPD3 transfers the responsibility to provide spacecraft operators with space surveillance data from the US Department of Defense (DoD) to the US Department of Commerce (DoC). In order to carry out its activities, the Department of Commerce received a budget of \$2.3 Million for the fiscal year 2020.[1] In order to dispose of appropriate tools and means to roll-out its activities, the Department of Commerce has required a total envelope of \$15 million for the fiscal year 2021. The important financial requirements driven by the efforts required to mitigate the COVID-19 crisis may prevent the Office for Space Commerce from accessing the entire budget they would require for FY2021. A lack of appropriate funding may in turn delay the implementation of the Department of Commerce initiatives towards the development of Space Traffic Management activities.

In Europe, the proposed budget by the European Commission for SSA and GOVSATCOM activities in the next Multiannual Financial Framework (2021 - 2027) is EUR 500M, the European Parliament has proposed an increase of this budget and asks for an envelope of EUR 1.2 B to cover both SSA and GOVSATCOM activities^[8]. The impact of the COVID-19 on institutional policies in the field of Space Traffic Management matters is unknown as the EU is still examining its potential positioning.



Image Credit: European Space Agency

2.7. Access to Space

As the means of providing access to space, the launcher industry is expected to be impacted by a change in other space domains. Potential impacts on the launcher industry are peculiar, as they must not only consider changes in Demand and Supply, but they must also factor in the changes on launch pads or spaceports. Indeed, the operation of a launch pad is essential in enabling access to space, and thus impacts the launch schedules which translates into channelled effects up to manufacturing lines as changes in launch schedules create congestion on the launch pad and imply a reduced cadence of launches requiring manufacture. We therefore look at the impact of the COVID-19 not only on the demand coming from the industry but also at the impact from the shutdown of spaceports and how both impact the ability to provide access to space services.

2.7.1. Demand

Level of Impact: Negative



The COVID-19 crisis is creating tensions on businesses that are slowing down their activity or, in the worst case, disappear or halt their business activities by placing themselves under corporate bankruptcy legislations. It is also susceptible to changes in launch schedules and priorities from either industrial or institutional players. Previous sections of this report have highlighted, segment by segment, the expected impact of the COVID-19 on supply and demand of satellites which will in turn impact the launcher industry.

The disappearance of commercial players that are either going bankrupt or going under the protection of insolvency laws like the US Chapter 11 creates a net stop on demand for access

to space. As a case in point, OneWeb placing itself under the protection of American Chapter 11 insolvency laws is bad news for launch services providers that had activity with the satellite manufacturer. Arianespace is one of such providers for which OneWeb's setback is critical. Indeed, Arianespace is not only losing a customer for the different launchers it services, but ArianeGroup's Ariane 6 (Ariane 62 & Ariane 64 variants) was also counting on OneWeb as its prime client for a maiden launch later this year that would have demonstrated the reliability of the launcher and unlocked its subsequent flights. As a direct consequence, the European Commission's two Galileo satellites initially scheduled for launch onboard Ariane 62 in late 2020 has been rescheduled for launch on a Soyuz-ST-B^[89].

Changes in launch schedules and priorities from industrial and institutional players are also expected to have direct as well as medium term impacts on the launch industry. For commercial players, difficulties in manufacturing satellites due to shortages in the supply chain and the confinement of workers might create delays and change expected launch schedules, especially for NewSpace companies that tend to have shorter delays between the end of manufacturing of their satellites and their expected launch date. This risk is increased by potential difficulties in access to finance that will force a reduction in the expected launch schedules, less funding for the manufacturing of satellites being available. Overall, these impacts could be particularly visible for operators or future operators of satellite constellations. On the institutional side, reprioritization of space budgets might also change launch schedules while potentially reducing institutional demand in the longer term for some programs as has been explored in this brief for activities like Space Exploration.

Delays in the launch of satellites will more generally require intensive efforts for the launch services industry to either tighten

deadlines and pack launches in limited timeframes or postpone the launch of several satellites. Postponing launches as such might have undesirable consequences for clients who might be in need for satellite replacement with potential income losses that could be foreseen and might thus lead to several possible reactions from the industry. Launch services providers might be tempted to make contractual amendments to prioritize clients in urgent needs, asking for premiums to such clients that might revolve to their insurance providers, if any, for compensation, or might offer discounts to deprioritized clients. For clients however, launch postponement might be critical especially when technology demonstration or commercial launch of services are required for fundraising and preventing a trajectory like the one of OneWeb.

2.7.2. Supply

Level of Impact: Slightly Negative



Scheduled launches around the globe have experienced series of postponements, impacting both public and private operators.

This delay is not uniform though, with countries like China or Russia maintaining launches as initially scheduled throughout confinement period. In China, the country has indeed performed launches through February^[90] and March^[91] from both its Sichuan and Hainan launch sites. Albeit the strategic impact of the launch industry for China has led the country to consider maintaining its launch infrastructures amid the COVID-19 crisis, the Chinese government has communicated vastly on how authorities including Wu Yansheng, the chairman of CASC audited the strict respect of mitigation guidelines by employees of launch facilities^[92]. Less surprising is the fact that Russia has also maintained its launches scheduled, the country being less heavily hit by the Coronavirus at the time this paper is being published. The Baikonur Cosmodrome has remained active with the latest launch being that of 34 OneWeb spacecraft on March 21st 2020^[93] aboard a Soyuz rocket.

While China and Russia maintain launch schedules active, the rest of the global launch activity has experienced a halt due to both the administrative closure of launch complexes as well as the impossibility to welcome customer's teams overseeing the final stages of payload integration. Administrative restrictions prevent the opening of launch facilities for business and they have been taken either preventively or forcedly by the spread of the Coronavirus. In France, the Centre Spatial Guyanais (CSG) in Kourou closed its activities as early as March 3rd while national shutdown would only be administratively required weeks later. Other launch sites, like Rocket Lab's New Zealand launch site have closed following administrative orders^[94], forcing launch service providers to postpone operations

Restrictions in mobility also prevent launches to take place. While SpaceX had initially scheduled the lift of Argentina's SAOCOM 1B an Earth Observation satellite on March 30th, the launch has been delayed due to the incapacity of Argentinian personnel to travel to Cape Canaveral, Florida, in order to approve the satellite is ready for launch^[95]. Similar mobility restrictions affect launch

complexes globally as long as the satellites requiring lift are not manufactured domestically.

It is yet to be seen if the launch of spacecrafts is to be reconsidered as a vital economic activity that will lead to the exemption of launch activities in the near future from confinement measures which would imply resuming launches. This could be envisaged for the most strategic launches in governmental Telecom or Earth Observation for instance, including the late April scheduled launch of GPS Block III satellite GPS III-03 aboard a Falcon-9 rocket. Rocket Lab has reportedly engaged active discussions with New Zealand's government to determine earliest possible dates for resuming launch operations and therefore maintains its launch vehicle and ground systems in a state of readiness for launch^[96]. Launch activities will thus most likely resume with domestic payloads to begin with, while frontiers remain closed to foreign visitors, and progressively retrieve a normal trajectory while entering de-confinement.

Impacts on manufacturing lines are also expected, with consequences on launches being variable depending on whether launch services providers are "launcher constrained" or "launch-schedule constrained"

Just like satellite manufacturing, rocket launcher manufacturing lines are also impacted by the COVID-19 outbreak. Industry practices are heterogeneous in that matter and are to be considered on a case by case basis, often decided by whether there has been a reported outbreak of Coronavirus among the manufacturing line employees.

Large manufacturers such as ArianeGroup and Vega Aerospace are pursuing rocket manufacturing^[97] but are at risk of more severe impact from the Coronavirus. SpaceX for instance has notified that a dozen of its employees at its Hawthorne manufacturing site are under quarantine with two tested positive^[98]. Rocket Lab on the other side has reportedly halted production of its Electron rocket, a decision that is not expected to challenge the company's business model that has announced having several launch vehicles ready and being able to manage a pause in production^[99].

This points out to specificities in business model and operating schemes approaches. While some launchers' manufacturers are able to produce enough quantities to anticipate demand for launch services, others are constrained by their production lines and need to maintain production flow in order to honor future, even though delayed, contracts. The former tends to be "launch-schedule constrained" meaning that their business model is mainly dependent on the launches they managed to secure from the market, and then to be startup companies operating smaller launch vehicles (Rocket Lab is one of such). The latter, more institutional players, have more secured bookings, and therefore need to ensure their manufacturing lines can proceed as normally as possible. These are the more at risk by the COVID-19 outbreak and delays in manufacturing could add to delays in launch complex operations and even further postpone some launches.

2.7.3. Private investment

Level of Impact: Negative



Access to finance should suffer from the COVID 19 due to risk aversion of investors of any sort. This will most likely have a differentiated impact based on the maturity of projects and the type of players considered. Indeed, long established launcher industrials are expected to be less impacted than the NewSpace actors.

Established launchers manufacturers should be impacted in their ease of access to finance but to lower levels than more recent projects that have more exposed business models. Prime rocket manufacturers on the market will benefit from their positive track record as well as the backlog of launches that will have been booked with their launchers and will therefore have a stronger case when looking for financing on the markets, whether this is done through loans or equity-funding with both financial markets and investors being less reluctant than for newly established players. In addition, most of current long established rocket manufacturers have a diversified portfolio of activities which can act as a safety net in case of reduction of the demand for access to space, thus facilitating access to finance by providing stronger business cases.

Regarding NewSpace however, the risks exists that microlaunchers projects still in their development phase will perish, due to the risk-aversion of investors that will increase their level of caution when deciding of their investments. Access to finance for riskier projects or less cash-generating business will most certainly harden, and just as OneWeb suffered from difficulties in accessing additional funding and had to resolve to enter under protection of US Chapter 11 Law, NewSpace launcher companies might have to undergo similar movements

if not simply disappear. The latest case in point is Astra Inc., the microlauncher company that recently announced it have to let go about 20% of its workforce^[100] in order to financially survive pandemics amid a failed attempt at winning the latest DARPA Challenge^[101].

Overall, we thus expect that the level of impact on access to finance for the launch industry of the COVID 19 will be negative for the NewSpace segment, but will only be slightly negative for other, more established players.

2.7.4. Public policy

Level of Impact: Neutral



Considering the strategic importance of access to space, it is not expected that institutional players will substantially modify their support to access to space assets, whether we refer to the operation of spaceports or the support to the launcher industry. While several spaceports have been shutdown globally, it is expected that the importance of resuming launches will facilitate the termination of administrative closures of spaceports in order to resume access to space activities in countries like France or the US. At the same time, a needed support to the launcher industry will certainly encourage governments to closely monitor the situation with regards to partial employment and working force support policies in order to ensure policies encourage the smooth operation of access to space manufacturing lines. In addition, institutional programs to support the development of new projects, including microlaunchers, like the "DARPA challenge" will likely maintain the attention of authorities because they provide a conditional means of access to finance, based on the demonstration of actual access to space capabilities and R&D progress, while allowing a clear competition between players.





3. Conclusion on the resilience of the Space sector to the COVID-19 crisis

Resilience of satellite manufacturing: Medium

The current impact of the COVID-19 outbreak in the satellite manufacturing industry is limited to delays in delivery due to activity slow-downs for some of the manufacturers. The uncertainty grows however in the medium term, in particular due to the expected higher pressure on governmental budgets, which could affect institutional orders, and on the repercussion of commercial customers financial fragility. In the long term the manufacturing industry might hope for a return to nominal levels of orders thanks to persistent needs for connectivity, observation and tracking services. The situation is more critical for small players. Start-ups and small sized suppliers foresee liquidity challenges in the short term, and many may struggle to survive without support from their investors and prime integrators.

The COVID-19 crisis will have triggered manufacturers' business continuity plans at every level of their supply chain, with various approaches developed to ensure at least partial activity. This global unexpected crisis could set the path for the evolution of their contingency plans, including actions such as implementing or reinforcing collaborative concurrent engineering platforms, reviewing their suppliers' footprint, or giving a higher importance to make-or-buy strategies. While big players in the sector adopted financial measures as a resilience strategy, small actors are more exposed should the crisis continue in the coming weeks and months.

Governments will have a key role in the sector's resilience, depending on their securisation of public budgets for critical defense and research programmes and indirectly by reassuring private investors and maintaining innovation budgets to keep stimulating smaller actors and start-ups.

Resilience of Earth Observation services: Medium

The COVID-19 is expected to have significant short-term impacts

on the EO downstream industry, and potentially slightly negative medium/long term impacts on budget availability for R&D and operational Earth Observation programmes. If we can expect an increase in demand for EO data and services, especially for Big Data Analytics companies monitoring critical infrastructure and impacts of crisis on production, the COVID-19 is adding delays to production and launches but it is also expected to have a very negative impact on the access to funding. Large scale programmes providing grants and support to EO downstream companies in Europe and in the US may have their budget negatively impacted, reducing the amount of money available to support the EO industry. On another hand, R&D programmes and grants related to space activities are expected to offer support to the EO downstream industry to develop applications and solutions that support the recovery of the global economy. Finally, the last few years have seen a very strong increase in private ventures, especially from VCs, in start-ups planning to develop large scale small satellites constellations, with more or less solid business cases. The expected liquidity dry-up might damage new entrants, leading to some casualties within the pool of start-ups aiming at developing and launching EO satellites capabilities in the near future, with incumbent players with operational capacities like Maxar and Airbus, even Planet, expected to be more resilient to the crisis.

The downstream EO industry could then be considered as resilient to the crisis. Indeed, the outputs of the COVID-19 episode may well be a more consolidated industry of strong players, including both solid start-ups and flexible incumbents, relying on demonstrated business cases with clearly identified demand and streams of revenues.

Resilience of Satcoms services: High

Satellite communications services are expected to be highly resilient to the effects of covid 19 crisis, with negative effects in demand limited to some verticals, and a robust supply of services. The dry-up of liquidities could add up to existing difficulties of major satellite operators, but should hit harder new market entrants. Some casualties are expected in this segment, akin to OneWeb's bankruptcy. In the medium-term, this crisis could lead to moderate market consolidation, but overall satellite communication services will stay a key business in space.

Downstream, the services to industries affected by the crisis and the subsequent recession will see a dip in revenue, for example,

the providers or in-flight connectivity or backhaul connexion for offshore oil rigs. Nevertheless, they should find ways to sustain business through the duress thanks to the relative flexibility of their costs (ability to re-negotiate contracts, pay-for-use agreements, etc.). Downstream consumer markets should stay strong during the crisis and after, and the services to other industries will follow their respective rebounds.

Resilience of Navigation services: Medium

Navigation infrastructures and services are rather resilient during this COVID-19 crisis, both in the short term and in the longer run. Through their role in the operation of critical infrastructures for nations (energy grids, financial system, telecom networks), as well as the huge number of professional and consumer applications requiring geolocation services, navigation constellations are highly strategic assets for governments, and their operation is maintained in such difficult times. Regarding the GNSS infrastructure, the few potential delays in the deployment and replenishment of the constellations do not constitute threats to the availability of the signals, considering the redundancy of their architecture and the interoperability between some constellations.

The user segment however is more sensitive to a crisis such as the COVID-19, and the direct impacts are sizable and can already be witnessed. Indeed, a large share of the markets for GNSS receivers are consumer markets driven by mobile phones and cars, which are not priorities for governments' economic measures, and which are directly affected by supply chains geographical footprints and by the decrease in goods consumption at global scale. This indirectly affects the sales of GNSS chipsets, and should keep affecting it in the coming months. In the medium to long term, the sales of GNSS equipment should improve and increase again to reach levels comparable to the pre-crisis situation. However, some experts fear a risk of a persistent decline in consumption levels, due for instance to reduced households' revenues in the context of an economic recession.

Resilience of Space Exploration: Low

Space exploration, in itself, is mostly limited to public endeavours from advanced spacefaring nations and is hence heavily dependent on nation space policies and space budgets. Even the emerging private space sector including companies such as SpaceX and Blue Origin is largely focused on procurement from the space agencies for upcoming exploration missions. Space exploration is also not considered a strategic endeavour like Access to Space or Earth Observation for most space faring nations, although development of major development exploration missions are a function of national politics and geopolitics, such as the ISS and the upcoming Artemis mission. In this context, space exploration is not expected to be very resilient to the current health crisis and the impending economic crisis. National space budgets are expected to be revised with critical components for the crisis recovery such as healthcare could be expecting a boost in their budgets. Hence, the resilience of the space exploration domain could be expected to be low in the medium term, until a stable economic growth period is achieved. This resilience, however, could vary, between the types of missions with politically driven exploration missions such as Artemis being far more resilient than science and

astronomy missions. Missions to the ISS are also expected to be resilient given the need for continuous presence as well as to continue the huge international collaboration efforts.

Resilience of SSA / SST: High

Operational aspects of SSA are not expected to be impacted by the crisis. Considering the importance of access to space surveillance data for the sustainability of the space environment, space surveillance data providers and spacecraft operators have ensured that their activities remain safeguarded despite the constraints posed by the COVID-19 crisis. In addition, the development of automated solutions for collision avoidance manoeuvres would greatly support space surveillance activities and further increase the safety of the space environment in the COVID-19 context.

However, due to the important financial and governmental means required to face the COVID-19 crisis, institutionally-funded budgets which were initially planned to support the development of Space Traffic Management activities may most probably be revised and reduced. Such budgetary restrictions may delay the implementation timeline of the development of guidelines and standards framing future Space Traffic Management activities. In addition, the potential financial difficulties triggered by the COVID-19 crisis may decrease the momentum of large constellation programmes. Should large constellation instigators follow the same path as OneWeb and face the obligation to put an end to their activities, this trend may be perceived as an argument to partially reduce investments in the development of STM capabilities.

Resilience of launcher industry: High

The launcher industry appears to be resilient to the COVID-19 crisis despite suffering from direct impacts due to the postponement of several launches following the closing of multiple launch pads including CSG in Kourou. While launch schedules and manufacturing lines are affected, launch backlogs are typically months long. As such the expected effect of the COVID-19 will push back expected launches, but shouldn't lead to any cancellation. In addition, the manufacturing of launchers has not been put to a halt for established players due to the necessity of maintaining cadences in order to produce necessary vehicles. For younger micro launcher companies, microlaunchers are usually produced using new manufacturing techniques and at higher paces since they can more easily be stored in storage facilities. Therefore, we expect launcher manufacturers to be able to either maintain production paces or be able to respond positively to the resuming of launches. One potential difficulty for launchers manufacturers might however arise in the case where the tightening of launch schedules at the end of year 2020 put pressure on launchers manufacturing lines. In such cases manufacturers might have to increase production cadences, if possible, or delay launches and thus risk losing potential customers.

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If you have any questions or wish to discuss the space sector and the challenges it faces, please contact us:



Luigi Scatteia

Partner, France
PwC Space Practice
+33 6 42 00 71 67
scatteia.luigi@pwc.com



Yann Perrot

Manager, France
PwC Space Practice
+33 7 85 37 82 36
yann.perrot@pwc.com

With contributions from

William Ricard
Robin Pradal
Aravind Ravichandran
Fiorella del Carmen Alvaro Cabrera
Mathieu Luinaud
Baptiste Fournier

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About PwC and the space sector

Data

The information presented in this document are based on available data as of March 2020, and are subject to change over time.

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The PwC Space Practice is part of the PwC Advisory practice, which includes strategy and consulting. The PwC Space Practice is fully dedicated to the space sector. Our team includes specialists from all space sectors who are supported by consultants from the global PwC network. Our expertise covers the entire space sector and spans the value chain, from upstream to downstream. We help entities, public and private, to face their business, technological and governance challenges in a constantly changing environment.

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